YISHUN INNOVA JUNIOR COLLEGE
JC2 PRELIMINARY EXAM
Higher 2

NAME **ANSWERS**

INDEX NO CG

BIOLOGY 9744/02

Paper 2 Structured Questions **30 Aug 2023**

Candidates answer on the Question Paper. **2 hours**

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, index no. and CG on this cover page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer all questions 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

At the end of the examination, **submit booklets A, B and C separately** to the invigilator.

For Examiner's Use	
Section A	
1	10
2	10
3	8
4	10
5	10
6	12
7	10
8	10
9	10
10	5
11	5
Total	100

This document consists of **29** printed pages and **1** blank page.

Answer **all** questions

1 Fig. 1.1 shows an electron micrograph of a chloroplast.

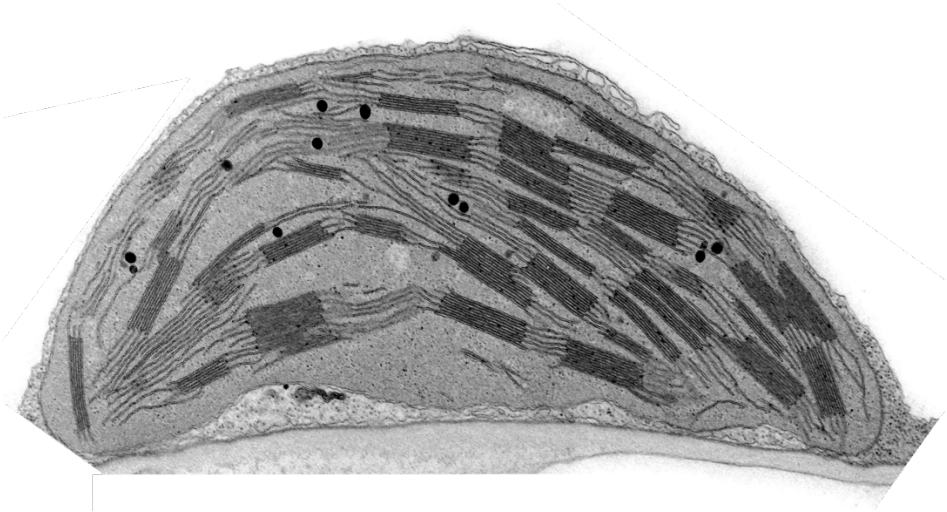

Fig. 1.1

(a) **(i)** On Fig. 1.1, use the letter **X** and a label line to identify where the light independent stage of photosynthesis occurs.

Label stroma [1]

(ii) Describe two ways in which the structure of the chloroplast is adapted for its function.

1 ***(fluid-filled matrix called) stroma***

contains reactants/substrates and enzymes required for Calvin cycle/ light independent reactions;

2 ***highly folded thylakoid membrane***

increase SA for embedding of photosynthetic pigments/ light harvesting complexes/ electron carriers of ETC/ ATP synthase for increased rate of light dependent reactions/ chemiosmosis/ photophosphorylation;

3 ***thylakoid membrane impermeable to H^+***

allow proton gradient to be set up across thylakoid membrane/ accumulation of H^+ in thylakoid space;

[2]

(iii) Chloroplasts and mitochondria both have double membranes. State two other structural similarities between chloroplast and mitochondria.

1 ***70S ribosomes;***

2 ***Circular DNA;***

3 ***Presence of ETC/ ATP synthase/ stalked particles/ proton pump on membranes;*** [2]

(b) Fig. 1.2 shows the relationship between CO_2 assimilation rate and increasing light intensity in a plant, when carbon dioxide concentration is not a limiting factor.

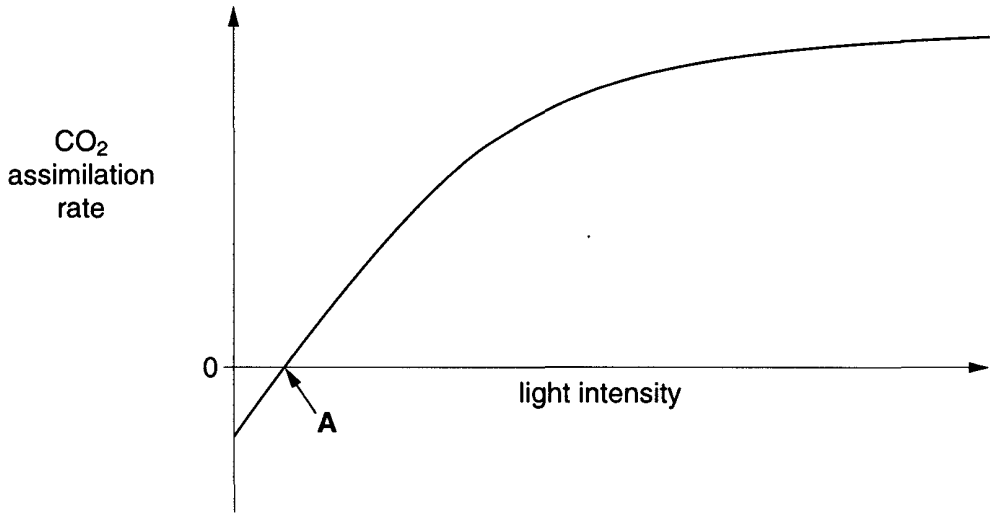

Fig. 1.2

(i) Explain why the CO_2 assimilation rate plateaus at high light intensity.

1 ***light saturation point has been reached***

at this point, maximum rate of chlorophyll a photoactivation is occurring (at both photosystems);

2 ***this means that maximum rate of production of ATP and NADPH is occurring***

therefore, maximum CO_2 assimilation rate is attained in Calvin cycle;

3 ***at higher light intensities, light intensity is no longer a limiting factor (as further increase in light intensity does not increase rate of photosynthesis)***

other factors are now limiting e.g. temperature; [3]

(ii) Describe what is occurring at point **A**.

1 ***A is the compensation point***

which is the light intensity at which respiration rate = photosynthetic rate;

2 ***products of photosynthesis (glucose & O_2) are used up for cellular respiration***

while products of (aerobic) respiration (water & CO_2) are used up for photosynthesis;

3 ***No net gain in dry mass***

thus no growth of plant; [2]

MP1 and 2 or 3

[Total: 10]

2 An investigation was carried out to find the optimum pH and the optimum temperature of an amylase obtained from the bacterium *Anoxybacillus thermarum*.

Fig. 2.1 shows the results of the investigation.

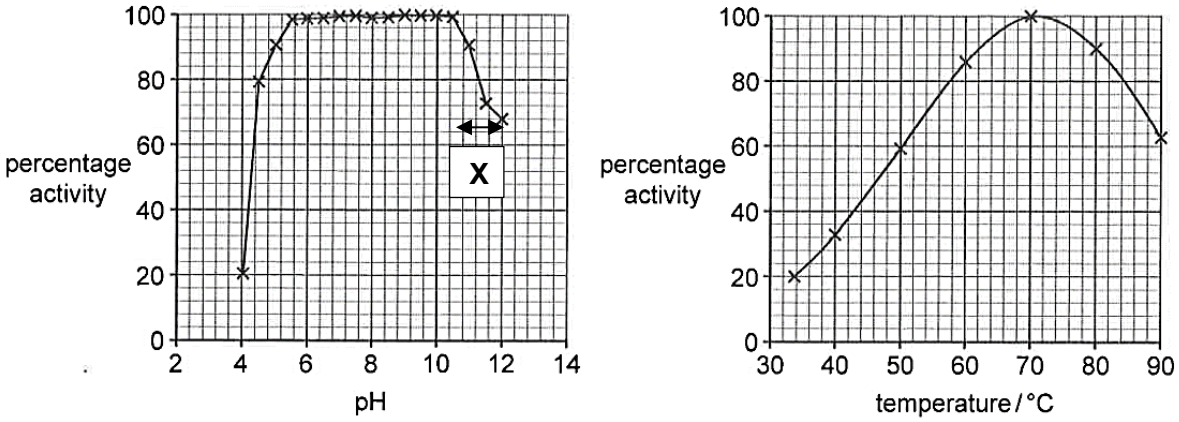

Fig. 2.1

(a) With reference to Fig. 2.1, compare the effect of temperature on the activity of the amylase and the effect of pH on the activity of the amylase.

Similarities:

1 ***percentage activity reaches maximum at 100 for both optimum temperature at 70°C and pH6.8 – 10.4;***

2 ***percentage activity is lower at lower (below optimum) & higher pH (above optimum) and lower (below optimum) and higher temperature (above optimum);***

Differences:

3 ***maximum percentage activity at 100 occurs at a range of pH (4.8 – 10.4) while maximum percentage activity occurs at a single temperature of 70°C;***

4 ***gradual increase of percentage activity from 20 – 100 over a longer range of temperatures (38 – 70oC) compared to sharp increase over a narrower pH range (4.0 – 6.8)***

5 ***gradual decrease of percentage activity from 100 to 62 after range of optimum pH vs sharp decline of percentage activity from 100 to 68 after optimum temperature.***

[3]

(b) Explain the percentage activity of amylase at **X**.

1 ***percentage activity declined sharply from 100 at pH 10.4 to 60 at pH 12***

beyond range of optimum pH 7 to 10.4, solution/environment of the enzymes has increased OH^- concentration/ decreased H^+concentration

2 ***Disrupts (intramolecular) ionic bonds and hydrogen bonds between R groups of amino acids***

which stabilizes secondary & tertiary structures of enzyme

3 ***enzyme unfolds and loses its specific 3D conformation, active site is no longer complementary to the substrate,***

Amylase/ enzyme is unable to form ES complex and rate of reaction decreases, amylase/ enzyme is said to be denatured [3]

Table 2.1 shows the optimum pH and optimum temperature for amylase from different species of bacteria.

Table 2.1

species of bacteria	optimum pH	optimum temperature /°C
Bacillus amyloliquefaciens	7.0	70
Bacillus circulans	4.9	48
Bacillus halodurans	10.5–11.0	60–65
Bacillus licheniformis	4.0–9.0	90
Bacillus subtilis	7.5	50
Geobacillus stearothermophilus	5.6	80

(b) **(i)** Using the data in Fig. 2.1 and Table 2.1, identify the bacterial species that has amylase most similar to amylase from *Anoxybacillus thermarum*.

Bacillus amyloliquefaciens; [1]

(ii) Suggest why the amylase molecules of some species of bacteria are able to work at higher temperatures than others.

1 due to presence of more disulfide bridges which are strong covalent bonds;

2 formed between sulfhydryl/ SH R groups of cysteine amino acids within polypeptide chain;

3 higher temperatures, higher energy required to break disulfide bridges to lose its 3D configuration shape;

[3]

[Total: 10]

3 **(a)** Stem cells from the human bone marrow that are involved in blood cell formation are described as multipotent, rather than totipotent.

Compare multipotent and totipotent stem cells.

Similarity – any 1

1 ***Both are undifferentiated, thus capable of differentiating into specialized cells;***

2 ***Both do not possess any specialized-cell structures, hence are unspecialized;***

3 ***Both undergo asymmetrical division in which one daughter cell is identical to parent cell while the other is a progenitor cell (which proceeds to further differentiate); owtte***

4 ***Both are capable of long-term self-renewal/indefinite replication due to expression of active telomerase;***

Difference – any 1

	Totipotent	***Multipotent***
4	***Found in zygote***	***Found in developed tissues / organs;***
5	***Able to differentiate into all cell types to form whole organism***	***Able to differentiate into a limited range of the same lineage;***

[2]

ER: Many students appeared to misunderstand the command term "compare" which necessitates highlighting both similarities and differences. A significant portion of the responses provided only differences. It was evident that a considerable number of students had not adequately revised this topic, particularly evident in the explanations provided about the potency of the stem cells. Several students offered partially complete definitions of stem cell potency, which limited the depth of their responses.

Furthermore, there seemed to be a clear mix-up between totipotent stem cells and embryonic stem cells. This confusion was underscored by errors like misidentifying the origin of totipotent stem cells as blastocysts or wrongly stating that totipotent stem cells cannot differentiate into extraembryonic cells.

Regarding multipotent stem cells, many responses were overly generalized, with students mentioning that these cells can only differentiate into "limited adult cells." A more precise understanding would have included that these cells differentiate into cells of the same lineage. It is imperative for students to understand the nuanced differences between these types of stem cells and respond accurately to the command term "compare."

(b) Some fully differentiated cells can be stimulated to change back into stem cells in tissue culture. Such cells are called induced pluripotent stem cells (iPS cells).

In *in vitro* experiments with human cells, it was discovered that the introduction of five genes would cause fully differentiated skin fibroblast cells to change to iPS cells. There is evidence to suggest that the introduction of the five genes caused an increase in the production of telomerase reverse transcriptase (TERT) in the fully differentiated cells.

(i) Explain how TERT may help to change the fully differentiated cells back into stem cells.

1 *TERT maintains / increases / extend the length of telomere / 3'-overhang;*

2 *telomere does not reach critically short length / cell does not reach hayflick limit*

after multiple rounds of cell division;

3 *Cells do not undergo apoptosis / escape apoptosis*

hence able to replicate indefinitely;

[3]

ER: A common challenge observed in student responses was the inability to identify the connection between telomerase reverse transcriptase (TERT) and telomerase. A significant portion of students incorrectly believed that TERT is involved in converting mRNA back to DNA. Many failed to recall the essential function of telomerase carrying an RNA template, using it to synthesize telomeres (DNA), which underpins its designation as a reverse transcriptase.

Understanding that an active telomerase indicates a cell's maintained telomere, thereby ensuring the Hayflick limit is not reached, was also missed by many. There was a prevalent misconception: a number of students believed that active telomerase prevents the end replication problem. This is not accurate. While the presence of active telomerase does restore the telomere, it does not prevent the inherent challenges with end replication that arise with each DNA replication cycle. It's crucial for students to differentiate between these two processes to avoid misconceptions.

(ii) Explain why it may be advantageous to use iPS cells in treating diseases in humans, instead of performing organ or tissue transplant.

1a1 *iPS cells were derived from patient's own cells*

1a2 *hence will not be recognised as foreign cells (by patient's immune system);*

2a *no tissue/ immune rejection when iPS cells introduced;*

OR

1b1 *transplanted cells have foreign antigens on their surface*

1b2 *hence will be recognised as foreign by patient's immune system;*

2b *elicit immune response which will destroy/ get rid of transplanted cells;*

3 *no need for patient to take immunosuppressant drugs*

which may cause patient to be susceptible to other infections; [2]

1a AND 2a OR 1b AND 2b + 3

A significant number of students correctly identified that the primary benefit of using induced pluripotent stem cells (iPSC) is the reduction in the risk of organ or tissue rejection. However, a comprehensive understanding was often lacking, as many did not delve into the reason behind this advantage. It's essential to

understand and elaborate on the underlying causes, not just state the observation. Notably, many students missed out on highlighting the subsequent reduced need for immunosuppressant drugs following the use of iPSC, which is a critical implication of this advantage. Future reviews should focus on understanding the deeper implications and connections in the topic.

(c) Suggest why the use of stem cells in treatment gives a greater risk of cancer in the future.

1 ***stem cells already have active telomerase***

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thus require <u>fewer</u> number of mutations to trigger uncontrolled cell division (leading to cancer); [1]

ER: A large proportion of students struggled to understand the relationship between the use of stem cells in treatments and the increased likelihood of cancer development. A crucial connection that was often missed is the shared characteristic between stem cells and cancer cells - their active telomerase activity. This link implies that for a stem cell to evolve into a cancer cell, it requires fewer mutations compared to a typical healthy somatic cell. The emphasis on "fewer mutations" was a pivotal aspect of the correct answer, yet it was omitted by many students. It's imperative that students understand the inherent similarities between certain cell types and the implications these similarities might have in therapeutic contexts.

[Total: 8]

4 Fig. 4.1 shows the structure of TLA-1 virus, which is a newly discovered virus which causes coral disease.

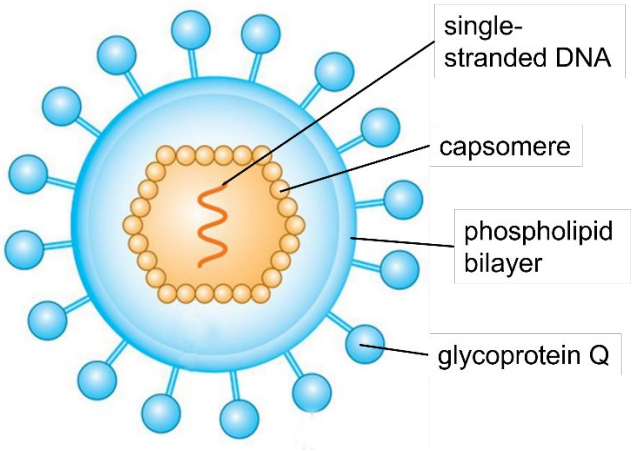


Fig. 4.1

(a) Describe two differences between the structures of TLA-1 virus and the Human Immunodeficiency Virus (HIV).

	Feature	*TLA-1*	*HIV*
1	*genome type*	*single-stranded DNA*	*single-stranded RNA*
2	*no. of strands*	*1*	*2*
3	*glycoprotein*	*1 type (glycoprotein Q only)*	*2 types (gp120 & gp41)*
4	*enzymes*	*no enzymes in capsid*	*Viral enzymes present in capsid (e.g. reverse transcriptase/ integrase/ protease)*

Any 2 [2]

Fig. 4.2 shows the number of T helper cells in the blood and the number of HIV viruses in the blood over the course of an untreated HIV infection.

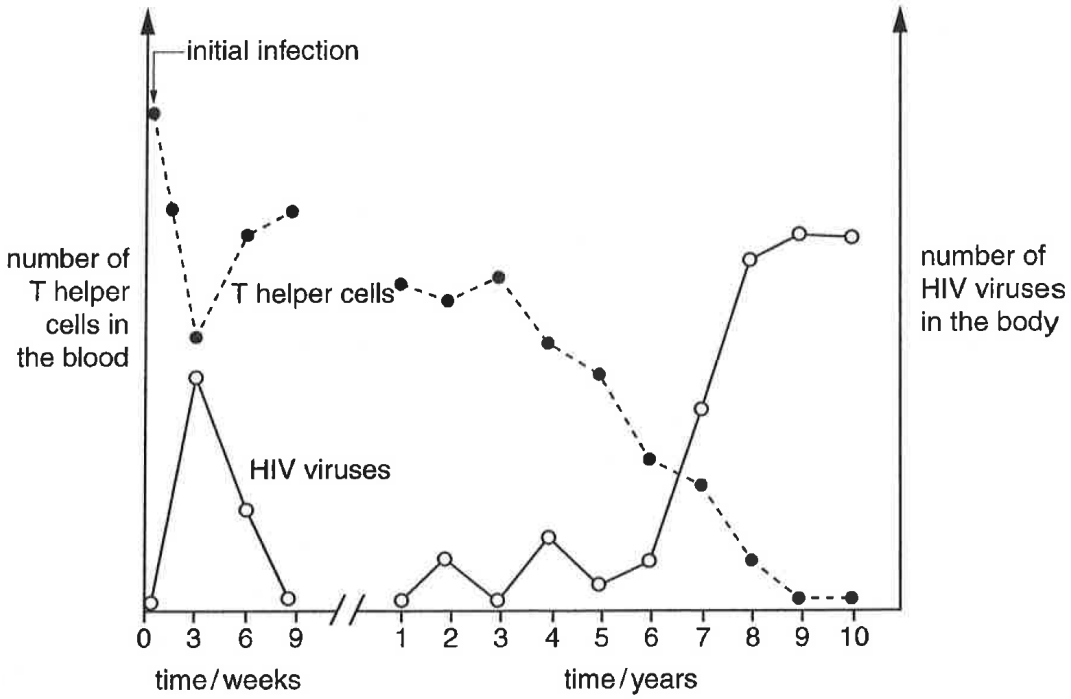


Fig. 4.2

(b) **(i)** Describe the changes shown in Fig. 4.2.

1 ***HIV virus number increased from low level at week 0 to moderate level at week 4, before decreasing back to low level at week 9***

HIV virus number increased from a low level in year 1 to a high level (plateau) in year 10;

2 ***T helper cell number decreased from high level at week 0 to moderate level at week 4, before increasing back to high level at week 9***

T helper cell number decreased from moderate level in year 1 to low level (plateau) in year 10; [2]

(ii) Suggest how the changes in the number of T helper cells from year 1 to year 10 would affect the health of the untreated HIV patient.

1 ***Process of destroying infected T helper cells***

results in inflammation/ fever/ swollen lymph nodes;

2 ***T helper cell numbers too low to effectively mediate (adaptive) immune response***

patient becomes immunocompromised;

3 ***Patient suffers from Acquired Immunodeficiency Syndrome/ AIDS***

becomes susceptible to opportunistic infections;

4 ***Insertional mutagenesis when formation of HIV provirus caused disruption of genes***

e.g. tumour suppressor gene, leading to cancer formation; [2]

Any 2

(iii) Explain why HIV is considered a retrovirus.

1 ***Contains reverse transcriptase enzyme***

which reverse transcribes (viral ss) RNA genome into (ds) DNA;

2 ***Viral DNA integrated into host chromosome***

via integraseforming provirus; [2]

(iv) Explain why viruses are considered obligate parasites.

1 ***Acellular/ Lack cellular/ biosynthetic machinery/ organelles***

required for survival/ metabolic reactions;

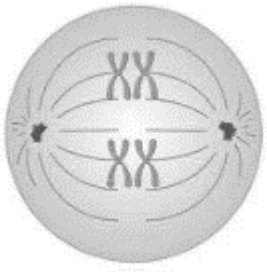
2 ***Viruses need to use host cell's resources***

for synthesis of viral proteins and nucleic acids to complete reproductive cycle; [2]

[Total: 10]

5 Fig 5.1 shows the electron micrographs of two stages of meiosis, **J** and **K**.

stage **J**



stage **K**

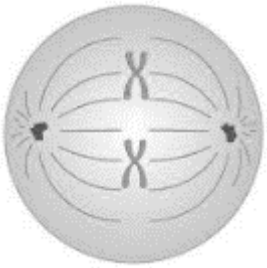


Fig. 5.1

(a) Name the stages of meiosis labelled **J** and **K** in Fig. 5.1 **and** describe the behaviour of chromosomes in each of these stages.

1 stage **J** *1. metaphase I*

behaviour of chromosomes in **J**

2 *the pairs of homologous chromosomes into 2 rows at the metaphase plate;*

3 stage **K** *2. metaphase II*

behaviour of chromosomes in **K**

4 *chromosomes are positioned along the metaphase plate/ cell equator in a single row;*

[4]

ER: Many candidates struggled with correctly identifying the stages in question. While a segment of students was able to identify the stages, they faltered when describing the behavior of chromosomes during those stages. Notably, there were instances where candidates included behavior not characteristic of the given stages, an example being the mention of crossing over between non-sister chromatids during metaphase I. A crucial distinction between the arrangement of chromosomes at the metaphase plate, specifically whether they line up in 2 rows versus 1 row, was overlooked by several. Terminological accuracy proved to be a challenge for many, with misuses involving terms such as "sister chromatids," "chromosomes," and "homologous chromosomes." Moreover,

some candidates introduced unestablished terms like "homologous sister chromatids," which hold no scientific credibility. It was also observed that a few students did not attempt this question, suggesting a possible gap in their understanding of the topic.

(b) Describe **four** main differences between mitosis and meiosis.

1. ***homologous chromosomes pair up to form bivalents (in synapsis) during prophase I of meiosis whereas***
   there is no pairing up of homologous chromosomes during prophase of mitosis;
2. ***Non-sister chromatids of homologous chromosomes may cross over at chiasmata during prophase I of meiosis whereas***
   there is no crossing over between non-sister chromatids of homologous chromosomes during prophase of mitosis;
3. ***Pairs of homologous chromosomes are arranged into 2 rows at the metaphase plate during metaphase I of meiosis whereas***
   chromosomes are arranged into single row at the metaphase plate during metaphase of mitosis;
4. ***Separation of homologous chromosomes during anaphase I of meiosis whereas***
   (sister) chromatids separate during anaphase of mitosis;
5. ***At the end of telophase II of meiosis, four genetically non-identical nuclei are formed whereas***
   at the end of telophase of mitosis, two genetically identical nuclei are formed;
6. ***Meiosis involves two (consecutive) nuclear divisions whereas***
   mitosis only involves one nuclear division;
7. ***At the end of meiosis, each nucleus contains half the amount of DNA as the parent cell whereas***
   at the end of mitosis, each nucleus contain the same amount of DNA as the parent cell; [4]

Any 4, AVP;

ER: Students are reminded of the importance of reading the question requirements with precision and not to make assumptions based on the content in the lecture notes. The lecture notes made a comprehensive comparison between mitotic and meiotic processes, which included the stages of interphase and cytokinesis. Contrarily, this Paper 2 question specifically assesses the knowledge of mitosis and meiosis, focusing solely on the nuclear divisions.

It is important to note that answers referencing the production of cells were not considered acceptable. This is because cytokinesis, the process of cell division, is distinct from nuclear division. The nuclear division concludes with the telophase, marked by the formation of daughter nuclei.

Furthermore, the paper evidenced a prevalent issue with the usage of terminologies. There were instances of incorrect and imprecise terms like "stage", "phase", and "cycle", resulting in ambiguous comparisons. Another observed shortfall was the lack of completeness in descriptions. Some responses omitted pivotal details. For instance, answers provided generic statements such as "no crossing over", rather than a precise description like "no crossing over between non-sister chromatids of homologous chromosomes in prophase I".

(c) In the absence of chromosomal aberration, gene mutation or events during stage **J**, outline how events **before** stage **J** and **after** meiosis lead to genetic variation between offspring of the same parents.

1. ***Non-sister chromatids of homologous chromosomes may cross over at chiasmata in prophase I***
   to exchange the alleles between the non-sister chromatids to form recombinant chromosomes;
2. ***Two random genetically non-identical haploid gametes contains chromosomes with different allelic combination***
   fuse to form a diploid (zygotic) cell with different genotype as the parents; [2]

ER: A noticeable portion of students chose not to attempt this section, which suggests a potential gap in understanding or confidence regarding the topic in question. This trend underlines the need for students to consistently review and engage with the entirety of the course material.

Misinterpretation of the question was another prominent issue. Despite the clear instructions in the question preamble to exclude details about mutations, several students incorporated such details in their responses. This serves as a reminder about the importance of thoroughly reading and comprehending the instructions before crafting an answer.

Furthermore, there was recurrent misuse of specific terms. Phrases like "non-identical sister chromatids" and "non-identical homologous chromosomes" were erroneously used, suggesting some confusion in understanding.

Regarding the topic of crossing over during prophase I, many answers were found lacking in completeness. Critical details, such as the distinction between "crossing over between non-sister chromatids", were frequently omitted. This indicates a need for a deeper and more nuanced understanding of the topic.

[Total:10]

6 The genes for eye colour and coat colour in mouse-deer are found on separate chromosomes. One gene is found on chromosome 3, while the other gene is found on the X chromosome. Female mouse-deer are XX and male mouse-deer are XY.

To investigate the inheritance of eye colour and coat colour in mouse-deer, scientists performed a reciprocal cross using purebred individuals. Table 6.1 shows the phenotypic ratio of the F_1 generations from the reciprocal cross.

Table 6.1

Cross	Parents (purebred)	F_1 phenotypic ratio	Number of F_1 progeny
1	Black eye, coloured-coat female X Pink eye, albino-coat male	1 black eye, coloured-coat female : 1 black eye, coloured-coat male	88
2	Black eye, coloured-coat male X Pink eye, albino-coat female	1 black eye, coloured-coat female : 1 pink eye, coloured-coat male	90

(a) Explain what is meant by 'reciprocal cross'.

Same characteristics/ traits are used/ investigated

but genders/ sexes are reversed/ switched; [1]

(b) State whether the gene coding for eye colour or coat colour is found on the X chromosome.

Gene coding for eye colour is found on X chromosome; [1]

(c) Explain your answer to **(b)**.

Gene coding for eye colour is X-linked,

because F_1 phenotypic ratio for eye colour is different for both crosses; OR

If gene coding for coat colour is X-linked, F_1 phenotypic ratio for cross 2

should be 1 black eye, coloured female : 1 black eye albino male; [1]

(d) Using appropriate symbols to represent alleles coding for eye colour and coat colour, draw a genetic diagram to illustrate cross 2 in Table 6.1.

Legend: (1m)
X^B – dominant allele for black eye
X^b – recessive allele for pink eye
E – dominant allele for coloured coat
e – recessive allele for albino coat

Parental phenotype	***Black eye, coloured male***	***Pink eye, albino female***
Parental genotype (1m)	***X^BY EE***	***X^bX^b ee***
Gametes (1m)	***(X^B E) (Y E)***	***(X^b e)***
Random fertilisation (1m) ***If gametes not circled, penalise once only***	***(X^BE)*** / ***(X^be)*** : ***X^BX^b Ee*** / ***X^bY Ee***	
F_1 genotypic ratio	***1 X^BX^b Ee***	***: 1 X^bY Ee***
F_1 phenotypic ratio	***1 black eye, coloured female***	***: 1 pink eye, coloured male***

If alleles for eye colour are not represented as X-linked, no marks

[4]

(e) The scientist proceeded with a more detailed count of the F_1 progeny from cross 2. He determined that there were 40 black eye, coloured-coat females and 50 pink eye, coloured-coat males.

To check if the deviation between the observed and expected numbers of the F_1 progeny from cross 2 was statistically significant, the scientist carried out the chi-squared (χ^2) test.

$$\chi^2 = \Sigma \frac{(O - E)^2}{E}$$

where Σ = sum of
O = observed value
E = expected value

degrees of freedom	probability, p				
	0.10	0.05	0.02	0.01	0.001
1	2.71	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.67	13.28	18.47

Using the formula for χ^2 and the probability table provided,

(i) State the expected numbers in cross 2 for

black eye, coloured-coat females: ***45***

pink eye, coloured-coat males: ***45*** [1]

(i) State the calculated chi-squared value, to 2 decimal places.

1.11; [1]

(ii) State the conclusions drawn from the chi-squared test.

1 ***since calculated χ^2 value = 1.11 < critical χ^2 value = 3.84***

at df = 1 and p = 0.05;

2 ***Difference between observed and expected results is not statistically significant***

and due to chance alone;

3 ***Observed results follow the expected 1:1;***

4 ***probability that chance alone explains the deviation between O and E results is p > 0.10;*** [3]

MP 1 + 2 and 3 or 4

[Total: 10]

7 Fig 7.1 shows the protein structure of G-protein linked receptor (GPLR).

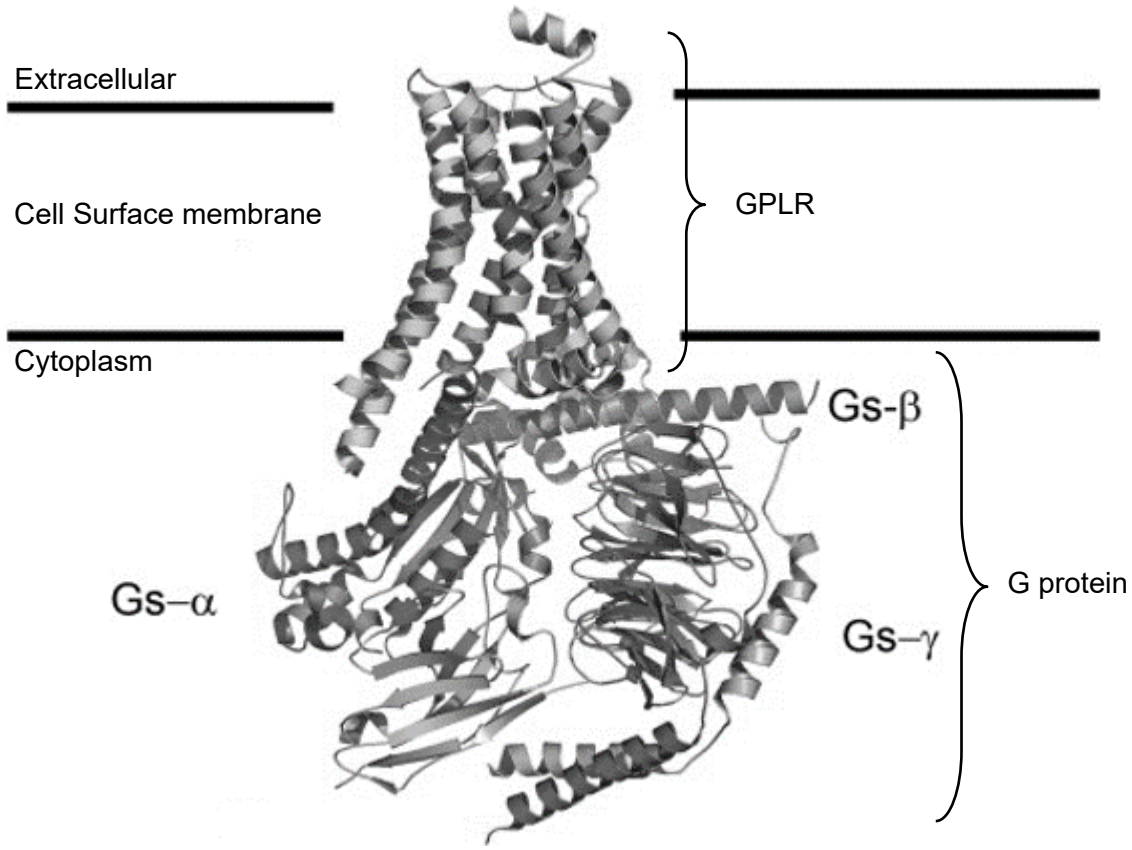


Fig. 7.1

(a) Describe how GPLR is anchored in the cell surface membrane.

1 The GPLR polypeptide is folded (in such as a way that)

the transmembrane region mainly consists of amino acids with hydrophobic R groups / hydrophobic amino acids;

2 These amino acids form hydrophobic interactions

with the fatty acids tails of the phospholipids in the cell surface membrane; [2]

ER: Many candidates overlooked mentioning the folding of the polypeptide to form the receptor's 7-transmembrane region. Moreover, a significant number omitted details about the types of amino acids present within this region. Among those who provided relevant answers, a direct leap was observed to describing the bonds associated with the transmembrane region and the cell surface membrane without emphasizing the nuanced details. It was apparent that a clear connection wasn't drawn by many candidates, particularly regarding the hydrophobic interactions between the non-polar amino acids in the transmembrane region and the fatty acid tails. Vague or overly general descriptions about the formation of these bonds were frequent. Additionally, a few ventured into discussions about hydrophilic interactions between the receptor's extracellular and intracellular regions with the negatively charged phosphate head, which was not the primary focus."

(b) State the highest level of protein structure for GPLR.

1 Tertiary ; [1]

ER: It was observed that a significant number of students incorrectly identified the highest level of protein structure for GPLR as quaternary. This common error underscores a lack of understanding that the receptor and the G-protein are distinct entities. The question specifically required students to identify the highest level of protein structure present in the receptor alone, which is tertiary. Additionally, it is worth noting that the syllabus lists GPLR as an exemplar of tertiary proteins. Students are expected to have an in-depth knowledge of this. This trend suggests the necessity for a focused revision on protein structures, particularly the nuances between different levels, to ensure accurate understanding and application in exam responses.

(b) GPLR signalling with glucagon prevents blood glucose concentration from dropping below the threshold level.

Explain **two** ways in which GPLR signalling with glucagon prevent the blood glucose concentration from dropping below threshold level.

1	*Trigger the cell surface membrane with embedded glucose transporters to invaginate inwards*
	to form vesicles with embedded glucose transporters to reduce the number of glucose transporters at the cell surface membrane;
2	*Increases the hydrolysis of glycogen to glucose / glycogenolysis in the liver / activation of glycogen phosphorylase*
	to enable the liver cells to release more glucose into the bloodstream / blood circulation;
3	*Decreases synthesis of glycogen from glucose / glycogenesis / inactivation of glycogen synthetase*
	to increase the amount of blood glucose;
4	*Increases the production of glucose / gluconeogenesis*
	from amino acids molecules or non-carbohydrate sources [2]

ER: While many candidates grasped the basic concept that glucagon leads to an elevation in blood glucose levels, there appeared to be a lack of deeper understanding regarding the specific cellular responses responsible for this increase. The question specifically sought explanations concerning the cellular events driving the rise in glucose, yet a noticeable fraction of students diverged to explain the glucagon signalling pathway, which wasn't pertinent to the query. Among those who touched upon the relevant processes, there was often an incomplete elucidation of glycogen's conversion to glucose and the inhibition of glycogen synthesis. A key misconception that emerged was the attribution of glycogen breakdown directly to glucagon. For clarity, glucagon is the hormone secreted by the pancreas's alpha cells, specifically from the islets of Langerhans, to elevate blood glucose levels. It's crucial to understand that the actual breakdown of glycogen in the liver is facilitated by the enzyme glycogen phosphorylase."

(c) G protein is made up of three subunits, Gs-α, Gs-β and Gs-γ. Inactive G protein is bound to GDP.

Explain how the activation of G protein results in the production of cyclic AMP (cAMP).

1	*GDP detaches from the Gs-α subunit in the activated G-protein*
	and binds to GTP; [idea of GTP displacing GDP]
2	*GTP-bound Gs-α subunit dissociates from Gs-βγ subunits*
	and translocates/ diffuses along the cell surface membrane;

3 GTP-bound Gs-α subunit binds to adenylyl cyclase

which results in the conversion of ATP to cAMP; [3]

ER: Candidates well-versed in the mechanisms of GPCR signalling were generally able to provide comprehensive and accurate responses. However, several misconceptions were evident. Notable inaccuracies included the assertion that GDP is phosphorylated to GTP, when in actuality, GTP displaces GDP in the G protein. Other misunderstandings involved the displacement of GDP by ATP, the incorrect dissociation of the gamma-subunit from the alpha-beta subunit, and the incorrect notion that GTP directly activates adenylyl cyclase. Additionally, it is noteworthy that a segment of students chose not to attempt this question."

(d) Receptor tyrosine kinases (RTKs) are another type of cell surface receptors for many polypeptide growth factors, cytokines, and hormones.

Describe **two** ways in which the signalling pathways of RTK and GPLR differ.

	GPLR	RTK
1	Does not involve dimerization of receptor upon ligand binding	RTK usually dimerise upon ligand binding ;
2	GTP displaces GDP in G protein to activate G protein	No involvement of GTP and G protein ;
3	No autophosphorylation / cross phosphorylation of tyrosine residues	Autophosphorylation / cross phosphorylation of tyrosine residues in the cytoplasmic domain of receptor ;
4	Activation of adenylyl cyclase	Does not involve adenylyl cyclase ;
5	Production of cAMP as 2nd messenger	Does not involve 2nd messenger ; [2]

Any **2**, AVP

ER: This comparative question was unfortunately not well-addressed by a significant portion of the candidates. It was evident that many students did not thoroughly read the question. The question specifically asked for details on the signalling pathway, emphasizing the signal transduction and application steps. Regrettably, many diverged by focusing on the ligand-receptor interaction and the subsequent cellular responses, which were not the primary topics of interest for this particular question."

[Total: 10]

8 The liver tissue was homogenized and cell fractionation was performed. A sample of mitochondria was obtained by differential centrifugation resuspended in a buffer.

The concentration of H^+ in two compartments within mitochondria was measured at regular intervals. 10 minutes after the start of the experiment, a 10nM pyruvate solution was added to the buffer containing mitochondria.

The results of the experiment are shown in Fig. 8.1.
(Will change the graph later)

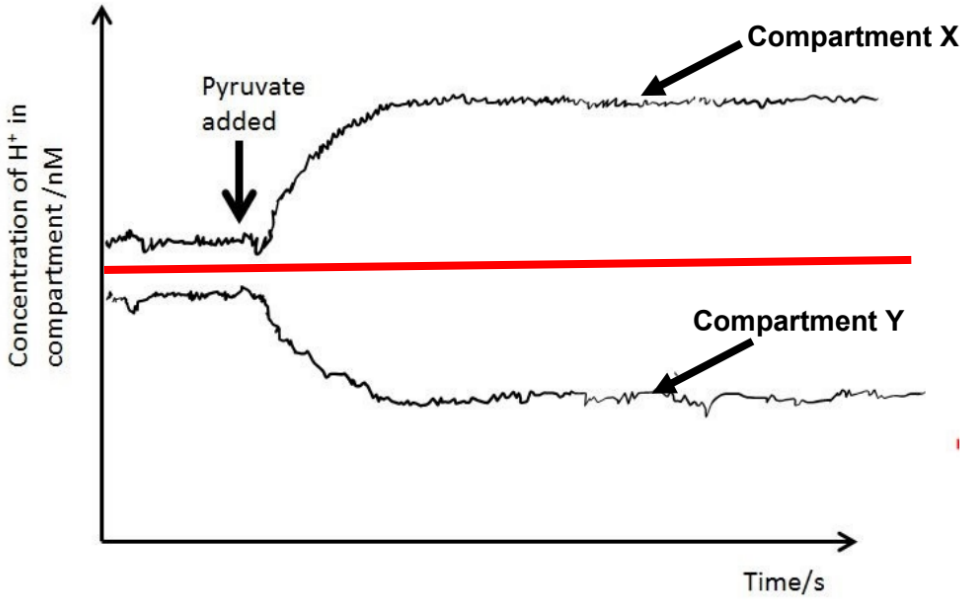


Fig. 8.1

(a) **(i)** Identify compartments **X** and **Y** in a mitochondrion.

X *Intermembranal/ intermembrane space;*

Y *mitochondrial matrix;* [1]

(ii) Explain the changes in the concentration of H^+ in compartment **X** following the addition of pyruvate into the buffer.

1 *pyruvate undergoes link reaction forming acetyl CoA and NADH*

acetyl CoA enters Krebs cycle in mitochondrial matrix resulting in formation of NADH and $FADH_2$;

2 *NADH and $FADH_2$ donate electrons to electron transport chain (ETC) located in inner membrane of mitochondria*

electron passed down ETC, energy is released and coupled to pump H^+;

3 *from mitochondrial matrix into intermembranal space*

resulting in increase in concentration of H^+ in compartment X; [3]

(b) A metabolic poison, 2,4-dinitrochlorobenzene (2DNP), acts as a proton ionophore, an agent that can transport protons across biological membranes down a concentration gradient.

(i) The experiment was repeated in the presence of high concentration of 2DNP.

Sketch on Fig. 8.1, a graph that shows the concentration of H^+ in compartment **Y** in the presence of 2DNP. [1]

(ii) Explain the effect of 2DNP on ATP synthesis.

1 ***2DNP enable H^+ to diffuse from intermembranal/intermembrane space to mitochondrial matrix***

prevents establishment of electrochemical proton gradient / proton motive force;

2 ***chemiosmosis /where H^+ flow down concentration gradient through the ATP synthase cannot occur***

no/less ATP formed; [2]

(c) Compare the production of ATP in photophosphorylation and oxidative phosphorylation.

Similarities

1 ***both involves flow of electron down electron transport chain of progressively increasing electronegativity;***

2 ***both involves generation of proton motive force / electrochemical H^+ gradient;***

3 ***both involves diffusion of H^+ from through ATP synthase complex, which phosphorylate ADP to ATP;***

Differences

No	*Feature*	*Photophosphorylation*	*Oxidative phosphorylation*
4	*electron donor*	*chlorophyll a in reaction centre of PSII/ water*	*reduced coenzyme, NADH/ $FADH_2$*
5	*final electron acceptor*	*NADP*	*oxygen*
6	*source of energy*	*light*	*oxidation of glucose/ NADH/ $FADH_2$*
7	*direction of H^+ pumped*	*pumped from stroma into thylakoid space*	*pumped from mitochondrial matrix into intermembranal space*
8	*direction of H^+ diffuse*	*from thylakoid space to stroma*	*from intermembranal space to mitochondrial matrix*

1 similiarity and 2 differences [3]

[Total: 10]

9 The aye-aye, *Daubentonia madagascariensis*, is a primate native to Madagascar. Aye-ayes are nocturnal (active at night) and make their nests high up in trees. They feed on insect larvae in the trunks of trees.

Fig. 9.1 shows an aye-aye.

Fig. 9.1

The International Union for Conservation of Nature (IUCN) is the world's largest global environmental organisation. The IUCN Red List of Threatened Species™ evaluates the conservation status of plant and animal species.

The aye-aye is categorised as endangered on the IUCN Red List, which means that it faces a very high risk of becoming extinct in the wild.

(a) **(i)** Table 9.1 shows the taxonomic classification of aye-aye.

Table 9.1

Domain	Eukarya
Kingdom	***Animalia***
Phylum	Chordata
Class	Mammalia
Order	Primates
Family	Daubentoniidae
Genus	***Daubentonia***
Species	*Daubentonia madagascariensis*

Complete Table 9.1. [3]

1m for every 2 correct answers

ER: It was apparent that numerous candidates were not well-versed with the taxonomy classification. Students are advised to utilize the mnemonic:

'King Philip Can Overthrow Five Giant Stones' to aid in recalling the order of classification: Kingdom, Phylum, Class, Order, Family, Genus, and Species. While some recognized the Aye-aye as an animal, they struggled to correctly identify its kingdom. Additionally, there was evident confusion in differentiating the genus from the species name."

(ii) Suggest **one** reason why aye-ayes have become endangered.

Habitat destruction / hunting / AVP with brief elaboration; [1]

ER: The majority of candidates performed commendably on this suggestive question. Frequent responses highlighted the impact of deforestation, particularly in terms of loss of habitat and depletion of food sources."

There are two main aye-aye populations on the island of Madagascar, one in the west and one in the east.

Fig. 9.2 is a map of Madagascar showing the location of the two main populations.

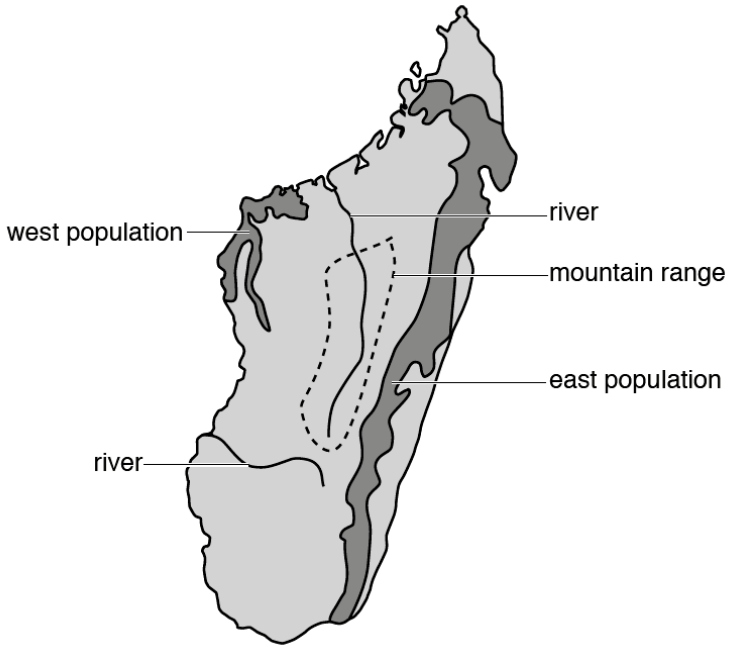


Fig. 9.2

A study into the variation in the DNA nucleotide sequence of aye-ayes showed that the genetic difference between the west and east populations has been gradually increasing over the past decades.

It is postulated that the two populations of aye-ayes may be experiencing divergent evolution.

(b) **(i)** State one advantage of using DNA nucleotide sequence in this study.

Using DNA nucleotide sequence … (continue with any of point)

1 *is objective / unambiguous*

as DNA bases (A, C, G, T) are universal ;

2 *is precise / accurate / quantifiable*

as it allows for inference of degree of relatedness between morphologically different organisms ;

3 *allows for comparison of genetic divergence of two populations within same species*

which are morphologically similar ;

4 *offers a limitless set of characters to be studied*

as each nucleotide can be considered a character to distinguish between species ;

5 *allows easy comparison / analysis of large amount molecular data*

because of advances in DNA molecular techniques;

Any 1 [1]

ER: Despite being a topic that is frequently examined, it was surprising to note that certain candidates were ill-prepared for this question. Many of those who attempted the question were able to achieve marks, typically by emphasizing the accuracy, precision, or objectivity afforded by using nucleotide sequences, given the universal nature of nucleotide bases. A significant distinction, which some candidates overlooked, is that it is the nucleotide bases that are universal, not the sequences themselves. Additionally, when referencing objectivity, precision, or quantifiability, it pertains to the process of utilizing nucleotide sequences in phylogenetic analyses rather than describing the nucleotide sequence itself as such. Several students who attempted the question, but did not secure marks, primarily struggled with the precise phrasing required for accurate answers."

(ii) With reference to Fig. 9.2, suggest why the two populations of aye-ayes may be experiencing divergent evolution.

1 *east and west populations of aye-ayes have phenotypic variation*

due to presence of genotypic variation;

2 *east and west Madagascar have different environmental conditions thus different selection pressures*

selects for different favourable phenotypes;

3 *aye-ayes selected for able to survive, reproduce and pass down favourable alleles to offspring*

leading to change in allelic frequencies in each population;

4 *different mutations accumulate in the east and west populations;*

5 *geographical isolation/ barrier e.g. rivers/ mountains between the 2 populations*

prevent interbreeding/ reduces gene flow resulting in increased genetic divergence between isolated populations; [4]

MP 2 and 5 compulsory

ER: It was observed that several students struggled to provide answers rooted in comprehensive content knowledge. An underlying issue appeared to be a misinterpretation or misunderstanding of the question's core focus, which aimed at eliciting understanding about the mechanism of speciation leading to divergent evolution. Those who had thoroughly revised the concept of speciation were generally successful in providing substantial and relevant responses. However, a notable gap in many answers was the omission of how phenotypic differences in the Aye-aye population arise from genotypic variations. Additionally, a significant number of students failed to elucidate the rationale for differing selection pressures."

(iii) As the two populations of aye-ayes continue to experience divergent evolution, they could eventually become two different species.

Name the type of speciation that would have occurred.

allopatric speciation; [1]

ER: A majority of the students correctly identified the speciation event as allopatric speciation. However, there was a subset of students who inaccurately inferred it to be sympatric speciation. This suggests that there might have been a misinterpretation of the provided diagram or an oversight of the geographical barrier depicted within it."

[Total: 10]

10 In Singapore, the Bacillus Calmette-Guerin (BCG) vaccine is used to prevent tuberculosis (TB). The vaccine contains the live, attenuated strain of *Mycobacterium bovis*.

The genus *Mycobacterium* is characterised by slender, non-motile rods with complex, lipid-rich cell walls, as shown in Fig. 10.1. Many mycobacterial species share similar growth and biochemical characteristics.

Fig. 10.1

(a) Describe how tuberculosis is transmitted from one person to another.

1 ***via aerosol drops***

when infected person sneezes/ coughs;

2 ***droplets containing M. tuberculosis***

inhaled by uninfected person; [2]

(b) Explain how vaccinating a person using the BCG vaccine can provide him long-term protection against tuberculosis.

1 ***live, attenuated strain of Mycobacterium bovis has similar antigens to M. tuberculosis***

e.g. lipid-rich (peptidoglycan) cell wall;

2 ***Immune system of person being vaccinated elicits an (adaptive) immune response***

T and B cells (and antibodies) target the specific antigen;

3 ***memory T and B cells produced***

confer immunological memory/ protect against future infection by M. tuberculosis;

4 ***(details of adaptive immune response) APC/ activated B cell takes in M. bovis, processes antigen and presents antigen (on MHC: peptide complex);***

activates naïve helper T cells;

5 *which secrete cytokines to stimulate (activated) B cells to undergo proliferation and differentiation*

to give effector (plasma) B cells and memory B cells; [3]

MP 1 + 3 compulsory

[Total: 5]

11 The *Aedes aegypti* mosquito is the main vector that transmits the viruses that cause dengue. The viruses are passed on to humans through the bites of an infective female *A. aegypti* mosquito, which mainly acquires the virus while feeding on the blood of an infected person.

Fig. 11.1 shows the monthly number of dengue cases from 2018 to 2021 with highest number of cases coinciding with summer.

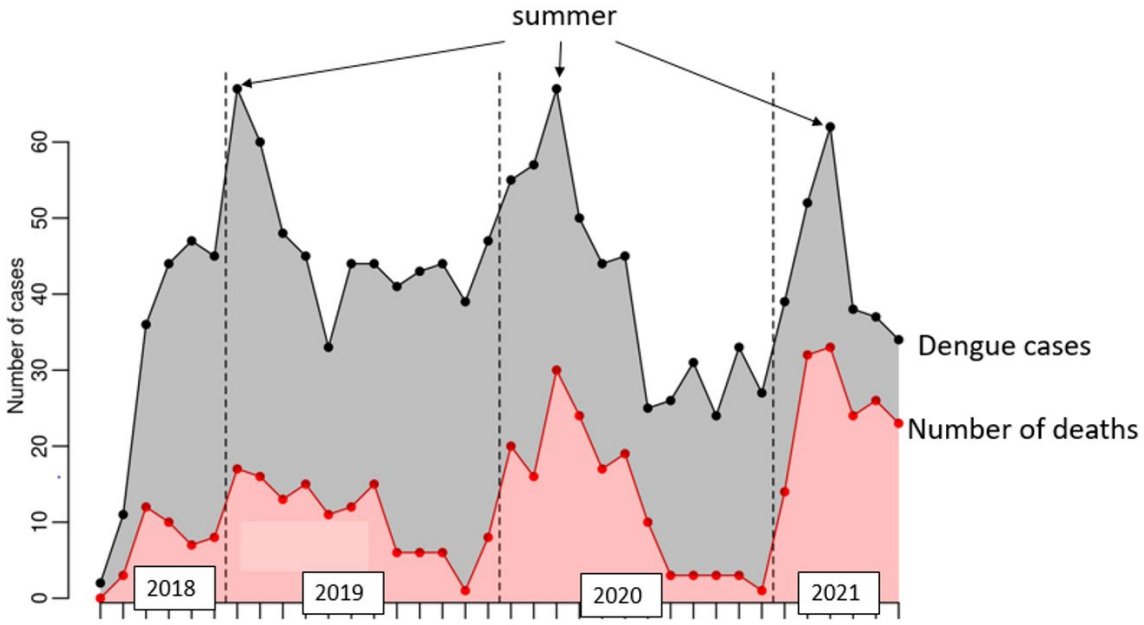


Fig. 11.1

(a) Describe the pattern of resurgence (sudden increase) of dengue cases from 2019 to 2021 shown in Fig.11.1.

1 ***cyclical pattern/repeated pattern***

2 ***no. of dengue cases is highest at beginning of all three years (above 60 cases) for 2019 to 2021..***

it then decreases as the year progresses across the months

[2]

(b) Suggest **three** possible ways in which climate change can result in the pattern described in **(a)**.

1 ***higher temperatures in summer due to climate change***

leads to faster pathogen development and shorter life cycles for mosquito vectors;

2 ***global warming of many regions previously not suitable as habitats for mosquitoes now results in***

more widespread breeding grounds for vectors;

3 ***climate change resulting in higher precipitation in some areas lead***

to ponding and more breeding places. [3]

AVP;

[Total: 3]

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