NAME: _____ CLASS: _____ INDEX: _____

CATHOLIC JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION
Higher 2

BIOLOGY
STRUCTURED QUESTIONS

9744/02
21 August 2023
2 hours

READ THESE INSTRUCTIONS FIRST

Write your **name (as per NRIC)**, **class**, and **index number** on all the work you hand in.

Write in dark blue or black pen on both sides of the paper.

[PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]

You may use a soft pencil for any diagrams, graphs or rough working.

Do not use staples, paper clips, highlighters, glue or correction fluid.

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

There are **11 questions with multiple subparts** in this paper.

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

For Examiner's Use	
Total	100
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	

Answer **all** questions

1 **(a)** *Thermotoga maritima* is a hyperthermophilic species of bacterium that lives in hot springs and thermal vents associated with volcanic activities. The bacteria can survive in waters at 80°C.

Two amino acids found in the primary structure of an enzyme in the bacterium are shown below:

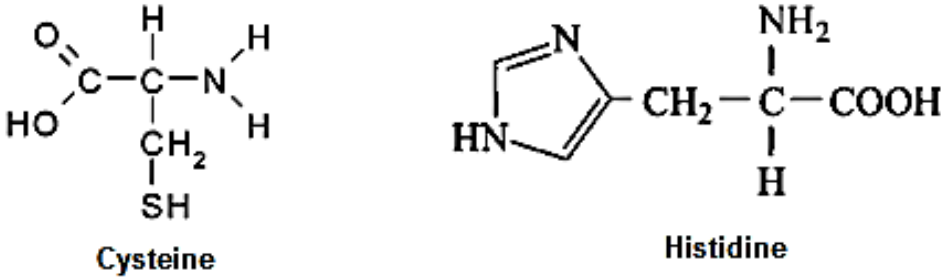

Fig. 1.1

(i) Part of the sequence of amino acids in the enzyme consist of Cys-His.

Draw a labelled diagram of the dipeptide that would result during this condensation. [2]

(ii) "Cysteine is found to be more common than most other amino acids in the *Thermotoga maritima* enzyme compared to those found in other species".

Suggest why this may be so.

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…… [2]

(b) Fig. 1.2 shows an example of one of the enzymes in *Thermotoga maritima*.

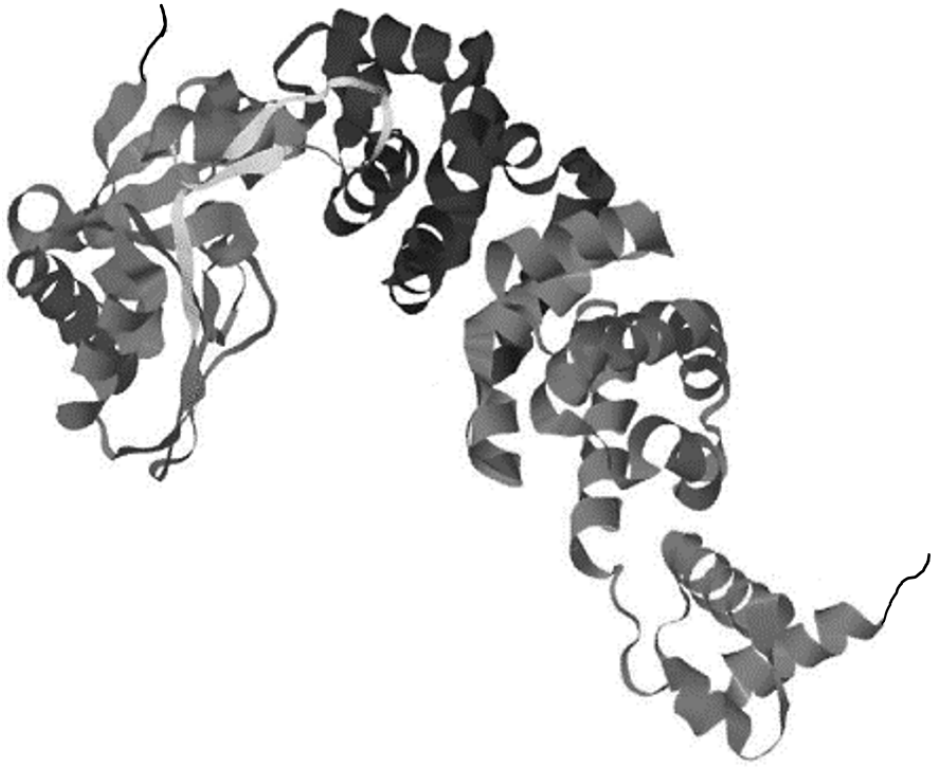

Fig. 1.2

With reference to the enzyme shown in Fig. 1.2,

(i) state the highest level of protein structure.

……..…….... [1]

(ii) identify the predominant secondary structure.

……..…….... [1]

(iii) describe how the structure of this enzyme is maintained by various bonds.

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(c) Fig. 1.3 shows the effect of ATP on enzymatic activity of the enzyme found in *Thermotoga maritima*.

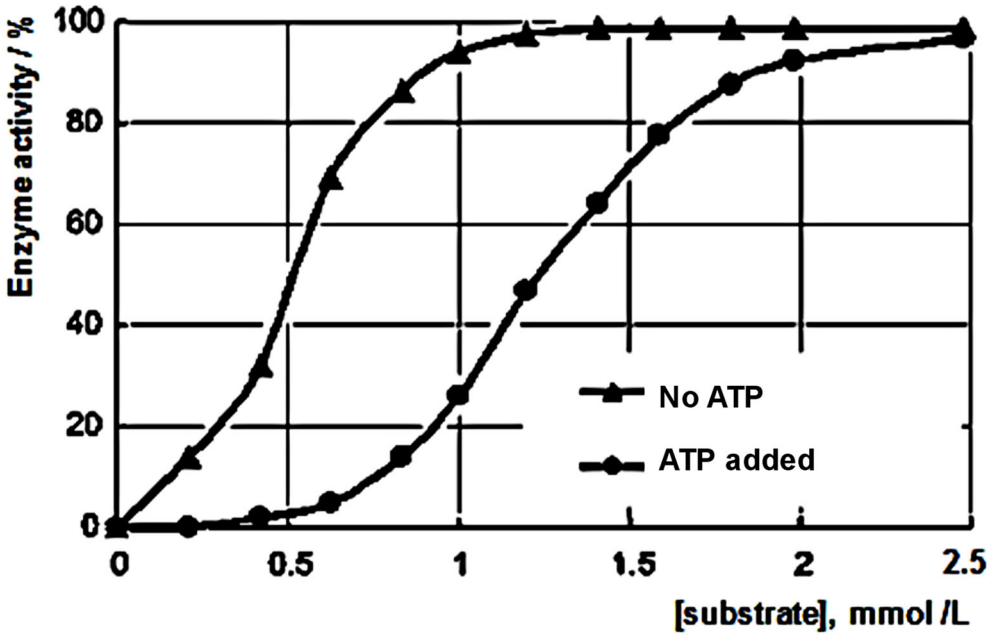

Fig. 1.3

(i) With reference to Fig. 1.3, state the type of inhibition ATP exerts on the enzyme from *Thermotoga maritime*. Explain how you derived at your answer.

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……... [2]

(ii) With reference to Fig. 1.3, describe the effects of ATP on enzymatic activity of *Thermotoga maritima*.

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……... [3]

[Total: 14]

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2 Glucose transporter type 4 (GLUT4) is an example of a carrier protein that transports glucose across the plasma membrane of muscle cells.

Fig. 2.1 below illustrates the steps involved in the transport of glucose by GLUT4 across the plasma membrane of a muscle cell.

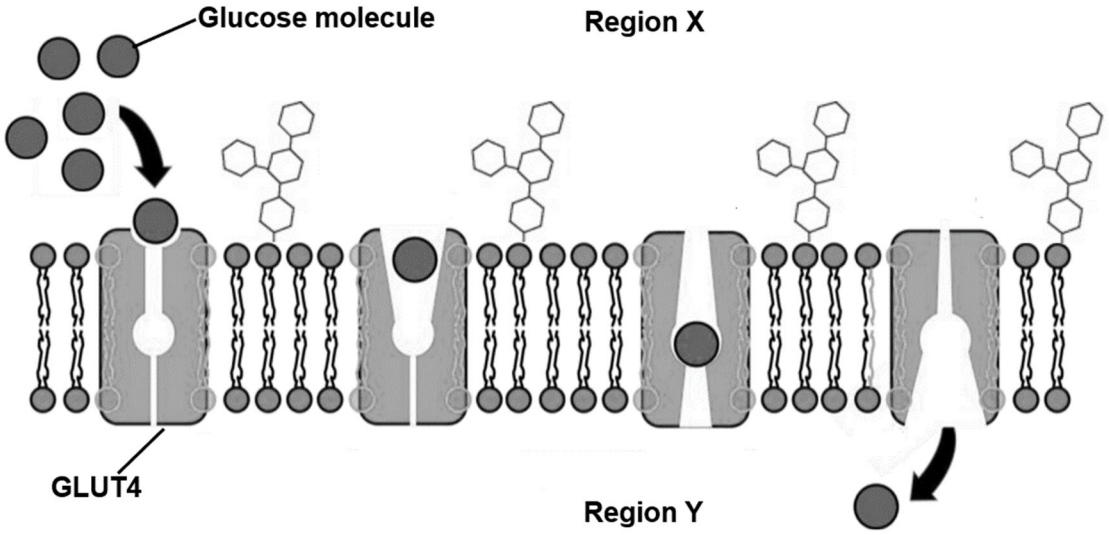

Fig. 2.1

With reference to Fig. 2.1,

(a) name the type of transport that is used to transport glucose across the plasma membrane.

…….. [1]

(b) provide two reasons for your answer in part **(a)**.

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…….. [2]

(c) explain how glucose is transported across the plasma membrane by GLUT4.

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…….. [2]

(d) **Region X** is the extracellular fluid and **Region Y** is the cytoplasm of a muscle cell. Do you agree? Justify your answer.

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…….. [1]

An experiment was conducted to investigate the effect of glucose concentration on the rate of movement of glucose across the plasma membrane of muscle cells.

(e) Based on the information in Fig.2.1, sketch a graph of the result of the experiment. [1]

Explain your answer:

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…….. [1]

[Total: 8]

3 **(a)** State how **one** structural feature of DNA contributes to its stability as a hereditary material.

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…… [1]

The "trombone" model of DNA replication postulates that two DNA polymerase enzymes work together in a protein complex during DNA replication.

Fig. 3.1 shows a DNA molecule undergoing DNA replication.

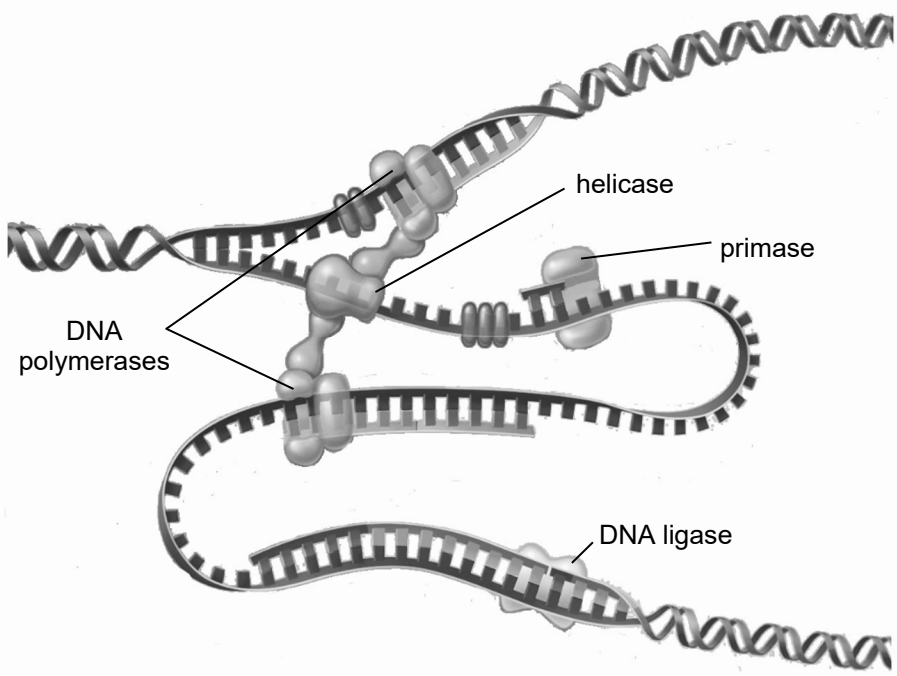

Fig. 3.1

(b) With reference to Fig. 3.1,

(i) compare how the synthesis of the lagging strand differs from that of the leading strand.

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…… [2]

(ii) suggest why it is necessary for two DNA polymerase enzymes to work together in a protein complex during DNA replication.

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…… [2]

(c) Explain how the end replication problem arises.

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…… [2]

[Total: 7]

4 Nucleolus is a large and dense region inside the nucleus. It consists of a fibrous part and a granular part. The large and small ribosomal subunits can be found within the granular part.

(a) Based on the information above as well as your knowledge on transcription and translation, outline how ribosomes are formed.

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…… [4]

Gene expression in eukaryotic cells is regulated at multiple levels.

Transferrin receptors (TfRs) are cell surface receptors and are involved in the uptake of extracellular iron.

The regulation of expression of transferrin receptors (TfRs) is illustrated in Fig. 4.1.
It involves the interaction between Iron Response Element-Binding Protein (IRE-BP) and Iron Response Element (IRE) which is a loop structure found on the mRNA.

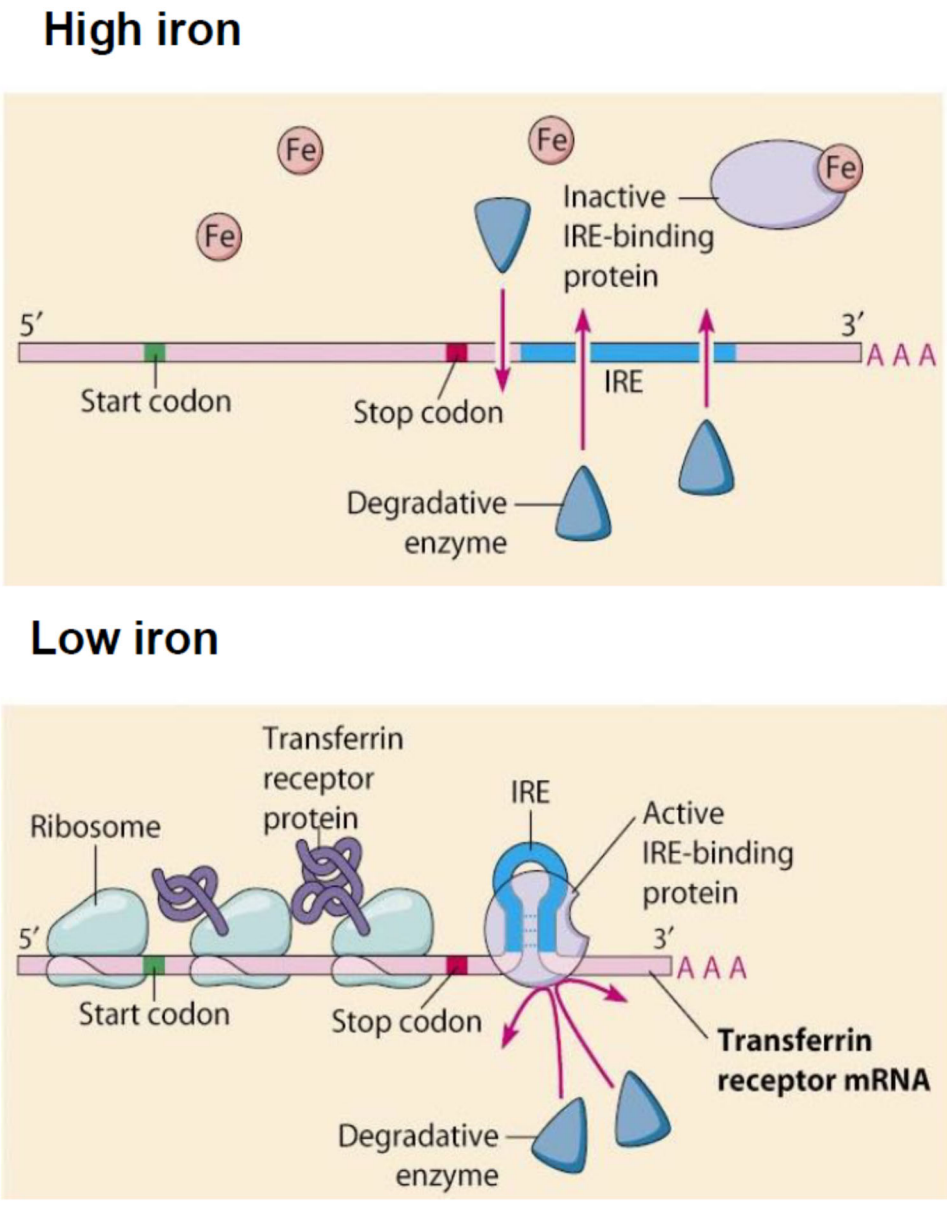

Fig 4.1

With reference to Fig 4.1.,

(b) (i) state the level of regulation shown.

……..……... [1]

(ii) explain how low cytosolic iron concentration results in an increased uptake of extracellular iron.

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…… [4]

Another example of a protein, Ferritin proteins; are involved in the storage of iron taken into the cell by TfRs.

The regulation of ferritin expression is illustrated in Fig. 4.2.

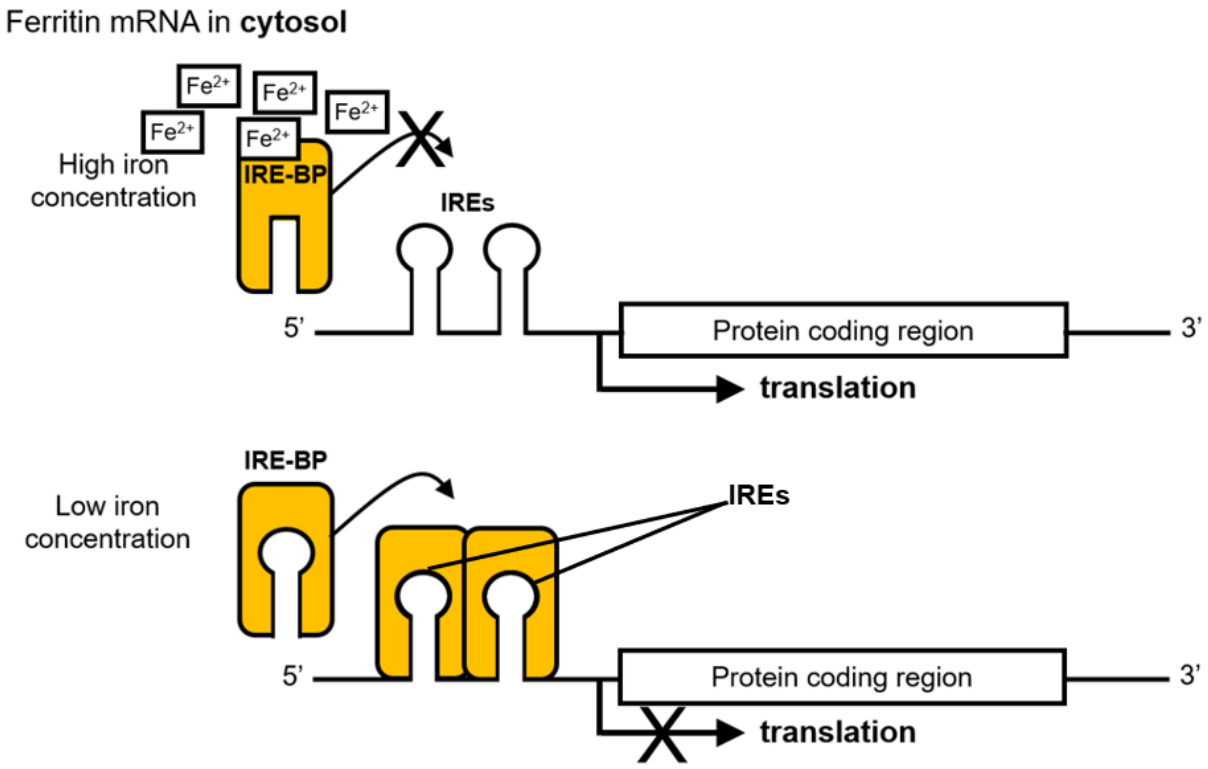

Fig 4.2

(c) Outline two differences in the regulation of ferritin and TfR expression.

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…… [2]

[Total: 11]

5 **(a)** Fig. 5.1 below shows a 18kb piece of DNA with positions of the restriction sites for restriction enzyme ***HaeIII***.

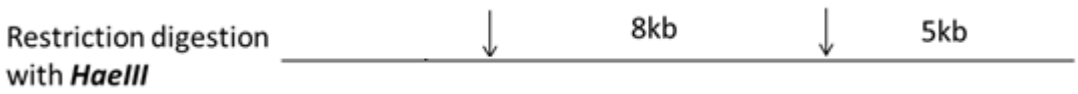
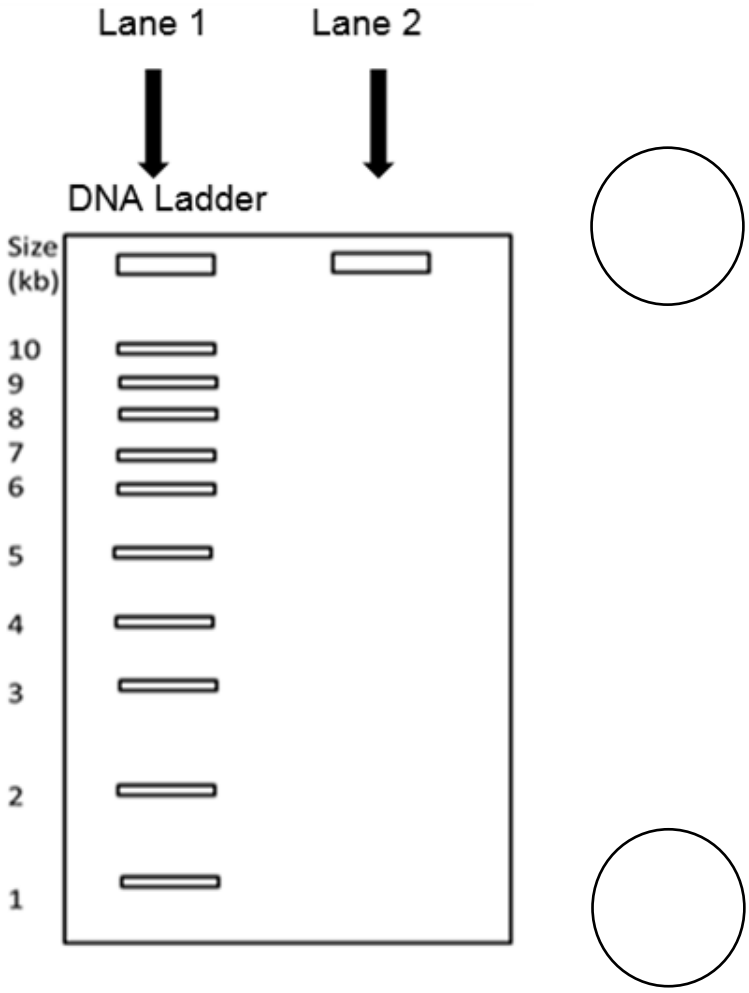


Fig 5.1

A restriction digestion using ***HaeIII*** enzyme was performed, followed by gel electrophoresis.

A DNA ladder, which is a set of DNA fragments of known lengths, is used to estimate the size of unknown DNA molecules, in lane 1.

On the diagram below,



(i) label the electrode / terminus with "**+**" or "**–** " in the circles provided. [1]

(ii) show the band pattern of the sample after the restriction digestion and gel electrophoresis in **lane 2**. [2]

(b) Explain how the separated DNA bands in the agarose gel can be visualised.

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…… [2]

(c) Sometimes, DNA bands do not appear as distinct bands but as a smear instead.

Fig. 5.2. shows an example of the smear.

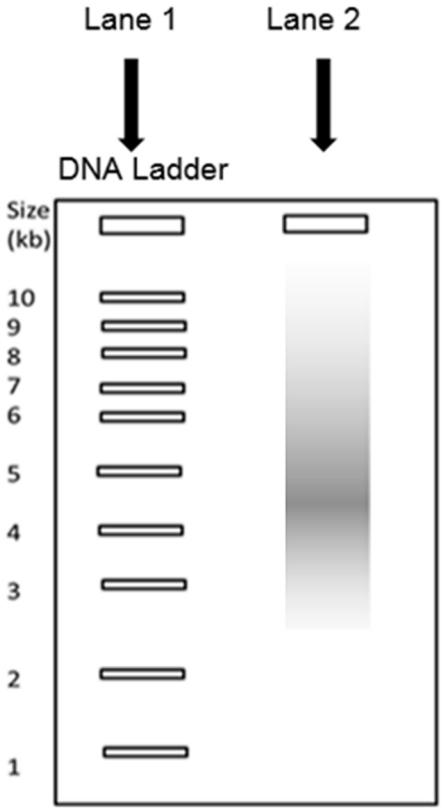

Fig 5.2

Suggest how the smear in Fig. 5.2 is formed.

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…… [2]

(d) Polymerase Chain Reaction (PCR) is a molecular technique commonly performed before agarose gel electrophoresis.

Discuss the advantage and limitation of PCR.

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…….. [2]

[Total: 9]

6 Pineapples have three types of leaves: spiny, spiny-tipped and non-spiny.

There are two gene loci involved in the formation of leaves in pineapple, the loci for **A**/**a** and **B**/**b** respectively.

The presence of allele **B** results in the formation of spiny-tipped leaves, while the presence of allele **b** results in the formation of spiny leaves.

The presence of allele **A** will prevent the formation of spiny-tipped leaves as well as spiny leaves.

In a particular study, homozygous plants were crossed to produce the F1 generation, which were then allowed to interbreed with the following results:

(a) Complete the table below. [2]

Cross	**Phenotypes**		
	Parents	**F_1 Ratio**	**F_2 Ratio**
1	**non-spiny X spiny**	**All non-spiny**	**12 non-spiny: 3 spiny-tipped: 1 spiny**
2	**spiny X spiny**		
3	**spiny tipped X spiny**		

(b) Draw a genetic diagram to explain cross 1. [5]

Fig. 6.1 below shows the inheritance of colour blindness.

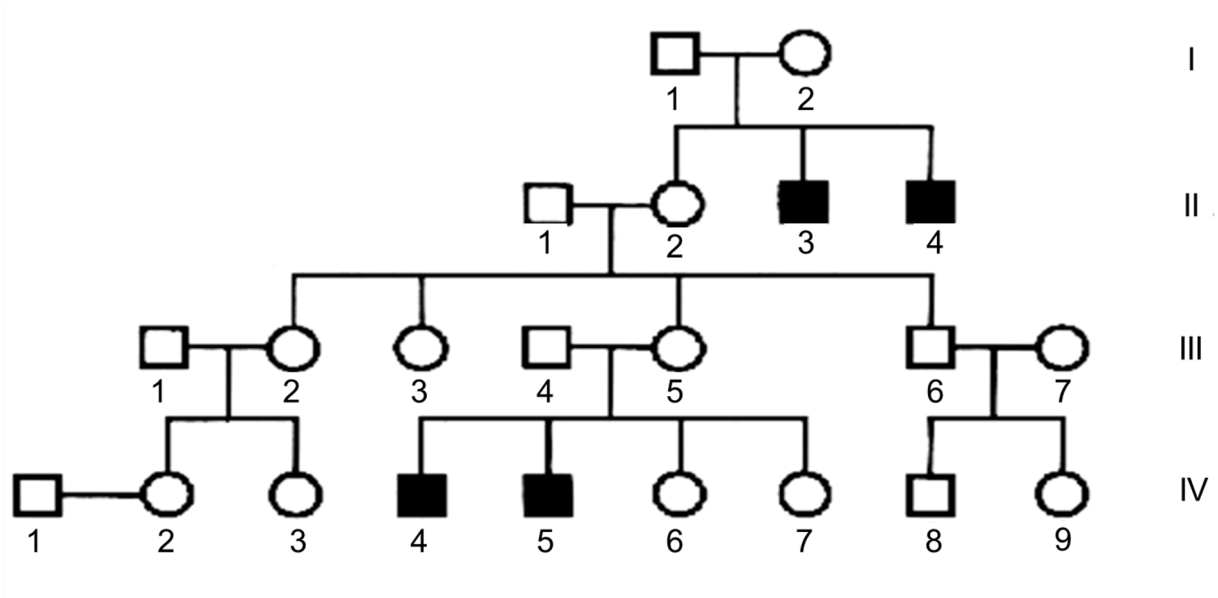

Fig 6.1

With reference to the Fig.6.1**,**

(c) explain the mode of inheritance of colour blindness.

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…… [2]

(d) Calculate the probability that the offspring of individual **Gen IV-1** and individual **Gen IV-2**, is a carrier. Show your working. [2]

[Total: 11]

7 Arabinose operon (*ara* operon) is an example of operon in *Escherichia coli*.

This operon has three structural genes, *araB*, *araA* and *araD*, which 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. These genes are not normally expressed in *E. coli*. However, when arabinose is present in the environment, the three Ara enzymes are produced.

(a) Based on the information above, state if the *ara* operon is an inducible or repressible system.

……... [1]

Fig. 7.1 shows the structure of the *ara* operon as well as its regulatory genes.

The promoter site is situated within *araI* and the CAP site (CAP-binding site) is the site where cAMP-CAP binds.

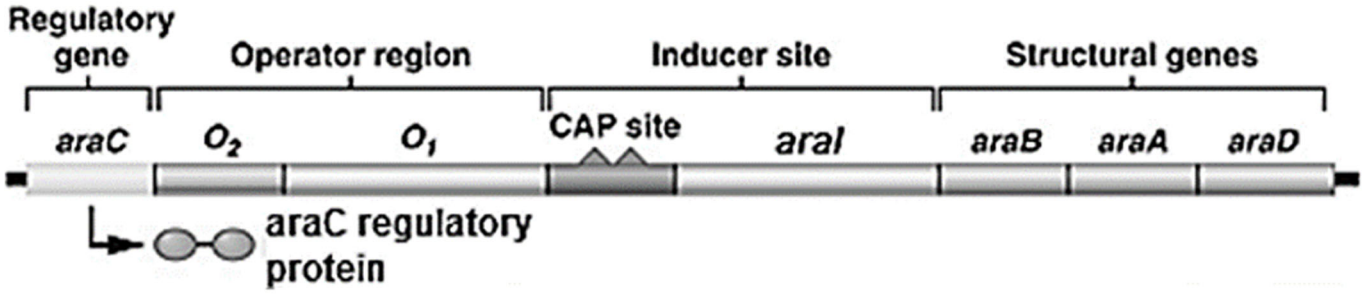

Fig. 7.1

(b) Compare the structure of the *ara* operon and *lac* operon.

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…… [4]

The *ara* operon has both positive and negative regulation, being activated in the presence of arabinose. This is illustrated in Fig. 7.2 below.

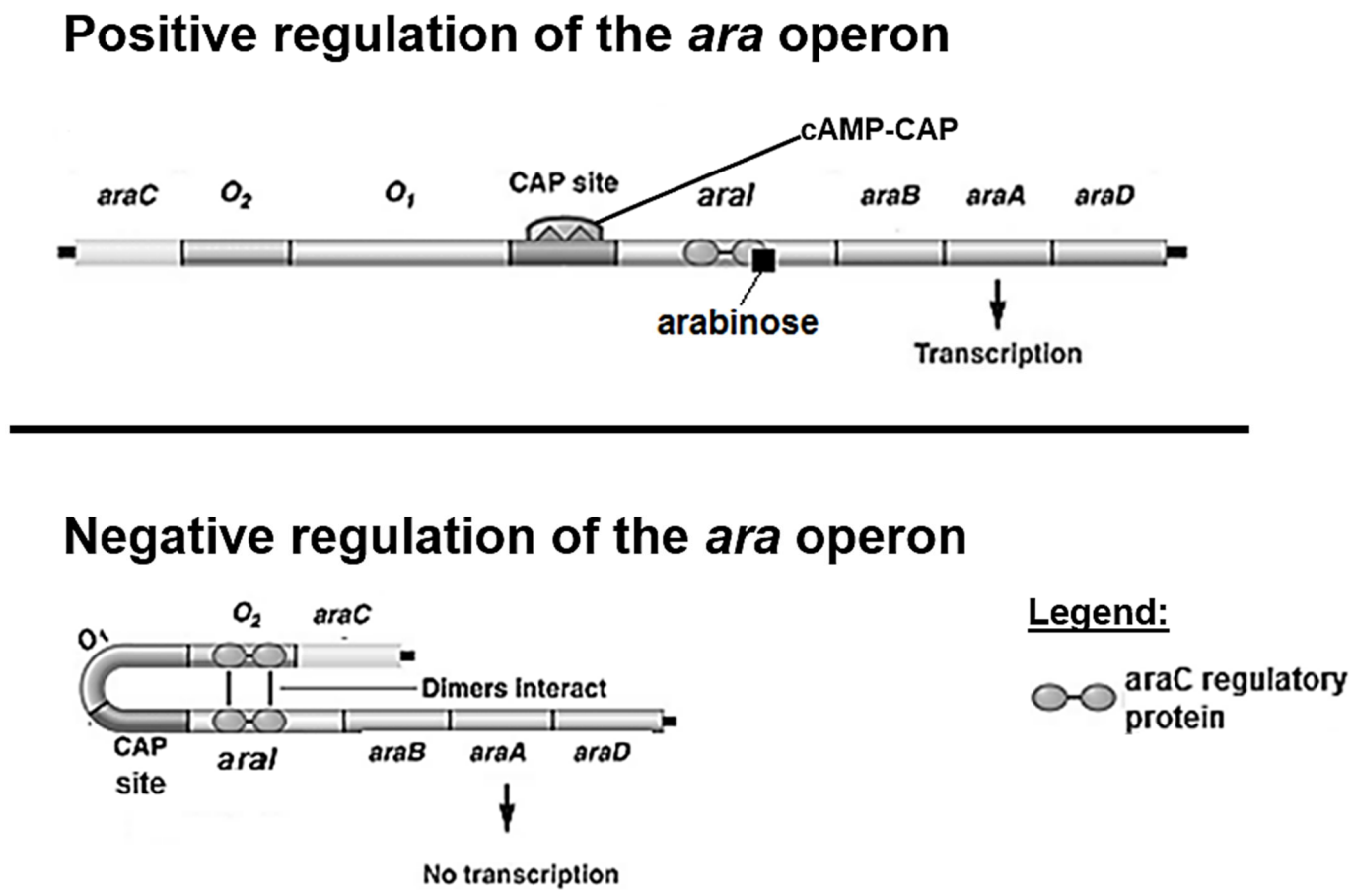

Fig. 7.2

With reference to Fig. 7.2,

(c) Describe and explain the **positive** regulation of the *ara* operon.

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…… [3]

(d) Contrast the **negative** regulation of the *ara* operon with that of the *lac* operon.

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…… [2]

(e) A deletion occurred at the beginning of the ***araA*** gene.
Predict the effect of this deletion on the gene product of the downstream structural gene, ***araD***.
Explain your answer.

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…… [2]

[Total: 12]

8 Fig. 8.1 shows a classic experiment used to show that physical contact between bacterial cell is necessary for conjugation to happen.

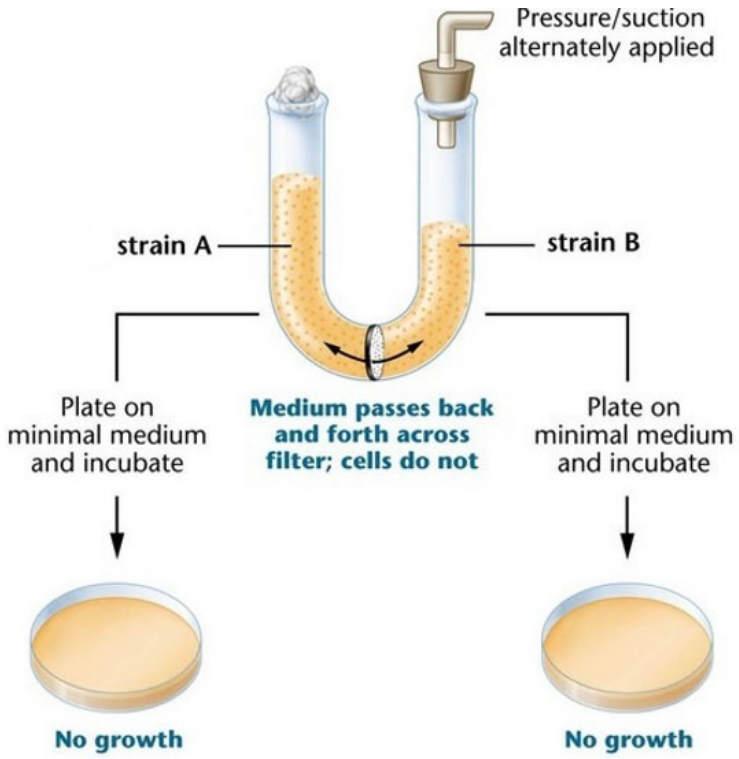

Fig. 8.1

A student tried to replicate the experiment but did not get the result shown in Fig. 8.1.

Instead, he observed a few bacterial colonies which are hybrids of strains A and B. Afterwards, he realised that he forgot to add in DNase when carrying out the experiment.

(a) Briefly describe the role of DNase in this experiment.

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…… [1]

(b) How does the lack of DNase in the experiment result in the growth of the hybrid bacterial colonies?

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…… [2]

The student above repeated the experiment, this time with DNase added. However, he continued to observe a few bacterial colonies which are hybrids of strains A and B.

The student confirmed that the filter was undamaged and there was no cross contamination between bacterial strain A and B.

(c) Suggest how bacterial colonies which are hybrids of strains A and B could have been obtained in the repeated experiment. Explain your answer.

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…… [2]

Bacteria reproduce asexually via binary fission to produce genetically identical daughter bacterial cells. Nevertheless, binary fission is considered one of the processes contributing to the extensive genetic variation in bacteria.

(d) Explain how binary fission contributes to the extensive genetic variation in bacteria.

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…… [2]

[Total: 7]

9 In a recent scientific expedition to study a vulnerable species of the cat family (*Felidae*), it was found that this species seemed to be heading for extinction. This species once spanned the globe, but its range is now limited to a few pockets in Africa. It was suggested that the species had somehow lost its genetic variation.

(a) Explain what is meant by a "species".

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…… [2]

(b) Explain the impact that low genetic variability in a population of this species has on its survival.

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…… [2]

(c) It was shown that different species of the cat family no longer interbreed.

Suggest and explain two reasons why interbreeding was not possible.

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…… [3]

Another species that is often found together with the cats is the zebra (*Equus grevy*i). The ancestors of zebra were known to be small black horses that thrived in thick forest vegetation.

In Africa, the presence of the Tsetse flies was a threat to the animal population, causing conditions like the African sleeping disease.

(d) Explain how the presence of the Tsetse flies affected the evolution of zebra.

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…… [3]

[Total: 10]

10 Helper T cells play a pivotal role in fighting against infection in our body.

Fig. 10.1 illustrates the change in concentration of Helper T cells in an infection.

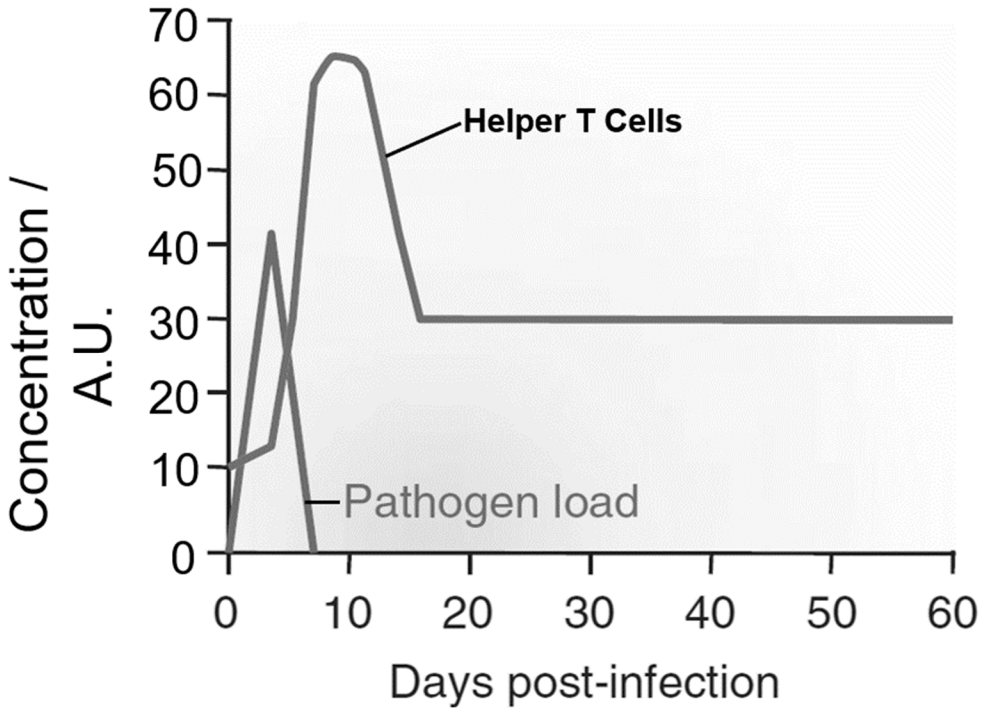

Fig. 10.1

(a) Describe the change in the concentration of Helper T cells from 0 to 20 days post-infection.

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…… [3]

(b) Explain how the change in concentration of Helper T cells affect the concentration of pathogen from 3 days post-infection onwards.

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…… [2]

(c) Based on Fig.10.1, suggest if this is the first time the person is infected with this pathogen. Justify your answer.

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…… [1]

[Total: 6]

11 Global warming has changed both the thickness and surface area of sea ice of the Arctic Ocean as well as the Southern Ocean that surrounds Antarctica. Sea ice is highly sensitive to changes in temperature.

Scientists have calculated a long-term mean for the surface area of sea ice in the Arctic Ocean and in the Southern Ocean around Antarctica. This mean value is used as a reference to examine changes in ice extent.

Fig. 11.1 shows the variations from this mean (zero line) over a period of time.

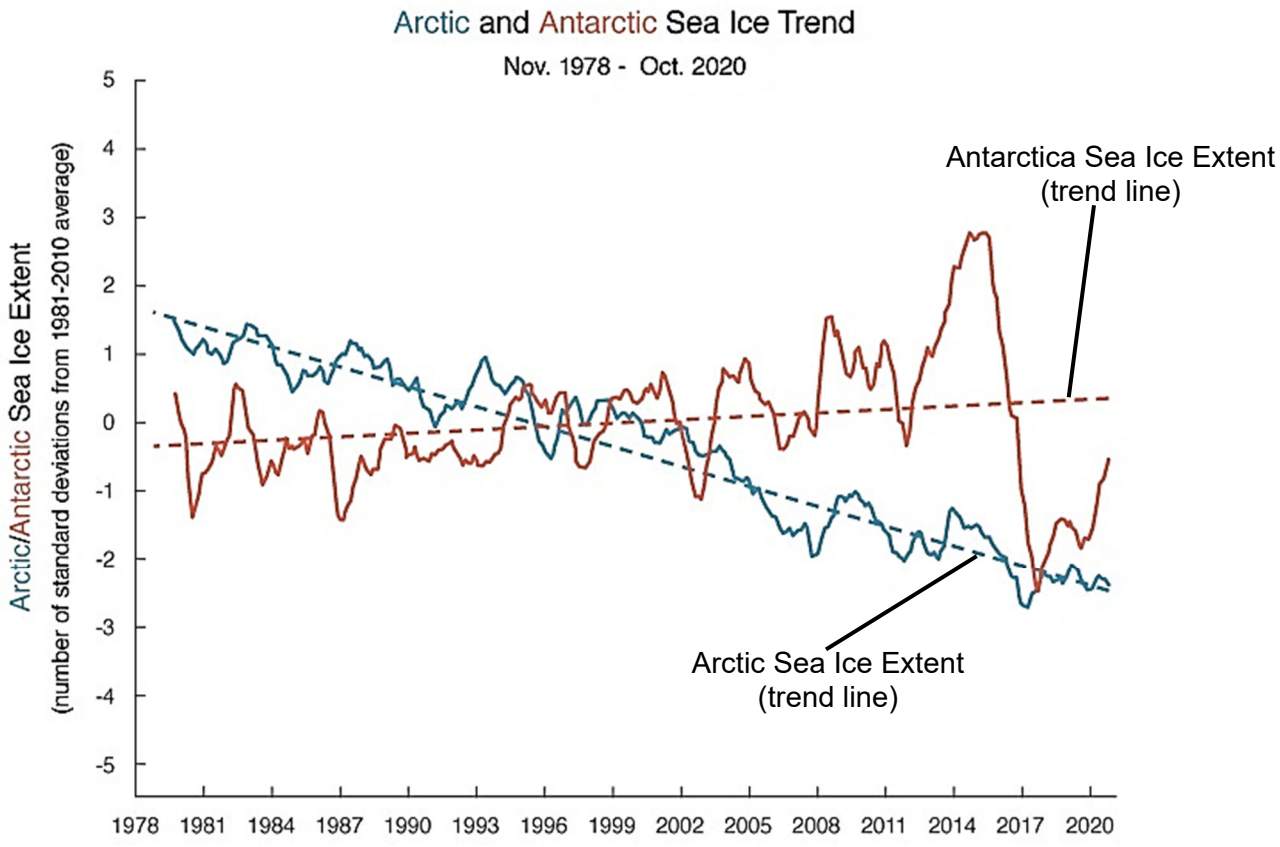

Fig. 11.1

(a) Distinguish between changes in the surface area of sea ice in the Arctic and Antarctica.

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(b) Discuss the data as evidence of global warming.

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[Total: 5]

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