H

TEMASEK JUNIOR COLLEGE

2023 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 **12 SEPTEMBER 2023**

PART I **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.
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Section A
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Section B
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For Examiner's Use	
1	/ 29
2	/ 11
3	/ 10
4 / 5	/ 25

Answer **all** questions in this section.

1 There are a variety of infectious diseases that can affect humans.

(a) Explain what is meant by an infectious disease.

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(b) The human immunodeficiency virus (HIV) causes the infectious disease known as autoimmune deficiency syndrome (AIDS).

(i) Compare the structures of HIV and a typical bacterium.

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HIV can integrate its genome into the host cell chromosome, thus forming a provirus. The provirus may remain transcriptionally silent for decades.

(ii) Suggest and explain **one** way in which the provirus can remain transcriptionally silent.

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The HIV/AIDS pandemic has had a very large impact on life expectancy in many African countries.

Table 1.1 shows the average life expectancy of individuals without and with HIV/AIDS and the percentage of the population tested positive for HIV in five African countries.

Table 1.1

country	average life expectancy / years		percentage of population tested positive for HIV / %
	without HIV/AIDS	with HIV/AIDS	
Botswana	72.4	33.9	35.8
Côte d'Ivoire	55.6	42.8	10.8
Kenya	65.6	45.5	14.0
South Africa	66.3	48.8	19.9
Zimbabwe	69.0	40.2	25.1

(iii) Using the data shown in Table 1.1, calculate the percentage decrease in average life expectancy for patients with HIV/AIDS in Zimbabwe.

Show your working and give your answer to the nearest whole number.

percentage decrease: …….. % [2]

(iv) After studying the data in Table 1.1, a student concluded that:

"The higher the percentage of population tested positive for HIV, the greater the decrease in life expectancy with HIV / AIDS".

With reference to Table 1.1, discuss the validity of the student's conclusion.

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(c) Another common infectious disease in developing nations is cholera. Cholera is caused by consuming food or water contaminated with a bacterium called *Vibrio cholerae*.

Fig. 1.1 shows a transmission electron micrograph of *Vibrio cholerae*.

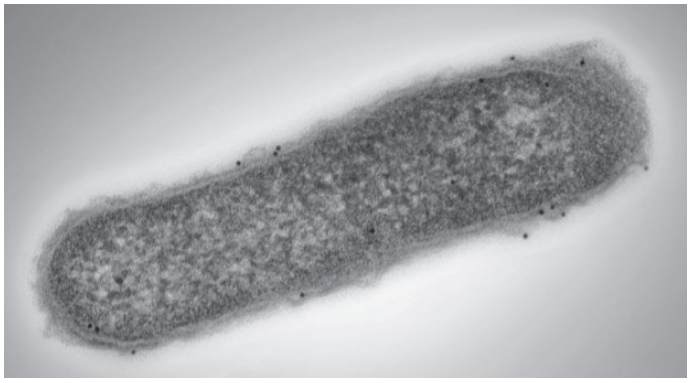

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Fig. 1.1

The symptoms of cholera are caused by the protein, cholaregen.

Choleragen is a protein made up of six polypeptides:

- a single copy of a polypeptide known as the **A** subunit that includes an extended alpha helix
- five polypeptides that together make the **B** subunit.

The **B** subunit of choleragen binds to a cell surface membrane component, known as GM1, of an intestinal epithelial cell. The complete choleragen protein then enters the cell by endocytosis. Once inside the cell, the **A** subunit of the protein acts as an enzyme, disrupting normal functions of the cell.

(i) List the levels of protein structure present in choleragen.

…… [1]

Fig. 1.2 shows the *ctxAB* operon which contains the structural genes that code for choleragen.

Fig. 1.2

H-NS and ToxT are proteins that are coded for by separate regulatory genes found upstream of the operon.

It is found that:

- high levels of H-NS would reduce the expression of the operon,
- high levels of ToxT would increase the expression of the operon,
- the operon has similar regulation as *lac* operon.

(ii) State the role of H-NS and ToxT proteins in the regulation of *ctxAB* operon.

H-NS: ……..…….……

ToxT: ……..…….…… [2]

(iii) In the laboratory, it is possible to produce a form of choleragen consisting of only **B** subunit as a vaccine against cholera.

Suggest why **B** subunit, rather than **A** subunit, is used in the production of the vaccine.

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Infection by *V. cholerae* causes severe watery diarrhea, which leads to dehydration (loss of water and ions) and even death if untreated.

Fig. 1.3 shows the signaling pathway activated by choleragen.

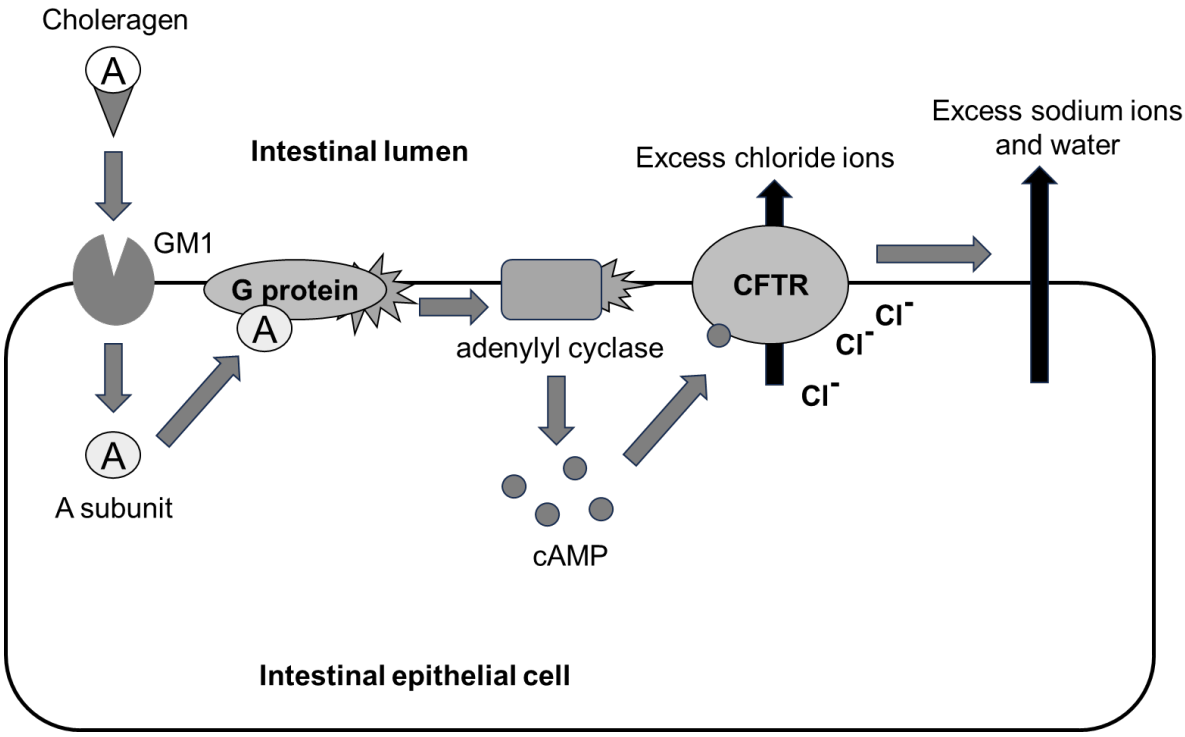

Fig. 1.3

(iv) With reference to Fig. 1.3, outline how choleragen **A** subunit can result in diarrhea after chloragen binds to receptor GM1.

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(d) Measles is a highly contagious, serious disease caused by the measles virus. The virus is normally spread through direct contact and through the air when an infected person coughs or sneezes. Nine out of ten people who are not immune will become infected when they share living space with an infected person.

The measles-containing vaccine (MCV) was developed in 1963 and is extremely effective at preventing the disease. Fig. 1.4 shows the global annual reported cases of measles and MCV coverage from 1980 to 2009. Immunization coverage refers to the percentage of population who receive one or more vaccines of interest in relation to the overall population.

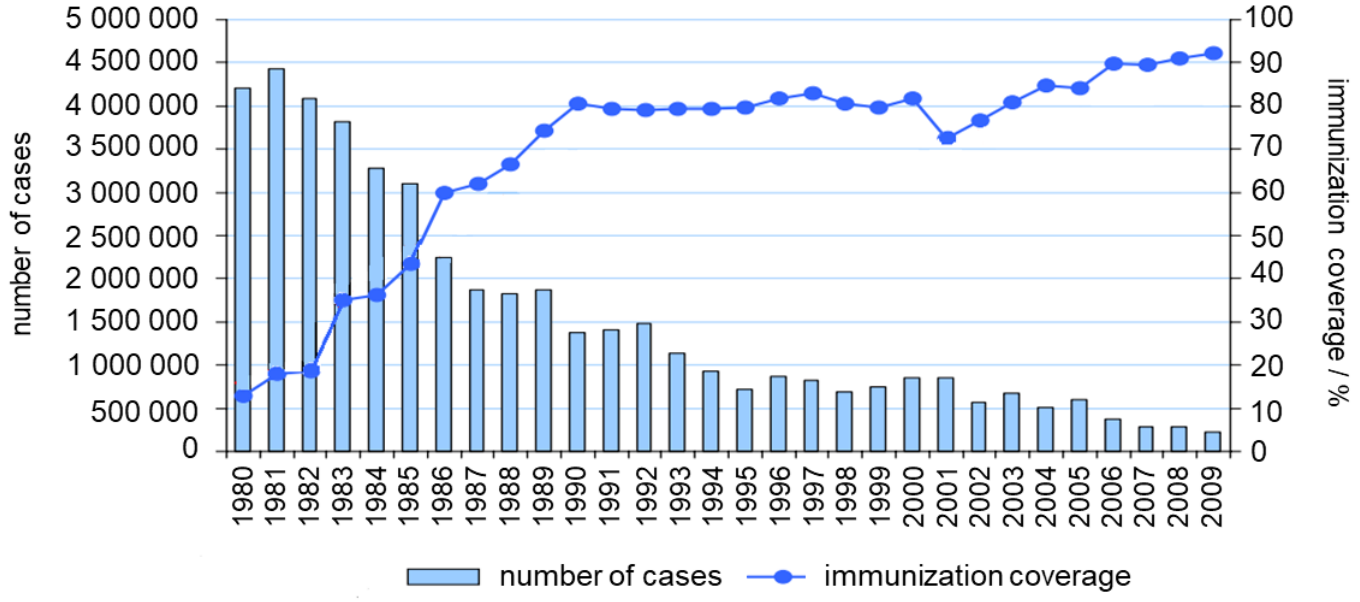

Fig. 1.4

(i) Comment on the relationship between immunization coverage and number of global annual reported cases.

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(ii) With reference to Fig. 1.4, evaluate if the changes in global annual cases can be attributed to the changes in immunization coverage.

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(e) Other than infectious diseases, human health can also be affected by other lifestyle diseases. Type II diabetes is a common lifestyle disease and is caused by dysregulation of insulin. Insulin is a peptide hormone secreted by the pancreas. It triggers a different cell signalling pathway and cellular response from choleragen.

The binding of insulin to the insulin receptor found on target cells such as muscle cells, triggers specific responses that eventually helps to lower the blood glucose levels.

In some diabetics, the insulin receptors are mutated and do not allow insulin to bind.

(i) Explain how a mutation to the gene coding for the insulin receptor can affect blood glucose levels.

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The hormone insulin is synthesised in the beta cells of the pancreas as preproinsulin.

Preproinsulin is non-functional and has to undergo post-translational modification to form the functional insulin that is secreted out of the cell.

Fig. 1.6 shows the process of post-translational modification to form the functional insulin.

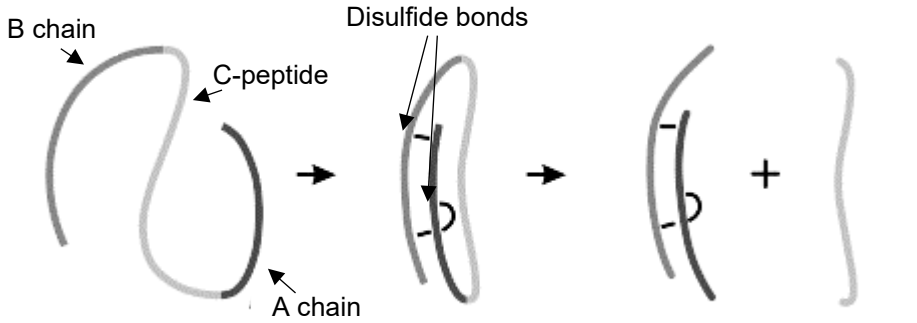

Fig. 1.6

(ii) With reference to Fig. 1.6, describe how post-translational modification of preproinsulin can give rise to the functional insulin.

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C-peptide will be released into the bloodstream together with the insulin hormone. The C-peptide does not serve any function, but they are useful for monitoring the levels of functioning beta cells in people with diabetes.

(iii) Predict the level of C-peptide in people with lesser number of functioning beta cells. Give a reason for your prediction.

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[Total: 29]

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End of Paper 3 [Part I]

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BIOLOGY 9744/03

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PART II **2 hours**

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For Examiner's Use	
2	/ 11
3	/ 10

2 Competition between genetically similar species of bird may lead to changes in one or more characteristics. One characteristic that results from this kind of selection is differences in the beaks. Researchers studied the beak lengths of two species of warblers. Fig. 2.1 shows the beak length of Pine Warblers (*Dendroica pinus*) and yellow-throated Warbles (*Dendroica dominica*) from three geographically isolated areas in USA.

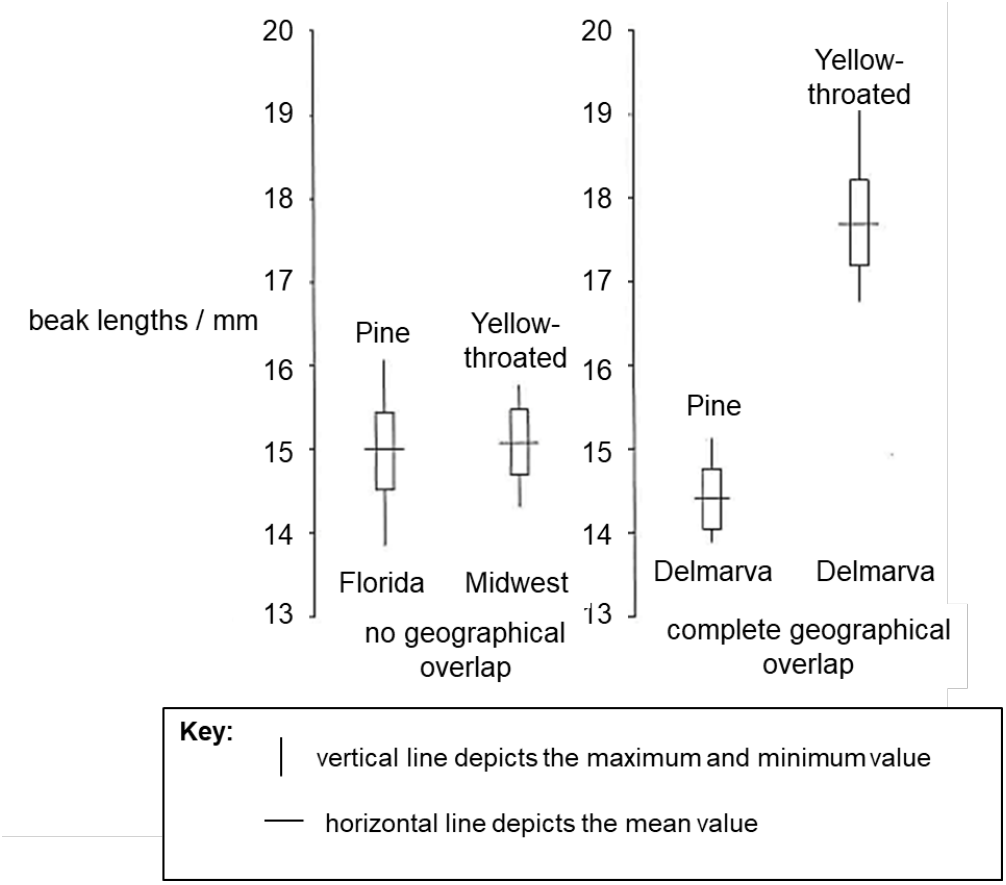

Fig. 2.1

(a) Complete **Table 2.1** to show the classification of one of the species of warbler. [2]

Table 2.1

kingdom	
phylum	Chordata
	Aves
order	Passeriformes
	Parulidae
genus	
species	*Dendroica pinus*

(b) **(i)** Identify the species with the shortest mean beak length.

……..…..……..…… [1]

(ii) Determine the difference in the mean beak length of the two populations of Yellow-throated Warbles in Midwest and Delmarva.

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(iii) Compare the range of variation in beak length of the Yellow-throated Warbles in Midwest to the beak length of the Yellow-throated Warbles in Delmarva.

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(c) Describe how the researchers could determine whether two warblers are of the same species.

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(d) Suggest an advantage for the longer beaks of Yellow-throated Warblers in Delmarva.

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(e) Using the Yellow-throated Warblers as an example, outline the concept of allopatric speciation.

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[Total: 11]

3 The area over which the Arctic ice sheet extends varies throughout the year. Fig. 3.1 shows the variation in the extent of the Arctic ice sheet for the months of July to November for the years 1979 and 2009.

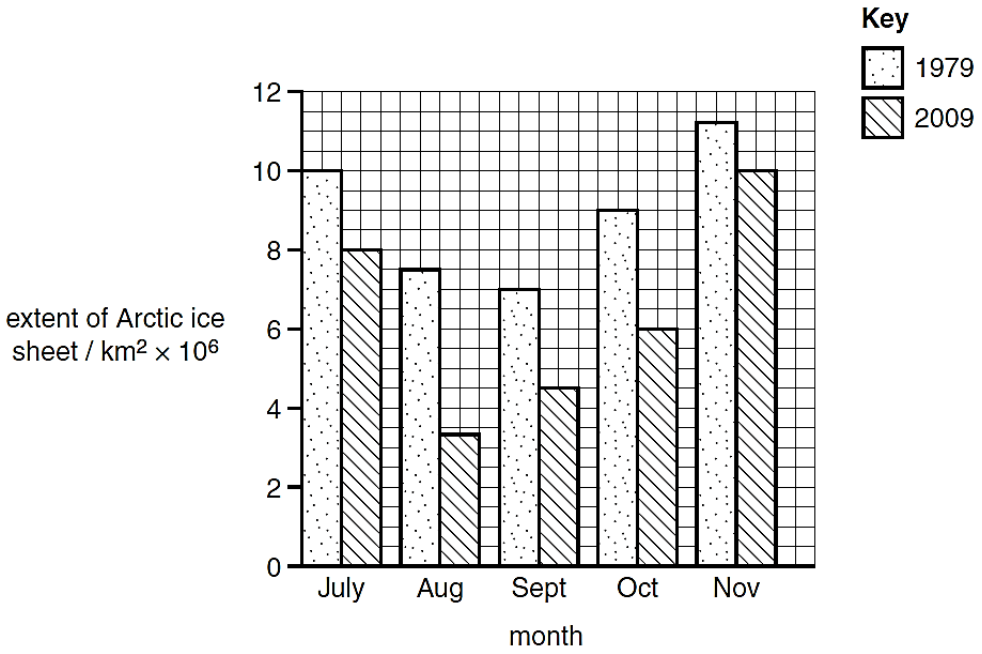

Fig. 3.1

(a) Suggest reasons for the reduction in the Arctic ice sheets from 1979 to 2009.

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(b) The polar bear, *Ursus maritimus*, moves across the Arctic ice sheet to hunt prey such as seals. When seals surface to breathe at cone-shaped breathing holes on the sea ice, a hunting polar bear which is waiting by the breathing hole will smack the head of the seal with both of its front paws to stun it, before biting and dragging the seal onto the ice. This method of still-hunting minimizes energy consumption and is the most successful strategy of hunting.

In 2008 the government of the USA classified *U. maritimus* as an endangered species because it is under the threat of extinction.

Suggest how climate change could have caused *U. maritimus* to become an endangered species.

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Climate change also affects plants.

Plants can be categorized based on the way they photosynthesize. Most plants are C3 plants because their first photosynthetic product is a three carbon compound. Examples of C3 plants include barley, oats, potato, rice, and wheat commonly grown in temperate regions.

On the other hand, C4 plants produce a four-carbon compound as their first photosynthetic product. Examples of C4 plants are common grass crops of tropical regions, such as maize, millet, sorghum and sugarcane.

The rate of carbon dioxide uptake at a range of carbon dioxide concentrations by barley, a C3 plant, and sugar cane, a C4 plant, were compared at two temperatures.

The results of the experiment are presented in Fig. 3.2.

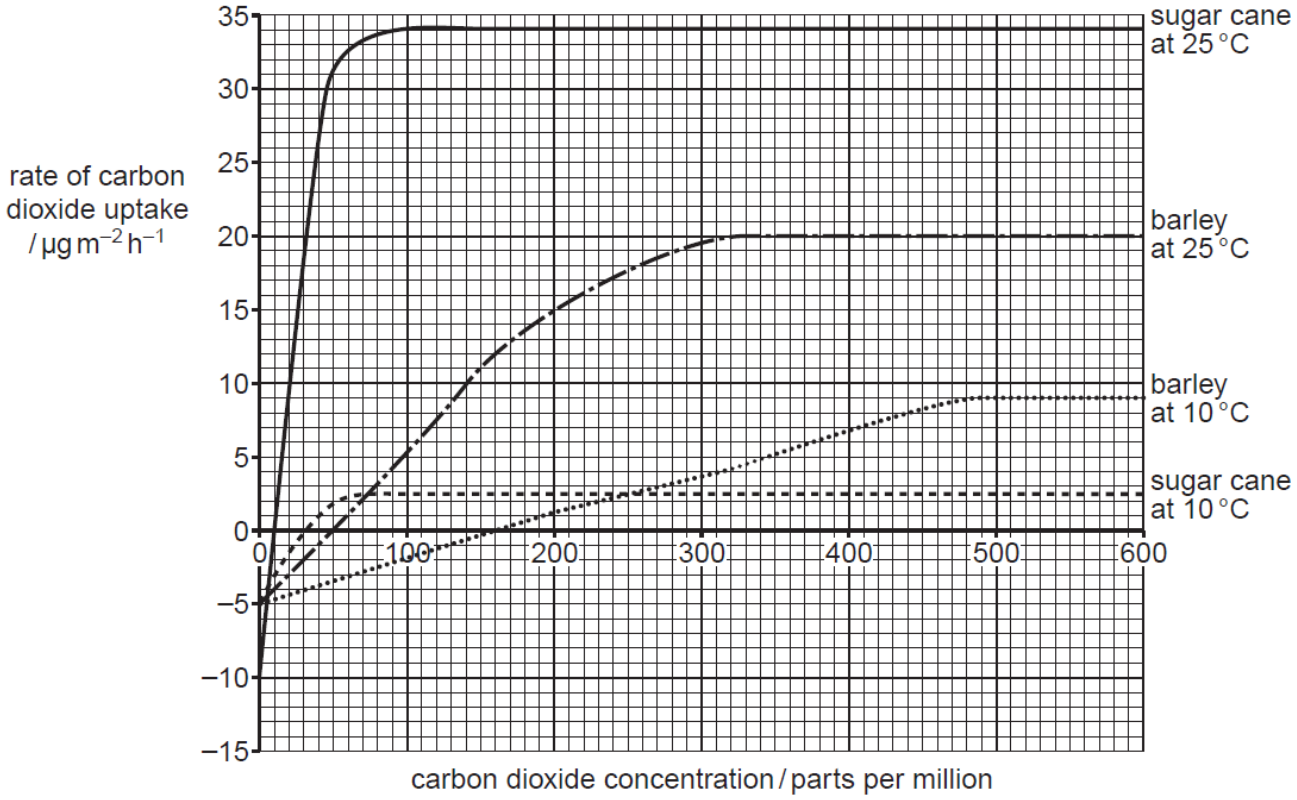

Fig. 3.2

The current carbon dioxide concentration in the atmosphere is more than 400 parts per million and it is likely to increase in the future. It is widely believed that the carbon dioxide concentration of the atmosphere affects the global mean surface temperature which in turn changes rainfall patterns.

Different types of crops require different amounts of water for optimal growth. Table 3.1 shows the mass of water each crop absorbs in a week for optimal growth regarding three C3 and three C4 plants which are important crops. Crops that absorb more water tend to grow better in regions with higher rainfall.

Table 3.1

crop	mass of water absorbed in a week / g
rice	682
potato	575
wheat	542
maize	350
millet	285
sorghum	204

(c) With reference to Fig. 3.2 and Table 3.1, discuss the likely impact of the predicted changes in carbon dioxide concentration, global temperatures and rainfall patterns on the global distribution of C3 and C4 plants.

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Climate change potentially affects the spread of diseases. Fig. 3.3 shows the worldwide distribution of dengue.

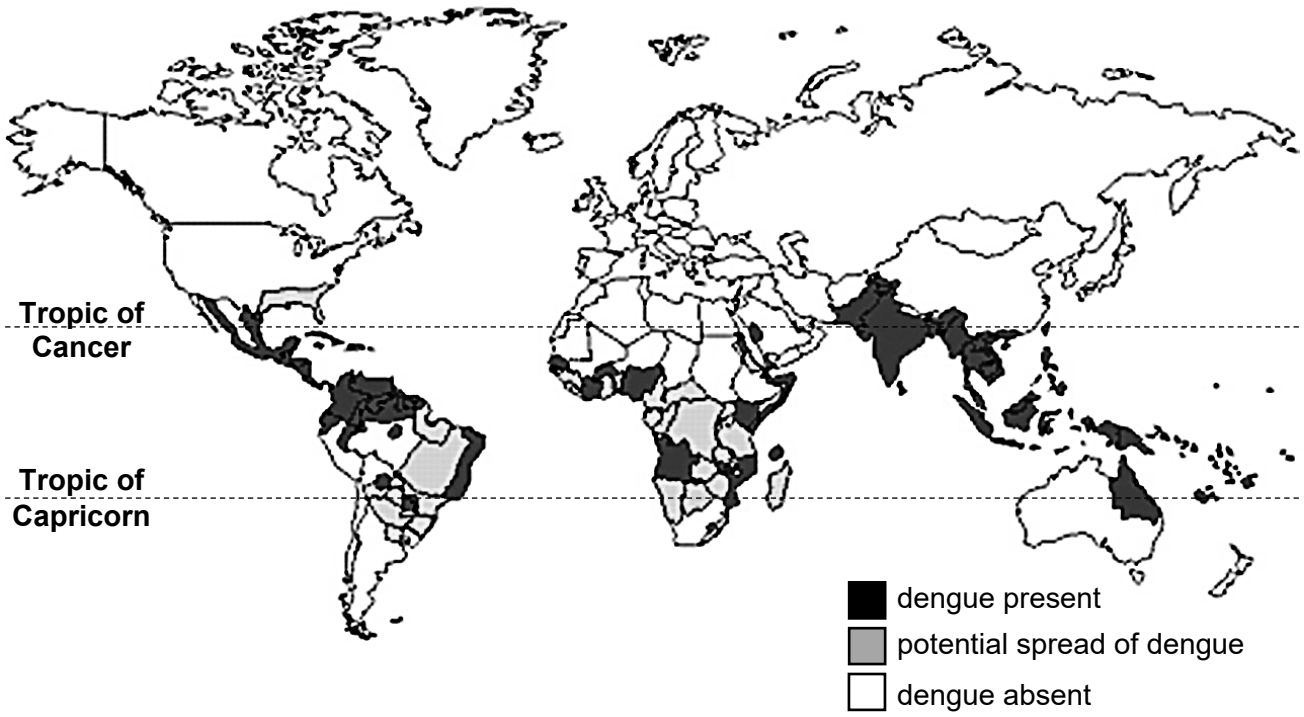

Fig. 3.3

Unlike dengue, influenza is found across the whole world.

(d) Explain why dengue shows the distribution pattern shown in Fig. 3.3, but influenza is found everywhere.

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[Total: 10]

End of Paper 3 [Part II]

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PART III **2 hours**

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Section B	
Essay **4* / 5*** **circle*	**/ 25**

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)** Outline the mitotic cell cycle and describe how this process could develop into one that results in cancerous cells instead. [10]

(b) Describe how genetic stability in eukaryotes is maintained at the molecular, cellular and population levels. [15]

[Total: 25]

5 **(a)** Despite selection pressures selecting for certain phenotypes, some phenotypes continue to persist in a population.

Explain how both genetic and environmental factors contribute to phenotypic expressions in eukaryotes and suggest how phenotypes which are **selected against** could be preserved in a population. [15]

(b) In eukaryotes, a mutation in the DNA can give rise to a new allele. In prokaryotes, a mutation in the DNA may give rise to a new gene with a novel function.

Outline how the allele frequency and the new gene frequency can increase in both eukaryotic and prokaryotic populations respectively. [10]

[Total: 25]

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End of Paper 3 [Part III]

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