H2

ANDERSON SERANGOON JUNIOR COLLEGE
HIGHER 2

2024 JC2 PRELIMINARY EXAMINATIONS

CANDIDATE NAME

CLASS

INDEX NUMBER

BIOLOGY

9744/03

PAPER 3
LONG STRUCTURED AND FREE RESPONSE QUESTIONS

10 SEPTEMBER 2024
TUESDAY

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.

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.

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

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 **24** printed pages.

Section A

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

1 Malaria is a disease caused by the *Plasmodium* parasite. There are four species of the *Plasmodium* parasite, of which *Plasmodium falciparum* is responsible for most of the deaths from this disease.

Fig.1.1 shows part of the life cycle of *P. falciparum*, which requires two hosts.

A female mosquito carrying *P. falciparum* injects the parasite, in a form known as a sporozoite, into the bloodstream of an uninfected person. The *P. falciparum* parasite multiplies in a liver cell before emerging as a different form, known as a merozoite, wrapped in the liver cell surface membrane. It enters a red blood cell and multiplies before causing the rupture of the red blood cell, releasing more parasites.

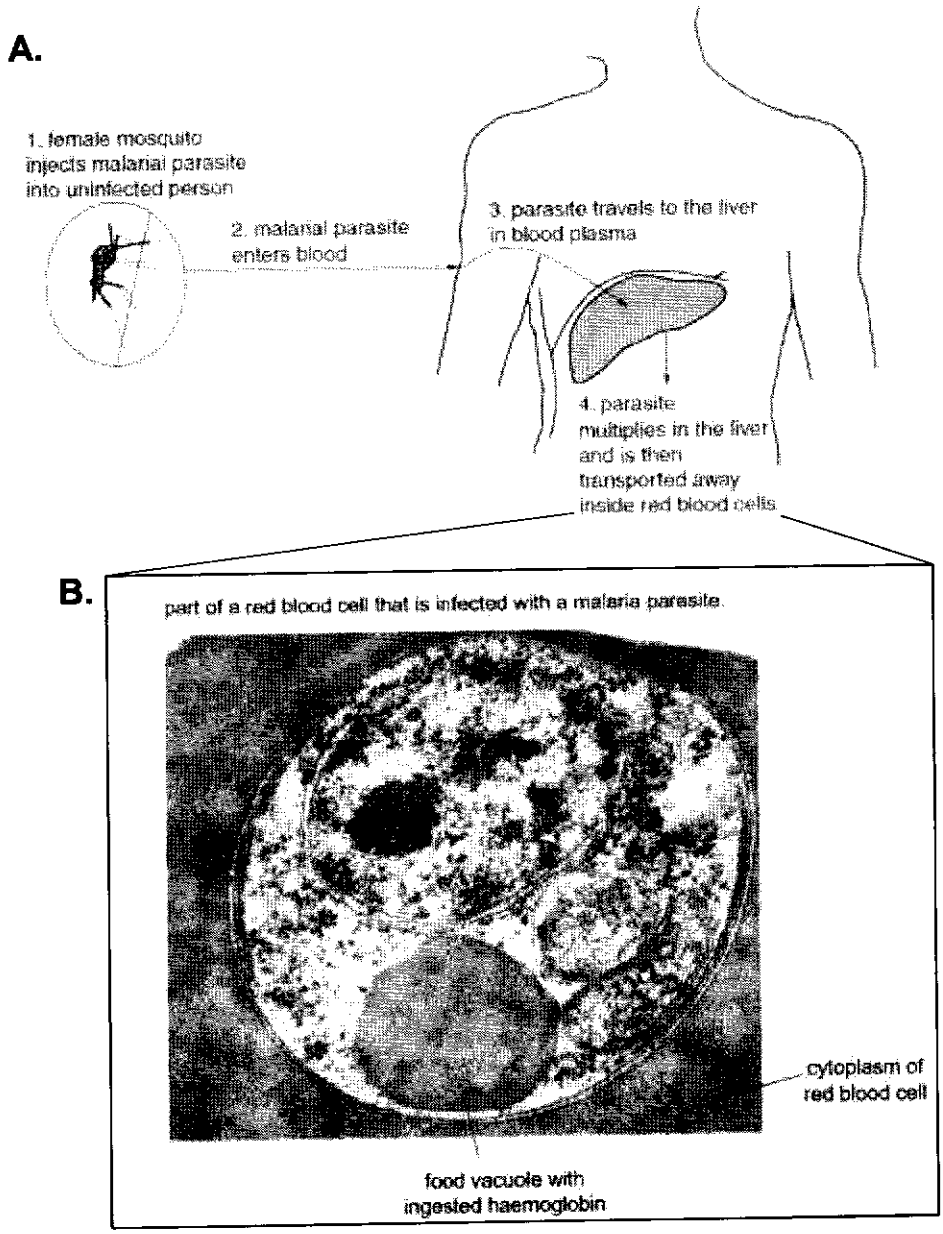

Fig. 1.1

(a) State **two** features, visible in Fig. 1.1B, that indicate that *P. falciparum* is eukaryotic.

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(b) To control the spread of malaria, research has been directed towards the development of a malarial vaccine. Much of this research relies on the fact that *P. falciparum* has different forms in its life cycle.

Researchers were able to extract both the sporozoite form (the form injected by mosquitoes) and the merozoite form (the form that leaves the liver, before entering red blood cells) of *P. falciparum*.

With reference to Fig. 1.1A, suggest why researchers finally chose to use the sporozoite form of *P. falciparum* instead of the merozoite form in the malarial vaccine.

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(c) In another trial, a naturally occurring mutant form of *P. falciparum* parasite discovered in Africa was tested for use as a vaccine against malaria. The mutant parasite develops normally in mosquitoes. In humans, however, the mutant *P. falciparum* infects liver cells but does not multiply and cannot enter red blood cells.

An investigation was conducted to test this vaccine using mice. Four test groups of 10 mice each were injected (inoculated) with mutant *P. falciparum* cells, followed by booster doses every six months after the first inoculation.

The effectiveness of the vaccine was then tested by injecting non-mutant (wild type) *P. falciparum* cells into all the mice.

Table 1.1 shows the results of the investigation.

Table 1.1

	number of mutant *P. falciparum* cells given to mice			percentage of mice not infected by non-mutant (wild type) *P. falciparum*
test group	first inoculation	first booster inoculation	second booster inoculation	
1	0	0	0	0
2	50 000	25 000	25 000	100
3	10 000	10 000	10 000	100
4	10 000	10 000	0	70

(i) Evaluate whether the results of this investigation is sufficient for researchers to recommend an effective vaccination plan against malaria.

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(ii) Volunteers who were injected with killed mutant *P. falciparum* cells produced antibodies, which provided some protection against malaria.

Outline the events that occur following injection of the killed mutant *P. falciparum*, which lead to the eventual production of antibodies.

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(d) While vaccination provides protection against malaria, the severity of a person's malarial infection can be influenced by the type of red blood cells (RBCs) present in their blood.

Haemoglobin (Hb) is the protein found in RBCs that is responsible for delivery of oxygen to tissues. HbS is a mutant form of the normal HbA protein and is responsible for causing sickle cell anaemia. Individuals who carry one copy of the HbS allele are protected against severe malaria.

From your knowledge of Hb structure, explain how having HbS protein protects such individuals against severe malarial infection.

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(e) The human ABO blood typing system is based on the presence or absence of A and B antigens on the surface of RBCs. A and B antigens are glycoproteins.

The ABO blood type is controlled by a single gene with three alleles: O, A and B.

- Individuals with RBC genotype AO and AA have type A blood with A antigens on the surface of their RBCs.
- Individuals with RBC genotype BO and BB have type B blood with B antigens on the surface of their RBCs.
- Individuals with RBC genotype AB have type AB blood with A and B antigens on the surface of their RBCs.
- Individuals with RBC genotype OO have type O blood. They do not have either A or B antigens on the surface of their RBCs.

Recent research has shown that type O blood may provide protection against severe malaria as type O blood is found to be more common in regions with high cases of malaria. This protection could be related to the reduced likelihood of formation of rosettes during malarial infection. Rosettes are clusters of cells formed when RBCs infected with *P. falciparum* bind spontaneously to uninfected RBCs.

Fig. 1.2 shows RBCs containing *P. falciparum* (arrow) surrounded by uninfected RBCs in a rosette formation. Rosettes are thought to shield infected RBCs from the host immune system as infected RBCs express parasite-specific proteins on their cell surface. The formation of rosettes is associated with severe malaria because the clustering of red blood cells can lead to blood vessel obstruction, causing impaired blood flow to organs.

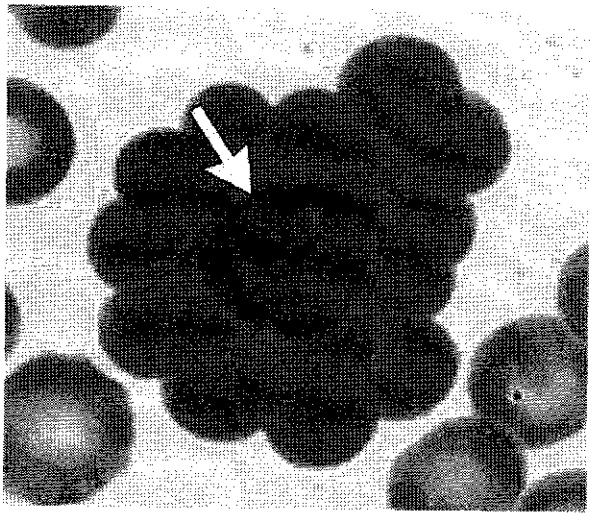

Fig. 1.2

(i) Suggest why individuals with type O blood are less likely to form rosettes compared to individuals with type A, B or AB blood when infected with malaria.

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(ii) Scientists hypothesised that when infected with malaria, individuals with type O blood are less likely to form large rosettes compared to individuals with type A , B or AB blood.

An investigation was carried out to test the scientists' hypothesis.

RBCs of different genotypes isolated from donors were incubated with *P. falciparum* allowing infection to take place. Rosette size and frequency of large rosettes (more than 4 uninfected RBCs per rosettes) formed were measured.

Fig. 1.3 and Fig 1.4 show the results of the investigation. Horizontal bars represent the mean rosette size and mean frequency of large rosettes for each genotype.

t-tests were conducted to compare the mean rosette size and the mean frequency of large rosettes for each genotype against those of the OO genotype.

The *p*-value calculated for each comparison is shown in brackets ( ).

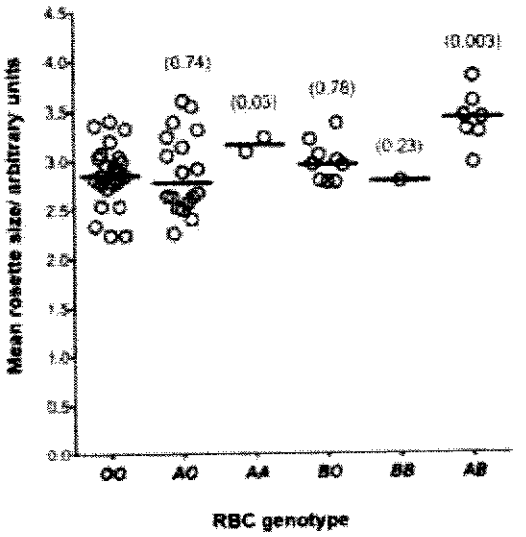

Fig. 1.3

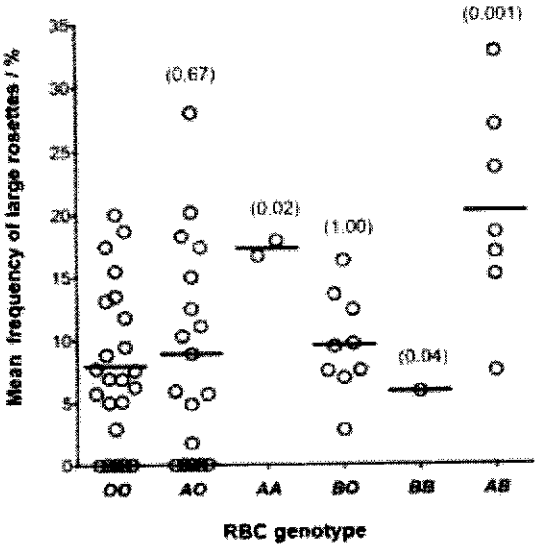

Fig. 1.4

Complete Table 1.2 to show whether the result of each genotype support the scientists' hypothesis.

Write **yes** if the result supports the hypothesis.
Write **no** if the result does not support the hypothesis.

Table 1.2

Genotype	Do the results support the scientists' hypothesis?	
	Fig. 1.3	Fig. 1.4
AO		
AA	yes	yes
BO		
BB		
AB		

[2]

(f) Drug therapy is the main method of treating malaria.

Chloroquine was one of the first drugs used to treat malaria. However, chloroquine-resistant (CQR) *P. falciparum* parasites soon emerged and are now widespread.

The resistance is caused by mutations of a gene called *pfcrt*. *pfcrt* encodes for a membrane transporter found in the haemoglobin-containing food vacuole in *P. falciparum*. In parasites that are still susceptible to chloroquine (non-CQR), chloroquine accumulates in the food vacuole of *P. falciparum* and interferes with the acquisition of nutrients, resulting in parasite death.

(i) Explain why CQR *P. falciparum* are now widespread.

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(ii) Analysis of the alleles of *pfcrt* gene in CQR *P. falciparum* from different parts of the world shows differences in one section of the gene only. The amino acid sequences coded for by this section are shown in Table 1.3, together with the amino acid sequence coded for by the allele found in non-CQR *P. falciparum*.

The amino acid sequence coded for by the rest of the gene is the same in all cases.

Table 1.3

allele of *pfcrt* gene	amino acid sequence coded for by allele of *pfcrt* gene
non-CQR	—Cys—Met—Asn—Lys—His—Ala—Glu—Asn—Ile —Met—
CQR from Africa	—Cys—Ile —Glu—Thr—His—Ser—Glu—Ser—Ile —Ile —
CQR from Asia	—Cys—Ile —Glu—Thr—His—Ser—Glu—Ser—Thr—Ile —
CQR from Peru and Brazil	—Ser—Met—Asn—Thr—His—Ser—Gln—Asp—Leu—Arg—
CQR from Colombia	—Cys—Met—Glu—Thr—Gln—Ser—Gln—Asn—Ile —Thr—

With reference to Table 1.3, calculate the mean number of amino acid changes coded for by the four CQR alleles in comparison with the non-CQR allele.

Show your working.

[1]

(iii) Suggest why the CQR alleles from Africa and Asia code for such similar sequences.

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(iv) It was found that the mutation that changes the amino acid from lysine (Lys) to threonine (Thr) occurs at the binding site of the chloroquine-resistance transporter.

Explain how this mutation of *pfcrt* gene results in chloroquine resistance in *P. falciparum*.

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[Total: 30]

2 In Asian cultivated rice crop *Oryza sativa*, the growth of red rice variety alongside the Loto variety has become a serious problem in rice cultivation. In the cultivation of Loto variety, red rice plants are considered weeds because they compete strongly for light and nutrients and have a negative effect on growth and grain yield of the Loto variety.

In order to develop suitable techniques against the expansion of weedy red rice, the complete sets of chromosomes (karyotypes) of red rice variety and Loto variety are compared to detect differences at the chromosomal level so as to obtain information on their genetic diversity.

The chromosomal analysis of both varieties was done by means of a chromosomal imaging method, as shown in Fig. 2.1. Intensity of the shaded regions represent level of chromatin condensation at the particular region of the chromosome.

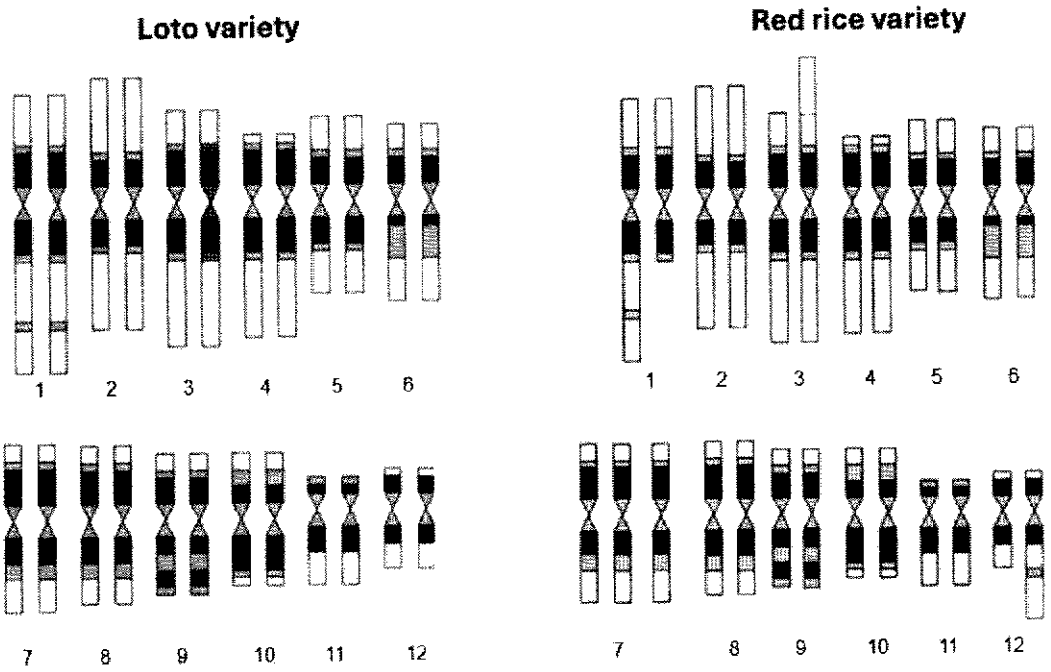

Fig. 2.1

(a) With reference to Fig. 2.1, describe the changes that occurred in the karyotype of red rice variety.

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(b) Explain how the changes mentioned in **(a)** may have arisen.

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(c) In West Africa, *Oryza sativa* (Asian cultivated rice) and *Oryza glaberrima* (African cultivated rice) are two important cultivated rice species that co-exist within the region.

- *O. sativa* has 24 chromosomes (2n = 24).
- *O. glaberrima* also has 24 chromosomes (2n = 24).
- Both species can be found growing in similar lowland tropical regions.
- *O. sativa* and *O. glaberrima* can be cross bred but the resulting offspring are usually sterile.
- Occasionally, cross breeding between these two species can result in fertile offspring with 48 chromosomes.

(i) Explain why the resulting offspring of *O. sativa* and *O. glaberrima* are usually sterile.

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(ii) Suggest how a new fertile rice species may have evolved from *O. sativa* and *O. glaberrima*.

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[Total: 10]

3 The production and consumption of animal proteins and plant proteins have different greenhouse gas emissions. Table 3.1 shows the mass of greenhouse gas released in the production of one serving of a variety of sources of protein.

Table 3.1

source of protein	mass of greenhouse gas released in the production of one serving of the protein / kg
beef	7.0
mutton	5.0
chicken	2.5
tofu (from soy beans)	1.0
nuts	0.5

(a) With reference to Table 3.1, explain why diets based on animal proteins and plant proteins have different greenhouse gas emissions.

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(b) A research team is investigating a gene that has many different mutations. Only one specific mutation generates a specific allele that is linked to reduced greenhouse gas emissions.

This mutation associated with reduced greenhouse gas emissions, involves a large segment of bases being deleted from the normal allele. The normal allele is 650bp long.

Scientists are exploring whether specific cattle possess the mutant allele that is linked to reduced greenhouse gas emissions. They collect DNA samples from four different cattle and analyse the DNA using molecular techniques in the following order: Polymerase Chain Reaction (PCR), gel electrophoresis, and southern blotting.

Explain the basis of the molecular techniques used to identify this mutant allele.

PCR

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gel electrophoresis

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(c) Table 3.2 shows the data collected for the different cattle (cattle **A**, cattle **B**, cattle **C**, and cattle **D**) after gel electrophoresis and southern blotting.

Table 3.2

cattle	size of DNA band / bp	presence of probe (identified by southern blotting)
A	400	no
B	450	yes
C	650	yes
D	850	yes

(i) Based on the data in Table 3.2, state the cattle(s) that is (are) likely to have the mutant allele linked to reduced greenhouse gas emissions.

Justify your answer.

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(ii) Suggest how the data collected by the scientists could be used in a cattle breeding program aimed at reducing greenhouse gas emissions.

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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 The control of cellular activities has important implications.

(a) Outline how gene expression is controlled in cells. [15]

(b) Pharmacogenetics is the study of how genes control an individual's response to medicinal drugs, such as genes encoding drug-metabolising enzymes and proteins that drugs act upon. Drug response within a population can appear as either continuous or discontinuous variation.

Distinguish between continuous and discontinuous variation **and** suggest why it is more difficult to design drugs for responses showing continuous variation within a population. [10]

[Total :25]

5 Cycles involve a series of biochemical reactions that are tightly regulated and interconnected.

(a) Outline the different cycles occurring in eukaryotic cells. [15]

(b) Phagotherapy is the therapeutic use of bacteriophages, which exploit their reproductive cycles, to treat pathogenic bacterial infections.

Distinguish the lysogenic and lytic cycles of bacteriophages **and** suggest the disadvantages of using phagotherapy to treat bacterial infections. [10]

[Total: 25]