Civics Group	A Level Index Number	Name (use BLOCK LETTERS)	**H2**

ST. ANDREW'S JUNIOR COLLEGE
2023 JC2 PRELIMINARY EXAMINATIONS

H2 BIOLOGY **9744/03**

Paper 3

Friday 15th September 2023 2 hours

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and index number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagram, graph or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.
Write your answers in the spaces provided on the question paper.

All working for numerical answers must be shown.

For Examiners' Use	
1	/40
2	/10
4 or 5	/25
Total	**/75**

This document consists of **21** printed pages.

[Turn over]

Answer **all** *questions*.

QUESTION 1

On October 14, 2021, the World Health Organization (WHO) released the Global Tuberculosis Report 2021, which showed that 9.87 million new cases of tuberculosis and 1.5 million people died of tuberculosis in 2020. Among them, the estimated number of new cases of tuberculosis in China in 2020 was 842,000 (833,000 in 2019), and the estimated incidence of tuberculosis was 59/100,000 (58/100,000 in 2019). Among the 30 countries with a high burden of tuberculosis, China ranks second in the number of estimated cases of tuberculosis and has over 30,000 deaths due to tuberculosis.

(a)(i) In Fig. 1.1 below, label X and Y appropriately, to reflect the pathogenesis of tuberculosis.

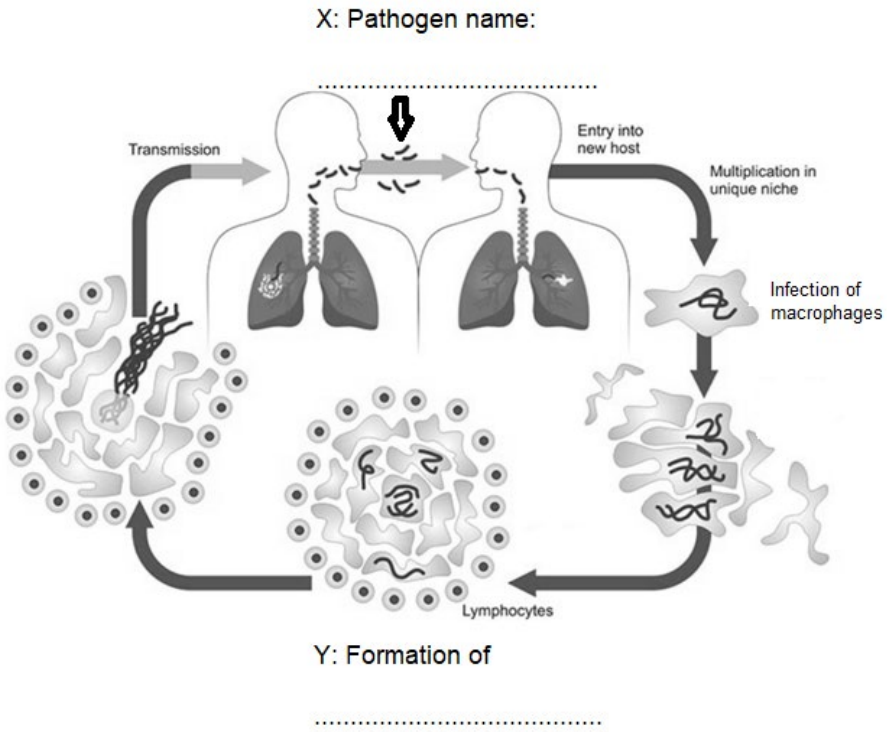

Fig. 1.1

[2]

(ii) With reference to a cellular organelle in the macrophages, describe how macrophages usually attempt to process engulfed bacteria.

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Fig. 1.2 shows the cell wall of the bacteria causing tuberculosis and its unique make up of fatty acids which are slightly different from those used in the synthesis of triglycerides in eukaryotes.

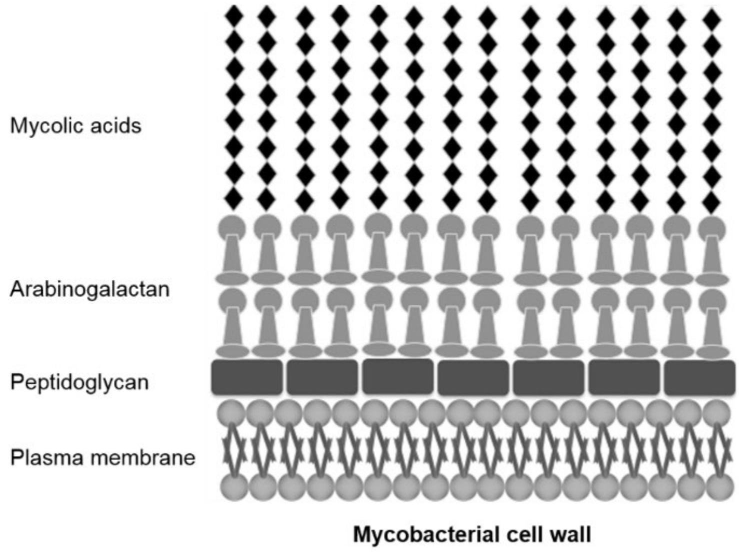

Fig. 1.2

(iii) With reference to Fig. 1.2, explain how the bacteria causing tuberculosis can evade the mechanisms of the macrophage host cells.

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(iv) Complete and annotate on the diagram below to show the production of a triglyceride from its constituents in eukaryotes.
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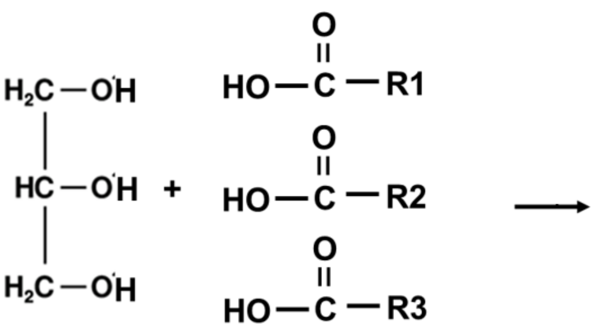

Most infections are latent and do not have symptoms. Latent infections can progress to active form of the disease which, if left untreated, kills about half of those infected.

The most common classic symptoms of active TB include chronic cough with blood-containing sputum, chest pain and shortness of breath.

(v) Explain the cause of the shortness of breath symptom of TB in its **active** stage.

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Bacteria causing tuberculosis is able to acquire genes coding for antibiotic resistance through various ways, leading to multi-drug resistant tuberculosis. An example is bacteria that are resistant to rifampicin, a key drug in the treatment of tuberculosis.

The mode of action of rifampicin in bacteria is by binding to the beta (β)-subunit of the RNA polymerase, inhibiting the elongation of messenger RNA.

In about 96% of bacteria resistant to rifampicin, there are mutations in the so-called “hot-spot region” of DNA transcribing into codons 507–533 of the *rpoB* gene, which codes for the beta (β)-subunit of bacterial RNA polymerase.

[edited from Palomino JC, Martin A. Drug Resistance Mechanisms in Mycobacterium tuberculosis. Antibiotics (Basel). 2014 Jul 2;3(3):317-40]

(vi) Calculate the length of the DNA in the “hot-spot region”. Represent your answer in bp.

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(vii) Explain why a mutation to the *rpoB* gene can lead to resistance to rifampicin.

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(viii) Discuss how natural selection could have led to the evolution of antibiotic rifampicin resistance in bacteria causing tuberculosis.

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(b) Table 1 below shows the effect of a newly discovered antibiotic X on the survival of bacteria causing tuberculosis.

The same volume of bacteria causing tuberculosis was plated on nutrient medium plates and incubated at 37°C overnight.

For control plates, there was no antibiotic added to the nutrient medium plates, while test plates contains the antibiotic. For each condition, 4 readings from 4 plates were measured to obtain replicate readings.

At the end of incubation, the number of bacterial colonies are counted and presented in Table 1.

Table 1: Effect of antibiotic X on the number of bacterial colonies after incubation

		Number of colonies				
Condition	Count 1	Count 2	Count 3	Count 4	Average (whole number)	Standard deviation (3 s.f.)
Control	55	61	58	73		
Test plates (antibiotic added)	13	20	7	12		

(i) Calculate the **average** and complete Table 1. Express your answers to **nearest whole number**. [1]

(ii) Using the formula below, calculate the **standard deviations** of bacterial colony count, in the presence and absence of antibiotic X. Complete Table 1. Express your answers to **3 significant figures.** [1]

standard deviation $$s = \sqrt{\frac{\sum(x-\bar{x})^2}{n-1}}$$

Legend
$\sum$ is summation of
x is observed values
$\bar{x}$ is the mean
n is the sample size (number of observations per condition)

(iii) With reference to Table 1's calculations for test plates (with antibiotic added), explain what is standard deviation and its implications.

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(iv) Using the average and standard deviation values calculated in **(b)(i)** and **(ii)**, as well as critical t-values in Table 2,

Calculate the $t_{calculated}$ value.

$$t = \frac{(x_1 - x_2)}{\sqrt{\frac{(s_1)^2}{n_1} + \frac{(s_2)^2}{n_2}}}$$

Where:

- **x1** is the mean of sample 1
- **s1** is the standard deviation of sample 1
- **n1** is the sample size of sample 1
- **x2** is the mean of sample 2
- **s2** is the standard deviation of sample 2
- **n2** is the sample size in sample 2

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T calculated value = ……

(v) Determine if there is a significant difference in the number of colonies after the addition of antibiotic X.

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Table 2: Student's t-test table of t critical values

df	.10	.05
1	3.078	6.314
2	1.886	2.920
3	1.638	2.353
4	1.533	2.132
5	1.476	2.015
6	1.440	1.943
7	1.415	1.895
8	1.397	1.860
9	1.383	1.833
10	1.372	1.812
11	1.363	1.796
12	1.356	1.782
13	1.350	1.771
14	1.345	1.761
15	1.341	1.753
16	1.337	1.746
17	1.333	1.740
18	1.330	1.734
19	1.328	1.729
20	1.325	1.725
21	1.323	1.721
22	1.321	1.717
23	1.319	1.714
24	1.318	1.711
25	1.316	1.708
26	1.315	1.706
27	1.314	1.703
28	1.313	1.701
29	1.311	1.699
30	1.310	1.697
40	1.303	1.684
60	1.296	1.671
120	1.289	1.658
c	1.282	1.645

(vi) Bacteriophages called mycobacteriophages is another treatment method for tuberculosis, as an alternative to administration of antibiotics.

Suggest a limitation for using mycobacteriophages against bacteria causing tuberculosis.

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(c) The biosynthesis of tryptophan, an amino acid, is essential for survival in bacteria. This process varies between different species of bacteria.

Fig. 1.3 shows the structure of an amino acid, tryptophan, in zwitterion form.

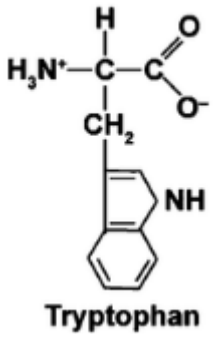

Fig. 1.3

(i) Circle the side chain of tryptophan. Suggest the chemical property of the side chain of the amino acid, tryptophan.

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In *Escherichia coli*, tryptophan synthesis involves the Trp operon, consisting of a group of functionally related genes under the control of one regulatory region. These genes code for enzymes which catalyze a series of reactions to form tryptophan.

(ii) Describe how the Trp operon is turned on in the absence of tryptophan.

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(iii) Explain what is meant by the biological species concept. Suggest why biological species concept cannot be used to classify bacteria into the different species.

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(d) Fig. 1.4 below shows a phylogenetic tree of different bacteria species **A**, **B**, **C**, **D** and **E**.

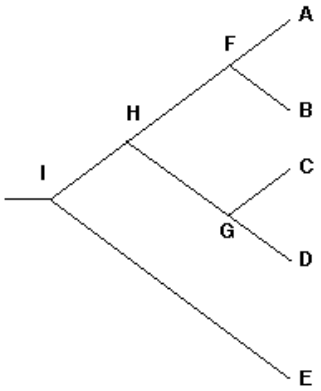

Fig. 1.4

Discuss two evolutionary conclusions which can be made about the relationships between the different bacteria species.

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(e) DNA–DNA hybridisation is a technique used to determine the similarity of DNA from different species.

In this technique:

- DNA is extracted from four bacteria species and a common gene is isolated.
- the gene is heated to separate the double strands into single strands;
- single-stranded DNA from different pairs of bacteria species are mixed together and cooled so that double strands of hybrid DNA form.

Fig. 1.5 shows the temperature (°C) needed to separate the hybrid DNA strands of the four bacteria species, *A, B, C and D.*

	A	***B***	***C***	***D***
A	99	95	81	80
B		98	82	82
C			99	95
D				97

Fig. 1.5

(i) With reference to Fig. 1.5, describe the difference in denaturation temperature for the *A*–*B* hybrid DNA and the *A*–*D* hybrid DNA.

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(ii) Infer on the degree of similarity in DNA sequence between species B and D to species A.

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(iii) Explain your answer in **(e)(ii).**

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(iv) Explain two advantages of using molecular methods in classifying organisms compared to using similarities in morphology.

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[Total: 40]

QUESTION 2

Fig. 2.1 shows the presence of zooxanthellae in corals.

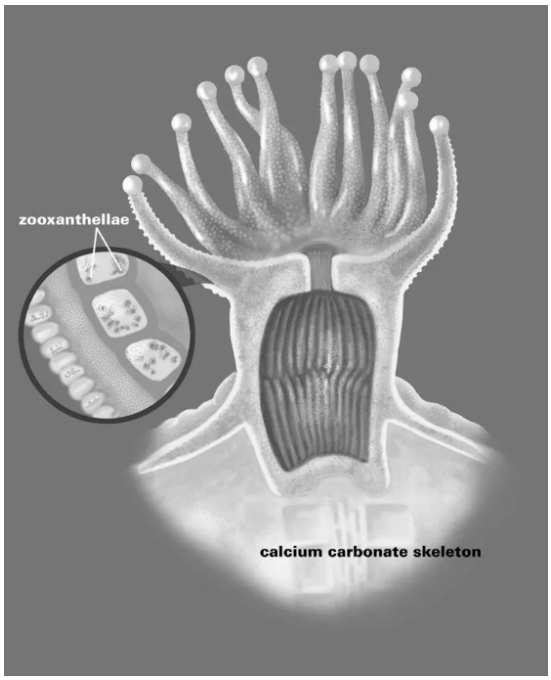

Fig. 2.1

(a) Describe, in detail, how zooxanthellae make use of light from the sun to benefit the corals.

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(b) Corals are affected by rising temperatures in ocean waters. Explain how.

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[Total: 10]

Essay

Answer **one** question only in this section.

Write your answers on the lined paper provided at the end of this question paper. Indicate the choice of question clearly on your answer.

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 sections (a), (b) etc., as indicated in the question.

4	**(a)**	Describe the structure and organization of eukaryotic genomes**.**	[10]
	(b)	Contrast between mitosis and meiosis; and state the significance of both processes in **named processes** of living organisms	[15]
5	**(a)**	Describe the reproductive cycles of bacteriophages that reproduce via a lytic cycle, such as theT4 phage.	[10]
	(b)	Outline the central dogma of molecular biology, and discuss whether bacteria and viruses (HIV, influenza, Bacteriophages) follow the principles of the central dogma.	[15]

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End of paper