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NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATIONS
Higher 2

CANDIDATE NAME

CLASS

BIOLOGY 9744/03

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

2 hours

READ THESE INSTRUCTIONS FIRST

Write your name and CT on all the work you hand in.
Write in dark blue or black pen.
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 on the separate Answer 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 no use appropriate units.

At the end of the examination, fasten all your work securely together.

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

For Examiner's Use	
Section A	
1	
2	
3	
Section B	
Total	

This document consists of **14** printed pages.

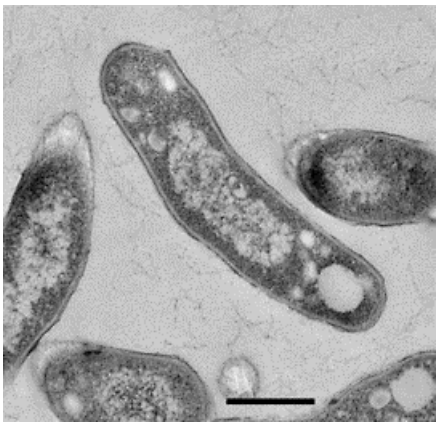
[Turn over

Section A

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

1 (a) Tuberculosis (TB) is a major cause of ill health worldwide. Prokaryotic *Mycobacterium tuberculosis* is the causative agent of TB.

Fig. 1.1 shows the longitudinal section of *M. tuberculosis*, viewed under the transmission electron microscope, with a scale bar representing 500nm.



Source: Muhsin Özel, Gudrun Holland/RKI

Fig. 1.1

(i) List **two** features visible in Fig. 1.1 that identify these cells as prokaryotes.

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[2]

(ii) Outline the process by which *M. tuberculosis* reproduce.

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[4]

(iii) Identify and explain **one** problem of trying to classify prokaryotes such as *M. tuberculosis*.

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[2]

(b) The World Health Organization (WHO) introduced a strategy in 2015 to end the global TB epidemic.

An important part of the strategy is to:

- identify people at risk of becoming infected with TB
- use methods to prevent transmission of TB.

(i) State the mode of transmission of *M. tuberculosis* to humans.

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[1]

(ii) The BCG vaccination is one method of prevention recommended for use in countries where TB is common. The BCG vaccine contains a non-pathogenic, living form of the microorganism that causes TB.

Complete Table 1.1 by using a tick (✓) to identify the type of immunity that develops in a person who has been given the BCG vaccination.

Table 1.1

artificial active immunity	
artificial passive immunity	
natural active immunity	
natural passive immunity	

[1]

(c) The treatment for people with active tuberculosis (TB) lasts six months and involves a combination of antibiotics. This is usually very effective if the person has a susceptible (non-resistant) strain of *M. tuberculosis*.

Table 1.2 summarises one recommended treatment strategy that involves a combination of antibiotics.

Table 1.2

antibiotic	**length of treatment**	**mode of action of antibiotic**
rifampicin (R)	6 months	enters bacterial cells and inhibits protein synthesis
isoniazid (H)	6 months	prevents the synthesis of cell wall components known as mycolic acids
ethambutol (E)	first two months	prevents mycolic acids from being added to the cell wall
pyrazinamide (Z)	first two months	prevents the synthesis of fatty acids

Susceptible strains of *M. tuberculosis* will be killed using any one of the antibiotics listed in Table 1.2. However, combination treatment is preferred as it is one method that can be used to reduce the impact to society of antibiotic resistance.

(i) Explain how antibiotic resistance in *M. tuberculosis* develops.

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[4]

(ii) With reference to Table 1.2, explain how combination treatment for TB can help to reduce the impact of antibiotic resistance compared to single antibiotic treatment.

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[3]

Rifampicin binds tightly to an RNA polymerase molecule close to its active site. This affects the activity of the enzyme.

(d) (i) Outline briefly the main role of RNA polymerase in *M. tuberculosis*.

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[2]

(ii) Suggest the effect of rifampicin on RNA polymerase.

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[2]

(e) 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* result in strains of *M. tuberculosis* that are resistant to rifampicin. In these strains, mutations often occur in two DNA triplets in this region, in positions 526 and 531.

Table 1.3 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 1.3 includes:

- the change in the **mRNA codon** for position 526 or position 531
- the amino acid change that has occurred as a result of the mutation
- 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*.

Table 1.3

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		

(i) Complete Table 1.3 to show the amino acid changes that have occurred in strains **F** and **G**. [1]

(ii) With reference to Table 1.3, list the strains of *M. tuberculosis* that show the greatest resistance to rifampicin.

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[1]

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

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[3]

(f) WHO Global Tuberculosis Report for 2019 published data on the estimated number of deaths from TB and HIV/AIDS in 2018. All deaths of people from TB who were infected with HIV were also counted as deaths of people with HIV/AIDS.

Fig. 1.2 shows these data. The dark grey boxes show the estimated number of deaths of people from TB who were also counted as deaths of people with HIV/AIDS.

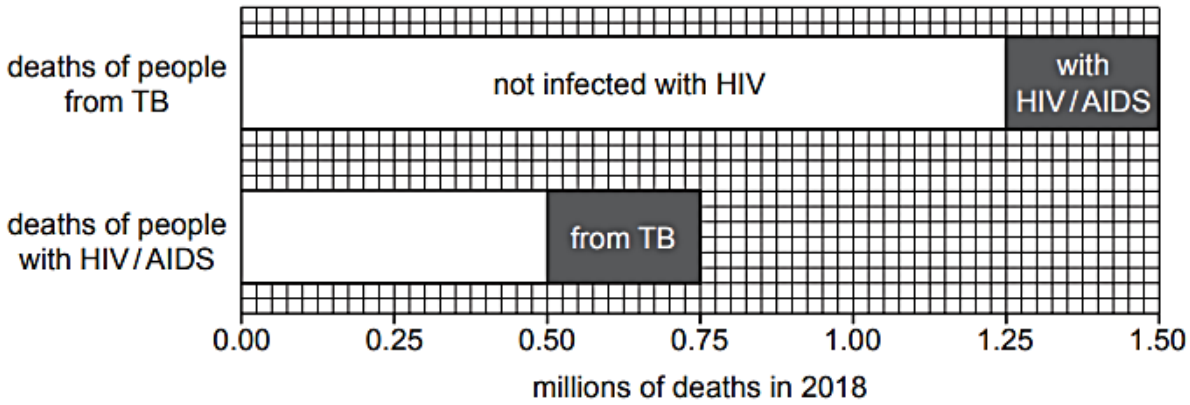

Fig. 1.2

A student used the data in Fig. 1.2 to predict that measures to control the spread of HIV will decrease the number of deaths from TB.

Discuss whether the data in Fig. 1.2 support this prediction.

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[3]

[Total: 29]

2 **(a)** All organisms respire. The ATP produced as a result of respiration is used as the energy currency of the cell.

(i) Outline **two** examples of movement in cells that use ATP.

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[2]

(ii) ATP cannot be stored in cells so it has to be continually re-synthesised to meet the demands of an organism.

A person with a total quantity of 0.2 moles of ATP needs to hydrolyse 150 moles of ATP per day.

Calculate how many times the total quantity of 0.2 moles of ATP has to be re-synthesised per hour to meet the demand of 150 moles per day.

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

answer = ... [2]

(iii) Name the stages in which chemiosmosis occurs in respiration and in photosynthesis.

respiration

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photosynthesis

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[2]

(b) Fur seals are mammals that are adapted to live in cold temperatures. Fur seals have large quantities of a type of fat tissue known as brown adipose tissue. Brown adipose cells contain many mitochondria. These mitochondria contain a transport protein called thermogenin.

Fig. 2.1 shows the role of thermogenin in a mitochondrion of a brown adipose cell when external temperatures are cold.

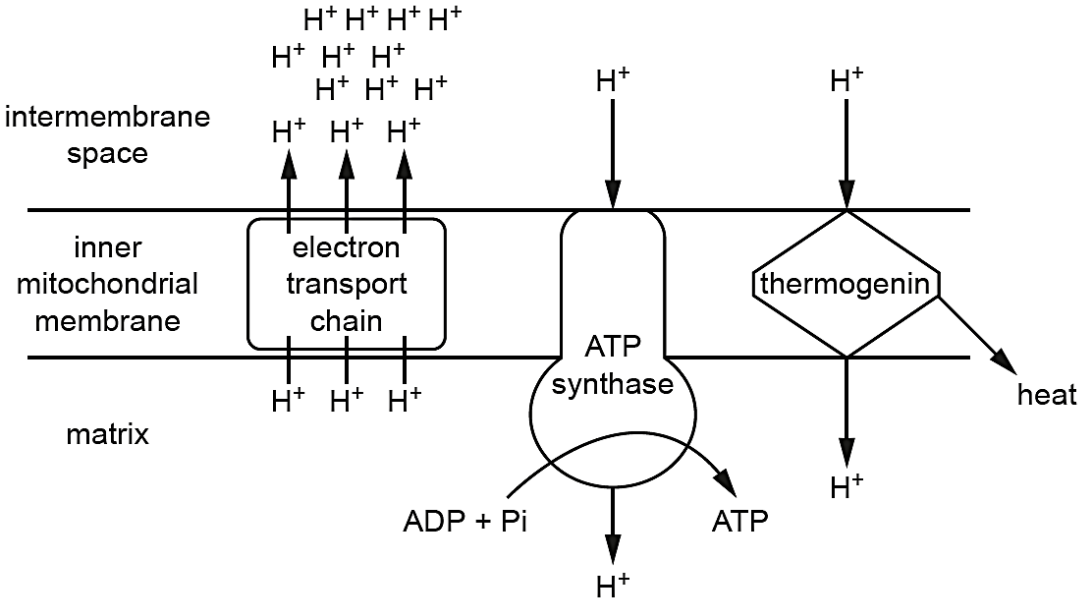

Fig. 2.1

(i) With reference to Fig. 2.1, describe **and** explain the effect of thermogenin on ATP synthesis.

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[3]

(ii) When the external temperature is warm, thermogenin cannot function.

When the external temperature becomes cold, thermogenin is able to function as a result of cell signalling:

- adrenaline is released
- adrenaline acts on G protein-coupled receptors found on brown adipose cells
- a sequence of events is triggered that results in the activation of the enzyme lipase
- lipase hydrolyses triglycerides in the cells into fatty acids
- fatty acids enter the mitochondrion
- thermogenin starts to function.

Outline the stages of cell signalling that trigger the functioning of thermogenin.

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[3]

[Total: 12]

3 **(a)** Scientists have produced structures known as virosomes, which are used in certain vaccines. Virosomes do not cause disease.

Fig. 3.1 is a diagram of a section through a virosome used in some vaccination to protect against the virus which causes influenza.

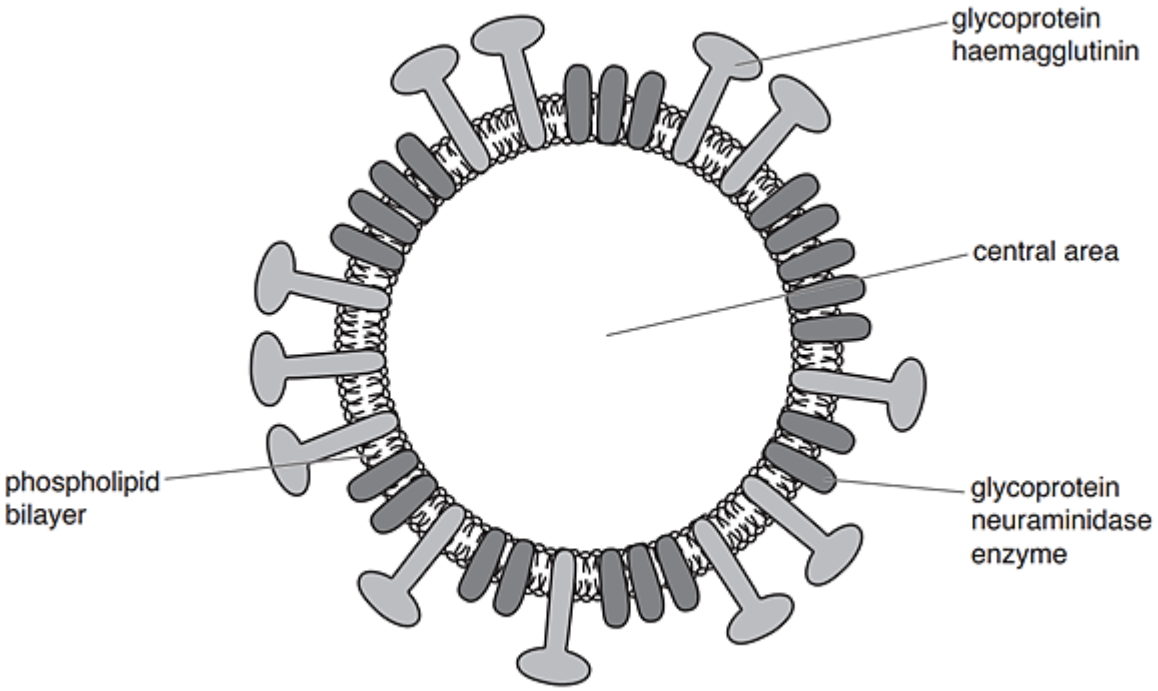

Fig. 3.1

(i) State the differences between the structure of a virosome and an influenza virus.

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[2]

(ii) Explain how the structure of the virosome shown in Fig. 3.1 suggests that the central area of the virosome is aqueous.

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[2]

(b) The glycoproteins haemagglutinin and neuraminidase are found in the influenza virus and in the virosomes used in a vaccine against the influenza virus.

Haemagglutinin binds to a receptor in the cell surface membrane of phagocytes.

Suggest why haemagglutinin is present in virosomes used in the vaccine for influenza.

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[3]

(c) Different strains of the influenza virus have formed as a result of mutations. Each strain of the virus contains the enzyme neuraminidase. Neuraminidase helps the virus to leave host cells after the virus has replicated. In each strain of the influenza virus, the primary structure of the active site of the neuraminidase enzyme remains unchanged.

Suggest why the primary structure of the active site of neuraminidase remains unchanged in each strain of the influenza virus.

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[2]

[Total: 9]

Section B

Answer **one** question in this section.

Write your answers on the separate answer paper provided.

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) 'All mutations in the cells of a human body are harmful.' [13]

Discuss this statement.

(b) Cycles play important roles in both natural and man-made biological processes. [12]

Explain the significance of cycles in biology.

[Total: 25]

5(a) 'All cells of a human body are genetically identical'. [13]

Discuss this statement.

(b) 'Membranes of different types of cells are involved in many different functions.' [12]

Explain this statement.

[Total: 25]