H

TEMASEK JUNIOR COLLEGE

2024 JC2 PRELIMINARY EXAMINATION

Higher 2

TEMASEK JUNIOR COLLEGE

CANDIDATE NAME									
CENTRE NUMBER	S					INDEX NUMBER			

BIOLOGY

9744/03

Paper 3 Long Structured and Free Response Questions

9 SEPTEMBER 2024

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Center number, index number 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.
DO **NOT** WRITE IN ANY BARCODES.

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

Section B
Answer any **one** question in spaces provided on the Question Paper.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show any working or if you do not use appropriate units.

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

For Examiner's Use	
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2	/ 11
3	/ 11
4 / 5	/ 25

This document consists of **25** printed pages and **3** blank pages.

Answer **all** questions in this section.

1 Tuberculosis (TB) is an infectious disease caused by the bacterium.

(a) Define the term infectious disease.

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…… [1]

(b) State the name of the pathogenic organism which causes TB and describe its mode of transmission.

Name of organism …… [1]

Mode of transmission ……..

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…… [1]

(c) One example of a defence mechanism against pathogens in the lungs involves the action of macrophages.

(i) State the location in the body where macrophages are formed.

…… [1]

(ii) Outline the mode of action of a macrophage.

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…… [2]

(iii) It is sometimes possible for the pathogenic bacteria to survive within macrophages.
Suggest **one** way in which these pathogenic bacteria may survive within a macrophage.

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…… [1]

(iv) The TB bacterium has many operons in its DNA. Suggest **one** advantage to the bacterial cell in having operons.

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…… [1]

Table 1.1 shows recent information about TB cases reported during one year in six different countries.

Table 1.1

country	region	number of cases	number of cases per 100 000 population
Germany	Europe	4000	5
India	Asia	2 300 000	185
Japan	Asia	27 000	21
South Africa	Africa	490 000	981
Swaziland	Africa	15 000	1287
United Kingdom	Europe	7900	13

(d) With reference to Table 1.1, explain the advantage of calculating the number of cases of TB per 100 000 population rather than stating the number of cases alone.

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…… [2]

Antibiotics are prescribed to people who have HIV for the treatment of secondary infections such as bacterial infections.

(e) Explain why antibiotics are prescribed to treat secondary infections, but not for HIV infection.

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…… [2]

Antibiotic rifampicin is observed to bind tightly to RNA polymerase molecule close to its active site.

This affects the activity of the enzyme during the synthesis of RNAs, involving the action of RNA polymerase.

(f) Suggest **two** ways in which rifampicin can affect the activity of RNA polymerase.

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…… [2]

Question 1 continues on page 6.

(g) RNA polymerase is composed of five different polypeptides. Gene *rpoB* codes for one of these polypeptides known as the β-subunit.

- One or more mutations in a specific region of *rpoB* gene result in strains of TB bacteria that are resistant to rifampicin.
- In these strains, mutations often occur in two DNA triplets, in positions 526 and 531.

Table 1.2 summarises the results of an investigation into seven rifampicin-resistant strains, **A** to **G**, that have amino acid changes for positions 526 and 531.

Table 1.2 includes:

- the change in the **mRNA codon** for position 526 or position 531
- the amino acid change that has occurred
- the **minimum** concentration of rifampicin required to inhibit growth of the bacterial strain (MIC)
- the number of **other** mutations occurring within the specific region of *rpoB* gene.

Table 1.2

Key
≈ approximately ⩾ greater than or equal to ⩽ less than or equal to

strain	codon involved	mRNA codon change	amino acid change	MIC / $\mu g\,cm^{-3}$	number of other mutations in the specific region
A	526	CAC → UAC	His → Tyr	⩽50	0
B	526	CAC → AAC	His → Asn	⩾100	1
C	526	CAC → CGC	His → Arg	≈50–75	2
D	526	CAC → CGC	His → Arg	⩾100	3
E	526	CAC → CGC	His → Arg	≈50	3
F	526	CAC → UUC	His →	⩾100	3
	531	UCG → UUG	Ser → Leu		
G	526	CAC → UAC	His →	⩾100	3
	531	UCG → UUC	Ser → Phe		

With reference to Table 1.2,

(i) complete Table 1.2 to show the amino acid changes that have occurred in strains **F** and **G**; [1]

(ii) list the strains of TB bacteria that show the greatest resistance to rifampicin;

…… [1]

(iii) suggest reasons to explain why strains **C**, **D** and **E** show different levels of resistance to rifampicin.

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…… [2]

In a different study involving HIV, it has been theorized that HIV evolved from Simian virus moving from chimpanzees and sooty mangabeys to infect humans.

Studies on a particular strain of Simian virus, SV40 has been shown to induce tumours in laboratory animals by causing cells to divide in an unregulated way.

Large T antigen (Tag) is a protein encoded by the SV40 genome. This protein is essential for SV40's tumour-forming capabilities. Tag has been shown to bind to and inactivate the tumour suppressor p53 protein.

(h) Give **one** role of p53 protein in a normal cell.

……

…… [1]

(i) Explain how the interaction of Tag with p53 protein would disrupt the normal control of cell division.

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…… [2]

Human papillomavirus (HPV) is another virus that inhibits p53. HPV can cause the development of cervical intraepithelial neoplasia (CIN), which leads to cervical cancer.

A recent study in Scotland assessed the impact of vaccination against HPV on the development of CIN.

Fig. 1.1 shows the effect of HPV-vaccination on the percentage of women found to have the most severe grade of CIN.

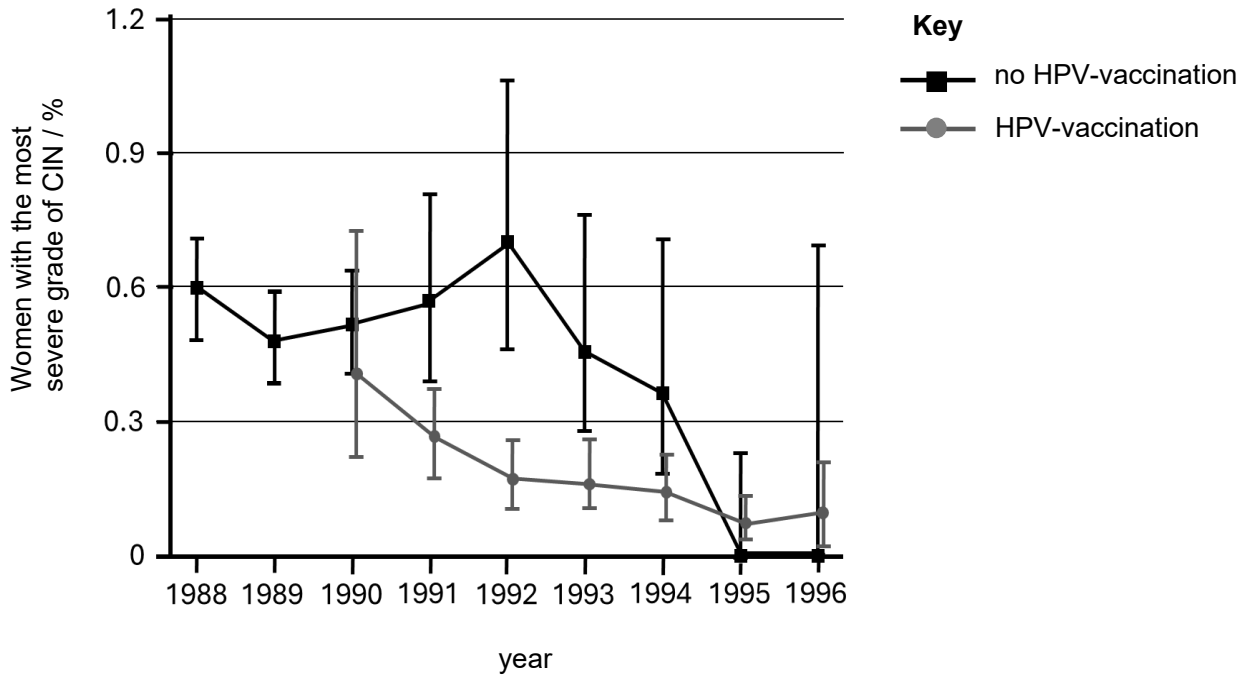

Fig. 1.1

(j) Explain how the data supports the suggestion that vaccination against HPV is effective in preventing development of CIN in both groups of women.

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…… [2]

(k) Apart from vaccination, human antibodies have been used in the treatment of some forms of cancer. However, the antibodies injected into the bloodstream can only reach a small percentage of the cancer cells located at the cancerous tumour.

Scientists discovered that some of the antibodies in the blood plasma of sharks have a different structure to the human antibodies.

Fig. 1.2 shows the structure of an antibody molecule found in the blood plasma of a shark.

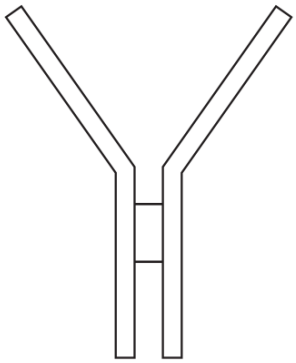

Fig. 1.2

(i) State how the quaternary structure of a human antibody molecule differs from the quaternary structure of the shark antibody molecule shown in Fig. 1.2.

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…… [1]

(ii) Shark antibodies are smaller than human antibodies. Scientists are researching the possibility of injecting shark antibodies into the bloodstream to treat cancerous tumours in humans.

Suggest how using the smaller shark antibodies may be more effective in reaching a greater percentage of cancer cells than human antibodies, leading to greater success at treating cancer.

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…… [1]

The presence of specific antibodies can also be used to detect diseases.

NMO is a disease that leads to damage of nerve cells in the spinal cord. A person with NMO produces anti-AQP4 antibody that attacks only these nerve cells.

Scientists measured the concentration of anti-AQP4 antibody in the blood of people with NMO. For each person, the scientists also determined the number of small bones known as vertebrae surrounding damaged nerve cells.

Each dot in the graph represents one individual in the study.

Their results are shown in Fig. 1.3.

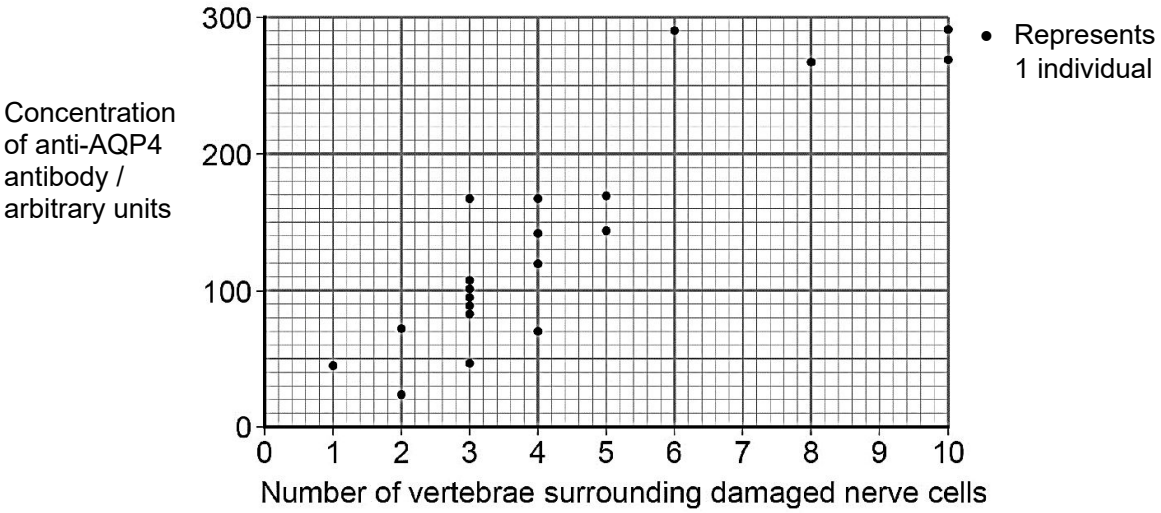

Fig. 1.3

(I) A scientist hypothesized that the concentration of anti-AQP4 antibody in a person's blood can be used to predict the number of vertebrae surrounding damaged nerve cells.

Using the information in Fig. 1.3, comment with reasons if this hypothesis is valid.

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…… [3]

[Total: 28]

2 *Myosotis* is a genus of small flowering plants. Many different *Myosotis* species grow on the islands of New Zealand, which are an important site of *Myosotis* evolution. Lowland *Myosotis* species grow at low altitude while alpine *Myosotis* species grow at high altitude at the tops of mountains.

Fig. 2.1 shows the three largest New Zealand islands.

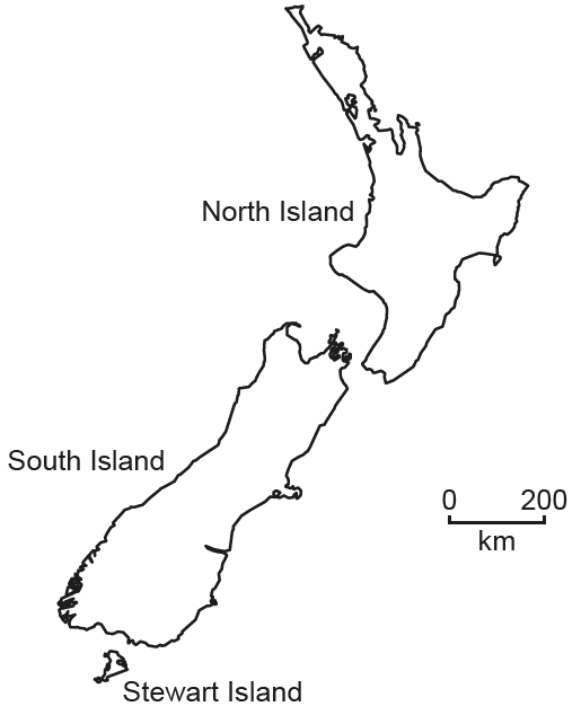

Fig. 2.1

Habitats of each island:

- North Island has mostly lowland habitat.
- South Island and Stewart Island have mountains with alpine habitats that are above the treeline.

Scientists wanted to obtain molecular data to determine the evolutionary relationships of New Zealand's *Myosotis* species. They extracted DNA from individuals of *Myosotis* species collected from three different islands in New Zealand.

DNA sequence data for three *Myosotis* species were compared. The results are described as follows:

.

1 In the alpine species *M. pygmaea*, individuals on South Island showed genetic differences from individuals of *M. pygmaea* on Stewart Island.

2 In the alpine species *M. pulvinaris*, individuals from different mountains on South Island showed genetic differences.

3 In the lowland species *M. pottsiana*, individuals from different areas of North Island showed overall genetic similarity.

(a) Discuss reasons for the results regarding the DNA sequence data of the three species.

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…… [5]

(b) State **two** factors, other than natural selection, that could drive genetic changes in populations of *Myosotis*.

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…… [2]

A large number of alpine plant species grow in the mountains of South Island. Alpine plants are defined as plants that live above the treeline, which is the height above which trees cannot grow. Many of South Island's alpine species live nowhere else in the world.

Fig. 2.2 shows two aspects of the history of South Island over the last 3.9 million years.

- The dashed line shows how the mean height of mountains in the Clyde region of South Island increased over time. The mountains in this range have a mean height of 2400 m at the present time.

- The solid line models the height of the treeline over time based on geological climate data. The treeline was higher when the climate was warmer, and the treeline was lower when the climate was colder, during ice ages.

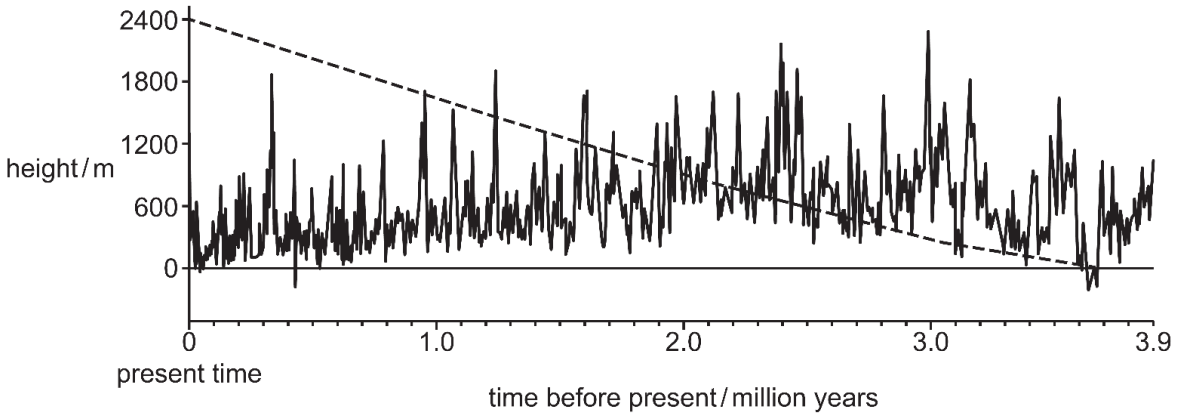

Fig. 2.2

(c) With reference to Fig. 2.2, identify with reasons the time period when South Island's alpine plant species developed.

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…… [2]

(d) Describe **two** advantages of using DNA sequence data in reconstructing phylogenetic relationships.

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…… [2]

[Total: 11]

3 The β-globin gene codes for the β-globin polypeptide of haemoglobin. It has two alleles, HbA (normal) and HbS (sickle cell).

There are three possible genotypes and phenotypes.
- HbS HbS, sickle cell anaemia, a severe disease
- HbA HbS, sickle cell trait with mild or no symptoms of sickle cell anaemia
- HbA HbA, normal (healthy)

(a) Explain why the mutation in the β-globin gene cause the HbS haemoglobin to form fibres.

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…… [2]

The mutation of the β-globin gene which gives rise to sickle cell anaemia also removes a recognition site of a restriction enzyme **R**, as shown in Fig. 3.1.

Enzyme **R** cuts DNA at the sites indicated by arrows (↓). The lengths of the resulting fragments are shown in kilobases (kb).

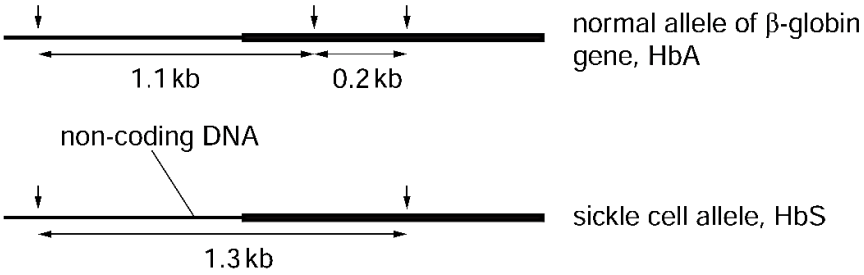

Fig. 3.1

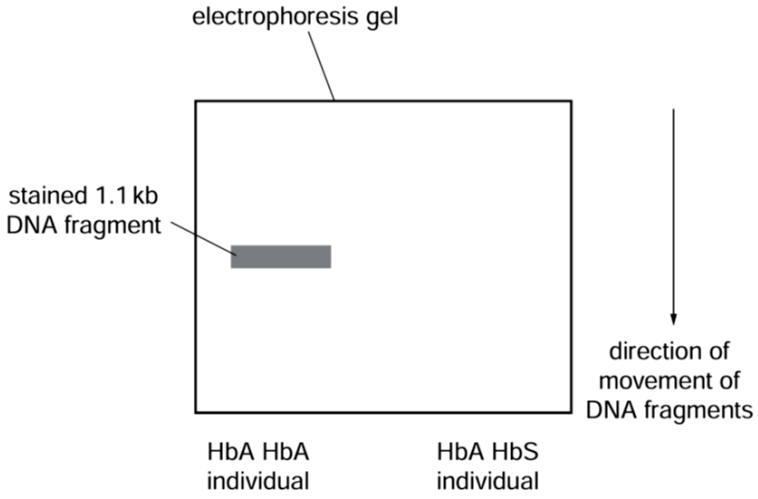

Fig. 3.2

Fig. 3.2 shows an electrophoresis gel with a DNA banding of an individual who is homozygous for the normal allele for β-globin, HbA HbA.

This band is the 1.1 kb fragment shown in Fig. 3.1. The location of 0.2 kb fragment is **not** shown in Fig. 3.2 due to the position of the bound radioactive probe.

(b) With reference to Fig. 3.1 and Fig. 3.2,

(i) state where the radioactive probe has bound on the normal and sickle cell allele;

…… [1]

(ii) complete Fig. 3.2 by drawing the DNA band that would result from an individual who is heterozygous for the sickle cell allele, HbA HbS; [1]

(iii) explain the position of the bands in **(b)(ii).**

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…… [3]

One way to detect and measure accurately the amount of RNA in a tissue sample is by RT-PCR (reverse transcriptase-polymerase chain reaction).

RT-PCR uses a reaction mixture containing:

- the RNA sample for testing
- reverse transcriptase
- DNA nucleotides
- primers
- DNA polymerase
- fluorescent dye.

The principle behind this method is shown in Fig 3.3.

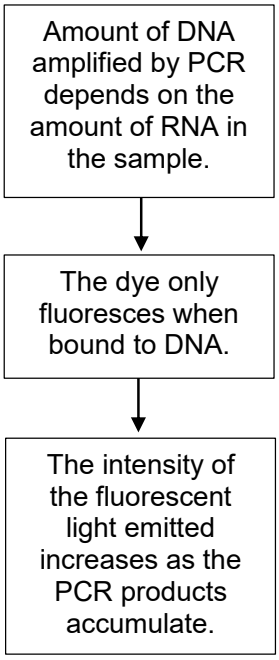

Fig. 3.3

(c) Any DNA in the tissue sample is hydrolysed by enzymes before the sample is added to the RT-PCR reaction mixture. Suggest why this must be done before RT-PCR.

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…… [1]

Fig. 3.4 shows the results from using RT-PCR to detect RNA in two different samples, **A** and **B**.

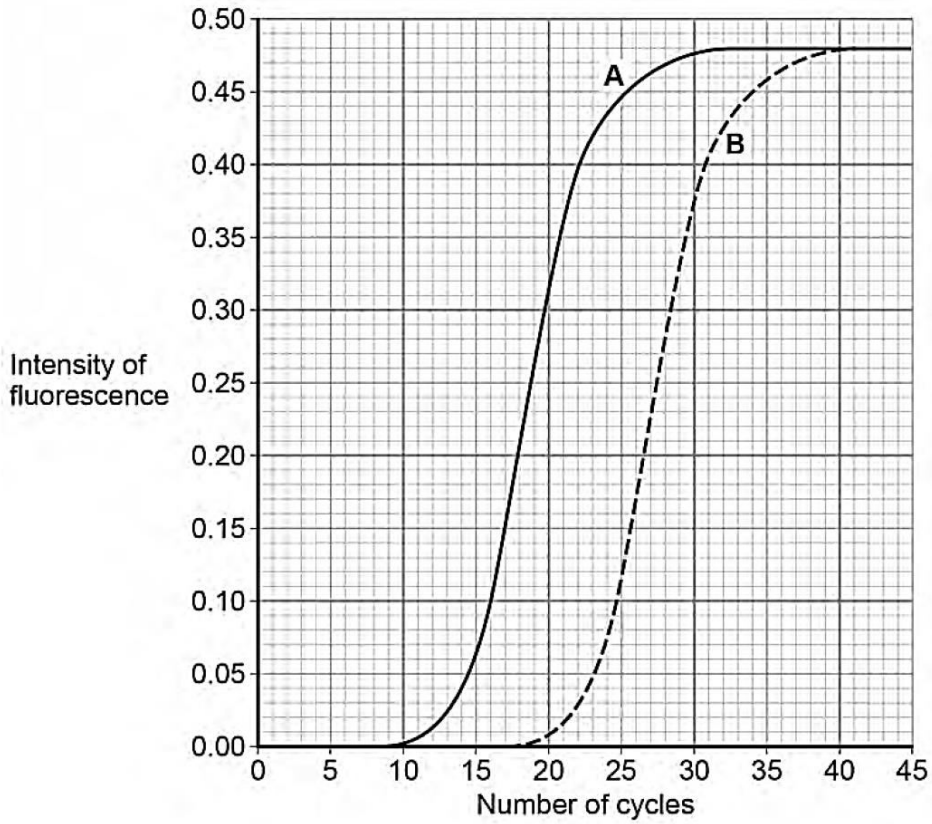

Fig. 3.4

A quantitative comparison can be made of the amount of RNA in samples **A** and **B**.

This involves determining the number of cycles required to reach 50% maximum concentration of DNA (**C**).

The amount of RNA in a sample can be measured as: 1 ÷ **C**

(d) Use the information in Fig. 3.4 to calculate the the RNA content in sample **A** and RNA content in sample **B**. Give your answer to **three significant figures.**

Sample **A** ……

Sample **B** …… [1]

(e) Suggest **one** reason why DNA replication stops in the polymerase chain reaction.

……

…… [1]

(f) Scientists have used the RT-PCR method to detect the presence of different RNA viruses in patients suffering from respiratory diseases.

Explain why a variety of different primers is required for this procedure.

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…… [1]

[Total: 11]

Section B

Answer **one** question in this section.

Write your answers on the lined paper provided at the end of this Question Paper.

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, distinguish between inducible and repressible systems of regulation in a prokaryote and explain how the inducible regulation allows the bacteria to respond to varying concentrations of lactose. [12]

(b) With reference to examples, describe the effect of climate change on the relationship between living organisms. [13]

[Total: 25]

5 **(a)** Explain how the structures of polysaccharides in plants allow them to carry out their functions. [12]

(b) Describe the molecular structure of the plasma membrane and with named examples, explain the role of membranes involved in transport of substances involving a plant cell and its organelles. [13]

[Total: 25]

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