Candidate Name: _____

Class	Adm No

H

millennia institute

2023 End-of-Year Examination

Pre-University 3

H2 Biology **9744/03**

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

2 hours

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your Admission number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, 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 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 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		
Section	**Question**	**Marks**
A	**1**	**/30**
	2	**/10**
	3	**/10**
B	**4/5**	**/25**
Total Marks		**/75**

This question paper consists of 21 printed pages, including 1 blank page.

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Section A

Answer **all** questions in this section.

1 The tomato plant (*Solanum lycopersicum*) is a crop harvested in many regions of the world for its edible fruit. Its red skin is primarily due to the presence of the organic compound lycopene, a pigment also found in many other fruits such as carrots and watermelon. Lycopene is only made up of carbon and hydrogen, as shown in Fig. 1.1.

Lycopene is also a precursor to many carotenoids, which absorb light from a certain wavelength during photosynthesis. In addition to carotenoids, other essential pigments are chlorophylls *a* and *b*.

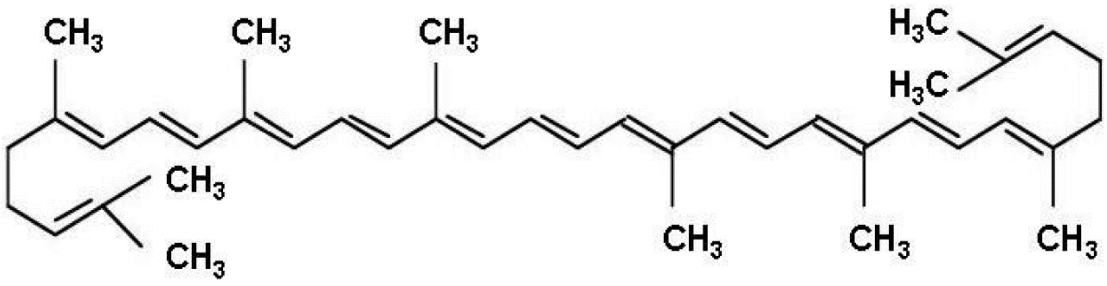

Fig. 1.1

(a) **(i)** Suggest a cellular structure in which lycopene can be found in a tomato cell. Explain your answer.

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…… [2]

Fig. 1.2 shows the absorption spectrum of lycopene and the action spectrum of the tomato plant.

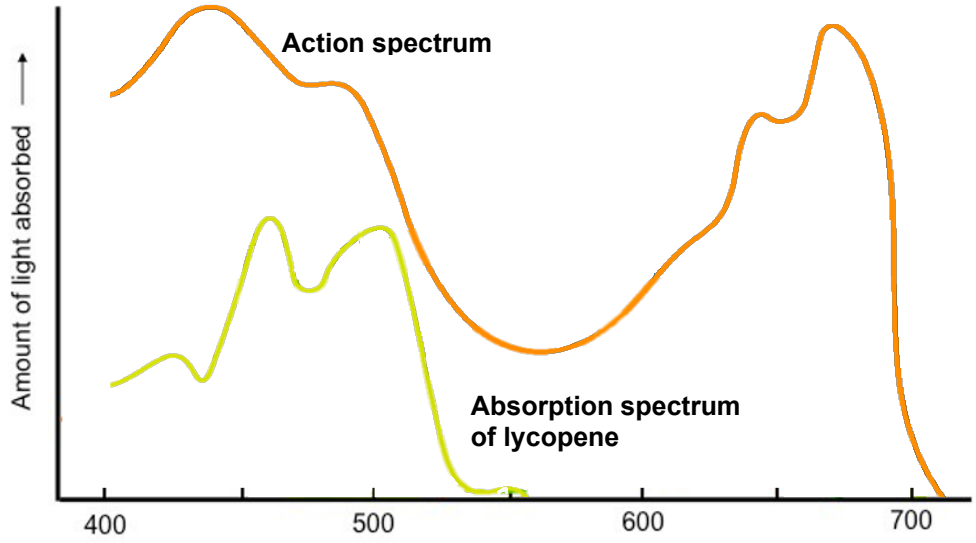

Fig. 1.2

(ii) With reference to Fig. 1.2, state the wavelength(s) of peak absorption by lycopene.

……... [1]

(iii) Explain how the data in Fig. 1.2 shows that lycopene is not the only photosynthesis pigment in the tomato plant.

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(b) Different conditions and variables can greatly affect the rate of photosynthesis that occurs in tomato plants. To investigate this, the net photosynthetic rate (P_N) was measured against photosynthetically active radiation (PAR). PAR measures the amount of photons that the plant is exposed to per unit area per unit time.

The plants were also subjected to four different levels of relative soil water content (RSMC), labelled T1 to T4. (RSMC) measures the amount of water in the soil.

Fig. 1.3 shows the results.

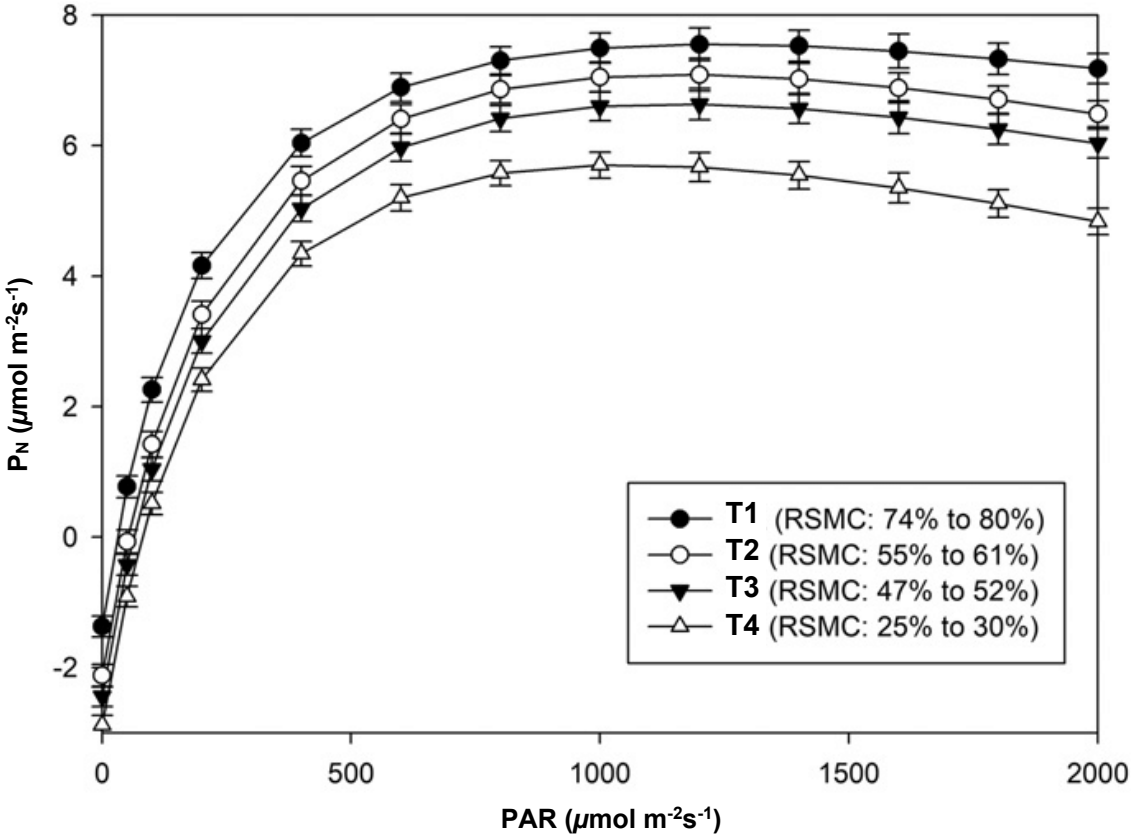

Fig. 1.3

(i) Explain the overall relationship between P_N and RSMC from 0 to 1000 μmol m^{-2} s^{-1}.

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…… [3]

(ii) Suggest and explain the overall trend observed from 1500 to 2000 μmol $m^{-2}s^{-1}$.

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…… [2]

(iii) Using Fig. 1.3, estimate the P_N when the PAR is 750 μmol $m^{-2}s^{-1}$ and the RSMC is between 55% to 61%.

…… [1]

(c) The products of the light-dependent reaction are important for the formation of carbohydrates in plants.

Outline how carbohydrate can be continually formed using these products.

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…… [4]

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Stressful conditions can lead to the damaging of plant DNA. This leads to the activation of multiple cell signalling pathways to repair the DNA, which involves halting the cell cycle at its checkpoints.

Fig. 1.4 shows one such simplified pathway, known as the DNA damage response (DDR) signalling pathway. DDR activation depends on two protein kinases, ATM and ATR. ATM responds to double-stranded breaks (DSBs), where a double-stranded DNA breaks off at both strands, and ATR is activated by the presence of single-stranded DNA and any defects in replication fork progression. The result of the pathway is the inhibition of cell cycle progression.

In response to the activation of ATM and/or ATR, the following pathways occur:

- Phosphorylation of the histone protein H2AX to form *γ*-H2AX (gamma-H2AX).
- The activation of SOG1, a transcription factor, activating proteins NAC44 and NAC85, which in turn will lead to the regulation of the M checkpoint.
- The expression of RBR1 and E2FA proteins, which are tumour suppressor proteins and WEE1, which is a G2 Checkpoint Kinase.

Through the activation of DDR, the DNA is subsequently repaired.

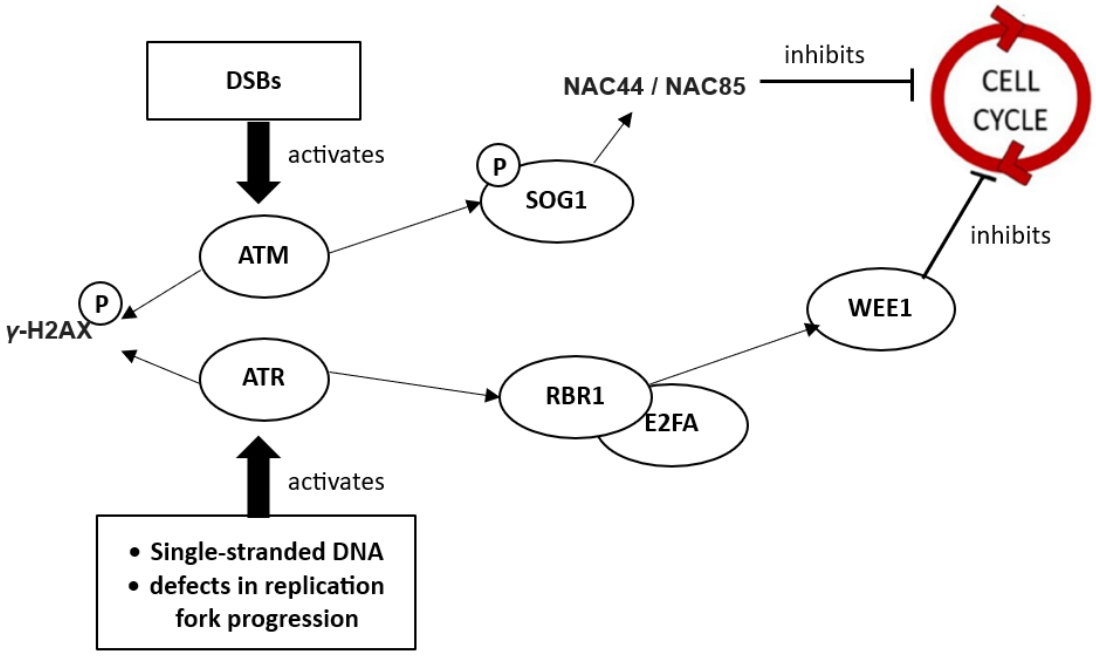

Fig. 1.4

Table 1.1 lists down three processes that will result from the activation of the DDR pathway.

Table 1.1

Which protein kinase ATM and/or ATR will be activated?	Protein(s) involved	Processes due to activation of ATM / ATR
		formation of heterochromatin
		cell size stops increasing
		spindle fibres not attached to centromere

(d) (i) Complete Table 1.1 by filling in the following:

- If protein kinase ATM, ATR or both activated the pathway.
- The protein(s) that fit the description: H2AX, SOG1, NAC44, NAC85, RBR1, E2FA and WEE1. You are to fill in all the protein names in the table, and you only need to fill in each protein once. [3]

(ii) Explain the importance of inhibiting cell cycle progression in the presence of DSBs and single-stranded DNA.

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…… [3]

(iii) Suggest why it is possible for tomato plants to have tumours but not cancer.

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…… [2]

(e) The gradual decline in tomato plant production over the years can also be attributed to diseases caused by plant viruses. One such virus is the tomato spotted wilt virus (TSWV), which was first described in Australia in 1919. Most TSWV variants are enveloped viruses, and their genetic material is distributed across three segments. They have been found to bear resemblance to a few animal-infecting viruses. One such example is the animal influenza virus, in which there is similarity in the type of genetic material and reproduction cycle.

TSWV is also the only plant virus transmitted to other types of crops, such as potatoes and cucumbers, via thrips, a type of insect that sucks the sap of plants.

Fig. 1.5 shows the structure of TSWV. Fig. 1.6 shows the thrip insect.

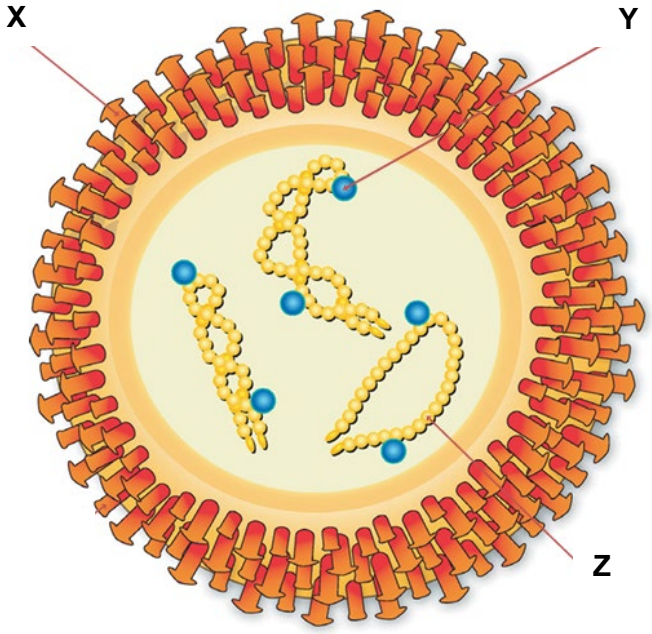

Fig. 1.5

Fig. 1.6

Using the information provided and your own knowledge of the influenza virus,

(i) Identify the structures **X, Y** and **Z**.

X: ……..

Y: ……..

Z: …….. [3]

(ii) Describe how the genetic material is replicated and used in the TSWV reproduction cycle.

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…… [3]

(iii) Identify how the thrip is able to transmit the virus from one plant to another.

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…… [1]

[Total: 30 marks]

2 Diseases can be characterised by defects that occur in many protein structures. For example, there are several diseases related to defects in the haemoglobin structure, which can lead conditions such as anaemia.

(a) State the effect on the haemoglobin's structure for the following defects and how it affects the function of the haemoglobin.

(i) No iron found in haem group

Effect on structure ……

……

Affected function ……..

…….. [2]

(ii) Hydrophilic amino acid residues in the interior of structure.

Effect on structure……

……

Affected function ……..

……... [2]

There are also many inherited diseases associated with the immune system. One such disease is Bruton Agammaglobulinemia, which is an inherited immunodeficiency disorder where B cells are unable to mature and the individual's immunity is compromised.

(b) **(i)** Describe three structural features of immunoglobin which allow it to perform its function.

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……... [3]

(ii) Explain why an individual's immunity is compromised when B cells are unable to mature.

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……... [2]

(iii) Researchers have found a way to genetically engineer plants to produce antibodies, known as plantibodies. Plantibodies can be extracted and injected into humans to fight diseases.

Suggest how using plantibodies could be advantageous over the natural methods of producing antibodies in humans.

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……... [1]

[Total: 10 marks]

3 *Acropora* is a genus of coral known for their size and hardness. They are also known to be the main contributors to the building of reefs. They contain numerous species and their phylogeny is well studied.

The number of single nucleotide polymorphisms (SNPs) shared between species can help to illustrate the relationship between these corals. SNPs are variations at a single position in a DNA sequence among individuals. A total of 1000 SNPs per species was investigated between three species, *A. hyacinthus, A. robusta* and *A. pichoni.* Table 3.1 shows the number of SNPs unique to each species when compared with one another.

Table 3.1

Comparison between species		Number of unique SNPs
A. hyacinthus	*A. robusta*	44
A. robusta	*A. pichoni*	724
A. pichoni	*A. hyacinthus*	487

(a) Using the information provided,

(i) calculate the number of shared SNPs between each species in the space below.

Between *A. hyacinthus* and *A. robusta*: ……

Between *A. robusta* and *A. pichoni*: ……

Between *A. pichoni* and *A. hyacinthus*: …… [3]

(ii) determine which two species have the most recent common ancestor. Explain your answer.

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…… [2]

(b) Explain why it is impossible for evolution to occur at the individual level.

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…… [3]

Fig. 3.1 shows a group of unicellular photosynthetic algae, zooxanthellae, that reside in the cells of these corals. The relationship between the zooxanthellae and the corals is known to be symbiotic.

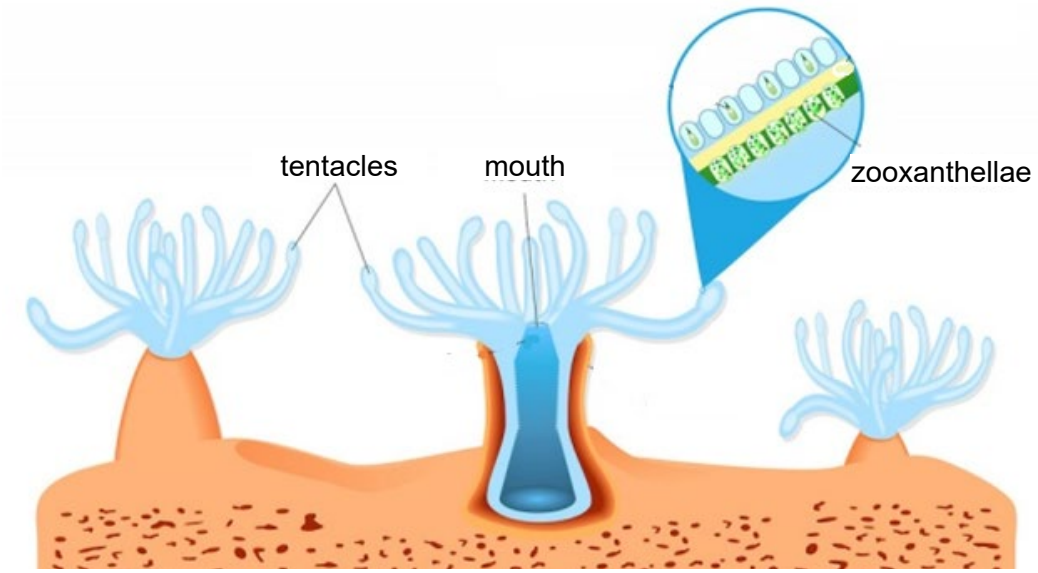

Fig. 3.1

(c) Describe how the relationship is symbiotic.

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…… [2]

[Total: 10 marks]

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 pose, where appropriate.

Your answers must be set out in parts (a) and (b), as indicated in the question.

4 **(a)** Prokaryotic and eukaryotic genomes are organised differently.

Explain how these differences affect the regulation of gene expression in prokaryotes and eukaryotes.

[10]

(b) With reference to the life cycle of *Aedes aegypti*, describe the impact of temperature on the mosquito vector and dengue transmission. **[15]**

[Total: 25]

5 **(a)** The cell theory is characterised by concepts that define a cell.

Explain how these concepts can be accounted for by both mitosis and the different types of stem cells.

[10]

(b) With reference to examples, explain how phenotype is linked to genotype and the environment. **[15]**

[Total: 25]

END OF PAPER

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