H2

ANDERSON SERANGOON JUNIOR COLLEGE
HIGHER 2

2022 JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME							
CLASS					INDEX NUMBER		

BIOLOGY 9744/03

PAPER 3
LONG STRUCTURED AND FREE RESPONSE QUESTIONS

15 SEPTEMBER 2022
THURSDAY

Candidates answer on the Question Paper.
No Additional Materials are required.

2 HOURS

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graph
Do not use paper clips, highlighters, glue or correction fluid.

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

Section B
Answer **any one** question in the spaces provided on the Question Paper.

For Examiner's Use	
1	/ 30
2	/ 10
3	/ 10
4 / 5	/ 25
Total	/ **75**

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, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of **23** printed pages and **1** blank page.

Section A

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

1 Lactose is a disaccharide found in milk. Lactase, an enzyme found in mammals and some fungi, catalyse the breakdown of lactose.

The lactase enzyme is made up of 4 identical polypeptide chains. In humans, molecules of lactase are embedded in the cell surface membrane of epithelial cells lining the small intestine. As the lactose molecules float by in the lumen, they are broken down.

(a) Explain how the polypeptide chains in lactase are held together and how they interact with the cell surface membrane.

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Question 1 continues on page 4

The products of lactose digestion, glucose and galactose, are actively absorbed by intestinal epithelial cells. This absorption is carried out by the sodium-glucose linked transporter (SGLT).

SGLT is a secondary active transporter that works together with sodium-potassium (Na^+-K^+) pump. SGLT transports glucose and galactose concurrently with entry of sodium ions (Na^+) into the intestinal epithelial cells. This transport of glucose and galactose uses the driving force generated by the sodium ion gradient created by Na^+-K^+ pump.

Fig. 1.1 illustrates the transport process.

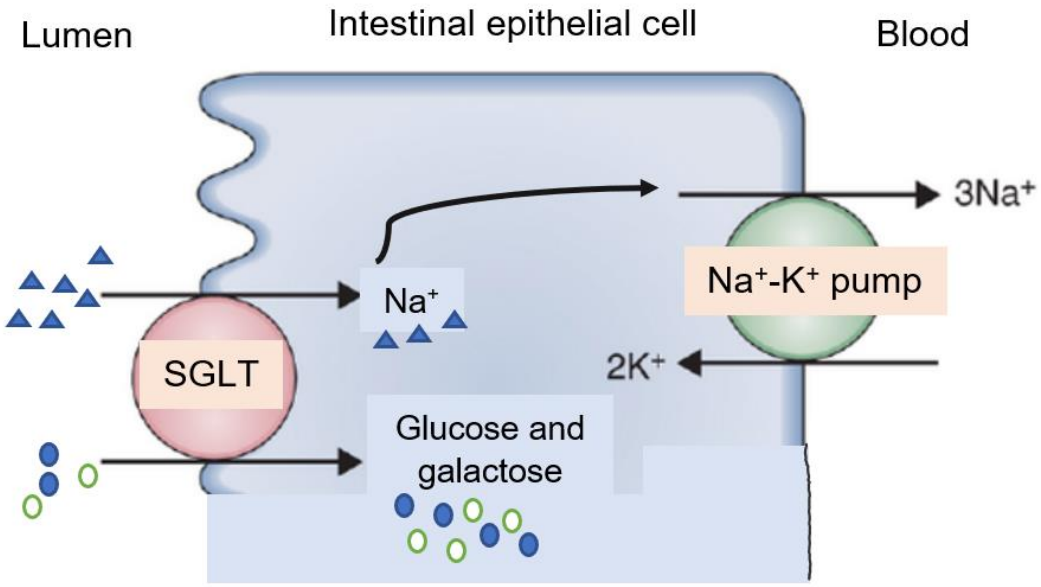

Fig. 1.1

Cyanide is a poison that binds with cytochrome oxidase, one of the electron carriers in the mitochondrial membrane.

It has been observed that the absorption of glucose and galactose from the lumen of the small intestine is reduced when the intestinal epithelial cells are treated with cyanide.

(b) Using Fig. 1.1 and all the information provided, explain why absorption of glucose and galactose from the lumen of the small intestine is reduced when the intestinal epithelial cells are treated with cyanide.

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(c) Many human adults do not produce lactase and are lactose intolerant. This means they cannot digest lactose. Lactose intolerance leads to side-effects such as abdominal pain after eating food containing lactose.

Scientists have investigated ways to produce low-lactose cow's milk from normal cow's milk for people who are lactose intolerant. One method involved extracting lactase from fungi and mixing the extracted lactase with normal cow's milk. This method is, however, ineffective because one of the products of lactose digestion, galactose, is an inhibitor of lactase.

(i) Explain the effect of galactose on lactase activity.

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(ii) Explain why product inhibition is useful when lactase is acting as an intracellular enzyme in fungi cells but can be a disadvantage when extracted lactase is used free in solution for the production of low-lactose cow's milk.

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Another method of producing low-lactose cow's milk involved immobilising extracted lactase within alginate beads and putting in high-lactose cow's milk. As the high-lactose cow's milk comes into contact with the alginate beads, the immobilised lactase hydrolyses the lactose.

Fig. 1.2 shows the set-up.

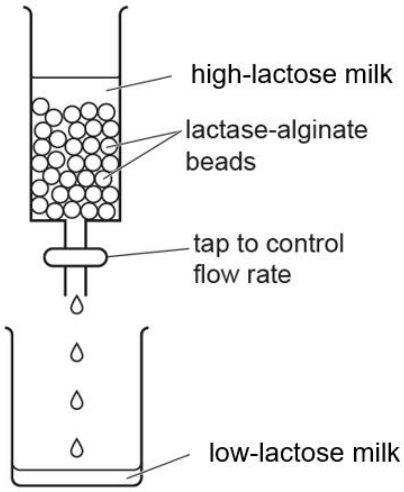

Fig. 1.2

(iii) Suggest how using immobilised lactase for the production of low-lactose cow's milk helps to reduce the problem of product inhibition.

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A company producing low-lactose cow's milk carried out an investigation to study the effect of drinking normal high-lactose cow's milk and the company's own processed low-lactose cow's milk.

Fig. 1.3 shows the results of the investigation which compares:

- the effects on 50 lactose-intolerant volunteers of drinking normal cow's milk
- the effects on the same 50 lactose-intolerant volunteers of drinking low-lactose cow's milk
- the effects on a control group of 15 volunteers, who were not lactose intolerant, of drinking normal cow's milk.

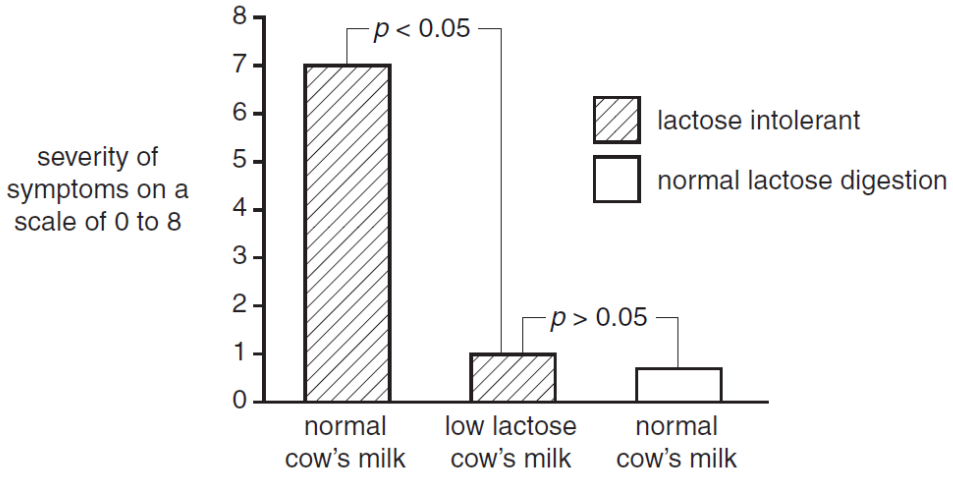

Fig. 1.3

(d) The company claimed that their processed low-lactose cow's milk is suitable for consumption by lactose-intolerant individuals.

With reference to the probability (*p*) values shown in Fig. 1.3, comment on the validity of the claim.

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(e) Scientists have found evidence of natural selection in humans.

- Originally, in human populations it was only babies and children that needed to digest lactose. The gene coding for the enzyme lactase (*LCT* gene) was switched off before adulthood.
- However, today, in many populations, only some adult individuals have lactose intolerance.
- A mutation has been identified that keeps the *LCT* gene switched on. An adult who has this mutation is able to digest lactose. This is called lactase persistence (which means lactose tolerance) .
- Lactase persistence increased in populations in Europe several thousand years ago. The increase in lactase persistence in Europe coincided with an increase in farming of cows for milk.

(i) Natural selection has caused an increase in lactase persistence in human populations.

State the type of selection that has caused this increase.

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(ii) Explain why there was selection for lactase persistence in humans several thousand years ago.

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The conclusion that lactase persistence is evidence of recent human evolution is further supported by a study. This study correlates lactase persistence allele frequency with fresh milk consumption and reliance on livestock (pastoral and non-pastoral populations) in Europe.

The result of this correlation study is represented in Fig. 1.4.

- Squares (■) and triangles (▲) represent pastoral populations with high (> 0.6) and low (< 0.4) lactase persistence frequency respectively.
- Non-pastoral populations are represented by diamonds (◆) .
- Pastoral populations raised livestock such as cattle and goats for food while non-pastoral populations grow crops for food.
- Allele frequency is calculated by dividing the number of times the allele of interest is observed in a population by the total number of copies of all the alleles at that particular genetic locus in the population.

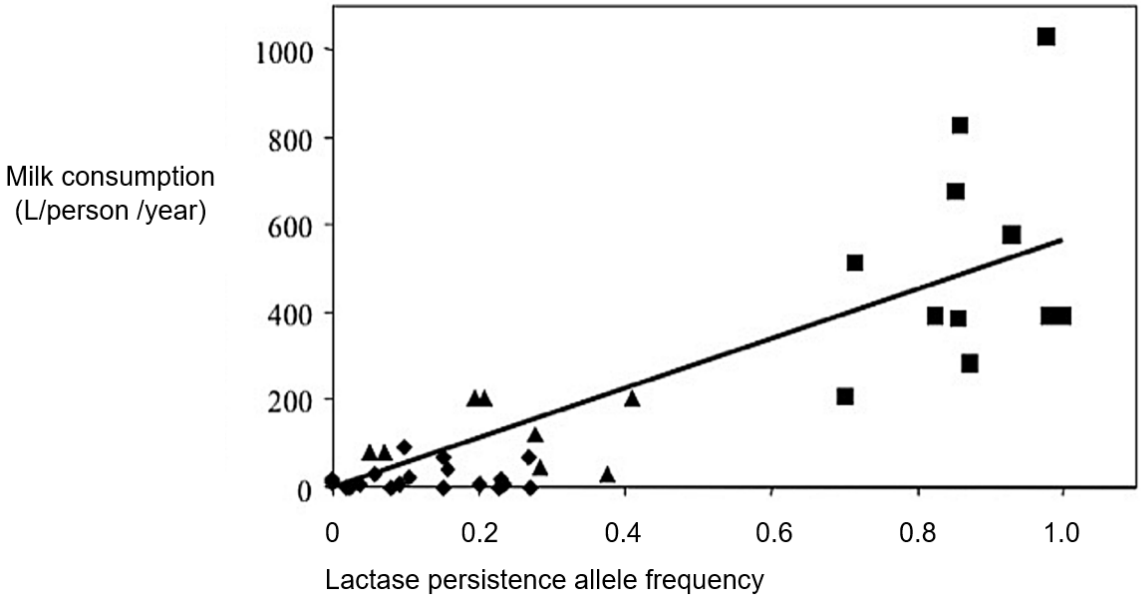

Fig. 1.4

(iii) The study concluded that direct fresh milk consumption has a stronger correlation with lactase persistence than reliance on livestock.

Use information from Fig. 1.4 to justify this conclusion.

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(iv) The mutation causing lactase persistence does **not** occur in the *LCT* gene.

Suggest and explain where the mutation that causes lactase persistence may occur.

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(f) In bacteria, the enzyme β-galactosidase breaks down lactose. β-galactosidase is an inducible enzyme but lactase is not.

(i) Explain what is meant by an inducible enzyme.

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(ii) Describe **two other** differences between the transcriptional control of the β -galactosidase gene in bacteria cells and the *LCT* gene in human cells.

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[Total: 30]

2 **(a)** Name the pathogen that causes tuberculosis (TB).

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(b) Antibiotics are drugs which are very important in the treatment and cure of some diseases, including TB.

(i) Describe the modes of action of antibiotics.

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(ii) Antibiotic treatment of active TB is done with a combination of several antibiotics that are taken over a period of about nine months.

Suggest why the antibiotics used to treat TB are taken in combination over a long period of time.

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(c) Fig. 2.1 shows the number of deaths from TB and the number of new cases of TB from 1925 to 2000 in Canada.

Antibiotics, such as streptomycin, were introduced in Canada from 1940.

Vaccine for TB was introduced in Canada for use from 1948.

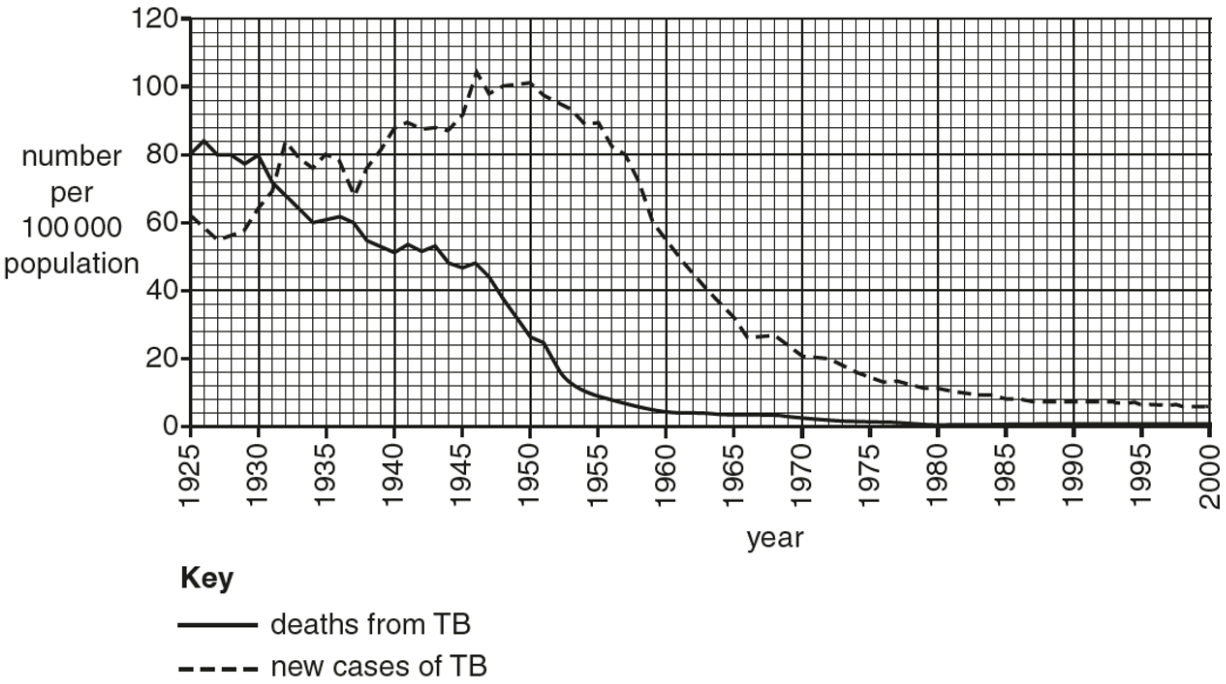

Fig. 2.1

(i) Use data from Fig. 2.1 to evaluate the effectiveness of the introduction of the antibiotics and vaccine and on the number of new cases and deaths from TB.

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(ii) Suggest why the numbers of new cases or deaths **per 100 000 population** were calculated instead of stating the numbers of new cases or deaths alone.

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[Total: 10]

Question 3 starts on page 15.

3 Mangroves are plants that are able to live in harsh coastal conditions through various adaptations. One such adaption is the ability to grow in low oxygen concentrations in waterlogged mud. Mangroves have lateral roots known as pneumatophores that grow upward out of the mud and water to absorb gases directly from the atmosphere as shown in Fig. 3.1.

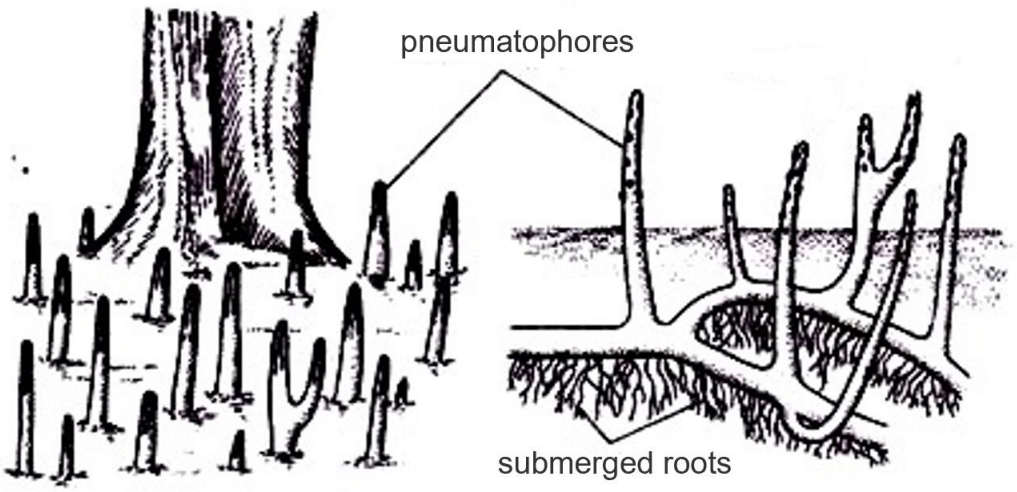

Fig. 3.1

(a) Explain how mangrove plants with more pneumatophores are able to yield more ATP.

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One effect of climate change is rising sea levels, often resulting in severe storm surge and coastal flooding.

(b) Explain how climate change can lead to rising sea levels.

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(c) In many tropical and subtropical regions, mangroves as shown in Fig. 3.2 reduce waves and storm surges, and serve as a first line of defense against flooding and erosion.

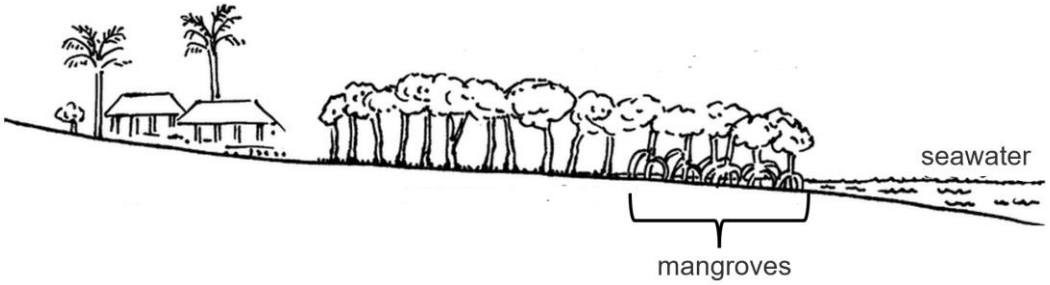

Fig. 3.2

One study quantifies global mangrove benefits by estimating the difference in flood damages between two scenarios: one “with mangroves” (current global extent of mangroves) and another “without mangroves”.

Table 3.1 shows the land flooded, people and property damaged with and without mangroves across 700,000 km of mangrove coastlines globally. The difference between scenarios is the benefits provided by current mangroves.

Table 3.1

global benefit of mangroves in terms of	annual expected		
	with mangroves	without mangroves	benefit
land flooded (x1000 km^2)	122	157	35
people affected (million)	53	68	
property loss ($US billion)	732	797	

(i) Calculate the annual expected benefit of mangroves in terms of people affected and property loss and fill in your answers in Table 3.1. [1]

(ii) With reference to Table 3.1, explain how **one** human activity could **directly** damage mangroves leading to greater climate change impact on humans.

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[Total: 10]

Section B

Answer **one** question 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)**, as indicated in the question.

4 **(a)** Describe how membrane fluidity is regulated in cells and explain the significance of membrane fluidity to the functions of vesicles. [13]

(b) Describe the structure of an antibody and explain how the vast diversity of antibodies is generated in B lymphocytes. [12]

[Total: 25]

5 **(a)** There are many examples of concentration gradients in a cell, for example, the proton gradient in mitochondria plays an important role in aerobic respiration.

Describe how the proton gradient is established in mitochondria and explain the importance of all concentration gradients in aerobic respiration. [13]

(b) Describe the life cycle of *Aedes aegypti* and discuss the possible impacts of global warming on geographical patterns of dengue disease. [12]

[Total: 25]

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