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 **20** printed pages.

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.

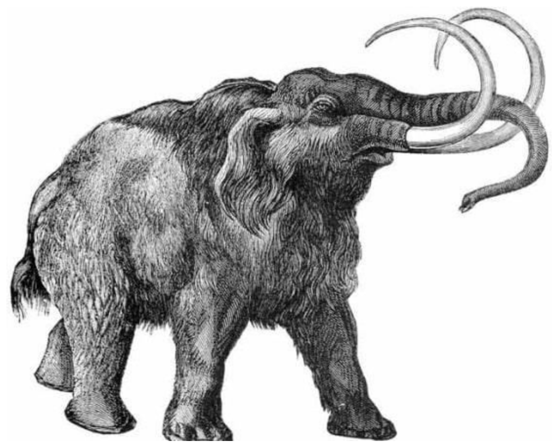

Fig. 1.1

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

....

....

....

....

.... [2]

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

....

....

....

....

....

....

....

....

.... [4]

(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]

(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]

Question 1 continues on page 6.

(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.

α-chain

```
                10        20        30        40        50        60        70
        ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
Hb A    VLSPADKTNVKAAWGKVGAHAGEYGAEALERMFLSFPTTKTYFPHFDLSHGSAQVKGHGKKVADALTNAVAHVDD

rHb AE  ...DK.......T.S...D..SD.V........F..................G.........GE...Q..G.L..
rHb WM  ...DN.......T.S...D..SD.V........F..................G.........GE...Q..G.L..
            *
           80        90       100       110       120       130       140
        ....|....|....|....|....|....|....|....|....|....|....|....|....|.
Hb A    MPNALSALSDLHAHKLRVDPVNFKLLSHCLLVTLAAHLPAEFTPAVHASLDKFLASVSTVLTSKYR

rHb AE  L.S...............................SS.Q.T....E.........SN..........
rHb WM  L.S...............................SS.Q.T....E.........SN..........
```

β-chain

```
                10        20        30        40        50        60        70
        ....|....|....|....|....|....|....|....|....|....|....|....|....|....|....|
Hb A    VHLTPEEKSAVTALWGKVNVDEVGGEALGRLLVVYPWTQRFFESFGDLSTPDAVMGNPKVKAHGKKVLGAFSDGL

rHb AE  .N..AA..TQ..N.......K.L.....S.........R....H......A...LH.A..L...E...TS.GE..
rHb WM  .N..AA..TQ.AN.......K.L.....S.........R....H......A...LH.A..L...E...TS.GE..
                   *
           80        90       100       110       120       130       140
        ....|....|....|....|....|....|....|....|....|....|....|....|....|....|.
Hb A    AHLDNLKGTFATLSELHCDKLHVDPENFRLLGNVLVCVLAHHFGKEFTPPVQAAYQKVVAGVANALAHKYH

rHb AE  K..........D........................I...R........D.....E...............
rHb WM  K.........SD.............O..........I...R........D.....E...............
                  *              *
```

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]

(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.

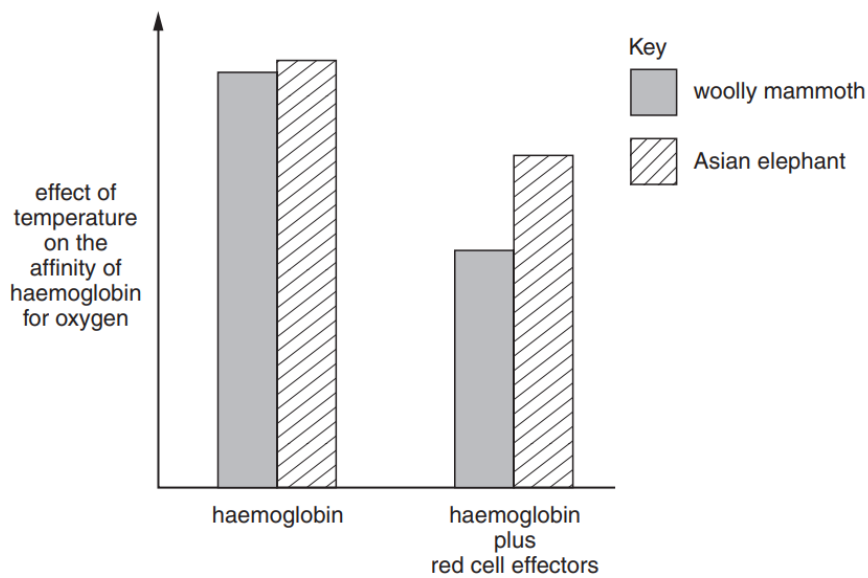

Fig. 1.3

(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]

(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 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.

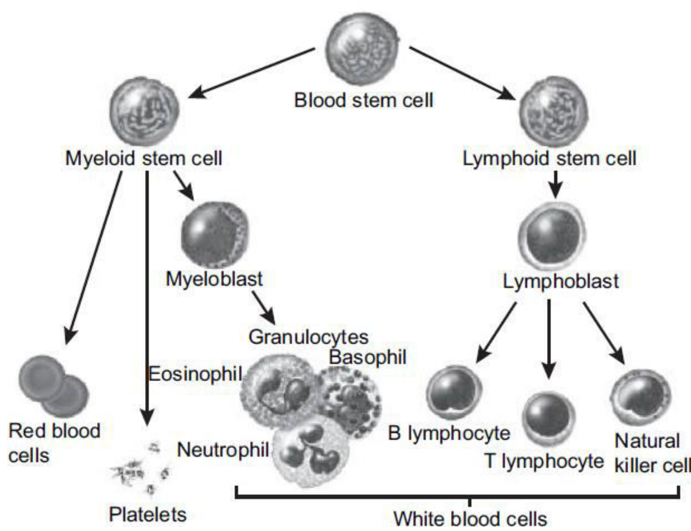

Fig. 1.4

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

....

....

....

....

....

.... [3]

(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.

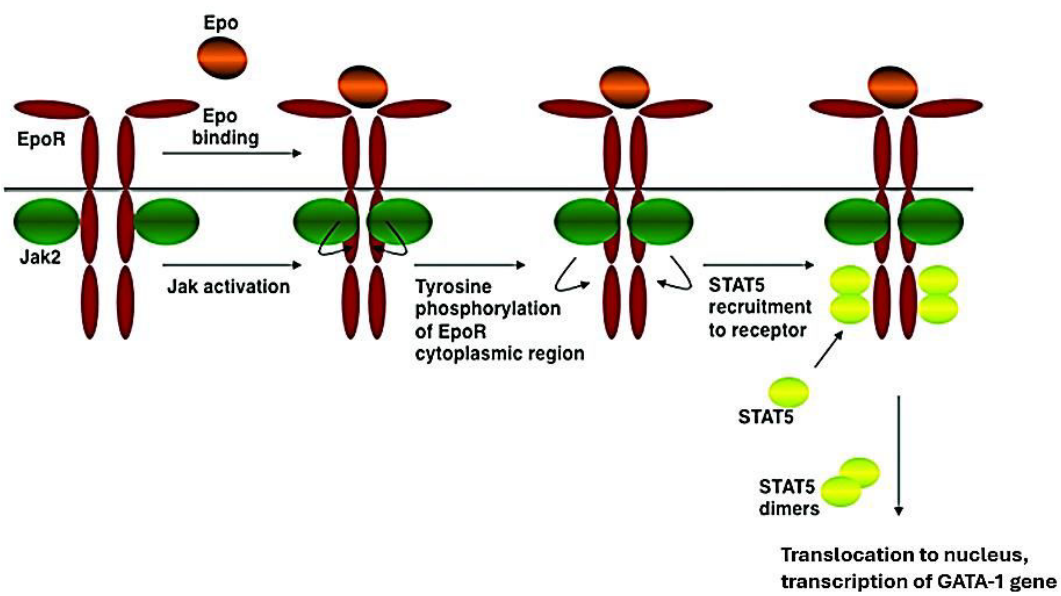

Fig. 1.5

(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]

(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]

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

....

....

....

....

....

....

.... [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]

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]

Question 2 continues on page 14.

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.

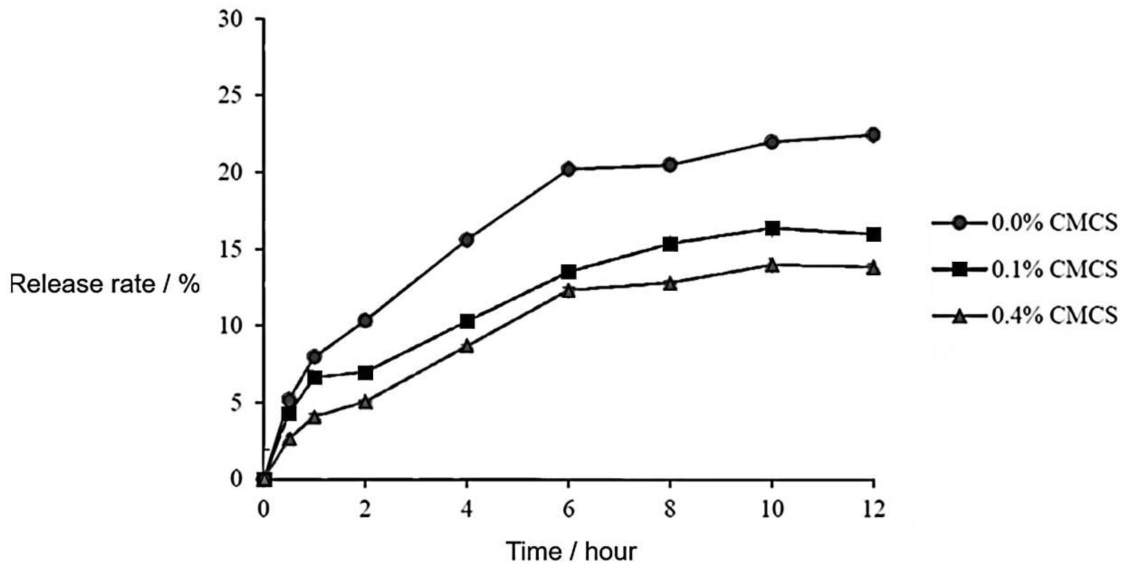

Fig. 2.1

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

....

....

....

....

.... [2]

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.

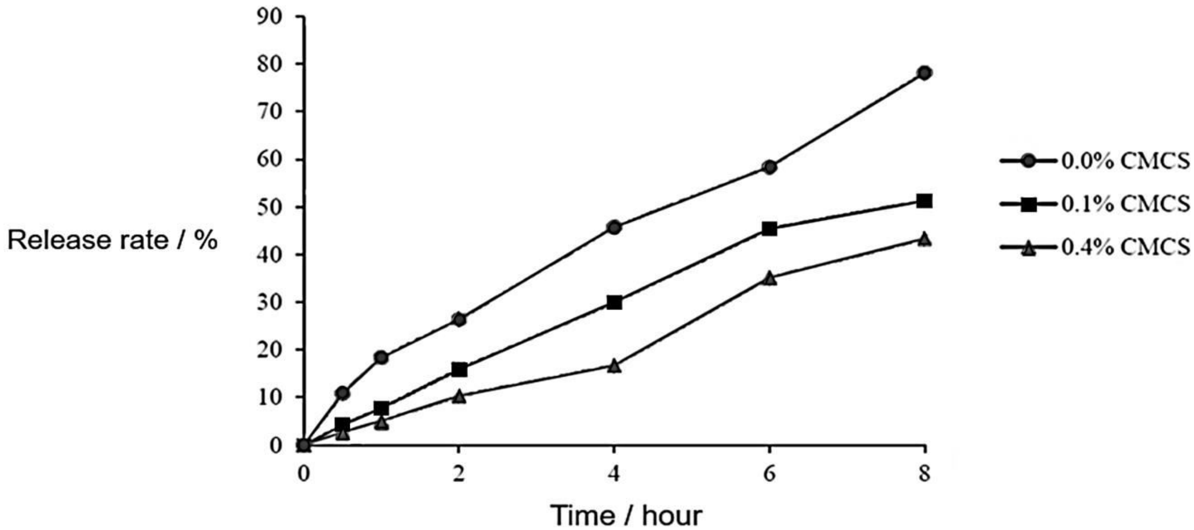

Fig. 2.2

(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]

[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.

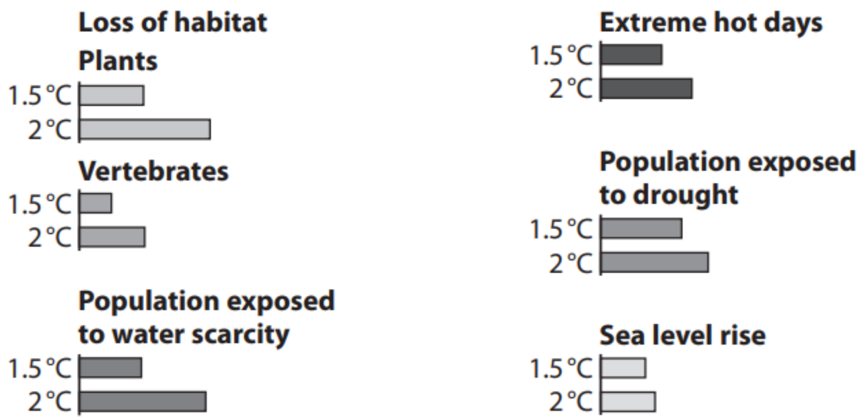

Fig. 3.1

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

....

....

.... [1]

(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.

....

[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]

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.

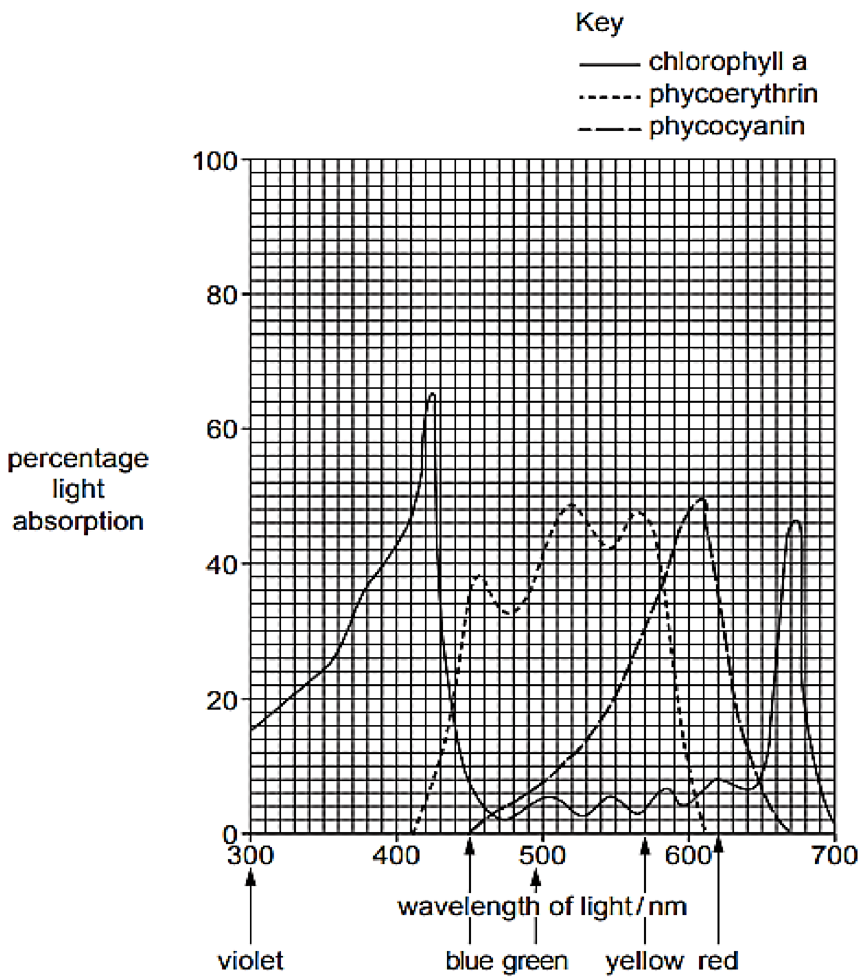

Fig. 3.2

(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]

(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]

[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]

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

[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]

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

[Total: 25]