HWA CHONG INSTITUTION
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME		**CT GROUP**	**22S7__**

CENTRE NUMBER					**INDEX NUMBER**				

BIOLOGY

9744/02

Paper 2 Structured Questions

21 August 2023

Candidates answer on the Question Paper.

2 hours

No Additional Materials are required.

INSTRUCTIONS TO CANDIDATES

There are **five** question booklets (**I** - **V**) to this paper. Write your **name** and **CT group** in the spaces provided at the top of this cover page and on the lines provided at the top of the cover pages of Booklets **II, III, IV** and **V.**

There are **ten** questions.

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

INFORMATION FOR CANDIDATES

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.

You are reminded of the need for good English and clear presentation in your answers.

For Examiners' Use	
1	**/ 11**
2	**/ 10**
3	**/ 12**
4	**/ 10**
5	**/ 12**
6	**/ 13**
7	**/ 12**
8	**/ 10**
9	**/ 5**
10	**/ 5**
Total	**/ 100**

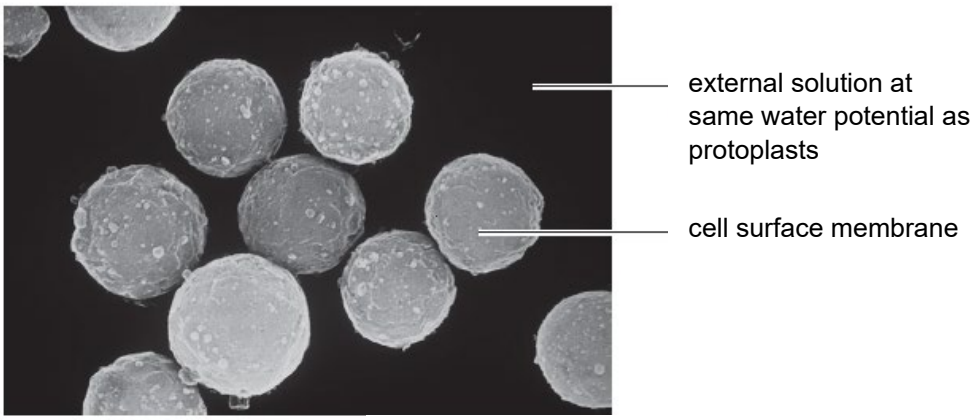
This document consists of **27** printed pages.

QUESTION 1

Bacterial cells are prokaryotic. The cells of plants are described as eukaryotic. Both the bacterial cell and the plant cell have a cell wall, but the main component of the bacterial cell wall is peptidoglycan and not cellulose.

(a) Protoplasts are plant cells that have had their cell walls removed by treatment with enzymes. Scientists often use protoplasts when researching ways to improve the yield of crop plants.

Fig. 1.1 is a scanning electronmicrograph of protoplasts of cells from the tobacco plant, *Nicotiana tabacum.*



magnification x256

Fig. 1.1

Explain why scientists keep the protoplasts in a solution that has the same water potential as the cell.

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After protoplast treatment, the cells can be stimulated to synthesise new cell wall material.

Fig. 1.2 is at a higher magnification than Fig. 1.1 and shows a scanning electronmicrograph of part of a protoplast in an early stage of cell wall synthesis.

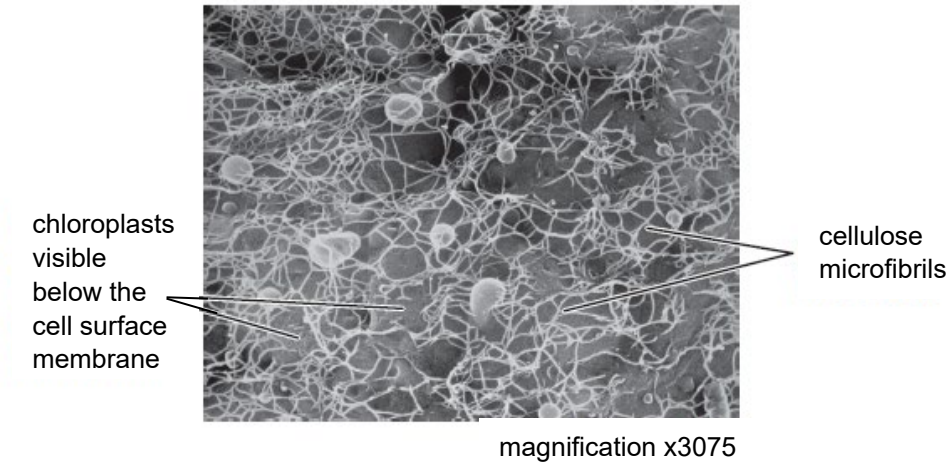

Fig. 1.2

(b) The cellulose microfibrils visible in Fig. 1.2 will form cellulose fibres. Each cellulose molecule is a polymer of β-glucose.

(i) Define the term *polymer*.

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..... [1]

(ii) Explain how the structure of a cellulose molecule allows for the formation of the cellulose microfibrils and fibres.

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Two main forms of bacteria *V. cholerae*, O1 and O139, are able to colonise the small intestine and cause cholera. These two forms are able to produce a toxin, choleragen, which causes the symptoms of diarrhoeal disease. *V. cholerae* has flagella that aid in its motility.

Monoclonal antibodies (mAbs) can be designed to act against components of the cell wall of bacteria. The cell wall has an outer membrane with lipopolysaccharide (LPS) molecules, shown in Fig. 1.3.

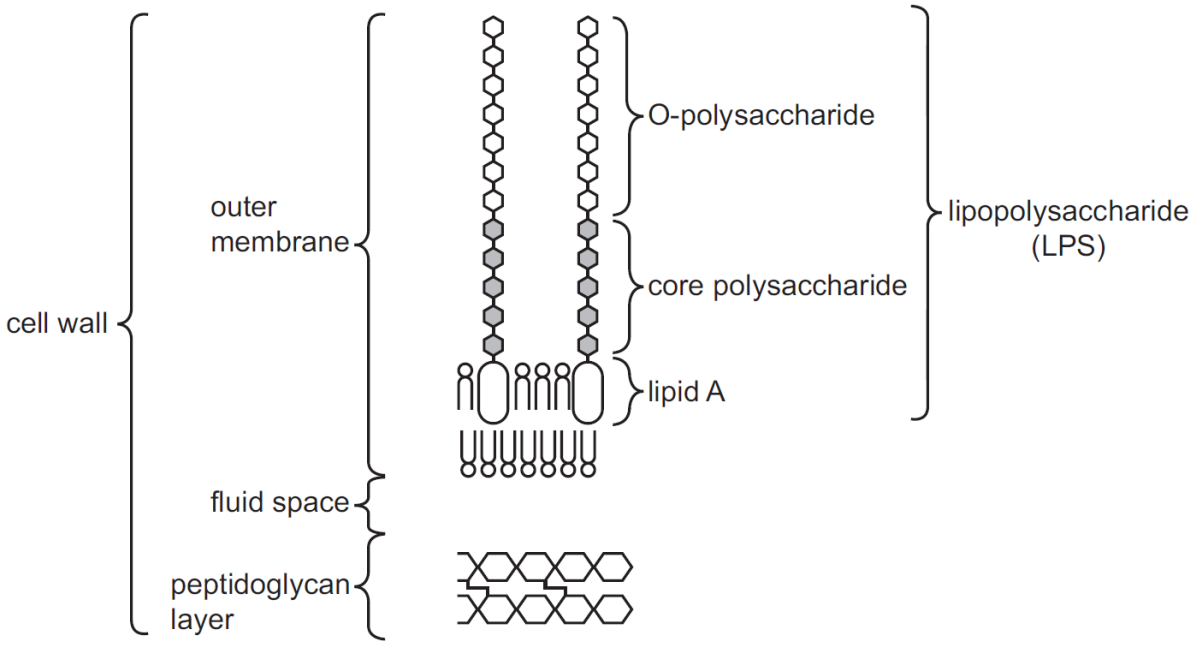

Fig. 1.3

The core polysaccharide and the lipid A components of the LPS molecules are the same in both *V. cholerae* O1 and *V. cholerae* O139. However they have different O-polysaccharides.

(c) Laboratory tests were carried out using two different monoclonal antibodies that had been designed and produced to act against the LPS of bacterial cultures of *V. cholerae* O1:

- mAb 2D6 acts against the O-polysaccharide
- mAb ZAC-3 acts against the core polysaccharide and lipid A components.

(i) Explain why the mAb ZAC-3 produced against the core polysaccharide and lipid A components will not act against the O-polysaccharide of the LPS molecules.

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(ii) The results of the tests showed that both mAbs were effective in causing agglutination (clumping) of bacteria and in preventing their motility. This suggests they may be useful for preventing cholera and for treating the disease.

Justify the claim that mAb 2D6 and mAb ZAC-3 are useful for preventing cholera and for treating the disease.

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[Total: 11]

QUESTION 2

Genetic information encoded in DNA is transcribed to different types of RNA. An example is the transfer RNA (tRNA) that is needed during translation.

Fig. 2.1 shows two representations of a tRNA molecule.

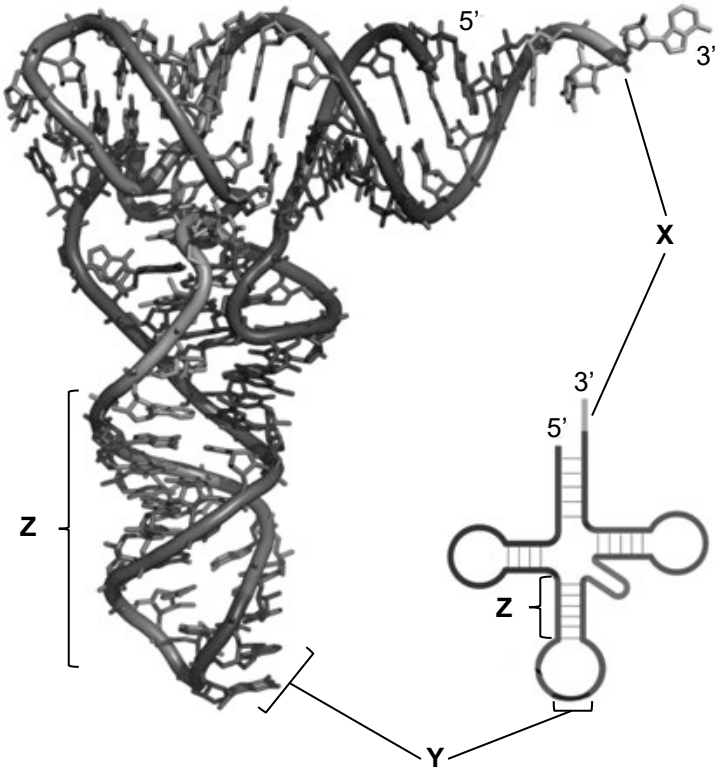

Fig. 2.1

(a) Name the structures labelled **X** and **Y** in Fig. 2.1.

X .....

Y ..... [2]

(b) Compare the structure of **Z** with the structure of DNA.

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(c) With reference to Fig. 2.1, explain how the tRNA acts as an adaptor molecule for translation.

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There are around 45 different tRNAs in a typical eukaryotic cell. There are 20 amino acids used in the process of translation.

(d) Suggest why each amino acid can be carried by more than one type of tRNA.

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[Total: 10]

QUESTION 3

In the bacterium *Escherichia coli*, the repressible system of operon regulation serves as a means of controlling the synthesis of a wide variety of enzymes involved in anabolic pathways.

An example is the *trp* operon, which contains a group of structural genes that are transcribed together.

Fig. 3.1 shows the *trp* operon when tryptophan is absent.

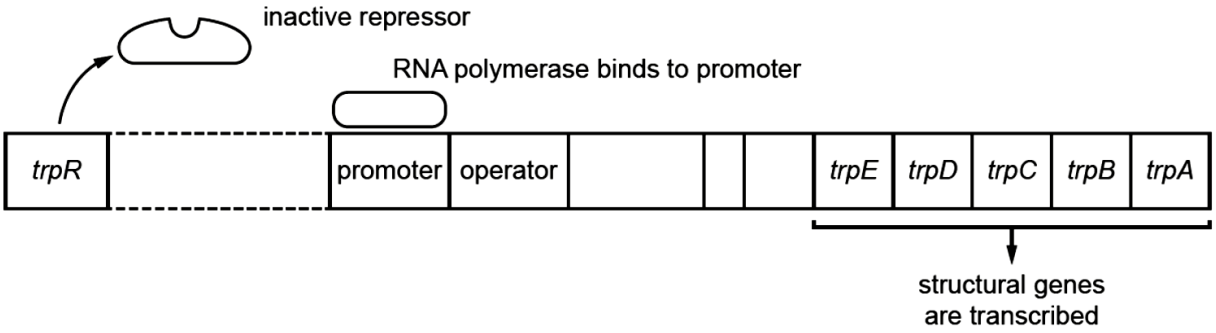

Fig. 3.1

(a) Suggest why the structural genes in *trp* operon are transcribed together.

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(b) *trpR* is a regulatory gene located upstream of the *trp* operon.

Describe the differences between the functions of *trpR* and *trpE*.

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(c)(i) On Fig. 3.2, draw the positions of RNA polymerase and the repressor molecule when tryptophan is present.

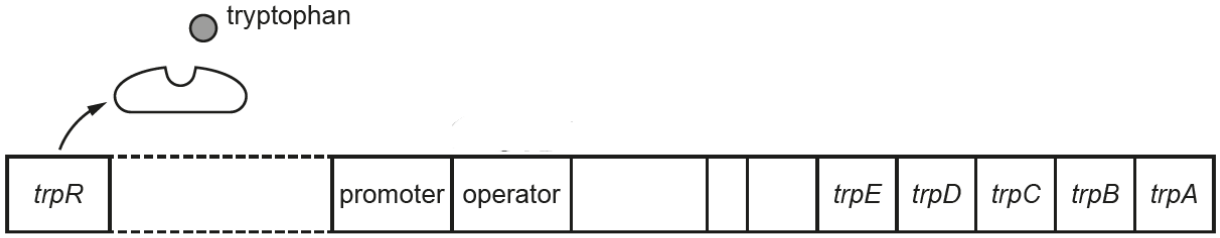

Fig. 3.2

[2]

(ii) Explain the significance of your answer in **(c)(i)**.

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Another operon found in *E. coli* is the *lac* operon, which produces the enzyme β-galactosidase.

E. coli can use glucose or disaccharides, such as lactose, in its metabolism. Lactose needs to be hydrolyzed by the enzyme β-galactosidase to form glucose and galactose, which can then be used by *E. coli*.

In an investigation into the growth of *E. coli*, a sample of the bacterium was grown in a medium that contained limited concentrations of glucose and lactose. The population size of *E. coli* was measured at regular intervals.

Fig. 3.3 shows the population growth curve obtained for this investigation.

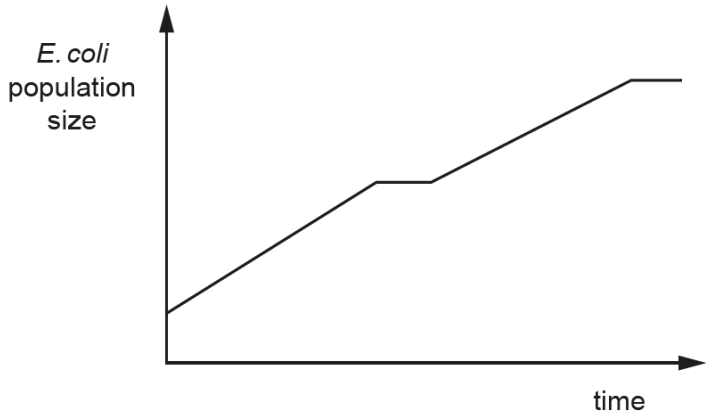

Fig. 3.3

(d) Describe **and** explain the population growth curve shown in Fig. 3.3.

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[Total: 12]

QUESTION 4

Albinism is caused by a recessive mutation in the *TYR* gene coding for the enzyme tyrosinase.

Tyrosinase is involved in the biosynthetic pathway that results in the production of melanin, the pigment responsible for the colour of hair, skin and eyes. A person with albinism has white hair, very pale skin and pink eye colour.

Fig. 4.1 shows the biosynthetic pathway involving tyrosinase.

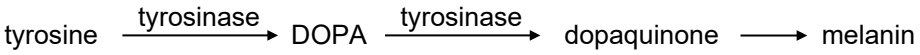

Fig. 4.1

There are a number of different types of mutations of the *TYR* gene that can result in an absence of melanin and cause albinism. These include base substitution or insertion mutations.

(a) State what is meant by *recessive mutation* in this context.

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(b) Explain how an insertion mutation in the *TYR* gene can lead to a lack of melanin in a person with albinism.

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One approach to prenatal screening for human genetic diseases involves:

- polymerase chain reaction (PCR) to amplify the sequence of interest, followed by
- gel electrophoresis to determine the length of the amplified sequence.

Fig. 4.2 shows the human *TYR* gene that comprises of five exons and four introns.

- In the normal allele, exon 2 is 216 base pairs long.
- Mutations commonly occur in exon 2, as shown by the asterisks (*).

A researcher considers the use of PCR followed by gel electrophoresis to detect mutations in exon 2 of the *TYR* gene.

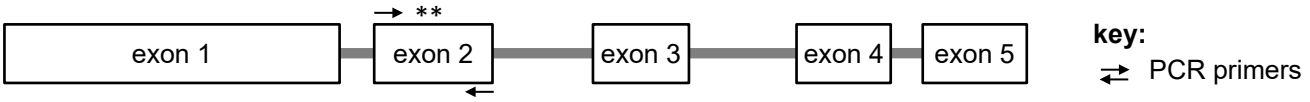

Fig. 4.2

(c) Describe the role of PCR primers in this context.

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(d) Discuss if PCR followed by gel electrophoresis can detect all types of mutations in exon 2 of the *TYR* gene.

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[Total: 10]

QUESTION 5

Fig. 5.1 shows actively dividing onion root tip cells undergoing a type of nuclear division that produces genetically identical cells.

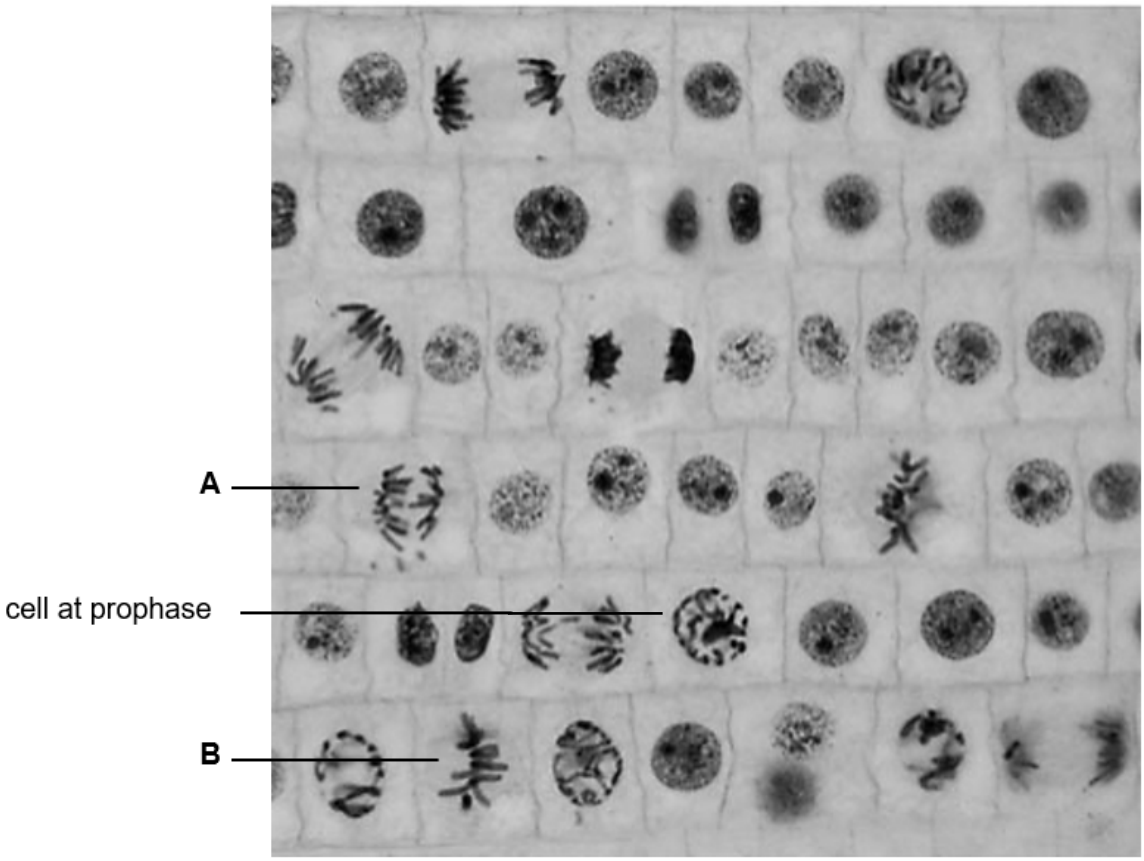

Fig. 5.1

(a)(i) Identify the phase of nuclear division that cell **B** is undergoing.

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(ii) Describe two observable differences between cell **B** and the cell at prophase.

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.....[2]

(b)(i) State the cell cycle checkpoint that determines if cell **B** can proceed to the phase shown by cell **A**.

.....[1]

(ii) Discuss the significance of the cell cycle checkpoint identified in **(b)(i)**.

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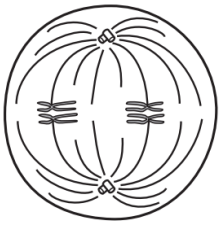
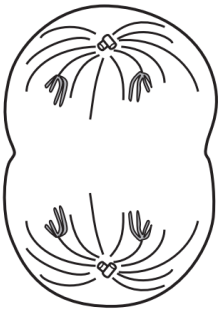
.....[2]

(c) Meiosis is described as a reduction division because the number of chromosomes in the daughter cells is reduced by half.

(i) Table 5.1 describes some of the events that take place during four of the different stages of meiosis in an animal cell.

Table 5.1

stage of meiosis	spindle fibres	diagram
metaphase I	attach to centromeres and arrange homologous pairs of chromosomes at the equator of the cell	
anaphase I		
	re-form spindle in daughter cells	
telophase II	disassemble	

Complete Table 5.1 by:

- outlining the behaviour of the spindle fibres during anaphase I
- identifying the stage of meiosis in which spindle fibres re-form the spindle in daughter cells
- drawing a diagram to show telophase II.

You do not need to add labels to your diagram showing telophase II. [4]

(ii) Explain the need for a reduction division during meiosis.

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[Total: 12]

QUESTION 6

Wing pattern in the butterfly species *Heliconius melpomene* is controlled by genes on autosomal chromosomes.

The gene for banding pattern in the upper wing has two alleles:

- a dominant allele **F** coding for a full band
- a recessive allele **f** coding for a broken band.

The gene for ray pattern in the lower wing has two alleles:

- a dominant allele **R** coding for rays
- a recessive allele **r** coding for no rays.

The inheritance of these genes is an example of **autosomal linkage**.

(a) Explain the meaning of the term *autosomal linkage*.

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..... [2]

A butterfly that was homozygous dominant for both genes was crossed with a butterfly that was homozygous recessive for both genes to produce the F1 generation. The offspring from the F1 generation were crossed to produce the F2 generation.

The observed number of individuals for each phenotype in the F2 generation is shown in Table 6.1.

Table 6.1

phenotype of F2 offspring	number of individuals
full band and rays	284
full band and no rays	21
broken band and rays	21
broken band and no rays	74

(b) (i) A chi-squared (χ^2) test was carried out to determine if the observed results fit the expected phenotypic ratio of 9:3:3:1.

Calculate the value of χ^2 and the number of degrees of freedom, using these formulae.

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

$$v = c - 1$$

key to symbols
O = observed 'value'
E = expected 'value'
v = degrees of freedom
c = number of classes

Show your working.

[3]

(ii) Table 6.2 shows the critical values for χ^2 at several different probabilities and degrees of freedom.

Table 6.2

degrees of freedom	probability, p							
	0.99	0.975	0.95	0.9	0.1	0.05	0.01	0.005
1	0.00	0.00	0.00	0.02	2.71	3.84	6.64	7.88
2	0.02	0.05	0.10	0.21	4.61	5.99	9.21	10.60
3	0.12	0.22	0.35	0.58	6.25	7.82	11.35	12.84
4	0.30	0.48	0.71	1.06	7.78	9.49	13.28	14.86
5	0.55	0.83	1.15	1.61	9.23	11.07	15.09	16.75

Use Table 6.2 and your answers to **(b)(i)** to explain how the observed results support the fact that this is an example of autosomal linkage.

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A test cross was then conducted on the offspring of the F1 generation. The results of this test cross are shown in Fig. 6.1.

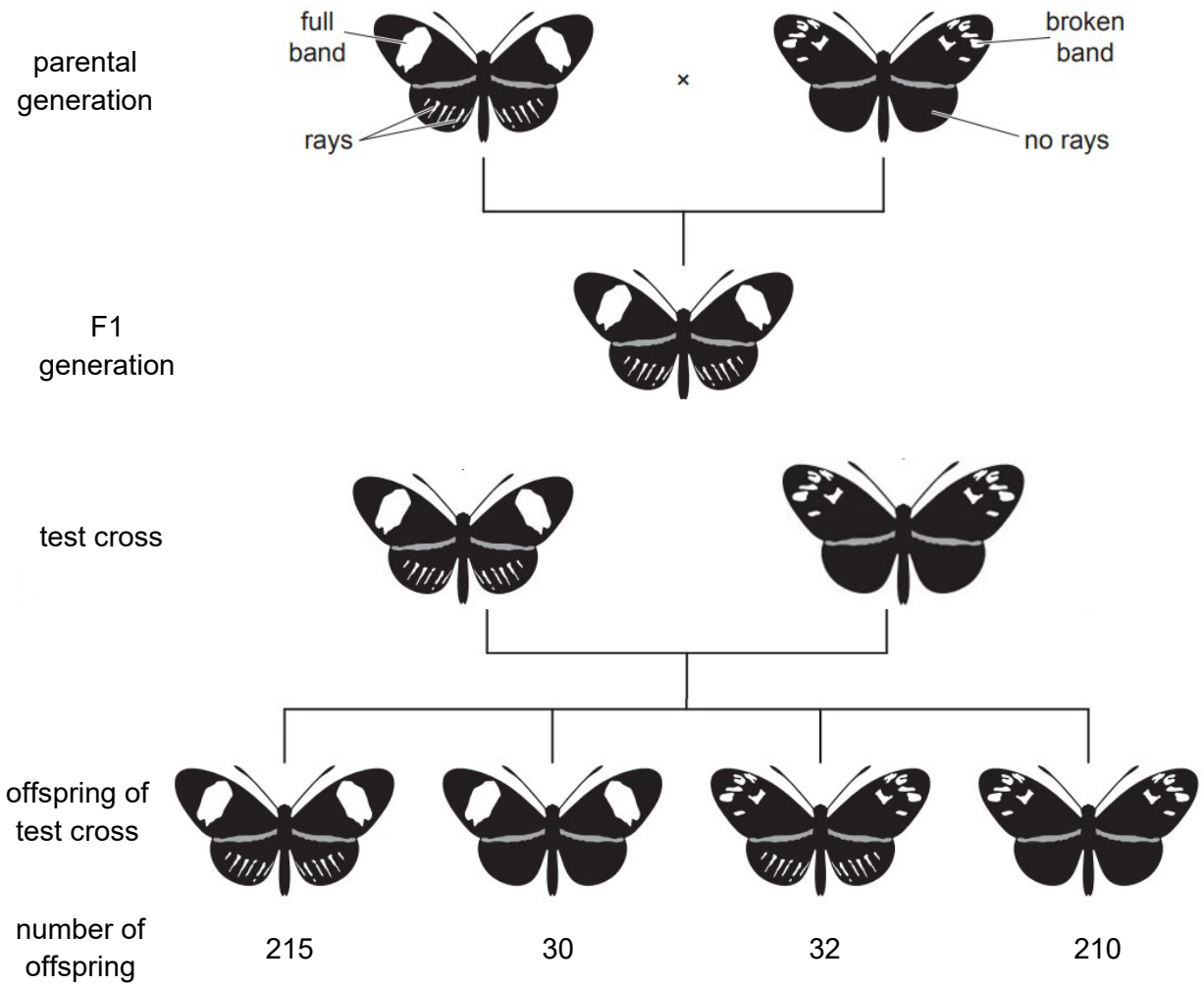

Fig. 6.1

(c) Draw a genetic diagram to show the results of the test cross shown in Fig. 6.1 on page 22.

[5]

[Total: 13]

QUESTION 7

Fig 7.1 shows the Krebs cycle and the reactions preceding it.

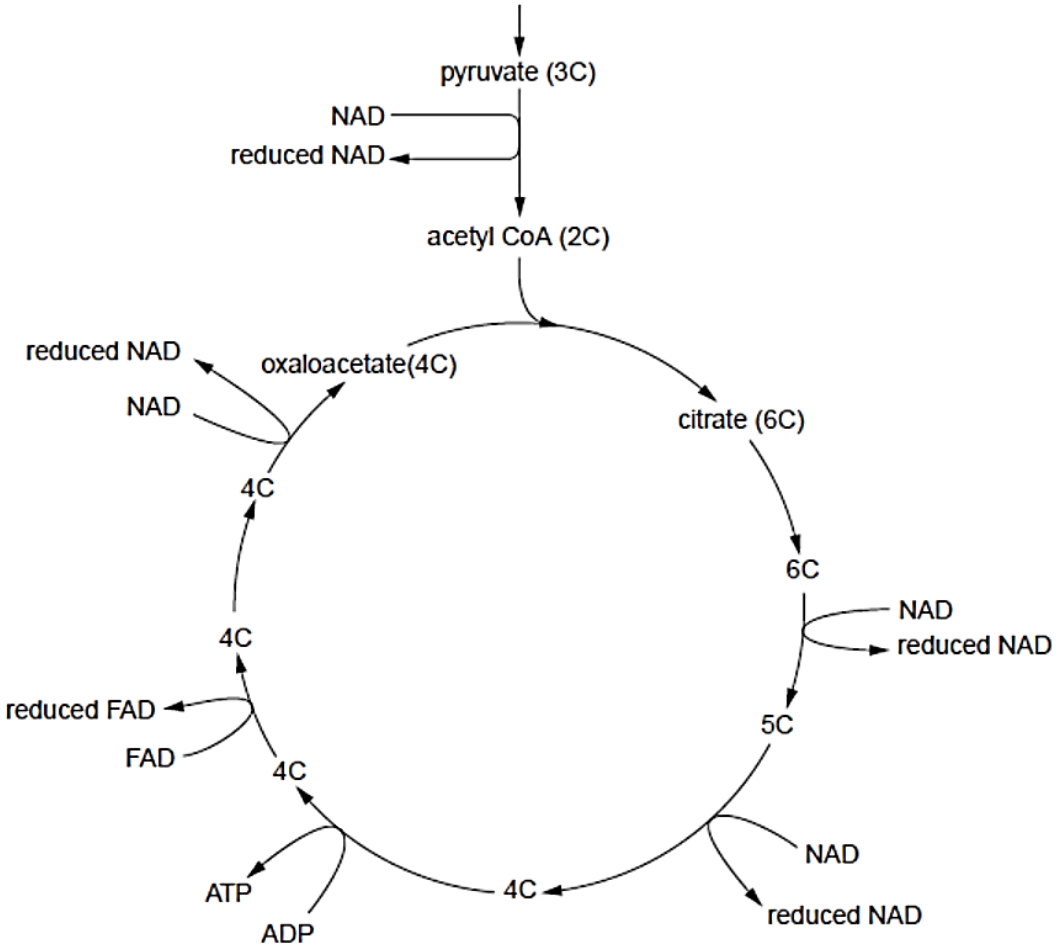

Fig. 7.1

(a) State precisely the name and location of the process that forms pyruvate.

name .....

location ..... [2]

(b) Label on Fig 7.1 the **three** stages where decarboxylation reactions occur with the letter **X**. [1]

(c) Outline how ATP is synthesised in the Krebs cycle.

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(d) Coenzymes are important in all four stages of aerobic respiration.

Describe **and** explain the role of the coenzymes NAD and FAD in aerobic respiration.

[4]

(e) Chemiosmosis is a process that occurs in mitochondria during aerobic respiration and in chloroplasts during photosynthesis.

Describe the differences between the process of chemiosmosis in mitochondria and the process of chemiosmosis in chloroplasts.

[3]

[Total: 12]

QUESTION 8

Mimulus is a plant genus containing a diverse range of species that have colourful flowers to attract pollinators, such as bees and hummingbirds. Pollinators transfer pollen between flowers for plant sexual reproduction.

Table 8.1 compares some features of two closely-related species of *Mimulus* that both grow in the same region of North America.

The features in which they differ are:

- the altitude at which the two species grow,
- their flower characteristics, including petal colour and the distance from the opening of the flower to the nectar on which the pollinators feed,
- the percentages of pollinator visits that they receive from bees or from hummingbirds.

Table 8.1

species of *Mimulus*	altitude / m	petal colour	distance to nectar / mm	percentage of visits from pollinator type	
				bee	hummingbird
M. lewisii	1600 – 3000	pink	14	100	0
M. cardinalis	0 - 2000	red	27	3	97

(a) With reference to the data in Table 8.1, explain the isolating mechanisms that prevent gene flow between *M. lewisii* and *M. cardinalis* populations.

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(b) Breeding experiments in the laboratory show that *M. lewisii* and *M. cardinalis* can breed together and produce offspring. The F1 hybrid offspring are fertile.

(i) Suggest, with reasons, what prediction can be made about the chromosome numbers of *M. lewisii* and *M. cardinalis*.

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(ii) The F1 hybrids produce 50% fewer seeds than either of the two parent species.

Explain how the reduced production of seeds by the inter-species (F1) hybrids can act as a post-zygotic isolating mechanism.

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[Total: 10]

QUESTION 9

The main cause of tuberculosis (TB) in humans is the bacterium *Mycobacterium tuberculosis*.

In a person with active TB, the pathogen can be present in airborne droplets that are exhaled. Generally, a healthy person who inhales these droplets has effective defense mechanisms in the gas exchange system to prevent infection.

(a) One example of a defense mechanism against pathogens in the gas exchange system involves the action of macrophages.

Describe **two other** defense mechanisms that **prevent** *Mycobacterium tuberculosis* in inhaled air from entering cells of the gas exchange system.

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Rifampicin is one antibiotic that can be used to kill mycobacterial cells. Rifampicin binds to a section of RNA polymerase that has attached to the DNA template strand.

(b)(i) Explain how binding to RNA polymerase allows rifampicin to kill mycobacterial cells.

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(ii) Suggest why rifampicin does **not** affect human cells.

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[Total: 5]

QUESTION 10

Mount Gongga, the highest mountain in the Hengduan Mountains, is located in Sichuan province, China. It has an elevation of 7556 m above sea level.

On Mount Gongga, regions with higher elevation experience lower temperatures and increased precipitation.

Scientists conducted a long-term study to investigate the effect of changes to climate on elevation shifts of the plants on Mount Gongga.

- To determine the mean elevation of each plant species in 1950, scientists obtained historical data on plant species occurrences from the National Specimen Information Infrastructure and the Chinese Virtual Herbarium.
- In 2018, they conducted a comprehensive field survey to determine the mean elevation of these same species of plants.
- There were 83 species of plants in total with data for both 1950 and 2018. All other plant species with incomplete data were excluded from the study.
- The results of the study are shown in Figure 10.1. Each point on the graph represents a single plant species.

It is estimated that the rapid climate warming in this area started during 1985–1990.

Fig. 10.1

(a) Using the data in Fig. 10.1, explain how climate change affects plant distribution.

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(b) Suggest why it would be difficult for the scientists to conclude that the changes in mean elevation for the plant species were due to climate change.

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[Total: 5]

--- END OF PAPER---