VICTORIA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
HIGHER 2

CANDIDATE NAME: ……

CT GROUP: ……

BIOLOGY 9744 /03

Paper 3 Long Structured and Free-response Questions **20 September 2023**

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name and CT group 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 in the space 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 your working or if you do not use appropriate units.

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

For Examiner's Use	
Section A	
1	/28
2	/12
3	/10
Section B	
	/25
Total	

Section A

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

1 Cells respond to changes in their internal as well as external environment.

Unicellular eukaryotes such as yeasts respond to changes in the glucose concentration in the environment.

Glucose is the preferred carbon source for Baker's yeasts (*Saccharomyces cerevisiae*) which metabolises glucose by a purely glycolytic process (fermentation), producing ethanol even under aerobic conditions. Presence of glucose represses the uptake and metabolism of other carbon sources such as galactose and maltose. When the glucose has been consumed, the cell switches to aerobic metabolism of the ethanol.

(a) (i) State the difference in the number of ATP produced from one molecule of glucose between fermentation and aerobic respiration.

[1]

(ii) Suggest why yeast cells undergo fermentation even in the presence of oxygen.

[2]

(b) Several components of the signalling pathway involved in glucose repression in yeast have been identified. These are shown in Fig.1.1. Snf1 is a protein kinase and binding of Mig1 to the promoter interferes with the binding of other proteins.

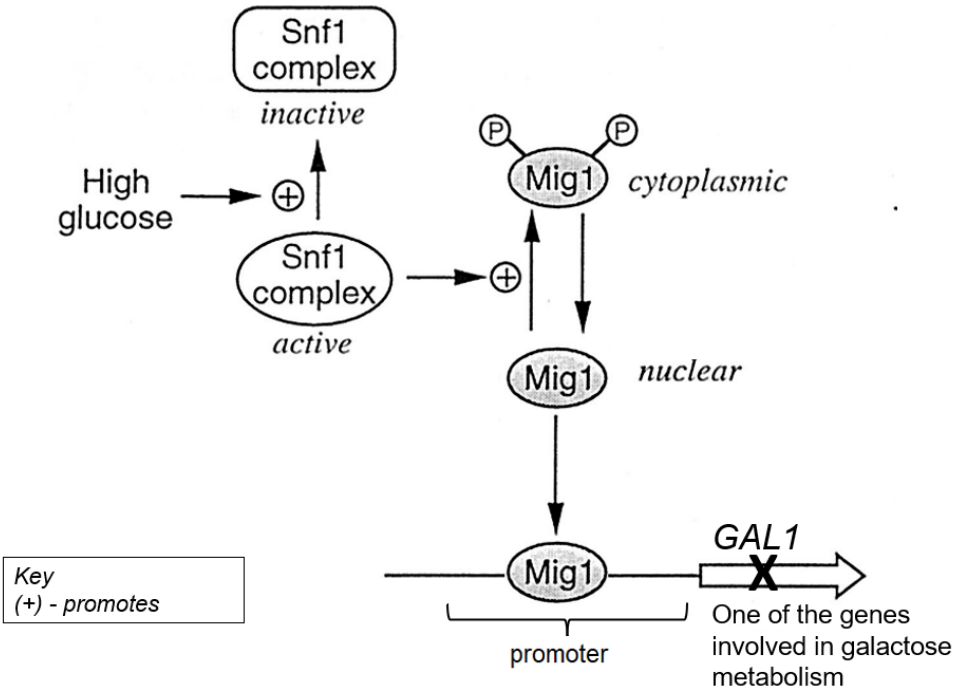

Fig 1.1

(i) With reference to the information given in Fig 1.1, explain how the presence of glucose in the environment is able to bring about the repression of *GAL1* gene.

[4]

Mig1 binds to 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

Promoter sites to which Mig1 binds are known as Mig1-binding promoter sites.

(ii) Explain how Mig1 recognises and binds to these sites.

[2]

Scientists analysed the yeast genome to look for DNA that matches the features shown by Mig1-binding promoter site. Analysis of four chromosomes (A-D) revealed the presence of 26 Mig1-binding promoter sites.

yeast chromosome	number of Mig1-binding promoter sites
A	1
B	9
C	2
D	14

Table 1.1

Since five different enzymes coded by five different genes are required for galactose metabolism, the expected number of Mig1-binding promoter sites for an individual diploid yeast is 10.

(iii) Explain why the expected number of Mig1-binding sites is 10.

[2]

(iv) Suggest reasons for the difference in the number of Mig1-binding promoter sites seen in Table 1.1 and the expected number.

[2]

(c) Changes in gene regulation was also observed in *Aedes* mosquitoes infected with dengue virus.

Scientists carried out experiments to study how the *Aedes* mosquitoes respond to infection by the dengue virus (DENV) after taking a blood meal infected with the virus.

Two groups of pre-mated females, 7–10 days old, were used for the experiment. One group was fed the DENV-2 infected blood while the control group was fed with uninfected blood. Engorged females were then sorted into tubes and kept in the incubator for 3 days with a 10% sucrose solution provided. Eggs were counted daily, from 3 to 7 days after receiving the blood meal. At the end of 7 days, the ovary of the mosquito was removed and the remaining mosquito homogenised. Analysis of the gene expression in the ovary was carried out. Fig 1.2 shows the experimental setup.

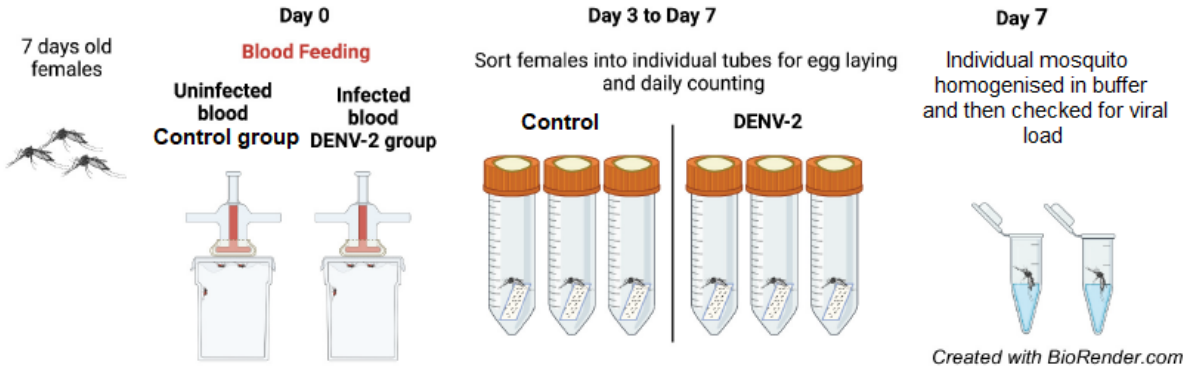

Fig 1.2 Experimental setup
Source: https://pubmed.ncbi.nlm.nih.gov/35814655/

(i) Explain the importance of the control group in this experiment.

[2]

Fig 1.3 shows the fecundity (number of eggs laid per mosquito) for the two groups of female mosquitoes.

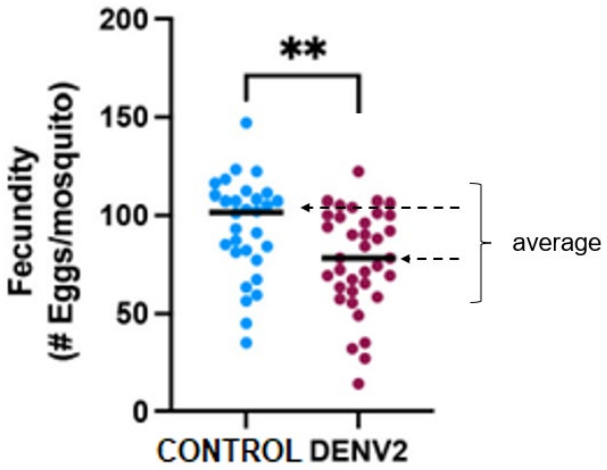

Fig 1.3
(**) – indicates that the $p < 0.01$

(ii) Suggest two reasons for the variation seen in the fecundity of the individual mosquitoes within each group.

[2]

A study of the ovarian tissues obtained from the infected mosquitoes showed the cells infected with the dengue virus exhibit reduced

- cytochrome c oxidase activity
- synthesis of ribosomal proteins
- RNA binding to proteins

(iii) Based on the information provided, explain the difference in the fecundity between the two groups of mosquitoes shown in Fig. 1.3.

[3]

(d) Two genes were found to be upregulated in the infected mosquitoes.

To investigate the role of these two genes (*Oatp*, *amd*), scientists carried out further studies using mosquito cell culture. Three cell cultures were set up, one as a control and two experimental.

In each experimental group, small interfering RNA (siRNA) specific to the mRNA produced by the gene was introduced into the cell culture.

Table 1.2 summarises the treatment for the control and experimental groups.

Setup	siRNA added
Control	None
Experiment 1 (E1)	specific for mRNA of *Oatp*
Experiment 2 (E2)	specific for mRNA of *amd*

Table 1.2

Fig 1.4 shows the sequence of events occurring in the cells after the introduction of siRNA.

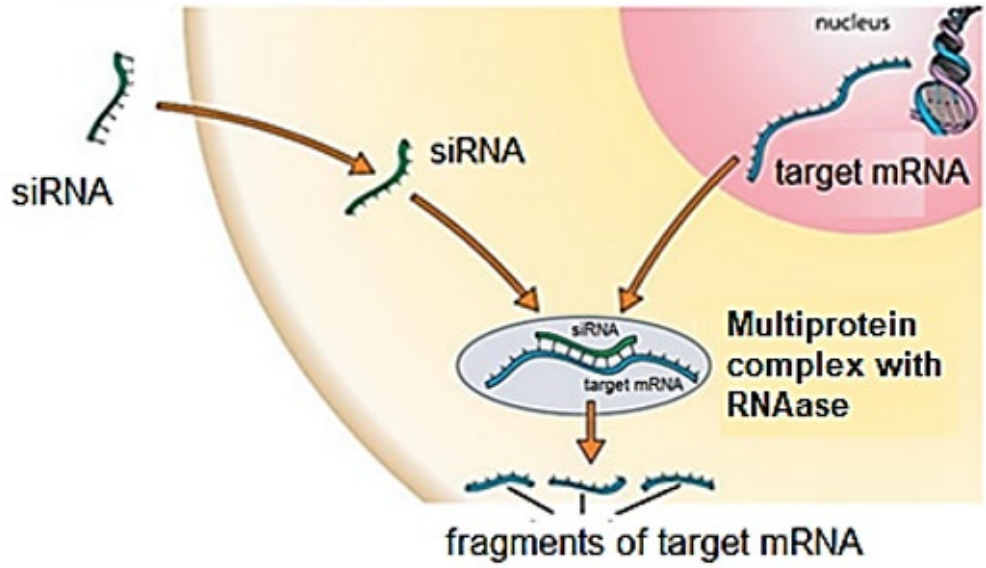

Fig 1.4

(i) With reference to Fig. 1.4, explain how siRNA can affect the expression of a gene.

[2]

The cells in both the control and experimental groups were then infected with the dengue virus. The number of copies of dengue RNA was then determined 24 hours post infection. The results are shown in Fig 1.5.

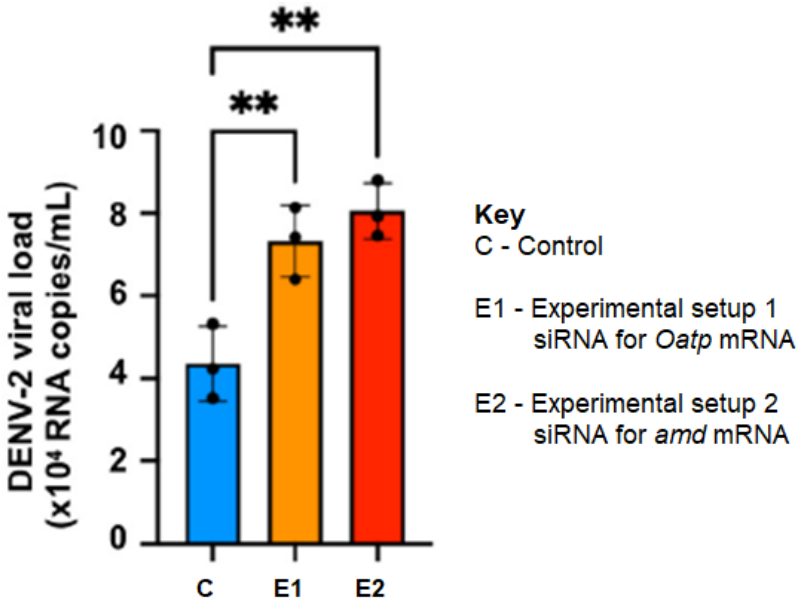

Fig. 1.5 (**) – indicates that the $p < 0.01$

(ii) With reference to Fig 1.4 and Fig 1.5, state a possible function of the two genes (*Oatp, amd*). Explain your answer.

[3]

(e) Diseases caused by viruses such as dengue fever, Covid-19, have caused significant concerns to humans. Medication such as antibiotics are not effective against viruses. Viruses are so unique that they are not even grouped into any of the three domains – Eukarya, Bacteria and Archaea which encompasses all life on earth. Members of these three domains are either unicellular or multicellular.

Justify why dengue virus should not be classified into any of these domains.

[3]

[Total: 28]

2 Cervical cancer occurs in the neck of the uterus.

Scientists investigated the link between cervical cancer and infection with some types of Human Papilloma Virus (HPV).

Fig. 2.1 shows the frequency of five different types of HPV in women who had cervical cancer.

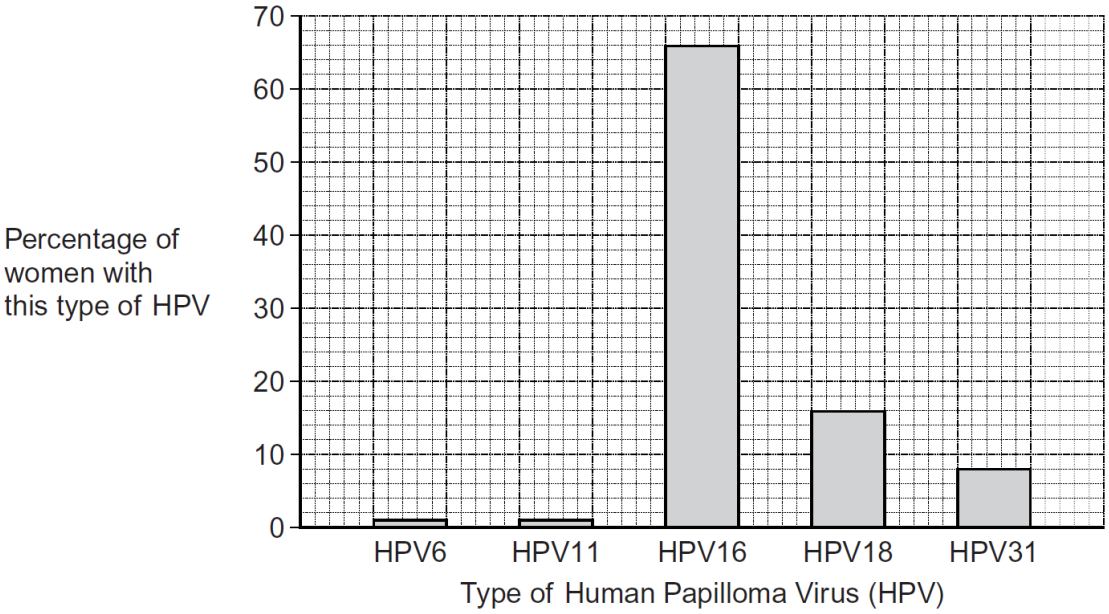

Fig. 2.1

(a) A local newspaper published an article about cervical cancer with the headline 'HPV causes cervical cancer'.

Evaluate this claim based on the data shown on Fig. 2.1.

[3]

When HPV16 infects a cervical cell, its genome integrates into the host genome. Fig. 2.2 shows the sequence of events leading to the development of HPV-related cervical cancer.

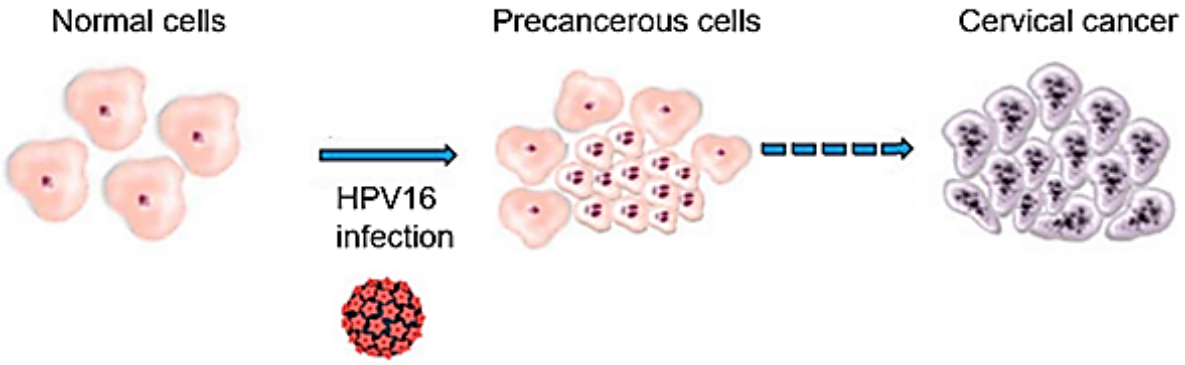

Fig. 2.2

(b) Suggest how HPV16 infection may cause the development of HPV-related cervical cancer.

[4]

(c) A vaccine can be used to produce immunity to HPV.

(i) Describe how memory cells are important in this process.

[3]

Some doctors suggested offering the vaccine to young men.

(ii) Explain the advantage of vaccinating young men as well as young women.

[2]

[Total: 12]

3 North America is home to diverse migratory bird species that travel long distances between their breeding grounds in the north and wintering grounds in the south. One such migratory bird species is the American robin. During the winter season, the robins migrate from the northern region of Canada to the southern region to seek for their food source – caterpillars.

Over the years, climate change has impacted the population of American robins, their migration pattern and possibly their survival.

Fig. 3.1 below shows the average global temperature over the years.

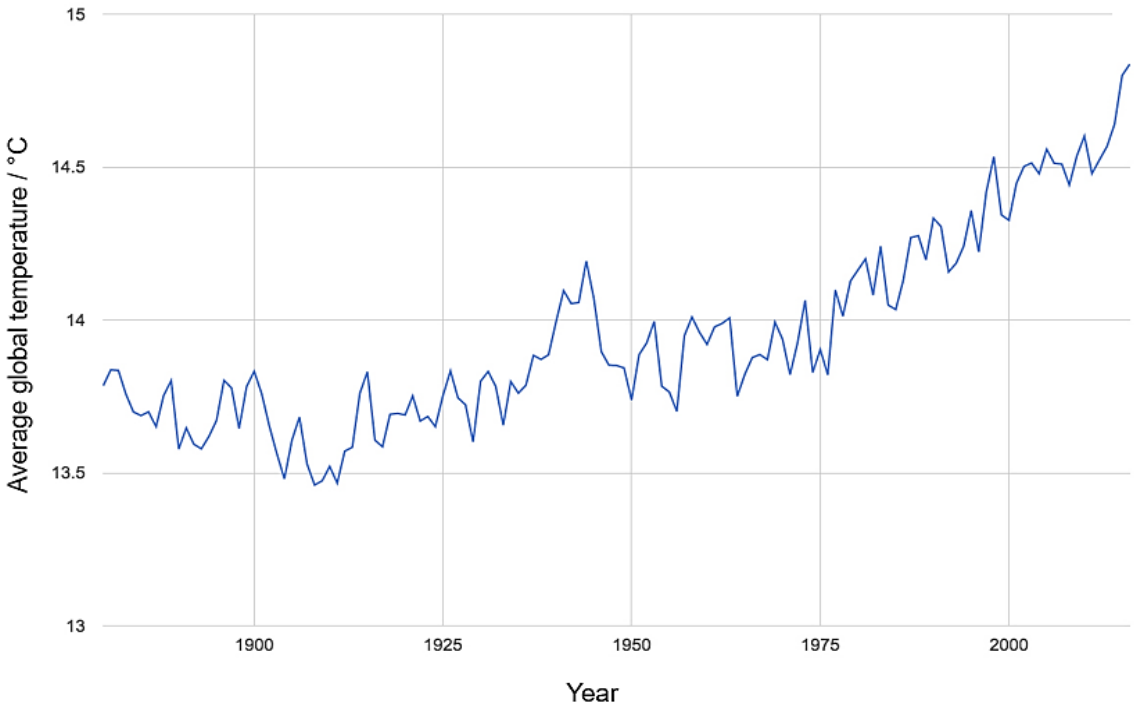

Fig. 3.1

Fig.3.2 shows the migration period of the robins from north Canada to south Canada in 1950 and 2000 while Fig.3.3 shows the period where there is great abundance of caterpillars in south Canada in 1950 and 2000.

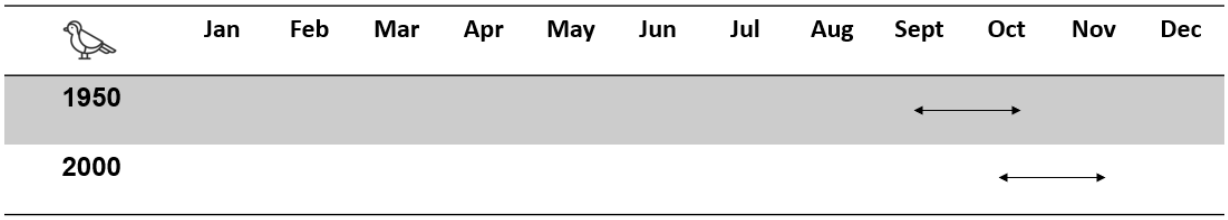

Fig. 3.2

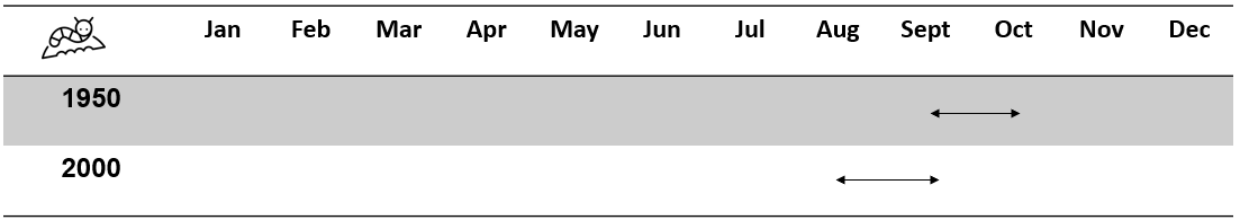

Fig 3.3

Climate change has been said to affect the migratory phenology of the American robins.

(a) Explain what is meant by the term “phenology”.

[1]

(b) With reference to Fig. 3.1 and 3.2, describe and explain how climate change has caused the change in the migration pattern.

[3]

(c) Explain why the caterpillars are found in abundance earlier as shown in Fig. 3.3.

[2]

(d) Discuss how the changes shown in Fig. 3.2 and Fig. 3.3 can impact the American robins.

[4]

[Total: 10]

Section B

Answer **one** question in this section

Write your answer 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), (b)** as indicated in the question.

4 **(a)** Explain the significance of named transmembrane proteins in the regulation and metabolism of glucose. [15]

(b) The human gut microbiome refers to the full array of microorganisms living in the gastrointestinal tract. These microorganisms include fungi, bacteria and viruses. These groups of microorganisms are dynamic and change in response to a host of environmental factors such as diet, exercise and other exposures.

Explain how the community of viruses and bacteria can facilitate phenotypic alterations of a bacterium resulting in its survival in an antibiotic rich gut environment. [10]

[Total: 25]

5 **(a)** Explain the normal functions of blood stem cells and discuss how the cells they differentiated into work together to provide effective immune responses against pathogens. [15]

(b) "Mutations are necessary for survival." Using named examples, discuss the validity of this statement. [10]

[Total: 25]

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