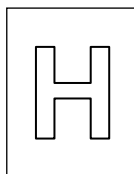


TIMED PRACTICE – PAPER 3



RAFFLES INSTITUTION
2025 Year 6 Preliminary Examination

Higher 2

CANDIDATE
NAME

--

CIVICS
GROUP

2	5	S	0	3	
---	---	---	---	---	--

INDEX
NUMBER

--	--	--	--	--	--

BIOLOGY

9744/03

Paper 3 Long Structured and Free-response Questions

17th Sept 2025

2 hours

Candidates answer on the Question Paper.
Additional Materials: Writing paper.

READ THESE INSTRUCTIONS FIRST

Write your index number, CT group & name in the spaces at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A

Answer **all** questions in the spaces provided on the Question Paper.

Section B

Answer any **one** question in the writing paper provided.

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.

At the end of the examination, **hand in your essay question SEPARATELY.**

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

For Examiner's Use	
Section A	
1	/ 31
2	/ 8
3	/ 16
Section B	
4 or 5	/ 20
Total	/ 75

This document consists of **15** printed pages.



Raffles Institution
Internal Examination

Section AAnswer **all** the questions in this section

- 1** Liver cells, or hepatocytes, are highly specialised and metabolically active. These cells are responsible for a vast array of vital functions, including the metabolism of carbohydrates, lipids, and proteins, detoxification of harmful substances, synthesis of plasma proteins, and bile production. Their constant activity makes them susceptible to damage from various factors such as viral infections (e.g., hepatitis), excessive alcohol consumption, and metabolic disorders like non-alcoholic fatty liver disease (NAFLD), which can impair their function and lead to serious health issues.

Fig. 1.1 is a transmission electron micrograph showing a section of a human liver cell.

**Fig. 1.1**

- (a) (i)** Name organelles **A** and **B** shown in Fig. 1.1.

A

B[1]

- (ii)** In liver cells, enzymes are attached to the membrane of smooth endoplasmic reticulum (SER).

With reference to the functions of smooth endoplasmic reticulum, suggest the advantages of having enzymes attached to the membrane rather than free in the lumen of the SER.

.....

.....

.....

.....[2]

Neutral lipids or non-polar lipids such as triglycerides and cholesterol esters are synthesised in the membrane of SER of the liver cell. Fig. 1.2 shows the formation of a lipid droplet (LD) from the endoplasmic reticulum membrane.

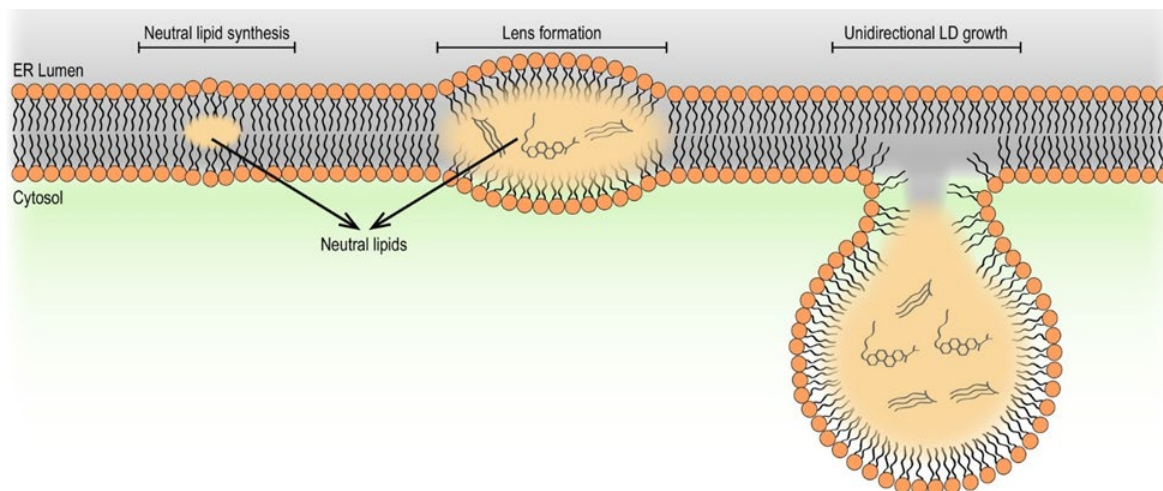


Fig. 1.2

- (b) (i)** Describe the formation of the lipid droplet shown in Fig. 1.2.

.....

.....

.....

.....

.....

.....[3]

- (ii)** Lipid droplets serve as energy storage within the cell. Based on the properties of the biomolecules involved, explain how a lipid droplet maintains its stable structure in the cytoplasm.

.....

.....

.....

.....[2]

- (c) Prostaglandins are another type of lipid synthesised at the SER. Prostaglandins are small lipids produced in many tissues of the body. One role of prostaglandins is to cause inflammation at the site of an injury or infection. Inflammation is the normal first response of the immune system to injury or infection.

Cyclooxygenase (COX) is an enzyme that catalyses one of the steps in the reaction pathway for the formation of prostaglandins from phospholipids. The reaction pathway occurs in the SER of cells. Part of the reaction pathway is shown in Fig. 1.3.

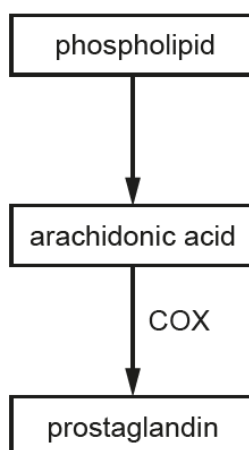


Fig. 1.3

- (i) Suggest an advantage for this reaction pathway occurring in the smooth endoplasmic reticulum of a cell rather than in the cytoplasm.

.....
.....[1]

- (ii) Inflammation may have side-effects, such as pain. Aspirin is a drug that can be used to reduce these side-effects by reducing the catalytic activity of the COX enzyme by modifying the R-group of one of the amino acids.

Explain how modifying the R-group of an amino acid in the COX enzyme can reduce the catalytic activity of the enzyme.

.....
.....
.....
.....
.....
.....[3]

A number of chemicals can disrupt mitochondrial respiration of the liver cell. Some of these are listed in Table 1.1.

Table 1.1

chemical	effect on mitochondrion
oligomycin	blocks proton flow through ATP synthase
FCCP	causes protons to leak out of the inter-membrane space back into the matrix without going through ATP synthase
antimycin-A + rotenone	stops electrons from being passed down the electron transport chain (rotenone and antimycin-A affects proteins along the electron transport chain)

Scientists measured the oxygen consumption rate (OCR) of some cells. They then investigated how the OCR changed when oligomycin was added at 23 minutes, followed by FCCP at 56 minutes, followed by antimycin-A + rotenone at 93 minutes.

Fig. 1.4 shows the results obtained.

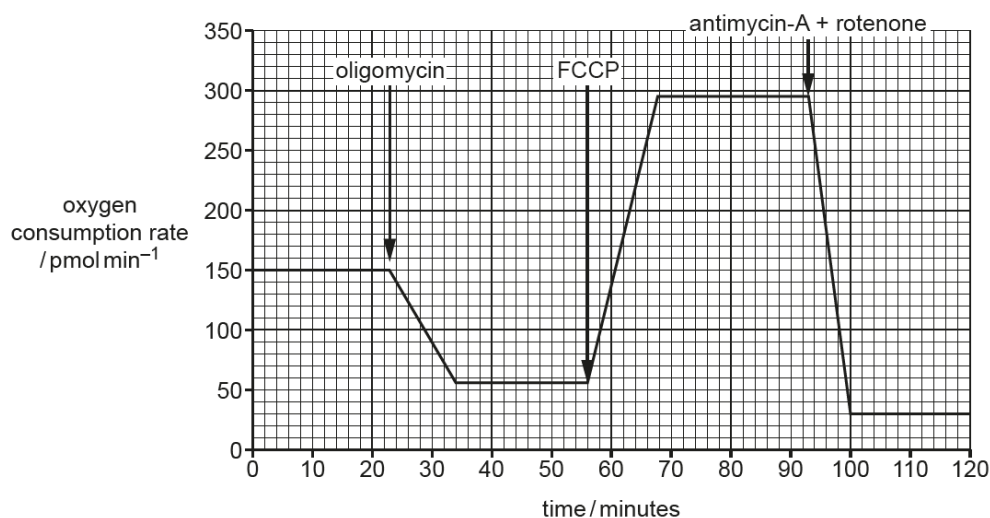


Fig. 1.4

- (d) (i) With reference to events at the inner mitochondrial membrane, describe and explain each of these **two** statements:

oligomycin causes a drop in OCR

.....

.....

.....

.....

.....

.....

[3]

FCCP causes a rise in OCR

.....

.....

.....

.....

.....

.....[3]

- (ii) Suggest why the oxygen consumption rate of the cell never falls to zero in these cells.

.....

.....[1]

During respiration, protons 'leak' through the inner mitochondrial membrane into the matrix. The OCR as a result of this leakage can be calculated by determining the difference between the OCR 20 minutes after the addition of oligomycin and the OCR 20 minutes after the addition of antimycin-A + rotenone.

- (iii) Use Fig. 1.2 to calculate the OCR caused by proton leakage.

..... pmol min⁻¹ [1]

- (e) Rotenone has been proposed as a possible treatment for cancer.

Explain why cancer cells are more likely to be affected by rotenone than non-cancer cells.

.....

.....

.....

.....[2]

- (f) Alanine transaminase (ALT) is an enzyme that is normally found only in the cytoplasm of liver cells.

Scientists can use the concentration of ALT in a person's blood as a measure of damage to liver cells.

Suggest why blood ALT concentration provides a measure of damage to liver cells.

.....

.....

.....

.....[2]

Another transaminase, aspartate transaminase (AST), is also found in the mitochondria of a variety of cells, including liver cells.

Table 1.2 shows the distribution of ALT and AST in the body, as well as the time taken for the quantity of each enzyme if released in the blood to halve.

Table 1.2

enzyme	location where found	percentage distribution in cell		time taken for quantity of enzyme if released in blood to halve/ hours
ALT	liver	cytoplasm	100	47
		mitochondria	0	
AST	heart, liver, skeletal muscle, pancreas and kidney	cytoplasm	20	17
		mitochondria	80	

- (g) The concentration of AST in the blood is not, by itself, a reliable indicator of liver damage.

Use Table 1.2 to explain why blood AST concentration by itself is **not** a reliable indicator of liver damage.

.....

.....

.....

.....[2]

- (h) In clinical practice, diagnosis of liver damage is based on both:
- the concentration of ALT in the blood; and
 - the ratio of concentration of AST:ALT in the blood.

Table 1.3 shows the liver conditions associated with different blood ALT concentrations and AST:ALT ratios.

Table 1.3

liver condition	blood ALT concentration / arbitrary units	AST:ALT
normal	1 to 40	0.8:1
acute (short-term) viral liver damage	100 to 1100	<0.8:1
acute non-alcoholic liver damage	30 to 100	<0.8:1
chronic (long-term) alcoholic liver damage	30 to 300	>2:1

- (i) Explain why using only blood ALT concentration, by itself is also **not** a good diagnostic tool for all types of liver damage.

.....

.....

.....

.....[2]

The blood concentrations of AST and ALT were measured in five people who had recently been admitted to hospital.

Table 1.4 shows the data collected.

Table 1.4

person	blood AST concentration / arbitrary units	blood ALT concentration / arbitrary units	AST:ALT
A	37	62	0.6:1
B	27	38	0.7:1
C	26	33	0.8:1
D	620	1034	0.6:1
E	140	54	2.6:1

- (ii) Use the information in Table 1.3 to identify the people in Table 1.4 who could be diagnosed with acute non-alcoholic liver damage.

.....[1]

- (iii) Alcohol causes damage to mitochondria.

Explain why alcohol damage to the liver can cause an increase in concentration of AST in the blood.

.....

.....

.....

.....[2]

[Total: 31]

- 2 Kiribati is a low-lying island nation situated close to the equator, in the middle of the Pacific Ocean. It comprises isolated, narrow islets that are at a maximum elevation of 3 m above sea level. Climate change research studies have projected estimates that two-thirds of the islands may be submerged by 2100 and become uninhabitable due to the impacts of climate change.

Fig. 2.1 shows part of Tarawa, one of Kiribati's islands, that has experienced flooding and coastal erosion (charted in 2013).

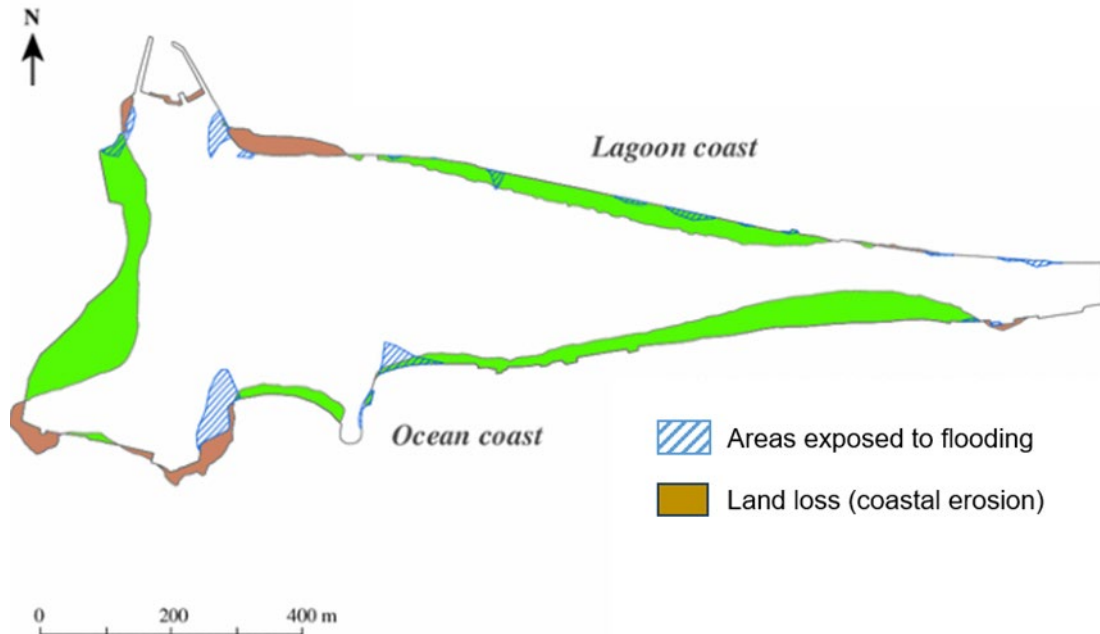


Fig. 2.1

- (a) (i) Describe two ways in which climate change may cause sea levels to rise.

1.
 2.
-[2]

- (ii) Explain the consequences of rising sea levels on Tarawa.

-
-
-
-
-
-[3]

Fig. 2.2 below shows the projected sea level rise, in metres, from 2020 to 2127 for Kiribati.

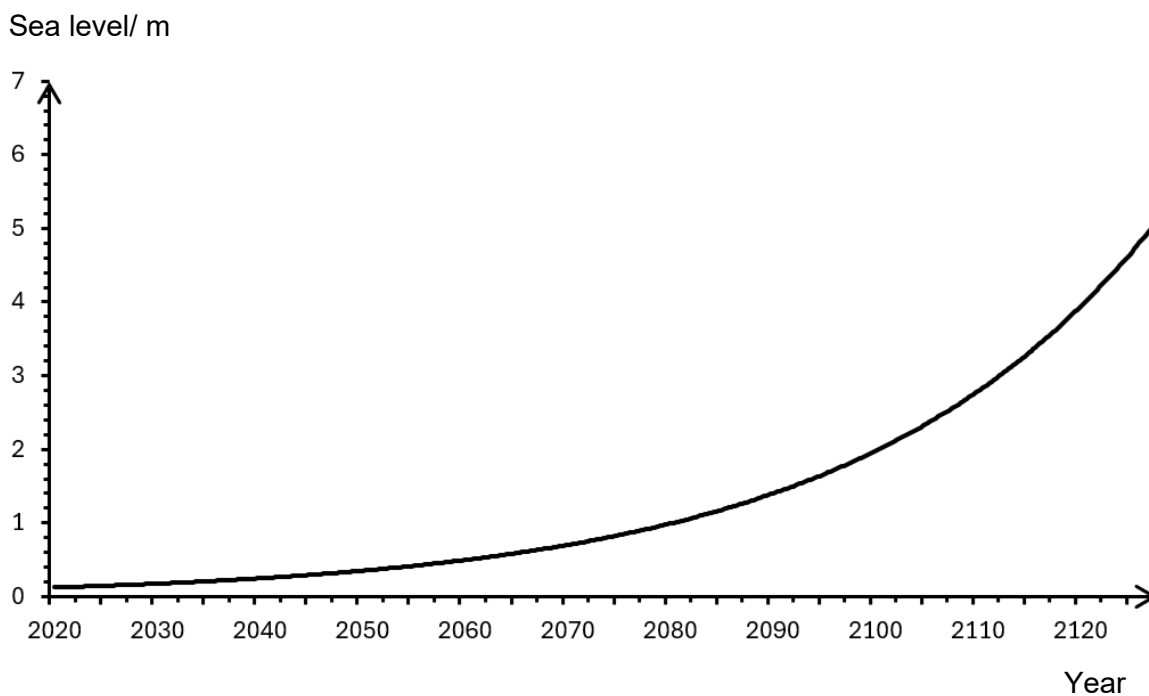


Fig. 2.2

- (b) (i) Based on Fig. 2.2, and the information given above, when is the estimated year that Kiribati will be fully submerged? Show on the graph how you arrived at your answer.

Estimated year:.....[2]

- (ii) Suggest a reason for the exponential increase in the graph after year 2110.

.....

.....[1]

[Total: 8]

- 3 The Hawaiian archipelago is a group of volcanic islands in the Pacific Ocean.

Fig. 3.1 shows the relative locations of five of these islands.



Fig. 3.1

Table 3.1 shows the size and age of these five islands and the total number of *Mecyclothorax* ground beetle species and their species density, on each island.

Data for the island of Maui is shown as two distinct regions, West and Haleakala. This is because they formed at different times from two separate volcanoes.

Table 3.1

island	area / km ²	age of island / million years	total number of <i>Mecyclothorax</i> species	species density / number of species per km ²
Hawai'i	10 433	0.4	30	0.003
Lāna'i	364	1.3	3	0.008
Maui (West)	443	1.3	27	0.061
Maui (Haleakalā)	1440	1.1	116	0.081
Moloka'i	673	1.9 – 1.8	43	0.064
O'ahu	1545	3.7 – 2.6	20	

Fig. 3.2 shows a ground beetle of the genus *Mecyclothorax*. All the beetle species of this genus on the Hawaiian archipelago descended from one original colonising species that reached Maui from Australia.

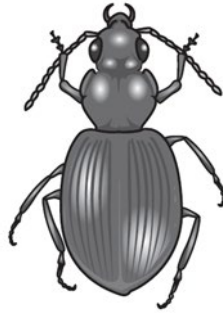


Fig. 3.2

- (a) (i) Complete Table 3.1 by calculating the density of *Mecyclothorax* beetle species on the island of O'ahu. [1]

- (ii) Use Table 3.1 to explain why the island of Hawai'i has the lowest density of *Mecyclothorax* beetle species.

.....

[2]

- (iii) Using information from Fig. 3.1 and Table 3.1, suggest why O'ahu has a lower number of *Mecyclothorax* beetle species than Moloka'i.

.....

[2]

- (b) The rate of speciation of *Mecyclothorax* beetles on the slopes of the volcano Haleakala, on Maui, is the highest recorded for any genus or location on earth.

The volcano last erupted 400 years ago. This produced lava flows which cut through ancient forest and vegetation, dividing it into many separate microhabitats.

Explain how the large number of *Mecyclothorax* beetle species on Haleakala developed.

.....

.....

.....

.....

.....

.....

.....

.....[4]

- (c) Table 3.2 shows the DNA sequences from 6 *Mecyclothorax* beetles species on Haleakala.

Table 3.2

Species A	A	A	C	T	T	G	A	A	G	G	G	G	A	A	C	T	T	C	A	G	G
Species B	G	A	T	G	A	G	A	A	G	G	T	T	A	C	C	G	C	A	T	A	C
Species C	A	A	C	G	A	C	T	G	T	G	T	G	G	G	G	C	T	C	G	G	G
Species D	A	A	C	T	T	G	A	A	T	G	G	G	A	A	C	T	T	C	G	G	G
Species E	C	T	T	G	G	G	C	A	A	C	T	G	T	C	T	G	T	C	A	G	T
Species F	A	G	A	C	T	T	A	T	T	A	T	C	C	G	C	G	A	C	G	T	C

Explain which species is the most closely related to Species A.

.....

.....

.....

.....[2]

In a follow-up study, scientists investigated a large population of a specific *Mecyclothorax* beetle species within an isolated forest patch on the slopes of Haleakala. They focused on a gene that controls exoskeleton coloration, which has two alleles: a dominant allele for dark coloration (**D**) and a recessive allele for light coloration (**d**).

- (d) (i) Explain what is meant by the Hardy-Weinberg model and state two conditions necessary for a population to maintain Hardy-Weinberg equilibrium.

.....

[2]

- (ii) Out of 500 beetles sampled from this isolated population, 45 beetles were observed to have the light coloration phenotype.

Assuming the population is in Hardy-Weinberg equilibrium, calculate the frequency of the heterozygous genotype. Show your working clearly.

[3]

[Total: 16]

Section B

Answer **one** question in this section.

Write your answers on the separate answer paper provided.

Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.

Your answers must be in continuous prose, where appropriate.

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

- 4** Understanding what causes disease in humans is essential for improving human health outcomes and guiding medical research.

Explain the causes of diseases in humans. [20]

- 5** The structure of DNA confers stability but also allows for variation. The DNA structure will also allow for its interaction with other biomolecules.

Relate the structure and chemical properties of DNA to its role in evolution. [20]

[Total: 20]

End of Paper