NAME : _____ CLASS : _____

JURONG PIONEER JUNIOR COLLEGE
JC2 Preliminary Examinations 2023

BIOLOGY
Higher 2

9744/03
18 September 2023

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 **16** printed pages.

Section A

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

1 Reindeer are semi-domesticated ruminants that have adapted to challenging environment characterised by long winters and marked annual fluctuations in daylight. Comparative genome analyses revealed several genes that may have promoted the adaptation of reindeer, such as those involved in vitamin D metabolism (*POR*), circadian rhythm (*GR1A1*), and tolerance to cold-triggered pain (*SCN11A1*).

(a) A study was carried out to examine the gene involved in vitamin D metabolism (*POR*) and the POR enzyme, which is an important enzyme in the vitamin D metabolic pathway. Vitamin D is made in the skin under the influence of UV light and is important in promoting calcium absorption and the mineralisation of bone for the rapid and robust growth of the antlers, which are important for various aspects of reindeer behaviour and reproductive success.

Samples were taken from the reindeer, as well as roe deer and goats to examine for POR enzyme activity in a reconstituted system consisting of the enzyme and substrate.

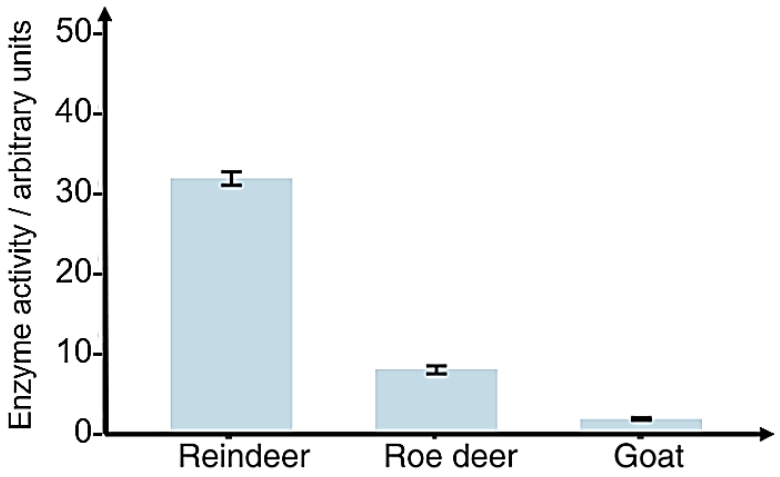

Fig. 1.1

With reference to Fig. 1.1, suggest how reindeer are able to produce sufficient vitamin D for their antler growth despite long winters with low amount of sunlight.

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(b) The reindeer do not exhibit 24-hour activity rhythms, and evidence suggests absent circadian activity, which is a useful adaptation in Arctic conditions.

Explain how DNA methylation and histone modification had altered the gene expression of *GR1A1*.

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Two subspecies of reindeer, *Rangifer tarandus*, live in North America. Members of the different subspecies belong to the same species but have some morphological differences and are found in different geographical locations.

Table 1.1 compares the features of the two North American reindeer subspecies.

Table 1.1

feature	woodland subspecies, *R. tarandus caribou*	barren ground subspecies, *R. tarandus groenlandicus*
habitat	southern woodland (warmer)	northern tundra (colder)
type of food	tree leaves, grass	lichens, moss
summer and winter feeding grounds overlap	yes	no
carry out long migrations	no	yes
body size	large	small
colour of fur	dark	light

(c) During the last ice age, an ice sheet separated southern and northern populations of *R. tarandus* to result in the two different subspecies.

Explain how this ice sheet affected the evolution of *R. tarandus* to result in the two different subspecies.

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(d) Assess the relative importance of natural selection and genetic drift in producing:

(i) the different colours of fur of the two subspecies of reindeer

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(ii) the different body sizes of the two subspecies of reindeer.

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(e) Hybridisation has occurred between individuals of the two subspecies which now live in the area previously covered by the ice sheet.

Comment on how the hybrid populations compare to the pure subspecies in terms of genetic variation and potential to adapt to climate change.

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(f) Outline how molecular techniques could be used to test the hypothesis that migratory behaviour in reindeer has a genetic basis.

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Question 1 continues on page 8

(g) Reindeer are currently listed as a vulnerable species by the International Union for Conservation of Nature (IUCN). Over the past 200 years, many species of animals and plants have become extinct.

Fig. 1.2 shows the changes between the years 1800 and 2000 in:

- the number of species becoming extinct
- the size of the world human population.

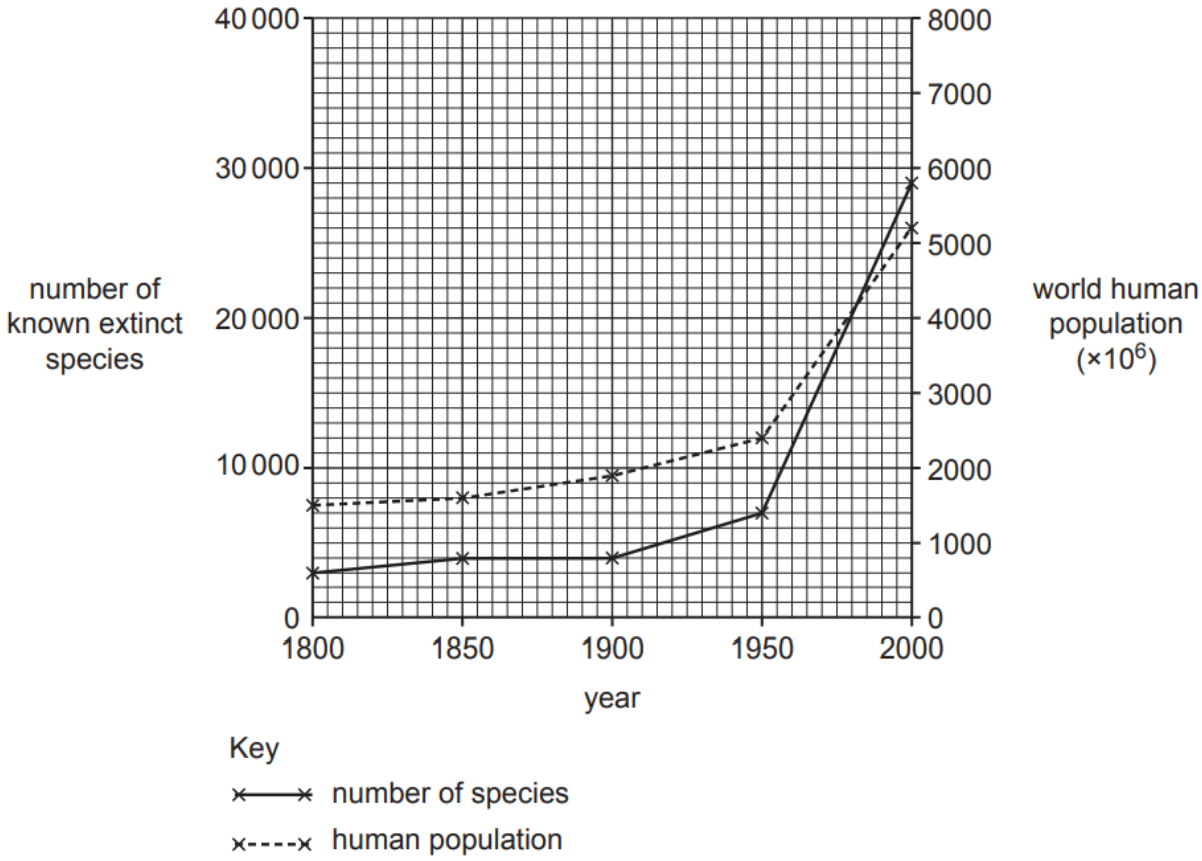

Fig. 1.2

(i) It has been suggested that there is a correlation between the number of species becoming extinct and the size of the world human population.

Suggest reasons for this possible correlation.

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(ii) Calculate the rate of species extinction per year between 1950 and 2000.

Show your working.

answer = ... species per year
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(h) Extinction of animal and plant species reduces biodiversity.

Outline why it is important to maintain biodiversity.

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[Total: 30]

2 Yeast cells respond to changes in glucose concentration in their environment by using transcription factors to switch off genes.

When glucose is present:

- Mig1 transcription factors bind to the promoters of five genes
- Mig1 binding to the promoters stops transcription of these genes. The genes that are repressed by Mig1 code for five enzymes that allow yeast cells to metabolise the sugar galactose when glucose is absent.

(a) Mig1 binds to Mig1-binding promoter sites with these features:

- 17 base pairs long
- includes a region of five repeating adenine-thymine pairs
- includes a region of six repeating cytosine-guanine pairs.

Bioinformatic techniques were used to analyse the yeast genome to look for sections of DNA that match these features. Bioinformatics involves utilising computer technology to manage biological information. The information obtained for four chromosomes is shown in Table 2.1.

Table. 2.1

yeast chromosome	chromosome size /base pairs	number of Mig1-binding promoter sites per chromosome
A	230018	1
B	813184	10
C	316620	2
D	1531933	14

(i) Suggest why bioinformatic techniques were used to obtain the information in Table 2.1.

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(ii) Identify, with a reason, the yeast cell chromosome that is most likely to include genes that code for enzymes that metabolise galactose.

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(iii) Mig1 binds to 27 promoters on these four chromosomes. Yeast cells also have other chromosomes where Mig1 binds to additional promoters.

Five different enzymes, coded by five genes, must be made for yeast cells to metabolise galactose.

Suggest why a diploid yeast cell has a larger number of Mig1-binding promoter sites than the expected number of ten.

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(b) The repression of genes involved in galactose metabolism in yeast is similar to events at the *lac* operon in the bacterium *Escherichia coli*.

Explain how *E. coli* represses the production of proteins needed to metabolise lactose.

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(c) In an investigation into the growth of *E. coli*, a sample of the bacterium was grown in a medium that contained limited concentrations of glucose and lactose. The population size of *E. coli* was measured at regular intervals.

Fig. 2.1 shows the population growth curve obtained for this investigation.

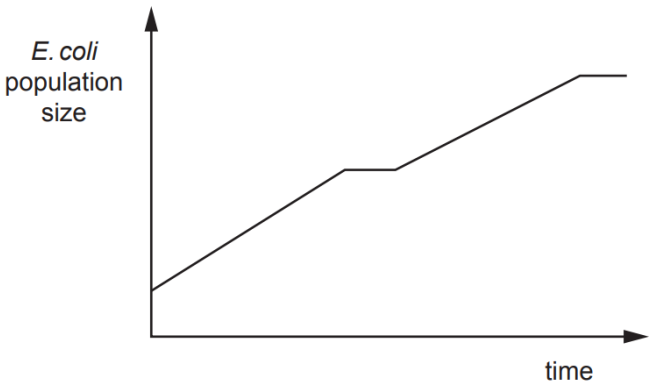

Fig. 2.1

Describe and suggest explanations for the population growth curve shown in Fig. 2.1.

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3 Fig. 3.1 shows the seaweed *Laminaria hyperborea*. This is a photosynthetic protoctist found in the coastal waters around Norway. The seaweed is grown commercially to obtain the glucose polysaccharide called alginate. This is used in certain food products.

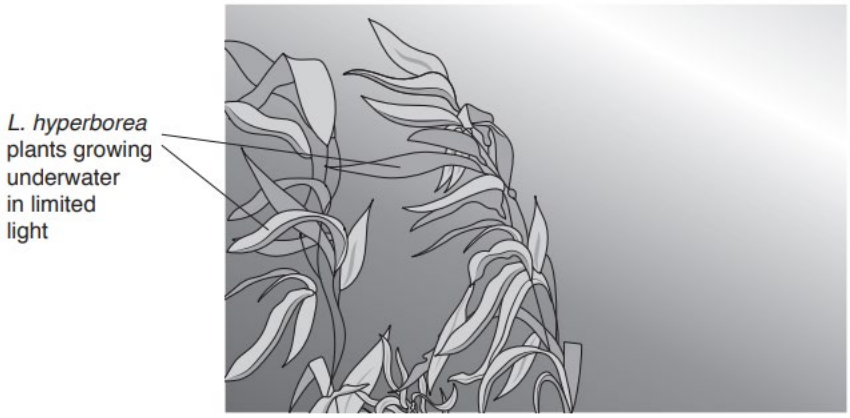

Fig. 3.1

An increase in carbon dioxide concentration in the atmosphere has resulted in higher concentrations of carbon dioxide in the ocean. This has caused a decrease in the pH of the ocean and has resulted in ocean acidification.

Scientists are studying seaweeds such as *L. hyperborea* because they absorb a large quantity of carbon dioxide during photosynthesis. This may help to increase the pH of the ocean and reverse ocean acidification.

(a) Outline the reactions occurring in the stroma that lead to the production of a polysaccharide, such as alginate.

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(b) Laboratory experiments were carried out to investigate the effect of day length on the rate of photosynthesis in another marine autotroph, *Zostera marina*.

- The temperature was controlled at 4°C.
- A low concentration of carbon dioxide dissolved in the water was used.
- The light exposure period (day length) was different for five groups of *Z. marina*.
- This was maintained for 10 days to allow *Z. marina* to adapt to these conditions.
- After 10 days, the rate of photosynthesis was measured for each group under the same controlled conditions.
- The experiment was repeated using five groups of *Z. marina* with a high concentration of carbon dioxide dissolved in water.

Table 3.1 shows the rate of photosynthesis for each group.

Table 3.1

day length / hours	rate of photosynthesis / arbitrary units	
	low carbon dioxide concentration	high carbon dioxide concentration
12	2.0	2.5
14	3.0	5.0
16	4.0	7.0
18	5.5	11.0
20	7.5	18.0

(i) With reference to Table 3.1, explain the difference in the rate of photosynthesis at high carbon dioxide concentration compared to low carbon dioxide concentration.

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(ii) With reference to Table 3.1, describe and explain the effect of increasing day length on the rate of photosynthesis for the *Z. marina* in high carbon dioxide concentration.

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(c) In the laboratory, a seaweed was grown in water with different pH values. All other variables, including temperature and light, were standardised. The mean rate of photosynthesis was calculated over a 24 hour period for each pH value. The results are shown in Fig 3.2.

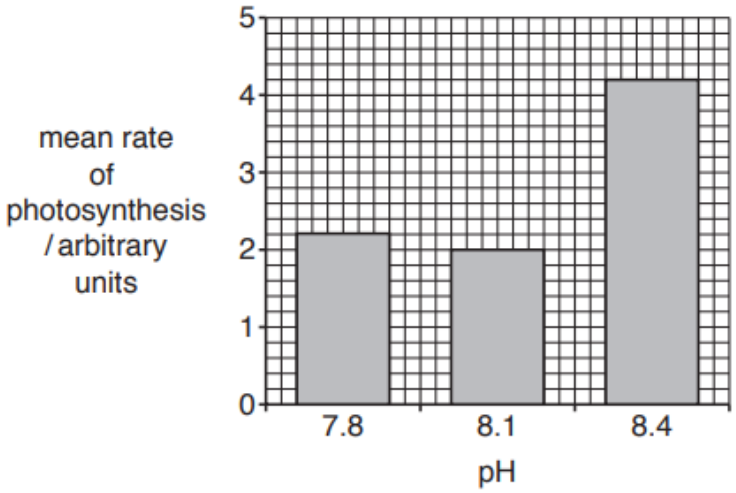

Fig. 3.2

The lower pH values on Fig. 3.2 represent ocean acidification.

Suggest why the results for the lower pH values do not fully support the idea that seaweeds can help to reduce ocean acidification.

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[Total: 10]

Section B

Answer **one** question in this section.

Write your answers on the 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)** Describe the roles of enzymes in the synthesis of a functional protein in eukaryotic cells. [15]

(b) Compare the interaction between a hormone and a cell surface receptor with the interaction between a substrate and an enzyme. [10]

[Total: 25]

5 **(a)** Explain why variation is important in natural selection and outline the sources of variation in eukaryotes. [15]

(b) Outline the main differences between prokaryotes and eukaryotes in terms of their cell structure and outline their evolutionary relationship. [10]

[Total: 25]