NAME : _____ CLASS : _____

JURONG PIONEER JUNIOR COLLEGE
JC2 Preliminary Examination 2024

BIOLOGY
Higher 2

9744/03
11 September 2024

Paper 3 Long Structured and Free-response Questions **2 hours**

Additional Materials: Answer Booklet

READ THESE INSTRUCTIONS FIRST

Write your class and name in the spaces at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, 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 Booklet provided.

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 not use appropriate units.

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

For Examiner's Use	
1	
2	
3	
Section B	
Total	

This document consists of **19** printed pages and **1** blank page.

Section A

Answer **all** questions in this section.

1 Mammoths are extinct mammals related to elephants. About three million years ago, the ancestors of mammoths migrated from Africa into Europe and Asia. There, about 1.7 million years ago, the steppe mammoth evolved and became adapted to the cooler conditions. Then, about 700 000 years ago, as the climate changed and the Arctic became much colder, the woolly mammoth evolved.

Characterised by its long, curved tusks, woolly mammoths showed several obvious adaptations to reduce heat loss, including thick fur, small ears and small tails.

Fig. 1.1 shows a drawing of a woolly mammoth.

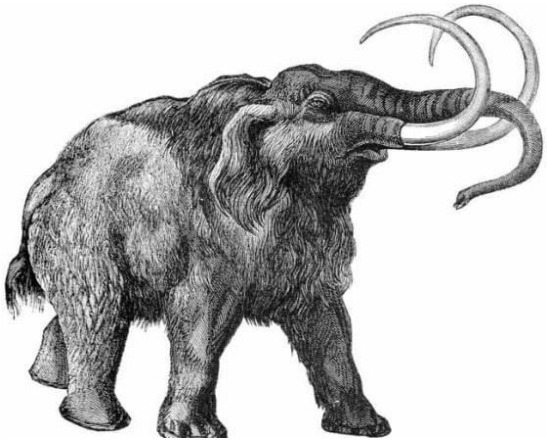

Fig. 1.1

(a) **(i)** Outline the sources of genetic variation which drives microevolution in a population.

..... [2]

1. **Gene mutations / chromosomal aberrations – ref. to changes to DNA sequences / chromosomal structure / number ;**
2. **1 relevant stage in meiosis ;**
   a) **Crossing over between non-sister chromatids of homologous chromosomes during prophase I in meiosis I to give new combination of alleles in gametes**
   b) **Independent assortment of chromosomes in meiosis leads to new combination of alleles in the gametes formed**
   c) **Independent assortment and segregation of homologous chromosomes during metaphase I and anaphase I new combination of alleles in the gametes formed**
   d) **Independent assortment and segregation of recombinant chromatids during metaphase II and anaphase II leads to new combination of alleles in the gametes formed**
3. **Random fusion of gametes during fertilisation ;**
4. **ref to gene flow - transfer of alleles from one population to another due to migration of fertile individuals ;**

5. **Genetic drift (ref to bottleneck effect/ founder's effect) change in allele frequency in a population due to chance ;**

(ii) Account for how natural selection may have brought about the evolution of the woolly mammoth from the steppe mammoth.

..... [4]

1. **when there is a change in selection pressure e.g. food, predator, climate / environmental conditions ;**
2. **(variation within the population) individuals who are better adapted to the environment / with favourable characteristics will be at a selective advantage ;**
3. **named adaptation explained ; e.g. better insulation / smaller surface area to volume ;**
4. **They will survive to maturity, reproduce and pass on their favourable allele / genes to their offspring ;**
5. **Over time, there is a <u>change in allele frequency</u> in the population ;**

(b) A frozen, 43 000 years old woolly mammoth was found in Siberia. Its DNA was extracted and sequenced. Bioinformatics was used to compare the sequences of the genes coding for the α and β chains of haemoglobin of woolly mammoths, modern Asian elephants and humans.

Explain why bioinformatics was used to compare these gene sequences **and** suggest a conclusion that could be made from the percentage similarity data obtained.

..... [2]

any one from:
why

1. **Large amount of DNA sequences ;**
2. **Unambiguous and objective - A, T, G, C are easily recognised and one cannot be confused with another / not subjective ;**
3. **Quantifiable and open to statistical analysis ;**
4. **AVP – relevant advantages of using molecular techniques in studying molecular homology ;**

any one from:
conclusions

5. **The fewer the differences between DNA sequences, the <u>more recently</u> two species have <u>diverged from a common ancestor</u> ; ora**

AVP: acts as molecular clock to reconstruct phylogenetic relationships ;

(c) In addition to DNA sequencing, Southern blotting followed by nucleic acid hybridisation can be used to analyse the genes for the α and β chains of haemoglobin in both woolly mammoth and the modern Asian elephants.

To visualise the results, autoradiography is carried out at the end. The images formed on the photographic X-ray film would correspond to the bands that contain the genes for the α and β chains of haemoglobin.

Outline the process of Southern blotting and nucleic acid hybridisation.

..... [4]

1. **Gel from gel electrophoresis is placed on top of a sponge soaked in alkaline solution, a nitrocellulose membrane, followed by a stack of paper towels, are placed on top of the gel ;**
2. **Alkaline solution is drawn upwards through the gel, denaturing the (double stranded) DNA fragments, transferring single-stranded fragments of DNA to the nitrocellulose membrane (where they adhere firmly in the same positions as they were in the gel) ;**
3. **Nitrocellulose membrane is placed in a sealed plastic bag containing radioactive single-stranded DNA probes (complementary to the DNA sequence of interest) ;**
4. **Which hybridise with DNA fragments (containing sequence of interest) on the nitrocellulose paper via complementary base pairing ;**
5. **Nitrocellulose membrane is removed from the bag and washed thoroughly to remove any unhybridised probes ; Autoradiography is then carried out to visualise the results.**

(d) Fig. 1.2 shows the amino acid residue differences among the α and β chains of haemoglobin in human (Hb A), Asian elephant (rHb AE), and woolly mammoth (rHb WM). Each amino acid residue is represented by a different letter of the alphabet. The differences between rHb AE and rHb WM compared to the Hb A sequence are shown. An asterisk (*) denotes the differences in amino acid between rHb WM and rHb AE.

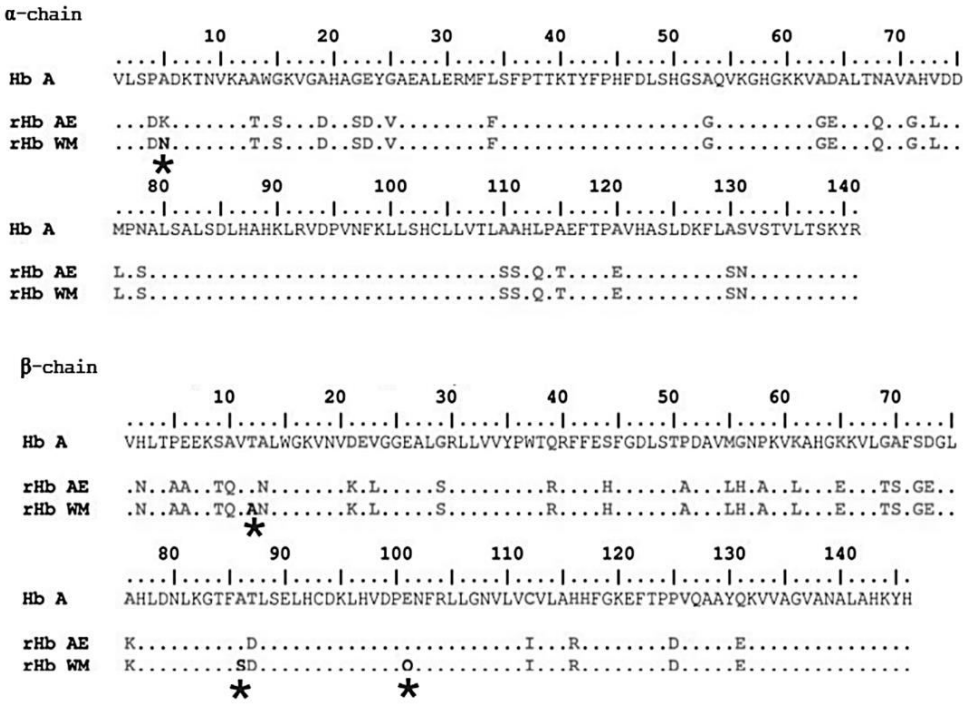

Fig.1.2

With reference to Fig.1.2, explain the likely effect of these differences on a molecule of woolly mammoth haemoglobin (rHb WM).

..... [5]

Data

1. **one different amino acid in the woolly mammoth's α chains (compared to AE) ;**
2. **three different amino acids in the woolly mammoth's β chains (compared to AE);**

OR

3. **differences in primary structure of haemoglobin / sequence of amino acids in haemoglobin ;**

Explain

4. **these amino acids may have different R groups which affects the bonds (any one named example of bond e.g. hydrogen bond) in the tertiary structure ;**
5. **results in change in the tertiary structure / 3D shape of α and β chains;**
6. **quaternary structure of haemoglobin (which includes 2 α and β chains) will be affected ;**
7. **greater effect on β chain ;**
8. **affect the property and function of haemoglobin ;**

Award MP 3 in place of MP1 and MP2 if students generalised the difference in primary structure without specifying specific data point from Fig. 1.1, i.e. max for describing difference is MP 1 + MP 2 or MP 3.

(e) Scientists synthesised woolly mammoth haemoglobin to investigate whether the different haemoglobin was part of the mammoth's adaptation to a cold climate.

The affinity of haemoglobin for oxygen is affected by the changes in temperature that can occur in mammals, for example in active muscle tissue or close to the skin surface.

It is advantageous for Arctic mammals to have haemoglobin whose affinity for oxygen is only slightly affected by changes in temperature. This is often achieved by using substances called 'red cell effectors', which bind to haemoglobin.

Fig. 1.3 compares the effect of temperature on the affinity for oxygen of woolly mammoth and Asian elephant haemoglobin, with and without red cell effectors.

Fig. 1.3

(i) Suggest why it is advantageous for Arctic mammals to have haemoglobin whose affinity for oxygen is only slightly affected by changes in temperature.

..... [1]

1. **still able to transport oxygen (in cold temperatures) so can maintain oxygen supply to surface tissues which is colder than core temperature ;**

(ii) Analyse the extent to which data in Fig. 1.3 provides evidence that woolly mammoth haemoglobin is better adapted for a cold climate than Asian elephant haemoglobin.

..... [3]

haemoglobin alone

1. **no / tiny difference in effect of temperature on haemoglobin alone ;**
2. **so no evidence (woolly mammoth haemoglobin) better adapted ;**

haemoglobin with red cell effector

3. **greater reduction in effect of temperature on haemoglobin with red cell effector in woolly mammoth ; ora**
4. **(so) woolly mammoth haemoglobin (with red cell effector) better adapted to cold ;**

Haemoglobin is a vital protein found in red blood cells. These cells are formed through the specialisation of myeloid stem cells in the bone marrow. Fig.1.4 illustrates the various developmental pathways of blood stem cell differentiation.

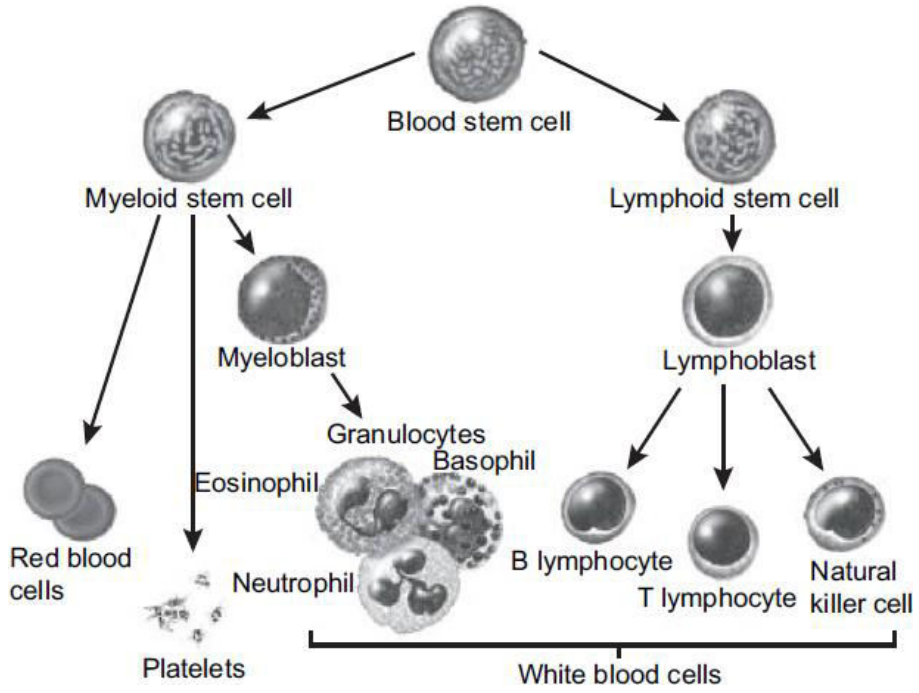

Fig. 1.4

(f) Describe the features **and** functions of myeloid stem cells.

..... [3]

1. **Myeloid stem cells are <u>multipotent</u> and have the ability to <u>differentiate into a limited and related range of cell types</u> and tissues in an organism ;**
2. **They undergo differentiation to form <u>blood</u> cells such as macrophages/red blood cells which are mainly involved in innate immunity ;**
3. **to <u>maintain</u> the specific tissue where they reside by <u>replacing worn-out or damaged red blood cells and white blood cells</u> ;**

(g) During erythropoiesis, the process of stimulating myeloid stem cells to develop into red blood cells, erythropoietin, also known as Epo is synthesised. Epo is a large glycoprotein synthesised by specialised cells in the kidneys of mammals. These cells are very sensitive to changes in oxygen concentration in the blood passing through the kidney and respond to a low oxygen concentration by increasing the synthesis of Epo.

Fig. 1.5 shows Epo stimulation of its receptors and activation of downstream signalling pathways in erythropoiesis. Epo binds to receptors of target cells such as myeloid stem cells. Epo-receptor (EpoR) signalling results in the activation of a target gene, *GATA-1* gene.

Upon expression of *GATA-1* gene, GATA-1 is a DNA binding protein. GATA-1 binds to DNA to upregulate the transcription of the *β-globin* gene in myeloid stem cells during erythropoiesis.

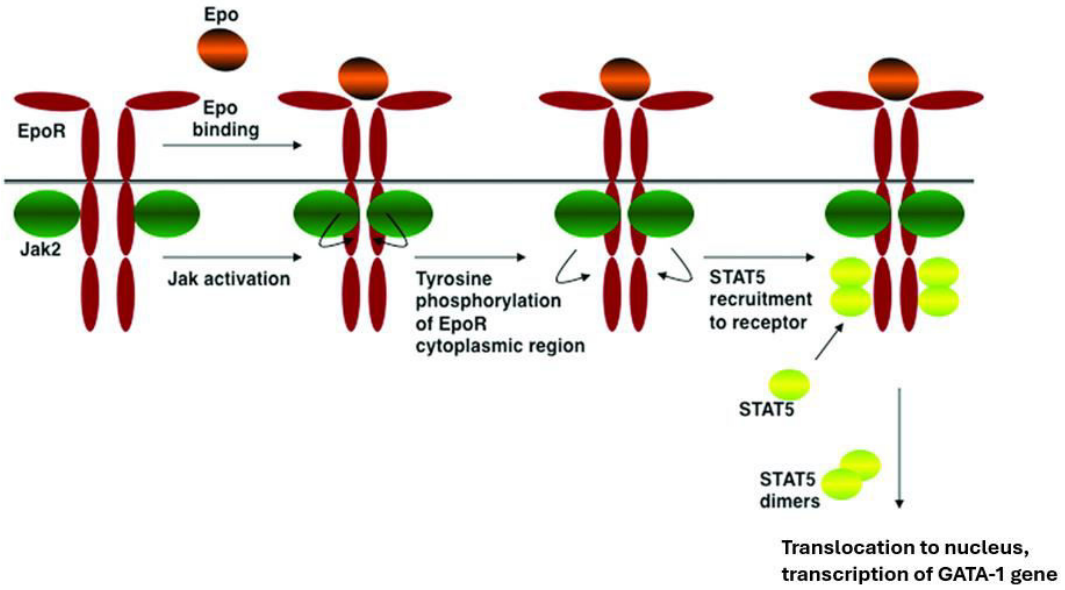

Fig. 1.5

(i) A low oxygen concentration leads to an increase in the quantity of mRNA coding for Epo in the specialised cells in the kidney.

Suggest why the researchers looked for mRNA transcribed from the *Epo* gene, rather than for the gene itself.

..... [2]

1. **<u>gene</u> would be present in every cell ;**
2. **(when gene expressed) mRNA is in <u>large</u> amounts which allows for studying of gene expression pattern ;**
3. **difficult to isolate/ identify /extract, gene ;**

(ii) All cells of the body are exposed to circulating blood plasma containing Epo, but only particular target cells respond.

Suggest **and** explain how Epo acts on target cells such as myeloid stem cells and why other cells are **not** affected.

..... [2]

1. **Epo is <u>complementary</u> in shape / charge to the <u>binding sites</u> of the Epo receptors (which allows Epo to recognise and bind to Epo receptors on specific target cells) ;**
2. **Epo is a <u>large</u> glycoprotein which binds to cell surface membrane of target cell to transmit the signal as the molecule is too big to pass through the cell surface membrane ;**
3. **<u>Only cells with Epo receptors</u> can respond to Epo (in response to low oxygen concentration) ;**

(iii) Explain how GATA-1 protein can upregulate transcription of the gene for β chain of haemoglobin.

..... [3]

1. **GATA-1 is an <u>activator</u>, will recognise and <u>bind to its enhancer</u> of β -globin gene ;**

2. **causing the DNA (between the promoter of the gene and enhancer) to <u>bend</u> ;**
3. **brings activator in contact with GTFs and RNA polymerase ;**
4. **recruits, positions and modifies the GTFs and RNA polymerase (at the promoter) ;**
5. **recruit histone acetyltransferase / chromatin remodeling complex (to promoter region) to decondense chromatin (OWTTW) / increase accessibility of the promoter to the GTFs and RNA polymerase ;**
6. **Facilitates the binding of the GTFs and RNA polymerase to the promoter to form a stable transcription initiation complex / accelerates the assembly of a transcription initiation complex at the promoter** ;

A: GTFs + RNA pol / transcription machinery

MP 1 + any 2 from MP 2-6 for max 3

[Total: 31]

2 Inflammation is a necessary protective response of the innate immune system to physiological triggers such as pathogens or damaged cells. Inflammation ensures that immune cells are recruited to the site of infection, enabling pathogen elimination.

(a) Identify **one** type of cell from the innate immune system **and** its function in the inflammatory response.

..... [1]

1. **Macrophage / Dendritic cell, phagocytoses pathogen / present antigens to cells from the adaptive immune system ;**
   OR
2. **Mast cell / Macrophage (A: if dendritic cell mentioned for mp1), releases cytokines / histamines to increase blood flow to site of infection ;**

In recent years, research has focused on the beneficial health effects of dietary phospholipids and their anti-inflammatory activities against chronic diseases, thus phospholipids are also available as dietary supplements.

A phospholipid is sometimes described as a modified triglyceride.

(b) Describe how a phospholipid differs from a triglyceride.

..... [2]

1. **Two fatty acids / hydrocarbon chains / tails compared to three in triglyceride ;**
2. **Presence of phosphate group (instead of 3rd fatty acid) compared to no phosphate group in triglyceride ;**

AVP: contain nitrogen / choline attached to phosphate head

Krill oil, a popular dietary supplement, contains phospholipids that can have multiple beneficial effects on inflammation-related disorders. Encapsulating these active compounds in nanoliposomes - a type of spherical lipid vesicle less than 200 nm in size - can enhance their effectiveness by targeting specific areas in the body more efficiently.

Experiments were conducted to compare the release rates of krill oil from nanoliposomes with or without a carboxymethyl chitosan (CMCS) coating. The CMCS coating serves as a biocompatible protective layer surrounding the nanoliposomes.

Fig. 2.1 shows the results of these experiments conducted in simulated gastric fluid (SGF),
a solution that mimics the acidic and enzymatic conditions found in the human stomach.

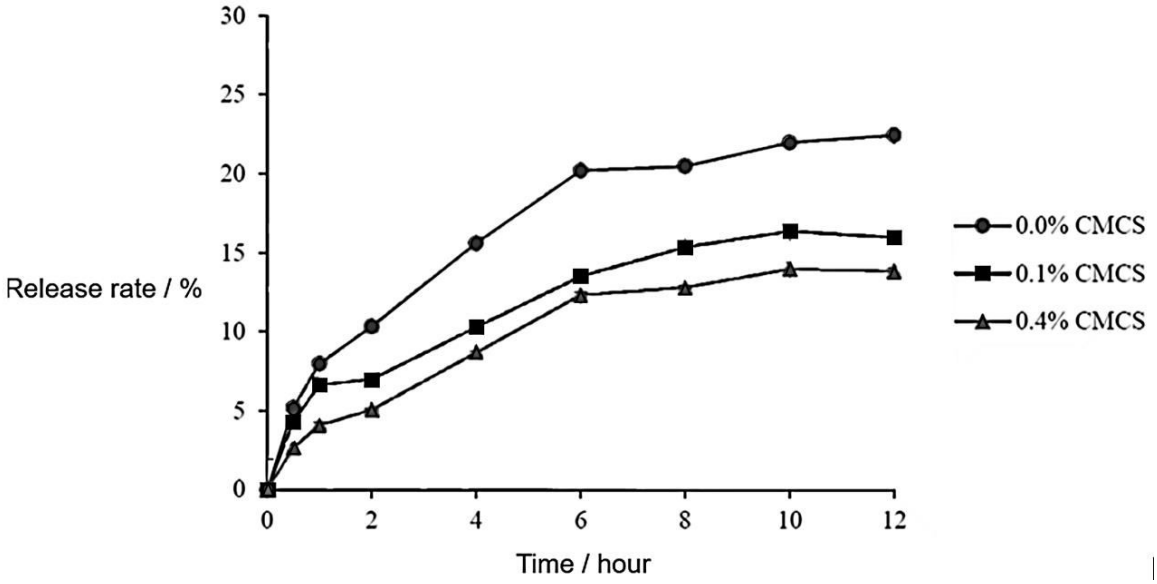

Fig. 2.1

(c) Describe how the CMCS coating affects the release rates of krill oil from nanoliposomes in SGF after 6 hours.

..... [2]

1. **Release rate of krill oil was slower in the presence of CMCS coating ;**
2. **Quote data: 13% release rate (with 0.1% CMCS) / 12% release rate (with 0.4% CMCS) compared to 20% release rate (without CMCS / 0.0% CMCS) ;**

Fig. 2.2 shows the results of similar experiments carried out in simulated intestinal fluid (SIF), a solution that replicates the conditions found in the human small intestine.

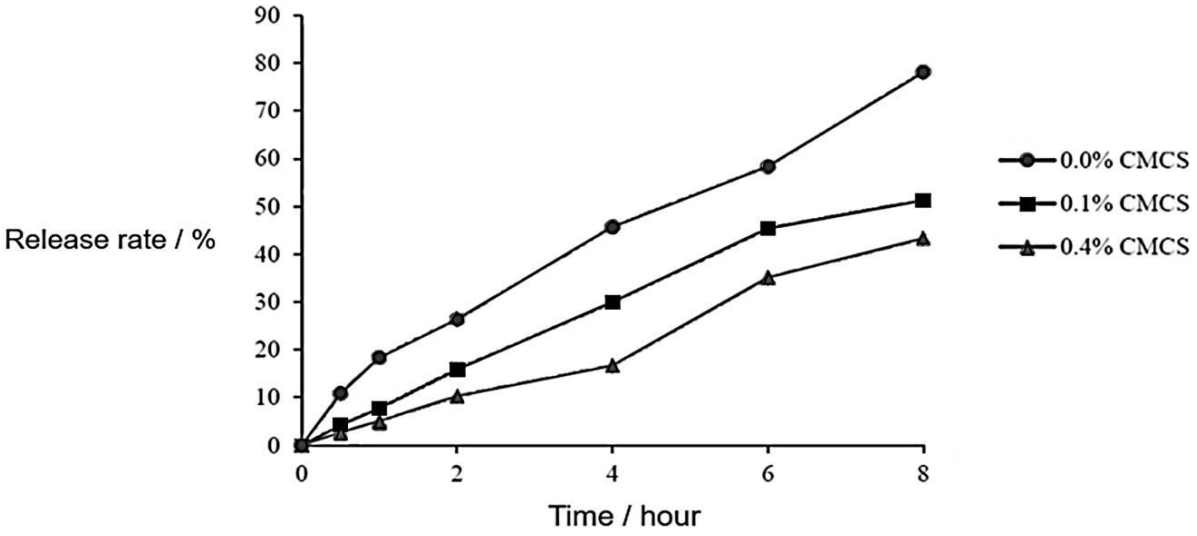

Fig. 2.2

(d) The small intestine is the key absorption site for the active compounds in krill oil.

Using the information provided and the data from Fig. 2.1 and Fig. 2.2, suggest **and** explain how the effectiveness of krill oil dietary supplements can be maximised.

..... [4]

1. **(compulsory) Place krill oil in nanoliposomes with CMCS coating ;**
2. **Rate of release of krill oil is, higher in small intestine (SIF) than in stomach (SGF) / lower in stomach (SGF) than in small intestine (SIF) ;**
3. **Quote data:**
   E.g. Any data set comparing release rates between SIF and SGF (with same concentration of CMCS and after same number of hours)
4. **(idea of) Lower chance of nanoliposomes bursting in the stomach before reaching the small intestine ;**
5. **(idea of) Most of the krill oil in the nanoliposomes will be released in the small intestine ;**
6. **Hence maximising the absorption of the active compounds (in krill oil) in the small intestine ;**

Max. 4

[Total: 9]

3 Global warming is one consequence of anthropogenic climate change.

Fig 3.1 is a model outlining some of the potential environmental impacts that could arise from an increase in temperature by either 1.5 °C or 2 °C.

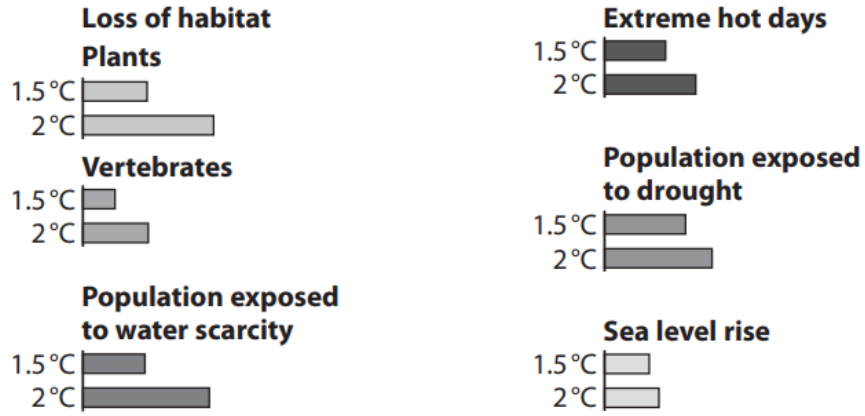

Fig. 3.1

(a) (i) Suggest why Fig. 3.1 is described as a model of the effects of an increase in temperature.

..... [1]

1. **making predictions based on, knowledge / data ;**
   A guess / an idea / estimation / what might happen
   A statistics / what has happened

2. **visual representation (of what might happen) ;**

(ii) Calculate the percentage increase in the population exposed to drought if the temperature increased by 2 °C and not 1.5 °C.

Assume the bars in the diagram are drawn to scale.

36.4 + % ; .....
[1]

(iii) Estimates indicate that the global leaf area expanded by 0.5 million km² from 2019 to 2020 due to increased human planting of trees and crops. Of this increase, China contributed 25%, achieving this through the planting of both forests and crops in equal amounts. India contributed 7% of the increase, focusing predominantly on crop planting.

Suggest the possible impacts of planting crops on global warming.

..... [2]

Positive impact on global warming

1. **CO_2 will be removed from the atmosphere, decreasing the greenhouse effect, minimising extreme weather events - heat waves / heavy rain should be reduced;**

Negative impact on global warming (max 1)

2. **planting crops may reduce carbon dioxide levels less than, forests / pre-existing crops ;**
3. **CO_2 released from machinery used in planting/harvesting crops / burning crops after harvest (to clear land for next planting season) ;**

Blue carbon refers to carbon captured by marine and coastal ecosystems. These ecosystems, including phytoplankton, algae and seagrasses are vital in mitigating climate change through carbon sequestration via the Calvin cycle.

Phytoplankton and algae, in particular, have the potential to store substantial amounts of carbon, with global estimates ranging from 50 to 60 billion tons annually.

(b) Red algae are multicellular aquatic protoctists. The cells of red algae have chloroplasts containing photosynthetic pigments. Many species of red algae live in deep waters.

Two of the accessory pigments of red algae chloroplasts are:

- phycoerythrin (appears red), often present in large concentrations
- phycocyanin (appears blue).

The first few metres of water nearest the surface absorb the red wavelengths of light. If the water also contains particles of organic material, it absorbs blue wavelengths.

Fig. 3.2 shows absorption spectra of some pigments in red algae chloroplasts.

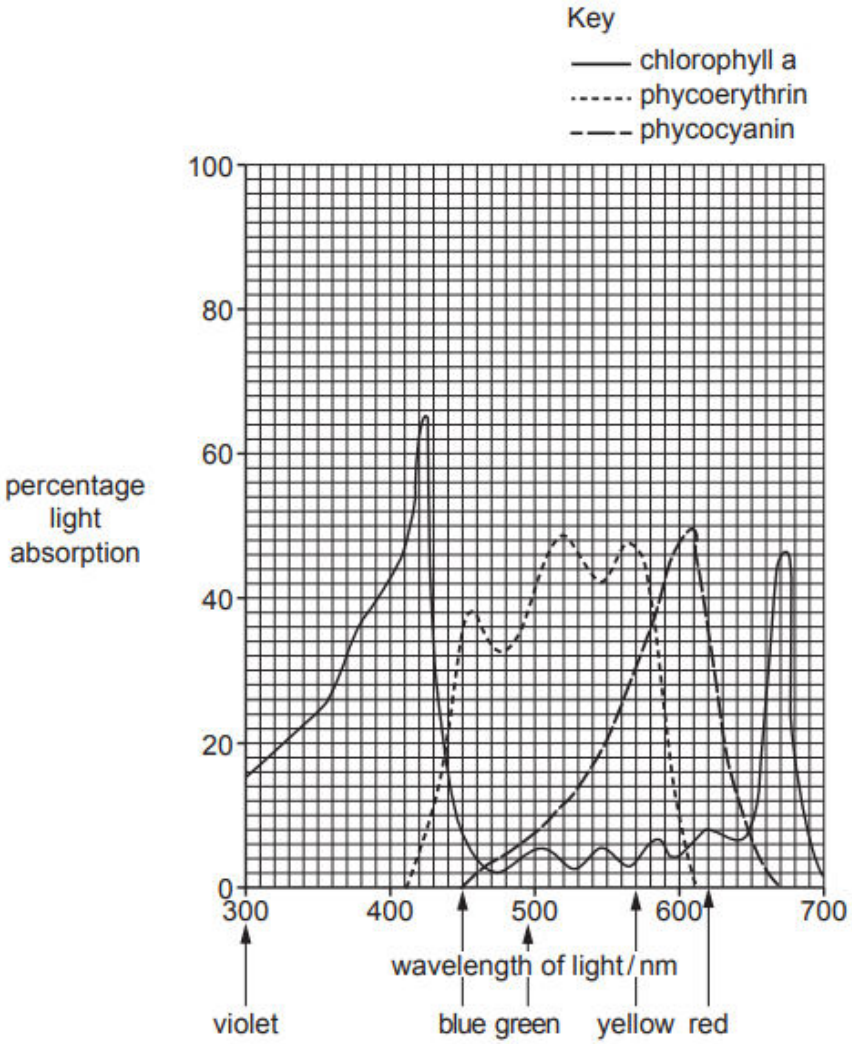

Fig. 3.2

(i) Describe the differences in the absorption spectra of the three photosynthetic pigments shown in Fig. 3.2 **and** explain how these differences help red algae to survive in deep water.

..... [3]

Description

1. **chlorophyll (a), has peaks / absorbs mainly, in blue and red, phycoerythrin absorbs in blue and green and yellow, phycocyanin absorbs in (green) yellow and red ;**

Explanation

2. **red algae / deep water, get(s) green (and yellow) light,**
3. **chlorophyll (a) absorbs, no / little, green (and yellow) light, phycoerythrin / phycocyanin, absorbs wavelengths not absorbed by chlorophyll (a) ;**
4. **combined pigments absorb, greater range of / any / all, wavelengths ;**

Survive in deep water

5. **increases / higher rate of, light dependent stage / photosynthesis, more glucose synthesise for growth ;**

(ii) Using the information provided, describe how Calvin cycle in phytoplankton and algae contributes to carbon sequestration **and** explain its role in mitigating climate change.

..... [3]

1. **carbon dioxide is fixed by combining with RuBP (catalysed by rubisco) to form glycerate phosphate ;**
2. **which are phosphorylated by ATP and reduced by NADPH to form triose phosphate;**
3. **Calvin cycle, remove / lead to reduction in 50 to 60 billion tons of carbon in the atmosphere annually, helping to <u>mitigate global warming</u> ;**

[Total: 10]

Section B

Answer **one** question in this section.

Write your answers to this question 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 parts **(a)** and **(b)**, as indicated in the question.

4 (a) Using named examples, explain how compartmentalisation within a eukaryotic cell aids the efficiency of metabolic processes. [15]

1. Compartmentalisation with the cell aids the efficiency of metabolic processes by isolating specific cellular environments and molecules for specific processes ;

<u>Nucleus</u>
2. Protects DNA / genetic material, stored in the nucleus from other metabolic processes occurring in the cytoplasm ;
3. Enables tight regulation of DNA replication / transcription of genes within nucleus ;
4. Separates transcription from translation, enabling different levels of regulation in gene expression ;
5. (Enzymes / biomolecules in nucleus enable) semi-conservative DNA replication / transcription / post-transcriptional modification ;

<u>Nucleolus</u>
6. Synthesis of rRNA and assembly of ribosomal subunits ;

<u>Rough Endoplasmic Reticulum (rER)</u>
7. Ribosomes on rER carry out protein synthesis / translation (of proteins destined for incorporation into cell surface membrane / for secretion) ;
8. (Enzymes / biomolecules in rER lumen) fold / modify proteins ;
9. Packages newly synthesised proteins into transport vesicles that are moved to (*cis* face of) Golgi body ;

<u>Smooth Endoplasmic Reticulum (sER)</u>
10. (Enzymes / biomolecules in sER enable) synthesis of lipids (e.g. phospholipids) ;
11. (Enzymes / biomolecules in sER enable) detoxification of drugs / poisons ;
12. In muscle cells, sER stores calcium ions, which aids in muscle contraction ;

<u>Golgi body</u>
13. Enables sequential modification / processing of proteins from *cis* to *trans* face ;
14. Enables further modification, sorting and packaging of proteins ;
15. into secretory vesicles (for moving to cell surface membrane) / lysosomes (for intracellular digestion) ;

Lysosomes

16. **Keeps hydrolytic enzymes away from cytoplasm / the rest of the cell ;**
17. **Prevents uncontrolled digestion of other organelles / hydrolysis of other biomolecules ;**
18. **Lower pH within lysosomes optimises hydrolytic enzyme activity ;**
19. **to carry out autolysis / digest phagocytosed material / digest worn-out organelles (idea of autophagy) ;**

Mitochondria

20. **Compartmentalises mitochondrion as the site for aerobic respiration ;**
21. **Protons can accumulate in the intermembrane space (to build up a proton gradient for chemiosmosis) ;**
22. **Enzymes needed for link reaction and Krebs cycle are found in the mitochondrial matrix ;**
23. **Hydrogen atom carriers / reduced NAD (and reduced FAD), can move easily (from link reaction and Krebs cycle) to electron carriers (in the ETC) ;**

Chloroplasts

24. **Compartmentalises chloroplast as the site for photosynthesis ;**
25. **Protons can accumulate in the thylakoid lumen / space (to build up a proton gradient for chemiosmosis) ;**
26. **Enzymes needed for Calvin cycle are found in the stroma ;**
27. **Hydrogen atom carriers / reduced NADP and ATP, can move easily from light dependent reactions (at thylakoid membrane) to light independent reactions (in the stroma) ;**

Max. 14 for mp1 to mp27

QWC:
Roles in compartmentalisation of at least two membrane bound organelles explained.

(b) Compare the structure and roles of centromeres and telomeres. [10]

Similarities

1. **Both centromeres and telomeres are non-coding DNA (sequences) ;**
2. **Both consists of tandem repeat (sequences) ;**
3. **Both are associated with / bound by specific proteins ;**
4. **Both have important roles in eukaryotic / linear chromosomes ;**

Differences (structure):

	feature	telomeres	centromeres
5	position on linear chromosome ;	Found at both ends of the chromosome	Found anywhere along the length of the chromosome (position is characteristic for each particular chromosome)
6	Length ;	Shorten with each round of DNA replication, (due to the end replication problem)	Remain the same after each round of DNA replication
7	presence of single-stranded region ;	Includes a single stranded region of DNA at their 3' ends (3' overhang)	No single-stranded region, double-stranded throughout
8	specific proteins that bind to these sequences ;	Telomere-specific binding proteins bind to telomeric DNA to form telomere (A: telomerase)	Centromere-associated proteins bind to centromeric DNA to form kinetochore
9	Presence of physical loops ;	t-loops can be found in telomeres	No physical loops found in centromeres

Differences (roles):

	feature	telomeres	centromeres
10	key role ;	Telomeres ensure genes are not lost / eroded due to end replication problem with each round of DNA replication, preventing loss of important genetic information	Centromeres ensure proper alignment and segregation of homologous chromosomes / sister chromatids to opposite poles of the cell
11	protection of chromosomes ;	Telomeres protect and stabilise the ends of chromosomes by preventing accidental fusion of the single-stranded end of one chromosome to the single stranded end of another chromosome ; OR by protecting the ends of the chromosomes from degradation by exonucleases	Centromeres stabilise / hold sister chromatids together (until anaphase of mitosis and anaphase II of meiosis II)
12	triggering apoptosis ;	Telomeres that are critically short trigger apoptosis (programmed cell death)	Centromeres do not trigger apoptosis
13	extension of these sequences ;	Telomeres allow their own extension, by providing an attachment point for the correct positioning of telomerase	Centromeres do not allow their own extension
14	regulation of cell division	Telomeres regulates the number of times a cell can divide before cell division ceases	Centromeres do not regulate the number of times a cell can divide

Max. 9 for content

QWC:
At least one point-to-point comparison for structure and one for function made.

[Total: 25]

5 (a) Nucleic acid is an important class of biomolecules found in all cells.

Outline the roles of nucleic acids in the synthesis of proteins in eukaryotic cells. [15]

1. **DNA ;**
2. **Each DNA molecule carries genetic code/information/instructions / contains genes for the synthesis of RNA or protein ;**
3. **each gene is a specific sequence of nucleotides which codes for a polypeptide or RNA ;**
4. **DNA as template for (replication and) transcription/synthesis of mRNA ;**

5. **mRNA ;**
6. **Acts as template for translation / polypeptide synthesis ;**
7. **Mature mRNA are exported out of nucleus via nuclear pores and enter the cytoplasm to bind to ribosomes / combine with large and small ribosomal subunits and initiator tRNA to form transcription initiation complex ;**
8. **one codon codes for one specific amino acid ;**
9. **mRNA strand codes for the amino acid sequence of specific polypeptide ;**
10. **Complementary base pairing between codon and anticodons ;**
    (*award once* in either mRNA or tRNA discussion pt 10 or 18)
11. **allow for excising of introns at splice sites for alternative RNA splicing ;**
12. **enables a single gene to code for more than one polypeptide, depending on which exons are spliced together to form a continuous coding sequence ;**
13. **Start and terminate translation via start (AUG) codon and stop (UAA, UGA, UAG) codons ;**

14. **tRNA ;**
15. **To act as an intermediate molecule between the codon of mRNA and the amino acid sequence of the polypeptide chain ;**
16. **To carry the correct amino acid from the cytoplasm to the polypeptide chain being synthesised at the ribosome ;**
    OR
17. **The 3' end with CCA stem serves as site for amino acid attachment to transfer/carry amino acids to the ribosomes during translation ; (*award 16 or 17*)**
18. **Anticodon on tRNA complementary base pairs with a particular codon on the mRNA via hydrogen bonding ; (*award once 10 or 18)***
19. **Ribosome recognition site – make specific base pairing with rRNA in the ribosomes; (*award once 19 or 23)***
20. **Has shape complementary to aminoacyl tRNA synthetase for activation of amino acid / has activating enzyme site for aminoacyl tRNA synthetase to catalyse the attachment of tRNA with its specific amino acid ;**

21. **rRNA ;**
22. **rRNA combines with proteins (in the nucleolus) to form small and large ribosomal subunits which will combine to form ribosomes (as site of protein synthesis) ;**
23. **rRNA in the small ribosomal subunit complementary base pair to the mRNA during translation ; (*award once 19 or 23)***
24. **rRNA in the large ribosomal subunit complementary base pair to tRNA in the P site and A site ;**
25. **A ribozyme, peptidyl transferase, in the large ribosomal subunit catalyses the formation of peptide bonds between adjacent amino acids ;**

QWC [1]
Includes at least two nucleic acids, and at least two roles in the synthesis of proteins, in separate paragraphs of different nucleic acids ;

(b) Explain the roles of proteins in signal transduction pathways. [10]

A. Receptor
1. **ligand receptor interaction ;**
2. **e.g. The G-protein linked receptor (GPLR) ;**
3. **receptor is <u>transmembrane</u>, span the <u>cell surface membrane</u> ;**
4. **has an <u>extracellular region / ligand binding site</u> A: ligand recognises and binds;**
5. **for ligand which is polar and unable to pass freely across the membrane ;**

6. **e.g Tyrosine kinase receptor (RTK) ;**
7. **<u>Ligand recognises and binds</u> to the specific binding site of tyrosine kinase receptors (RTK) on the target cell surface membrane, causing the two receptor polypeptides to undergo a <u>conformational change and dimerise</u> ;**

B. Transducer
8. **relay signals within the cell after receptor is activated ;**
9. **e.g. G protein, adenyl cyclase, relay protein ; ;**
10. **GPLR has an <u>intracellular/cytoplasmic region</u>, which serves as the <u>specific binding site for G protein</u> ;**
11. **A molecule of GTP replaces GDP on the <u>G protein</u> ;**
12. **The activated G-protein dissociates from the GPLR and activates inactive adenyl cyclase to active adenyl cyclase ;**

13. **Dimerisation activates the tyrosine kinase region of each polypeptide of RTK leading to cross phosphorylation ;**
14. **Activated RTK is recognised by specific relay proteins ;**

C. Signal amplifier
15. **Enzyme cascade comprising of kinases can amplify the original signal ;**
16. **Kinase phosphorylates downstream proteins leading to activation ;**
17. **Second messengers such as cAMP is formed from the conversion of ATP catalysed by adenyl cyclase ;**

D. Inhibition of signal
18. **Phosphatases removes phosphate from phosphorylated proteins ;**
19. **Leading to inactivation of kinases/ proteins ;**

E. Cellular response effector
20. **e.g. transcription factors, enzymes, cytoskeletal proteins ; ;**
21. **Regulate gene expression, activate enzymes in metabolic pathways or rearrangement of cytoskeleton (any corresponding one) ;**

Max 2 for MP9 and max 2 for MP 20

<u>QWC ;</u>
Good spread of knowledge communicated without ambiguity to include at least 3 functions of protein in signal transduction i.e. at least one MP from any 3 categories A-E

Suggested modification
A. Receptor

1. **e.g. GPLR / RTK ;**

2. allows ligand receptor interaction ;
3. has an extracellular region / ligand binding site that is complementary to specific ligand / allow ligand to recognise and bind ;
4. for ligands which are hydrophilic / polar / charged that is unable to pass freely across the membrane ;
5. with transmembrane region / span the CSM that anchors the receptor ;
6. able to undergo conformational change upon ligand binding to,

   allow G prot to bind, activating it (for GPLR) <u>OR</u>

   dimerise and activate TK to result in cross phosphorylation (for RTK)

B. Transducer

7. transducers relay signals within the cell after receptor is activated ;
8. e.g. G protein / adenyl cyclase / relay protein ;
9. G protein binds to intracellular / cytoplasmic region of GPLR resulting in GTP replacing GDP on the G protein ;
10. activated G-protein dissociates from the GPLR and activates adenyl cyclase ;
11. activated adenyl cyclase converts ATP to second messenger, cAMP ;
12. specific relay proteins recognise and bind phosphorylated tyrosine (on intracellular tail of RTK) and become activated;

C. Signal amplifier

13. kinases catalyse sequential <u>phosphorylation</u> of proteins (in an enzyme / phosphorylation cascade)
14. that activates multiple downstream proteins ;
15. resulting in <u>amplification</u> the original signal ;
16. triggering <u>numerous reactions</u> in the cell at once ;

D. Inhibition of signal

17. phosphatases removes phosphate from phosphorylated proteins ;
18. leading to inactivation of kinases / proteins ;

E. Cellular response effector

19. e.g. transcription factors, enzymes, cytoskeletal proteins ;
20. TFs regulate gene expression (in nucleus) by turning on / off specific genes ;
21. activate enzymes in metabolic pathways / (cite specific e.g. glycogen synthetase / glycogen phosphorylase) ;

22. rearrangement of cytoskeleton / (cite specific e.g. transporting secreatory vesicles with insulin leading to insulin secretion) ;