TEMASEK JUNIOR COLLEGE

2023 JC2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE NAME									
CENTRE NUMBER	S					INDEX NUMBER				

BIOLOGY 9744/02

Paper 2 Structured Questions **(Part I)** **25 AUGUST 2023**

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your Center number, index number and 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.
DO **NOT** WRITE IN ANY BARCODES.
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 any 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.

For Examiner's Use	
1	/ 12
2	/ 11
3	/ 11
4	/ 10
5	/ 8

This document consists of **16** printed pages.

Answer **all** questions.

1 Fig. 1.1 shows an electron micrograph of a plant cell.

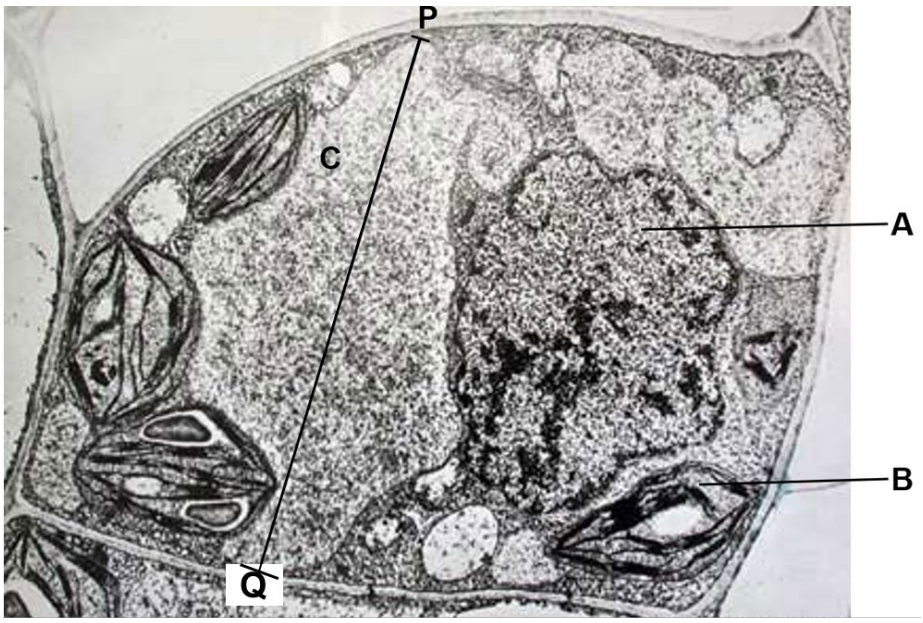

Fig. 1.1

(a) Identify the organelles labelled **A**, **B**, and **C** in Fig. 1.1.

A: ……..

B: ……..

C: …….. [3]

(b) Use a line to label the cell wall, **D**. [1]

(c) The magnification of the photomicrograph is 560x.

Calculate the actual length of organelle **C** in μm, along the line **P**-**Q**. Show your working.

actual length of organelle **C:** …… μm [2]

(d) Compare the structural features of organelle **A** and organelle **B**.

.....

.....

.....

.....

..... [2]

(e) A factor that can limit the rate of photosynthesis is the rate of regeneration of RuBP.

Sedoheptulose-1,7-bisphosphatase (SBPase) is an enzyme in the Calvin cycle that controls the rate of regeneration of RuBP. SBPase is coded for by the gene *SBPase*, which is present in most plants.

In an experiment, 2 wheat plants were studied.

- one was genetically modified to make more SBPase by introducing the *SBPase* gene from another grass species.
- one was not modified (wild type).

Fig. 1.2 shows the mean mass of plant for the wild type plants and genetically modified plants.

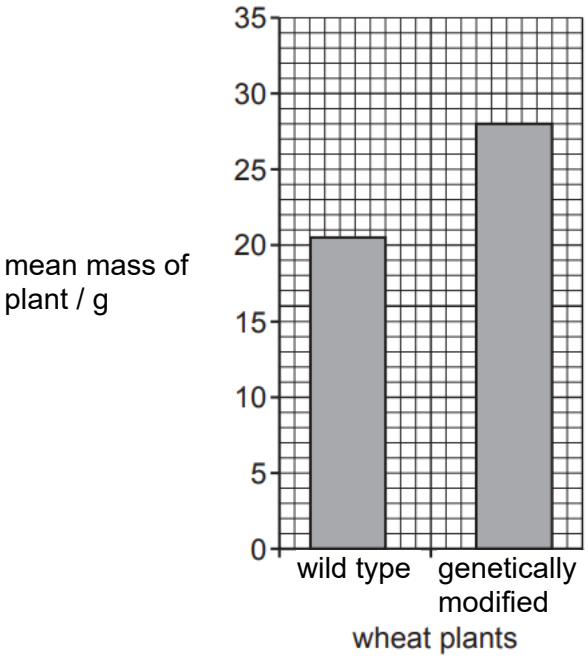

Fig. 1.2

Suggest and explain why genetically modified plants have a different mean mass than wild type plants.

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…… [4]

[Total: 12]

Question 2 starts on Page 6.

2 Fig. 2.1 shows an electron micrograph of a mitochondrion. The labelled arrows **X** and **Y** both represent a structural feature of this organelle.

Fig. 2.1

The table below shows the protein composition of various areas in the mitochondrion in Fig. 2.1.

Table 2.1

labels	protein composition / %
X	6
Y	21
region between **X** and **Y**	6
inside mitochondria	67
total	100

(a) Using the information in Table 2.1 above,

(i) state the name of the structures labelled **X** and **Y**;

X ……...

Y …….. [2]

(ii) account for the abundance of protein inside the mitochondrion**.**

……

……

……

…… [2]

Newborns have a large amount of brown fat tissue, which contains abundant mitochondria. Brown fat cells express the protein, thermogenin, which is embedded in the inner mitochondrial membrane. Protons flow through the channel in thermogenin instead of ATP synthase. As a result, the proton gradient is less steep, and energy is released in the form of heat. This keeps the babies warm.

The mitochondrial matrix has a pH of about 7.8. The intermembrane space of mitochondria in different cells exhibits different pH values, as shown in Table 2.2.

Table 2.2

cells from which mitochondria are isolated	pH in intermembrane space
resting muscle	7.0
muscle during exercise	6.8
brown fat	7.4

(b) **(i)** Explain the difference in pH values in the intermembrane space and the matrix of the mitochondria in the resting muscle cells.

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……

…… [3]

(ii) Explain how low oxygen concentration will result in the newborns suffering from a drop in body temperatures.

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……

…… [2]

(iii) The respiratory processes in the mitochondria require oxygen. Explain how oxygen is transported into the mitochondria.

……

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……

……

…… [2]

[Total: 11]

3 Glycogen phosphorylase is an enzyme involved in glycogenolysis.

Fig 3.1 shows a model of the enzyme glycogen phosphorylase. Glycogen phosphorylase catalyses the hydrolysis of glycosidic bonds to break up glycogen into glucose subunits. The active site of glycogen phosphorylase is located in a slight depression on one side of the molecule. The three amino acids that form the active site are Serine, Histidine and Aspartic Acid. These three amino acids are some distance apart on the polypeptide chain but close together in the active site.

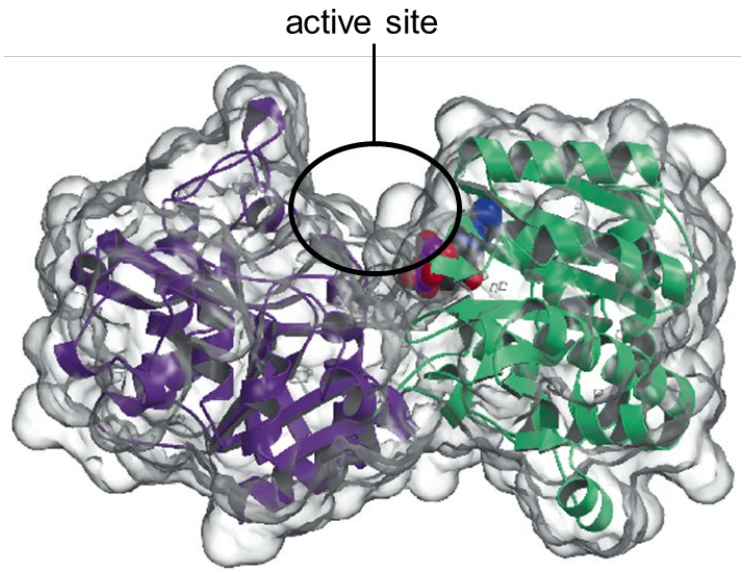

Fig. 3.1

(a) Explain how the substrate may be attached to the enzyme.

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.....

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.....

..... [2]

(b) Explain what determines the precise position of the three amino acids in the active site of the enzyme.

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..... [3]

(c) On Fig. 3.2, draw the predicted changes in enzyme activity as pH changes.

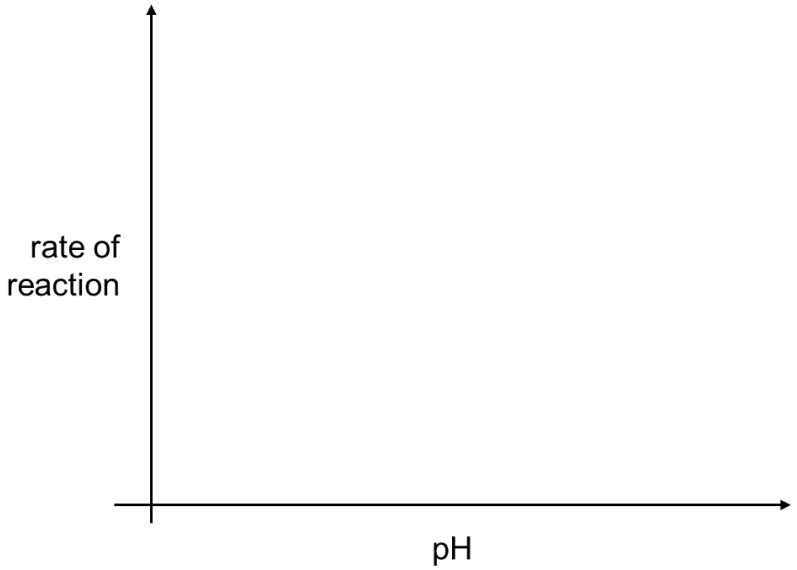

Fig. 3.2

[1]

Fig. 3.3 shows a cell signalling pathway that regulates the activity of glycogen phosphorylase.

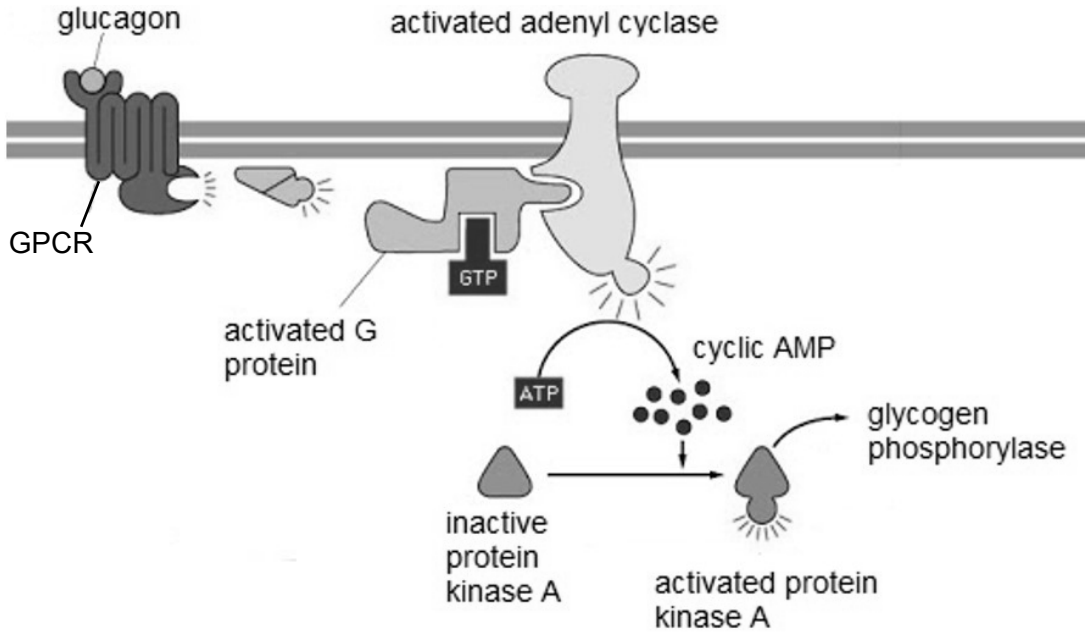

Fig. 3.3

(d) With reference to Fig. 3.3 and your own knowledge,

(i) describe how G protein is activated upon binding of glucagon to GPCR;

……

……

……

……

…… [2]

(ii) explain how the signal is amplified in the pathway.

……

…… [1]

(e) An inhibitor of protein kinase A is introduced into the cells of an individual. Predict and explain what would happen to the individual after prolonged hours of fasting.

……

……

……

……

…… [2]

[Total: 11]

4 Using fluorescent dye, centromere can be visualised as a single dot. The centromere of a chromosome with pair of chromatids will appear as one dot.

The total number of dots corresponds to the total number of centromeres within the cell.

Table 4.1 shows the number of dots observed per cell, at various stages of meiosis.

Table 4.1

stage of meiosis	**prophase I**	**prophase II**	**anaphase II**	**telophase II**
number of dots observed per cell	**16**			**16**

(a) With reference to Table 4.1,

(i) complete Table 4.1 by stating the number of dots (i.e. centromeres) observed in prophase II and anaphase II respectively; [2]

(ii) explain your answer in **(a)(i).**

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……

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……

……

……

…… [3]

In a separate experiment, scientists studied the movement of chromosomes during meiosis in the animal cell.

The changes in distance between a corresponding region of a pair of homologous chromosomes (**X**) were measured over the course of the first meiotic division.

The results are shown in Fig 4.1 below.

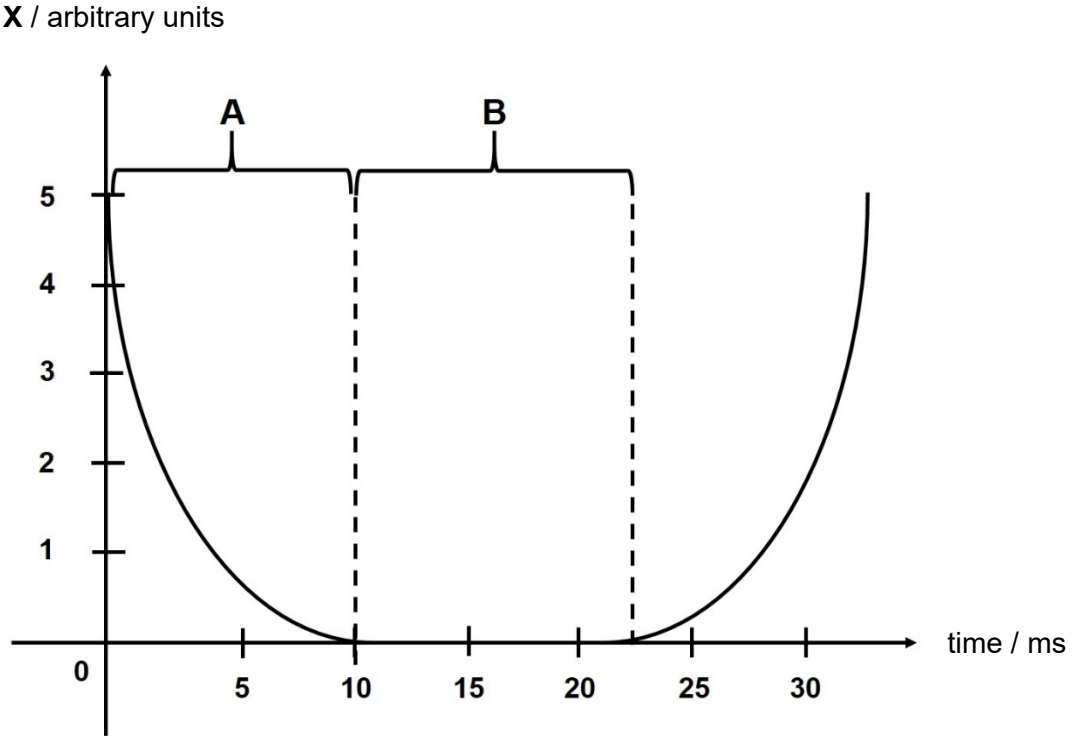

Fig. 4.1

(b) With reference to Fig. 4.1,

(i) identify the stage of meiosis at part **A**;

..... [1]

(ii) account for the changes at part **B**.

.....

.....

.....

.....

..... [2]

(c) State the role of the following processes in sexually reproducing organisms:

(i) meiosis

……

…… [1]

(ii) mitosis

……

…… [1]

[Total: 10]

5 Multicellular organisms are made up of different types of cells that form tissues and organs with specialised functions. All of these cells were originally stem cells.

(a) (i) Describe how totipotent stem cells differ from pluripotent stem cells.

……

……

……

……

…… [2]

(ii) Stem cells differentiate to become specific cell types through a process called specialisation. Specialisation occurs through differential gene expression.

All totipotent stem cells contain the same genes. However, not all of these genes are ultimately expressed in specialized cells.

Suggest one way how this can take place.

……

…… [1]

The differentiation of a eukaryotic stem cell into a specialised cell is controlled by many genes.

Fig. 5.1 summarises the interactions of some of these genes. The arrows represent the genes being switched on.

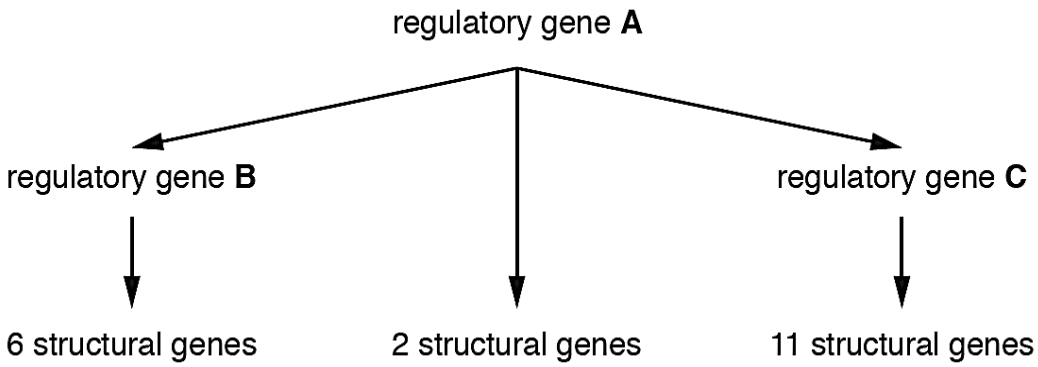

Fig. 5.1

(b) With reference to Fig. 5.1, explain how regulatory genes **A**, **B** and **C** are able to switch on other genes.

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..... [3]

In the differentiation of lymphoid stem cells, somatic hypermutation also occurs.

(c) Explain how somatic hypermutation differs from mRNA splicing.

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.....

..... [2]

[Total: 8]

[End of Paper 2 Part 1]

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10	/ 8

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6 Fig 6.1 represents the main sequence of events in oxidative phosphorylation.

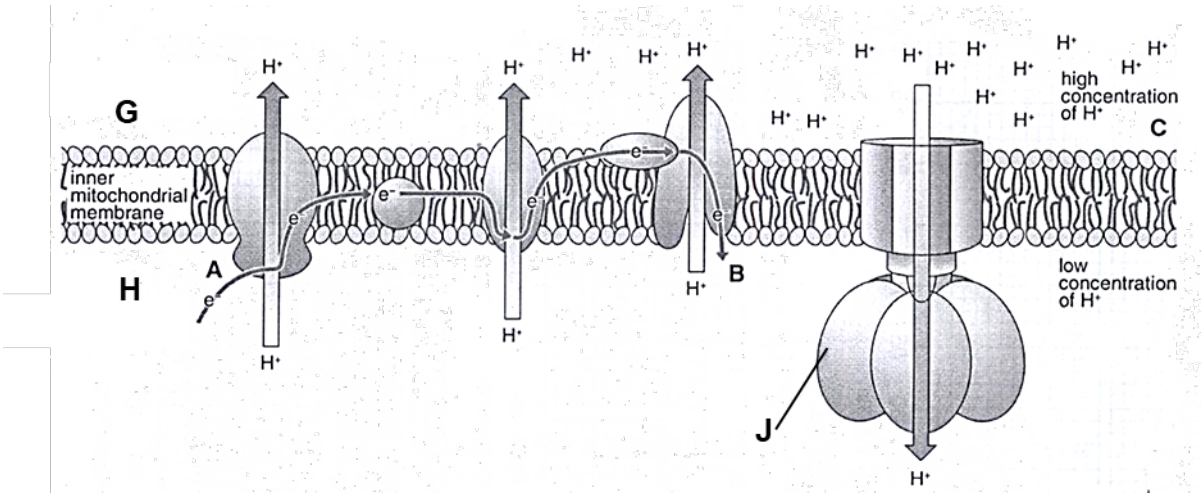

Fig. 6.1

(a) With reference to Fig. 6.1, identify the following:

Region **G**: .....

Region **H**: .....

Protein **J**: ..... [3]

(b) Briefly describe how ATP is synthesized during oxidative phosphorylation.

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..... [2]

In the mitochondria, replication of mtDNA is gives rise to many copies of mtDNA per mitochondrion. Fig. 6.2 shows a schematic diagram of the initiation of mtDNA replication.

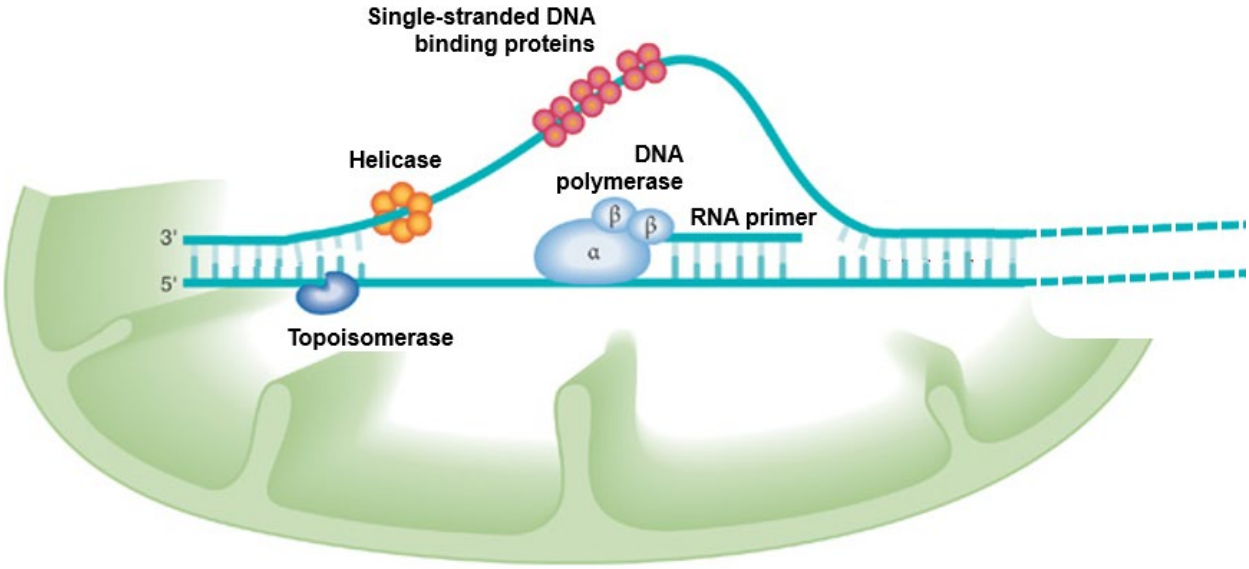

Fig. 6.2

(c) Compare the process in Fig. 6.2 and the polymerase chain reaction.

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..... [2]

Mutations in the mtDNA often occur in the form of multiple or large-scale deletions involving several genes. As the number of mutated mtDNA copies increases in the cell, an individual will start to show symptoms such as lactate accumulation. The presence of normal and mutated mtDNA in the cells can be analysed using the following procedure.

1. Cells are homogenised. The cell mixture is first centrifuged at low speed and the pellet (solid residue) is removed.
2. The supernatant (liquid component) is then centrifuged again at a higher speed so that the mitochondria can be found in the pellet.
3. mtDNA is extracted from the mitochondria.
4. Restriction enzymes are added which cut the mtDNA at specific nucleotide sequences.
5. Gel electrophoresis is carried out.

Scientists carried out the above procedure using normal and mutated mtDNA from two different individuals – a patient suffering from lactate accumulation and a healthy individual. The results are shown in Fig. 6.4.

The DNA ladder was loaded in lane M. DNA sample from the patient was loaded in lane 1, while DNA sample from the healthy individual was loaded in lane 2.

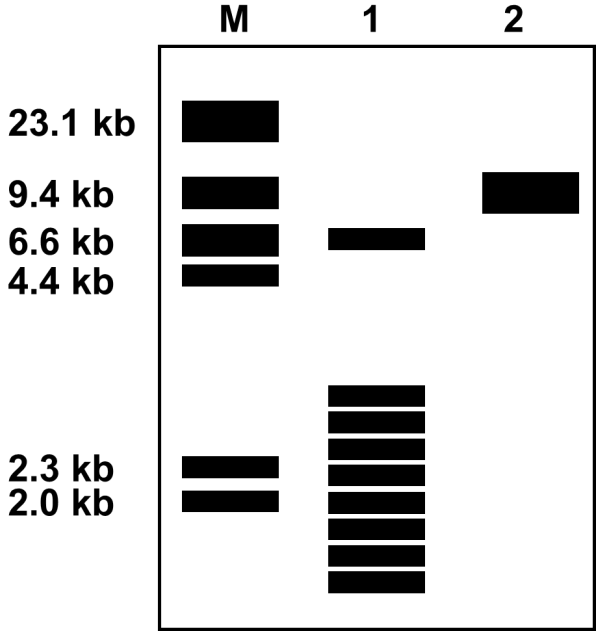

Fig. 6.4

(d) (i) Describe how the bands in a gel electrophoresis can be visualised.

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……...

……..

……..

…… [2]

(ii) Explain why it was necessary to remove the pellet in step 1.

……..

……...

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……..

…… [2]

(iii) Using the information provided, explain why different band patterns are observed for lanes 1 and 2.

……..

……...

……..

……...

……..

……..

…… [3]

[Total: 14]

7 A study was carried out to examine the effectiveness of bacteriophages in treating *E. coli* bacterial infections.

(a) Name an example for

(i) a virulent phage;

…… [1]

(ii) a temperate phage.

…… [1]

(b) Suggest why the use of bacteriophages is a better alternative to antibiotic therapy.

……

…… [1]

(c) Some Asian strains of the bacterium causing cholera, *Vibrio cholera*, have a gene named *SXT* on the F plasmid. The *SXT* gene confers resistance to commonly used antibiotics. *SXT* gene is also present in other bacterial species.

When some Asian strains of *Vibrio cholera* containing *SXT* gene is placed in a medium with other strains of *Vibrio cholera* which do not contain *SXT*, all the bacterial cells were found to contain *SXT* after some time.

(i) Name the process that enables *SXT* gene to be passed from Asian strains of *Vibrio cholera* containing *SXT* to strains of *Vibrio cholera* which do not contain *SXT*.

…… [1]

(ii) Suggest **two** advantages of the process described in **(c)(i)** as compared to other mechanisms in generating genetic variation in bacterial cells.

……..

……...

……..

……..

…… [2]

(d) Transfer of DNA from one species of bacterium to another is thought to be increased due to the so-called 'SOS response' of bacteria to DNA damage.

Measurements were made of the frequency of transfer of *SXT* gene from two species of donor bacteria grown in the presence or absence of two antibiotics.

- mitomycin, which is known to damage DNA;
- ciproflaxin, which is commonly prescribed for use against bacterial infections.

The results of the investigation are shown in Fig. 7.1.

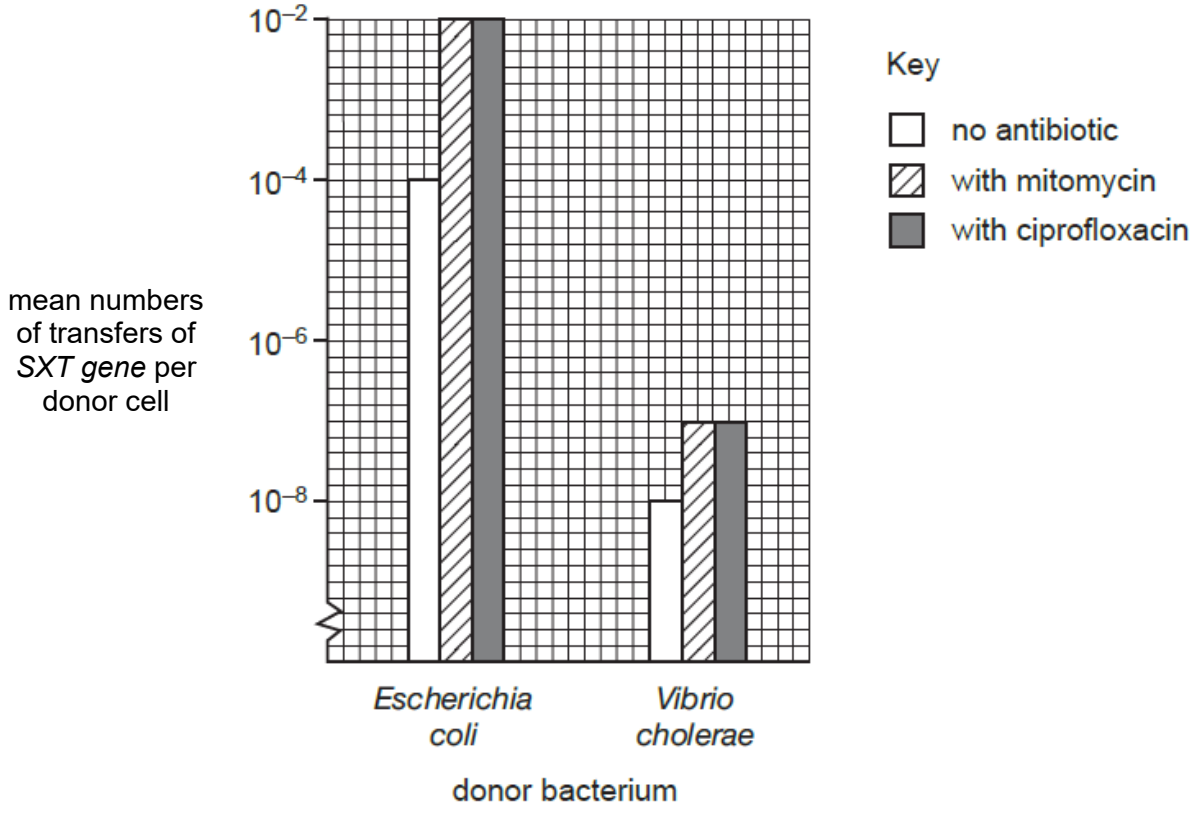

Fig. 7.1

(i) With reference to Fig. 7.1, compare the effect of the antibiotics on transfer of SXT from the two species of donor bacteria.

……..

……...

……..

……...

……..

……..

…… [3]

(ii) Suggest the likely effect on the frequency of the *SXT* gene when an infected patient did not complete the full course of ciprofloxacin.

……..

…… [1]

[Total: 10]

8 It was hypothesized that persons with higher weight have a higher chance of contracting breast cancer. To investigate the hypothesis, a mini study was done by recording the weight of the persons with or without breast cancer.

Table 8.1 shows the results of the study.

Table 8.1

weight of person with breast cancer / kg	weight of person without breast cancer / kg
80	60
73	55
86	65
109	53
87	60
70	55
65	45
80	59
66	56
77	70

(a) State the null and alternative hypothesis for this study.

null hypothesis

……

……

alternative hypothesis:

……

…… [2]

Table 8.2 shows the critical values for the *t*-distribution.

Table 8.2

degrees of freedom	probability, p, for one-tailed test				
	0.10	0.05	0.025	0.01	0.005
	probability, p, for two-tailed test				
	0.20	0.10	0.05	0.025	0.01
1	1.00	6.31	12.71	63.66	636.62
2	0.82	2.92	4.30	9.92	31.60
3	0.76	2.35	3.18	5.84	12.92
4	0.74	2.13	2.78	4.60	8.61
5	0.73	2.02	2.57	4.03	6.87
6	0.72	1.94	2.45	3.71	5.96
7	0.71	1.89	2.36	3.50	5.41
8	0.70	1.86	2.31	3.36	5.04
9	0.70	1.83	2.26	3.25	4.78
10	0.70	1.81	2.23	3.17	4.53
11	0.70	1.80	2.20	3.11	4.44
12	0.70	1.78	2.18	3.05	4.32
13	0.69	1.77	2.16	3.01	4.22
14	0.69	1.76	2.14	2.98	4.14
15	0.69	1.75	2.13	2.95	4.07
16	0.69	1.75	2.12	2.92	4.01
17	0.69	1.74	2.11	2.90	3.97
18	0.69	1.73	2.10	2.88	3.92
19	0.69	1.73	2.09	2.86	3.88
20	0.69	1.72	2.09	2.85	3.85

The formulae to calculate standard deviation and the *t* value are:

standard deviation $s = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}}$

t-test $t = \frac{|\bar{x}_1 - \bar{x}_2|}{\sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}}$

Key to symbols

s* = standard deviation | $\sum$ = 'sum of' | $\bar{x}$ = mean

n = sample size (number of observations) | x = observation

v = degrees of freedom | O = observed 'value'

(b) Carry out the *t*-test in the space provided.

[3]

(c) State the conclusion for the *t*-test.

.....

.....

.....

.....

..... [2]

(d) Comment on the validity of this study.

.....

..... [1]

[Total: 8]

9 The *Oncorhynchus* genus of fish contains five species of Pacific Salmon residing in the Pacific Ocean.

Fig. 9.1 shows two different ways of classifying the same five species of Pacific Salmon where

- classification **X** is based on morphological characteristics,
- classification **Y** is based on genetic characteristics.

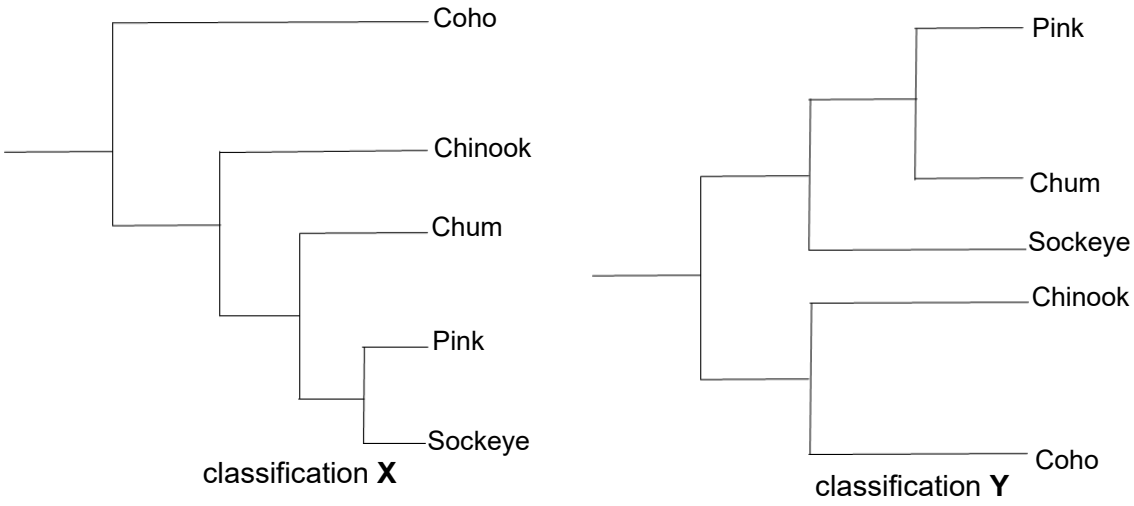

Fig. 9.1

(a) (i) Describe **two** differences in the evolutionary relationships amongst these five species of Pacific Salmon based on the two classifications shown in Fig. 9.1.

……..

……...

……..

……..

…… [2]

(ii) State **one** reason why classification **Y** is a better representation of evolutionary relationships than classification **X**.

……..

…… [1]

The coho salmon spend equal time in freshwater streams, when they are young, and in the salt water, when they are adults.

Adults migrate back to the freshwater stream to spawn (release sperm or eggs).

Some males, known as jacks, begin the migration to the freshwater stream much earlier in their adult lives than the normal breeding adult males, known as hooknoses.

Fig. 9.2 depicts hooknoses and jacks. Jacks are much smaller than hooknoses and do not develop the hooked snout and large teeth.

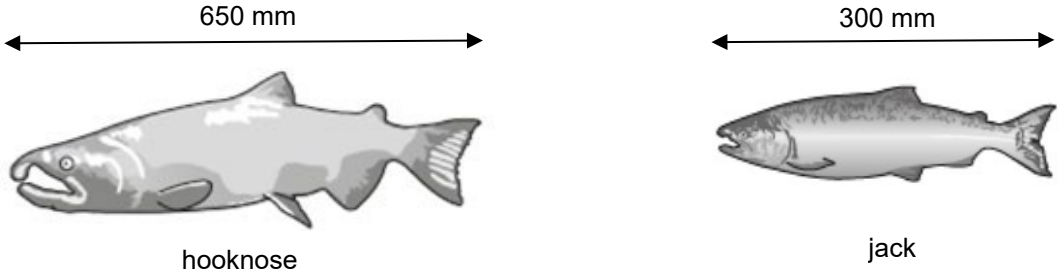

Fig. 9.2

Jacks and hooknoses employ different breeding strategies in order to spawn successfully.

- Jacks sneak around the smaller boulders on the stream bed and attempt to stealthily mate with a female.
- Hooknoses swim within the open water and fight aggressively amongst one another for the opportunity to mate with a female.

(b) Suggest **two** reasons why jacks are able to spawn as successfully as hooknoses.

……

……

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…… [2]

Fig. 9.3 shows the variation in the body length of reproductively mature males in an original population of coho salmon, **before** evolution of the jack reproductive phenotype.

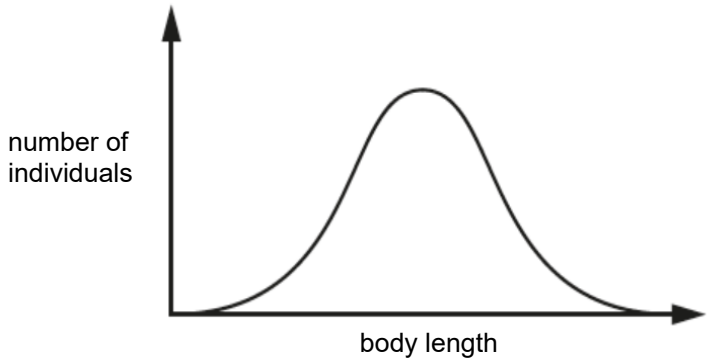

Fig. 9.3

Selection has since acted over time on this original population to change the distribution of body length in reproductively mature male salmon.

(c) (i) Sketch a curve on Fig. 9.3 to show the new distribution of body length in the present-day population of reproductively mature male salmon. [1]

(ii) Explain the type of selection that has occurred.

……..

……...

……..

……..

…… [2]

[Total: 8]

10 A person who is confirmed as SARS-CoV-2-positive has also tested positive for the presence of antibodies to the virus.

(a) Outline the events that lead to the production of antibodies specific to SARS-CoV-2.

……

……

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……

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…… [5]

As of June 2023, there are currently 8 common variants of the SARS-CoV-2 virus. These variants were observed to have slightly different glycoprotein spikes.

(b) Describe how these slightly different variants of the SARS-CoV-2 virus come about.

……

……

……

……

…… [2]

Various anti-SARS-CoV-2 antibodies, which can bind to different parts of the same virus, are found in the infected person.

(c) Suggest the significance of having various anti-SARS-CoV-2 antibodies produced in the infected person.

……

…… [1]

[Total: 8]

[End of Paper 2 Part 2]

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