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 Mark scheme

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.

Conceptual error (C)	Data Quoting (D)	Expression (E)	Misreading the question (Q)

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

This document consists of **XX** 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.

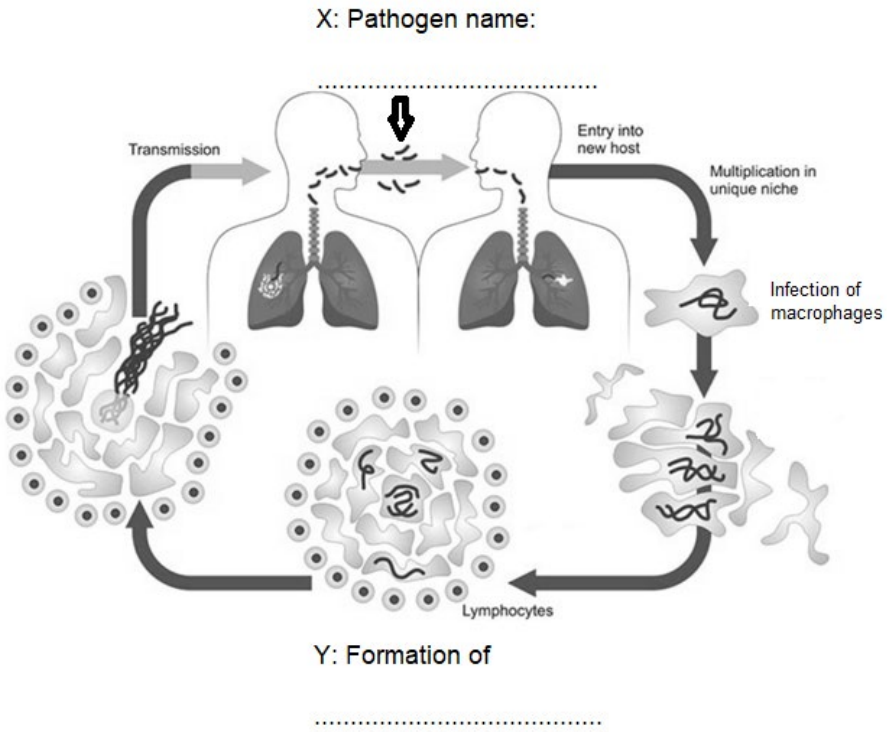


Fig. 1.1

[2]

Ans:

X: Mycobacterium tuberculosis [Reject: bacteria] [Accept: italics]

Y: granuloma [Accept: Tubercle]

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

……..……..……..……...[2]

1. Lysosomes contain **hydrolytic enzymes** in macrophages, (e.g. proteases), which hydrolyzes bacteria;
2. after lysosomes **fused with phagosomes/endocytic vesicle containing bacteria;**

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.

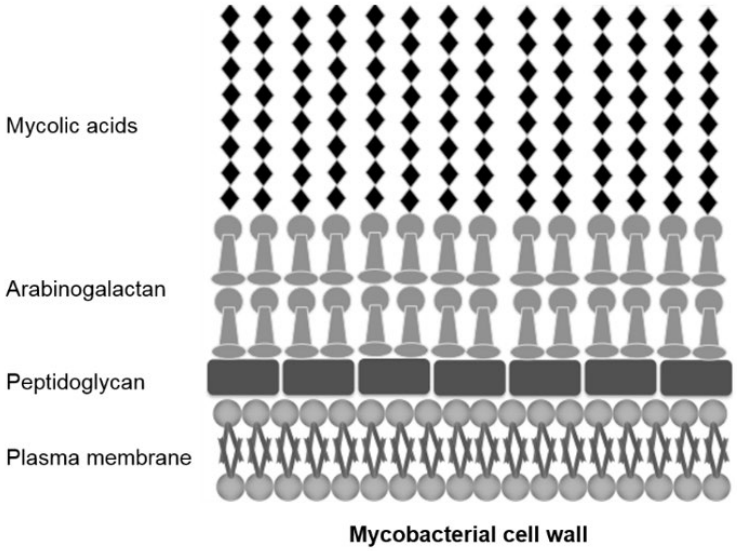


Fig. 1.2

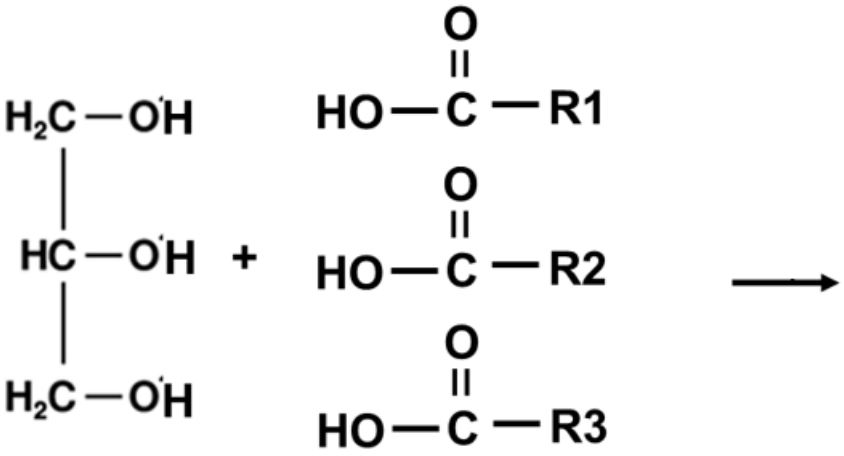
(iii) With reference to Fig. 1.2, explain how the bacteria causing tuberculosis can evade the mechanisms of the macrophage host cells.

……..……..……...[1]

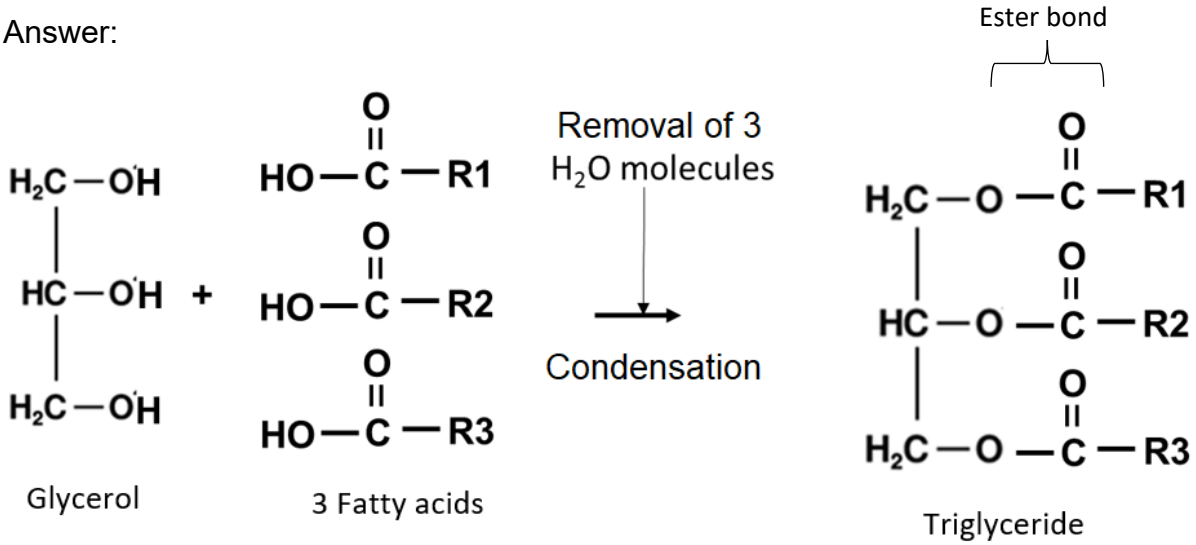
1. Their mycolic acid wax coat on their cell walls also **protects them against** hydrolytic **enzymes** in lysosomes;

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

……..……..……[2]



Answer:



1. Correction drawing of triglyceride molecule;
2. Annotation: naming of glycerol, 3 fatty acids; removal of **3 water molecules**; and label of ester bonds

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.
……..…………………………………………………………………..……..…………....[2]

1. **Bacteria** destroy **alveoli** (e.g. by releasing toxins or infecting **alveolar** epithelial cells) /causes other **immune cells** trying to contain the infection to release toxins which destroy **alveoli** tissue and form cavities in the lungs; (these damaged areas may become infected with other bacteria and form pockets of pus)
2. Damage of alveoli leads to less surface area for diffusion processes / increases diffusion distance in the lungs; (leading to wheezing for air). [Accept: less efficient gaseous exchange]

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.

…………………. bp

[2]

1. Number of codons = 533 – 507 +1 = 27;

2. Each codon consists of 3 bases, length of DNA = 27 x 3 = 81 bp; [allow ecf: e.g. 26 x 3 = 78 bp]

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

……..[3]

1. Ref. change to **DNA** sequence will lead to altered **mRNA** / codon sequence;
2. Ref. altered **amino acid** sequence; and **3D conformation** of the beta subunit RNA polymerase;
3. Rifampicin is unable to **recognize** through 3D conformation / **bind** to (beta subunit of) RNA polymerase; **unable to inhibit transcription in bacteria / cannot inhibit elongation of mRNA chain**; (leading to resistance of rifampicin) [Reject: answers mentioning only on RNA polymerase unable to catalyse transcription without any reference to antibiotic rifampicin]

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

……..…….....…[4]

1. **Genetic variation** in susceptibility to antibiotics exists in the bacterial populations due to **mutations**;
2. Bacteria are subjected to selection pressure + e.g. **introduction of antibiotics;**
3. Bacteria with genes coding for antibiotic resistance are at a **selective advantage + reason** able to avoid binding of rifampicin to RNA polymerase;
4. Such bacteria can better **survive** and **reproduce** / by binary fission, **passing down the advantages alleles** [reject: traits/characteristics] to their offspring;
5. Ref. pass on resistant allele by **horizontal gene transfer** / transduction/ conjugation / transformation to other bacteria cells; (followed by passing on of such alleles to progeny cells by binary fission)
6. Over time, **allele frequencies change** and bacteria resistant to rifamcipin become predominant (in the population);

[Max 4]

(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		

Ans:

		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	62	7.90 (3s.f) Accept: 7.89
Test plates (antibiotic added)	13	20	7	12	13	5.35 (3s.f)

(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.

……[2]

1 Standard deviation is the **deviation from the mean** number of bacterial colonies;
2 and determines the **range** of the number bacterial colonies;
3 [Evidence with quoted or manipulated data] The number of colonies ranges from 7.7 (13.0 – 5.35) to 18.4 (13.0 + 5.35) [Accept: 8 to 18 if students round to whole number to represent colonies] for plates with antibiotic added / the number of colonies deviates 5.35 colonies from the mean of 13.0;
4 [Implications] Standard deviation is an indication of the reliability / reproducibility of the data collected. Since standard deviation for plates with antibiotics added is high, results are not very reliable / reproducible;

[Any 2]

(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

……..[1]

1. One mark for correct calculation of value (step 2) – 10.271 (3 d.p)

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

……..[2]

1. One mark for correct calculation of DoF (Ans: 6) and identification of Tcritical value of 1.943 (step 3,4);
2. One mark for correct comparision of Tcalculated and Tcritical and making a correct conclusion:

$t_{calculated}$ of 10.271 is higher than $t_{critical}$ (1.943); there is a significant difference between the number of colonies counted in the presence and absence of antibiotic X (step 5);

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

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

Working for Reference:

Step 1: Null hypothesis:

There is no significant difference in the number of colonies counted in the presence and absence of antibiotic X

Step 2: Calculation of experimental t-value

$x_1 - x_2 = 62 - 13 = 49$
$(s_1)^2 = (7.90)^2 = 62.41$
$(s_1)^2 / n = 62.41 / 4 = 15.60$
$(s_2)^2 = (5.35)^2 = 28.62$
$(s_2)^2 / n = (5.35)^2 / 4 = 7.16$

$t = 49/\sqrt{\{15.60 + 7.16\}}$

$t_{calculated}$ = **10.271 (3 dp according to T table)**

Step 3: Calculation of Degrees of Freedom
Degrees of Freedom is sum of sample sizes for control and test minus 2 = 8-2 = **6**.

Step 4: Stating of $t_{critical}$ value (from Table of significance, looking at p=0.05)
$t_{critical}$ value for 6 DoF and p value 0.05 is **1.943**.

Step 5: Comparison between $t_{calculated}$ and $t_{critical}$
$t_{calculated}$ of 10.271 is higher than $t_{critical}$ (1.943) . Null hypothesis is not accepted.

Conclusion:
There is a significant difference between the number of colonies counted in the presence and absence of antibiotic X.

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.

……[1]

1. Ref. *M. tuberculosis* bacteria is not easily accessed due to its presence inside host macrophages/cells;
2. AVP: possibility of bacteria having random mutation to change the shape of its receptors; thus, phage attachment sites cannot bind;
   / mycobacteriophages are targeted by the human immune system and eliminated before it is able to affect the targeted bacteria;
   / phage might undergo latency and outcomes are not immediate;
   [Any 1]

(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.

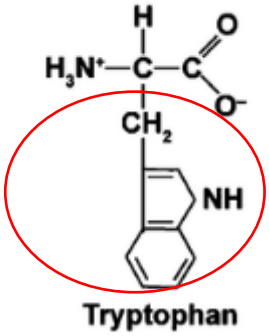


Fig. 1.3

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

……[1]

1. Correct circling of side chain / R group; **and** correct chemical property: Non-polar / hydrophobic;

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.

……[4]

1 The *trp* repressor protein coded by the regulatory gene (trpR) is **constitutively** expressed, normally in its **inactive** (non DNA-binding) **form ;**

2 In absence of tryptophan, *trp* repressor **remains in the inactive form** and does not bind to the *trp* operator site;
3 RNA polymerase recognises and **binds** to the promoter of the *trp* operon;
4 and initiates **transcription** of the 5 structural genes, *trpE*, *trpD*, *trpC*, *trpB* and *trpA* ; *(*mentioned in qn: *trp* operon is switched on ;
Repressible enzymes are synthesized for tryptophan biosynthesis; [Reject: tryptophan is synthesized after transcription])

(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.

…… [2]

1 [Definition] The Biological species concept states that organisms of the same species have the ability to interbreed to produce a **viable** and **fertile** offspring;
2 Ref. bacteria is **asexual**;

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

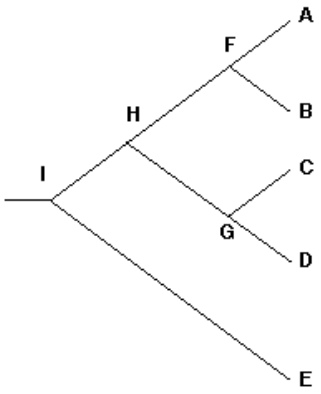


Fig. 1.4

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

…… [2]

1. Species A, B / C and D share more common characteristics with each other than any of them share with Species E;
/ Species I is the common ancestor of A, B, C, D and E;
2. Species H is the most recent common ancestor for A and D;
3. Species F is a common ancestor for A and B;
4. Species G is a common ancestor for C and D;

[Any 2]

Rejected answers:

- Any reference to taxonomy terms e.g. same genus etc.

(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.

……[1]

1. [Describe] The denaturation temperature of *A*-*B* hybrid DNA of 95°C is **higher** than that of the *A*-*D* hybrid DNA, which is 80°C;

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

……[1]

1. There is **higher molecular homology** in the DNA sequence between species *A* and *B* than between *A* and *D*;

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

……[1]

[Explain]

1. Ref. **more hydrogen bonds** are found in the *A*-*B* hybrid DNA than in the *A*-*D* hybrid DNA, hence requires higher temperature to denature; (higher temperature involves

more heat energy, which can be converted to kinetic energy to break the hydrogen bonds)

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

……[2]

1. **Quantifiable** and **open to statistical analysis**;
   Limited morphogical data available;
2. **Unambiguous** and **objective**;
   Morphological data may differ depending on the way in which it was classified
3. **Not affected by convergent evolution** /
   some characteristics may be analogous / similar morphology may not have been inherited from common ancestor;
4. AVP: Molecular methods allow a wider range of organisms that can be analysed based on common gene / amino acid sequence; vs limited options for morphology based on shared characteristics;

[Any 2]

[40 marks]

QUESTION 2

Fig. 2.1 shows the presence of zooxanthellae in corals.

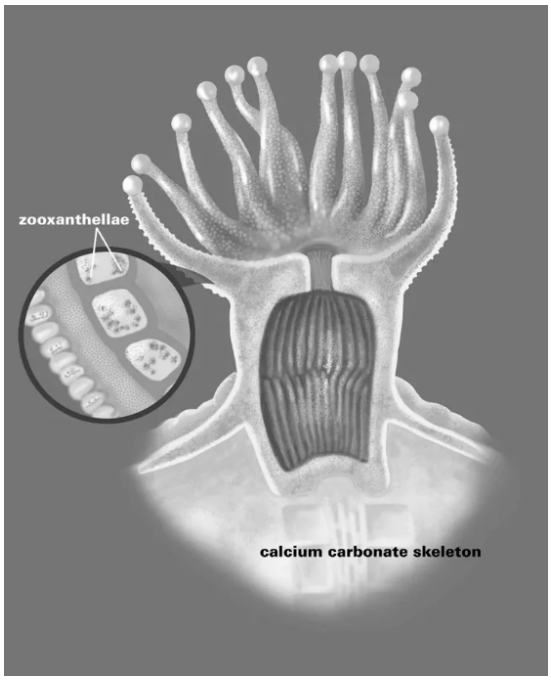


Fig. 2.1

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

……..……..[7]

Ref. photophosphorylation: Non-cyclic photophosphorylation involves photosystem I & II

PSII

1. Light shines on (light harvesting complexes in) PS II, leading to electron excitation at special chlorophyll a ; electron captured by primary electron acceptor (PEA) ;
2. *Ref.* electrons (from PEA) are transported along the series of electron carriers of progressively **lower** energy levels **;**
3. energy released from the electron transport is used to pump H^+ from the stroma, across the thylakoid membrane and into the thylakoid space (via active transport) ;
4. [chemiosmosis with elaboration] a proton gradient is generated across the thylakoid membrane ; H^+ ions diffuse through the ATP synthase ; from the thylakoid space into the stroma of the chloroplast / down a concentration gradient ;
5. ATP synthase complex catalyses the synthesis of ATP from ADP and Pi ;

PSI

6. [Light shines on PS I, leading to electron excitation at special chlorophyll a ; electron captured by primary electron acceptor (PEA) = photo-excited electrons] **Photo-excited electrons** from PS I are passed (along the series of electron carriers in electron

transport chain) to $NADP^+$; H^+ ions from the stroma and the electrons from PS I reduce $NADP^+$ to NADPH;

Ref. Calvin cycle:

7. 3 CO_2 is fixed with 3 ribulose bisphosphate (RuBP) to form 6 glycerate-3-phosphate/phosphoglycerate* (GP) (catalyzed by Rubisco);
8. 6 GP are reduced by 6 NADPH to form 6 glyceraldehyde 3-phosphate (G3P)/ triose phosphate. The energy for this reaction is provided by 6 ATP.;
9. 1 G3P exits Calvin cycle in **each round of the Calvin cycle** to form glucose monomers (with another G3P) / Two triose phosphate/G3P combine to form one glucose monomer;

[Max 6]

Benefit to corals: *[At least 1]*

10. (Zooxanthellae supply the coral with) glucose (which are the product of photosynthesis) for use as substrate for aerobic respiration in the coral ;
11. Excess glucose (provided by zooxanthellae) are polymerized to form glycogen for storage (for subsequent breakdown for respiration) ;
    [**Reject**: starch, amylose, amylopectin which are storage carbohydrates for plant and zooxanthellae]
12. Ref. oxygen gas, produced via **photolysis**, released by zooxanthellae for corals to respire ;

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

……[3]

1. Ref. Absorption of **more carbon dioxide which dissolves** when ocean waters get warmer ; **ocean pH decreases** / ocean acidification occurs ;
2. Hard **corals cannot absorb calcium carbonate** they need to maintain their **skeletons**, stony skeletons that support corals will dissolve and corals destroyed ;

AND

3. eventual **death of coral**
   [due to lack of strengthening of skeletons to help corals withstand breakage caused by currents, waves, storms, and boring & biting by worms, molluses, and parrot fish / due to corals unable to grow up towards lights to support photosynthesis of zooxanthellae, hence lack of glucose and nutrients from zooxanthellae supplied to coral]

OR

1. **Photosynthesis in zooxanthellae is disrupted** at higher than usual temperatures, thus producing an excess of **products that are toxic** ;

2. Coral polyp metabolism is affected and **corals expels the zooxanthellae**, (leaving the coral skeleton bleached)

AND

3. eventual **death of corals**
[due to lack of glucose and nutrients provided by zooxanthellae]

[10 marks]

Essay

Answer **one** question only 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 sections (a), (b) etc., as indicated in the question.

3 **(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]

4 **(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]

End of Paper

QUESTION 3

(a) Describe the structure and organization of eukaryotic genomes**.** [10]

Organisation of eukaryotic genome

4 ***successive*** levels of DNA organization: [max 5]

1 DNA is wound around a histone octamer to form a nucleosome; nucleosomes are linked together by linker DNA (to form "beads on the string" structure) *(1st level)* ;

2 Ref. ionic bonds between positively charged amino acids of histones and negatively charged DNA; (in formation of each nucleosome)

3 Interactions between histone tails of neighbouring nucleosomes, linker DNA and the H1 histone result in formation of the 30nm chromatin fibre / solenoid *(2nd level)* ;

4 The solenoid then attached to a non-histone protein scaffold to form looped domains / radial loops*(3rd level) ;*

5 During interphase, the radial loops are present on the nuclear lamina (a protein meshwork near the inner nuclear membrane);

6 During prophase, the radial loops are present on the central protein scaffold to form chromatin fibre of about 300-nm.

7 ref. to radial loops fold further to compact / condense to form metaphase chromosome *(4th level) ;*

[Max 4]

	Eukaryotic genome structure
Points specified in syllabus	
8 Genome size / Amount of DNA	Larger genomes, 10 Mb – 100,000 Mb / more total DNA per cell, about 1000 times more DNA.
9 Gene length	Longer gene sequences / presence of more intragenic *(within genes)* spaces (e.g. introns)
10 Chromosome structure	Linear DNA molecule with 2 ends
11 Packing of DNA	Eukaryotic DNA is complexed with histones and other proteins to form chromatin; DNA is coiled around histone octamer core and subsequently further packed into higher order chromatin structure.
12 Introns	Presence of introns within genes. (Introns account for the main difference in average length between human and prokaryotic genes)

Points <u>not</u> specified in syllabus	
13 Chromosome number	<u>Many</u> chromosomes / Diploid or polyploid
14 Presence and absence of operons	Absence of operons.
15 Repetitive sequences	Many repetitive DNA sequences
16 Coding and non-coding DNA	Most of DNA are non-coding.
17 Origins of replication	Many origins of replication present
18 Presence of extrachromosomal DNA	Circular, double-stranded DNA in mitochondria / chloroplasts.
19 Telomeres	Present

QwC: [1mark] QwC: Obtain at least 1 mark each from structure and organization of genome.

QwC: [1mark] Scientific argument exemplified by points touching on both similarity (minimum 2 points) and differences (minimum 2 correct sets)

(b) Contrast between mitosis and meiosis; and state the significance of both processes in **named processes** of living organisms. [15]

[Difference between mitosis and meiosis] [Max 7]

Feature	Mitosis	Meiosis
Products of nuclear division	**1** daughter cells are produced per mitotic cycle.	daughter cells, each **haploid**, called gametes are produced per meiotic cycle.
Ploidy of dividing cells	2 Dividing cells can be **haploid**, **diploid or polyploid**.	Dividing cells are **diploid or polyploid**.
Type of dividing cells	3 Occurs in almost all **somatic cells**.	Occurs only in **specialized cells of the germ line.**
Genetic content of daughter cells	4 Genetic content of daughter cells is **genetically identical** to the parental cell in terms of **chromosome number and genetic sequence**. [in the absence of mutation]	Genetic content of daughter cells **is not genetically identical** as **chromosome number** has been **halved** and the **genetic sequence** is **not identical**. [in the absence of mutation]
Genetic Variation in next generation	5 It does not lead to genetic variation in the next generation as daughter cells are **genetically identical** to parent cells.	It leads to genetic variation in the next generation as the daughter cells are **genetically non-identical** due to **crossing over** of portions of non-sister chromatids of homologous chromosomes during **prophase I** as well as **independent assortment** of homologous chromosomes during **metaphase I.**
Number of divisions per cycle	**6 One** nuclear and cytoplasmic division per cycle	**Two** nuclear and cytoplasmic divisions per cycle
Pairing of homologous chromosomes	7 Homologous chromosomes **do not pair up** during prophase.	Homologous chromosomes **pair up** during **prophase I**.
Crossing over of homologous chromosomes	**8 Chiasmata** are not formed and there is **no crossing over** between homologous chromosomes during **prophase.**	**Chiasmata** and **crossing over** may occur between non-sister chromatids of homologous chromosomes during **prophase I**.
Alignment of chromosomes during metaphase	9 Chromosomes **align singly** at the equator of the spindle during **metaphase**.	Homologous chromosomes **align in pairs** at the equator of the spindle during **metaphase I** but **align singly** at **metaphase II**.
Division of centromere	10 Centromere **divides in anaphase**.	Centromere **does not divide in anaphase I,** but then it **divides in anaphase II**.
Separation of chromatids/ chromosomes during anaphase	**11 Sister chromatids separate** and move to the opposite pole of the spindle and become independent chromosomes.	During **anaphase I, homologous chromosomes separate** and move to the opposite pole of the spindle. During **anaphase II**, **genetically non-identical chromatids** separate and move to the opposite pole of the spindle.
Additional division of products	12 Mitotic products are usually capable of undergoing additional mitotic divisions.	Meiotic products cannot undergo additional meiotic divisions although they may undergo mitotic divisions.
Occurrence in organism's life cycle	13 Occurs at the zygote stage and continues throughout the life of the organism.	Occurs only after a higher organism has begun to mature. Occurs in the diploid zygotes of many algae and fungi to restore its haploidy.

[Max 7]

[Significance of mitosis in named processes]

14 Growth;
Increase in number of genetically identical cells within the organism ensures that new cells are identical to existing cells so that they carry out the same function;

15 Repair;
Ensures that damaged cells lost in normal processes of wear and tear and disease are replaced with exact copies of the original cells in order for the tissue to function properly;

16 Asexual reproduction;
Ensures that offspring are genetically identical to the parent for continued survival of the species;
17 Allows rapid colonisation of new habitat for unicellular organisms such as amoeba & fungi;

18 Clonal expansion of lymphocytes;
Allows production of large numbers of lymphocytes recognising the same antigen;

19 Stem cell symmetric division to form more stem cells;
Allows for replenishing of stem cell pool;

20 Stem cell assymmetric division to form progenitor cells;
Allows for differentiation of progenitor cells into differentiated cells;

21 Cancer cell division;
Allows for formation of tumour;

[Reject: bacteria binary fission]

[Significance of meiosis in named processes]

22 Crossing over between non-sister chromatids of homologous chromosomes leads to exchange of equivalent portions of the chromatids ; results in new combinations of alleles ;
23 **Independent assortment of homologous chromosomes** at metaphase I and anaphase I;
Results in gametes with different combination of paternal and maternal alleles;

24 **Random fusion** of these genetically variable gametes results in genetic variation in zygote / individual / population / species after fertilisation.

QwC: Obtain at least 1 mark from the contrast and significance categories.

QUESTION 4

(a) Describe the reproductive cycles of bacteriophages that reproduce via a lytic cycle, such as theT4 phage. [10]

Name	**T4 Bacteriophage**
Reproductive cycle	**Lytic cycle**
Adsorption	1. Attachment sites on the phage tail fibre(s) recognize and bind to complementary receptor sites on the bacterial cell wall
Penetration	2. Lysozyme at tip of base plate degrades the bacterial cell wall and plasma membrane; 3. tail sheath **contracts and** drives a hollow tube through the cell wall and membrane into the bacterium. **Injection of** genome into the bacterial cytoplasm
Replication	4. **Viral** DNA is used as a template to make **new viral DNA genome** using the **host** DNA polymerase. 5. **Viral** DNA is transcribed to form **viral** mRNA using **host** RNA polymerase. 6. Viral mRNA is then translated to form **viral** proteins and enzymes using **host** ribosomes, that are used to: 7. Name any 1 example ▪ shut down the **host's** macromolecular (protein, RNA, DNA) synthesis; ▪ hydrolyse the **DNA of the host**, recycling the nucleotides for the synthesis of new copies of **phage DNA** (virus) ▪ direct **host's** transcription and translation machinery e.g. RNA polymerase and ribosomes to synthesize **phage** enzymes and **phage** structural components for the assembly of new T4 phages.
Maturation	8. Viral proteins self-assemble to form the capsid head, tail and tail fiber**s** of the new bacteriophages. 9. The phage genome is packaged inside the capsid head. 10. Lysozyme is packaged into base plate.
Release	11. Phage-encoded **lysozyme** breaks down bacterial peptidoglycan cell wall, **lysis** of host cell and **release** of viral particles which spread to nearby cells and infect them.

QwC: Obtain at least 1 mark each from minimum of 3 out of 5 stages of reproduction cycle.

(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]

Outline of Central Dogma:

1. DNA can be used as a template to make new DNA (DNA replication);
2. DNA can be used as a template to make new RNA (rRNA, mRNA, tRNA) (transcription);
3. RNA can be used as a template to make new proteins (translation);

<u>Examples of bacteria and viruses following the Central Dogma:</u>

4. Bacteria expresses genes to form proteins;
5. e.g. of proteins of the lac operon or trp operon etc;

6. Bacteria duplicates its own chromosome /DNA during binary fission;

7. [HIV]: After activation stage, HIV provirus exists as DNA form, which is read and expressed to form viral proteins;
8. [Influenza] + RNA is equivalent as mRNA, which is used as a template for translation to form viral proteins;

9. [Bacteriophage] Phage genome is DNA, which uses its own viral DNA replication machinery / host DNA polymerase to form new DNA genome;
10. Phage DNA is used as a template to form mRNA using host RNA polymerase;
11. mRNA is used as a template to make viral proteins using host ribosomes;

<u>Challenge of Central Dogma:</u>

12. Not all RNA can be coded to form proteins, e.g. rRNA, tRNA, miRNA etc;

HIV reproductive cycle:

13. + RNA genome is used as a template to form cDNA during reverse transcription;

Influenza virus reproductive cycle:

14. - RNA genome is used as a template to form + RNA;
15. + RNA is used a template for form -RNA genome;
16. DNA is not used as a template to form mRNA;
17. AVP

QwC: Obtain at least 1 mark each from the outline, examples following the central dogma, and examples challenging the central dogma;