RIVER VALLEY HIGH SCHOOL

JC 2 PRELIMINARY EXAMINATION

CANDIDATE NAME										
CENTRE NUMBER	S					CLASS	22J	INDEX NUMBER				

BIOLOGY **9744/02**

Paper 2 Structured Questions **13 September 2023**

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre 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 ON 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 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.

For Examiner's Use	
1	
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Total	

Answer **all** questions.

1 Collagen is the dominant protein in extracellular tissues such as bone, skin, and other connective tissues.

(a) **(i)** Name the most common tripeptide repeat in tropocollagen. [1]

(ii) Explain the significance of the most common amino acid in the tripeptide repeat. [2]

(iii) Compare between the hydrogen bonds within tropocollagen and within an alpha helix of a protein. [3]

Fig 1.1 shows (a) diagrams of young and aged epidermal skin tissue and (b) the scanning electron micrographs of collagen fibrils under the epidermal layer of young and aged skin.

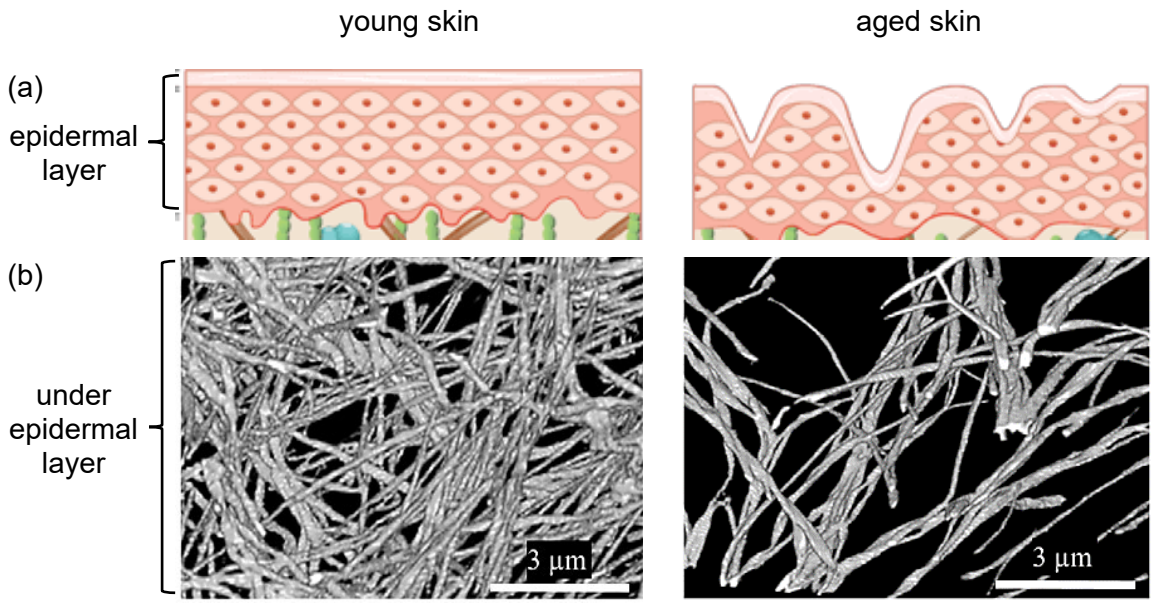


Fig. 1.1

(b) (i) Describe how collagen fibres are formed from tropocollagen. [2]

(ii) With reference to Fig. 1.1, explain how changes in collagen affect the skin as a person ages. [2]

[Total: 10]

2 **(a)** Describe the roles of membranes within a cell. [2]

ATP synthesis is catalysed by the enzyme ATP synthase. The process involves the coupling of H^+ ion movement through ATP synthase with the catalysis of ATP formation.

Fig. 2.1 shows a diagram of ATP synthase in a mitochondrion.

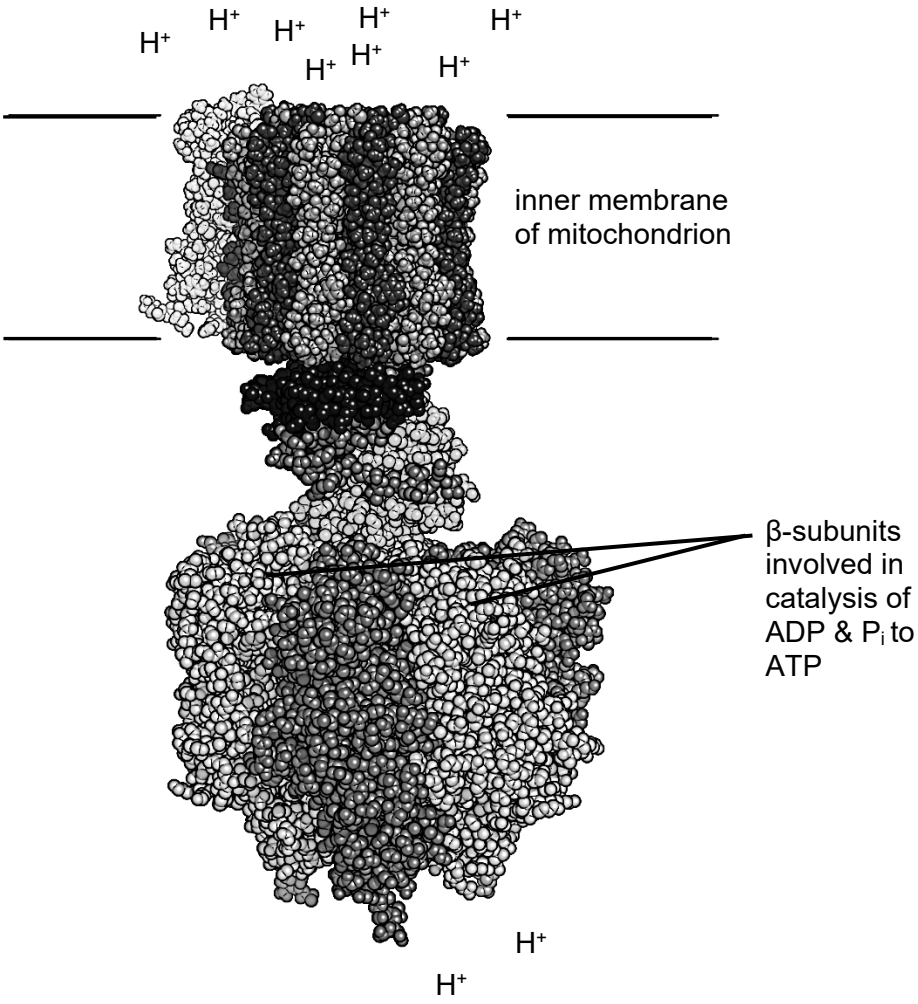


Fig. 2.1

(b) Describe how H^+ ions are moved across the membrane in Fig. 2.1. [2]

Question 2 continues on page 6

ATP synthase is found in all living organisms because ATP synthesis is an essential process for survival. ATP synthase is therefore one of the most conserved proteins in all living organisms including prokaryotes and animals. More than 60% of the amino-acid residues of the β-subunit are the same in all living organisms across Kingdoms.

Fig. 2.2 shows the effect of increasing ADP concentration in different mixtures **A**, **B** and **C**. Their contents are shown below:

- Mixture **A** contains substrates and ATP synthase from prokaryote or animal.
- Mixture **B** contains substrates, an inhibitor and ATP synthase from prokaryote.
- Mixture **C** contains substrates, an inhibitor and ATP synthase from animal.

The inhibitor used for **B** and **C** are the same.

Data used to plot the graphs were normalised to allow for comparison.

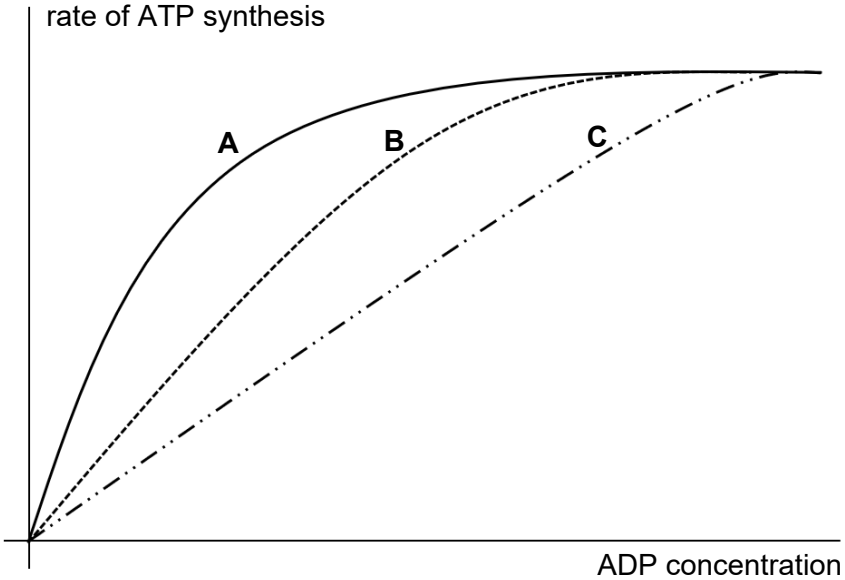


Fig. 2.2

(c) Using information provided in this question, explain how the data in Fig. 2.2 shows the change in binding affinity of ATP synthase to ADP across the Kingdoms **and** why certain amino-acid residues in the β-subunit must be conserved. [4]

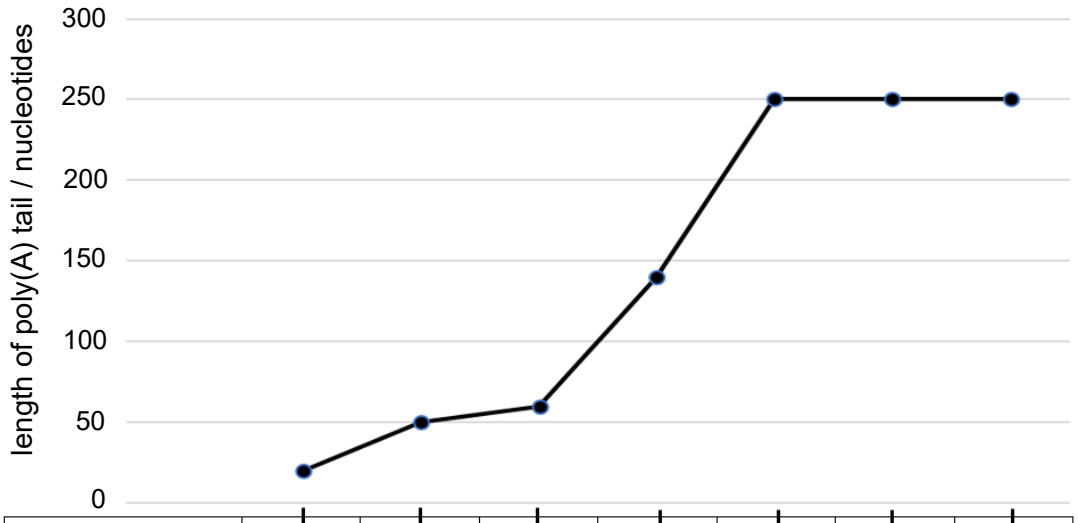
(d) ATP synthase facilitates both the transportation of H^+ ions and the production of ATP.

Describe two features that are similar between the processes. [2]

[Total: 10]

3 In a developing oocyte, mRNAs are synthesized and then exported to the cytoplasm. However, these mRNAs are not immediately translated but are stored in the cytoplasm for future use in a zygote.

Fig. 3.1 shows the changes to the 3' end of a mature mRNA in a zygote starting from 20 minutes after fertilisation **and** the corresponding amount of protein synthesized.



time / min	20	40	60	80	100	120	140
concentration of protein	×	✓	✓	✓✓	✓✓✓	✓✓✓	✓✓✓

key

× no production

✓

✓✓

✓✓✓ high concentration

Fig. 3.1

(a) With reference to Fig. 3.1, explain the relationship between the length of poly(A) tail of the mRNA and the concentration of protein produced. [3]

During formation of functional protein, the polypeptide chain must be folded properly in the endoplasmic reticulum (ER). Disruption of protein folding causes misfolded proteins to accumulate, triggering the unfolded protein response (UPR). UPR activates a kinase known as PERK and leads to halting of translation.

Fig. 3.2 shows the UPR pathway.

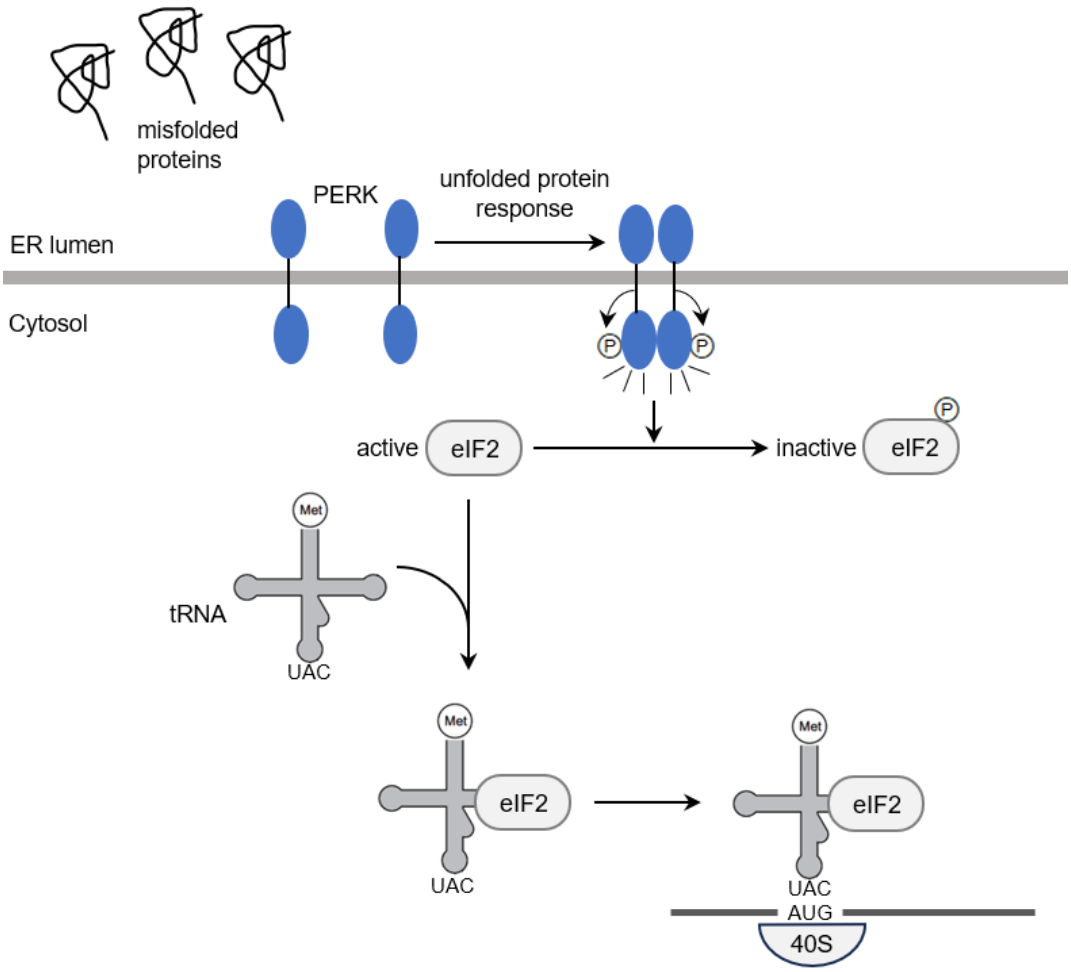


Fig. 3.2

(b) Using Fig. 3.2, explain how activation of the UPR stops translation. [3]

(c) Describe how misfolded proteins can be degraded in the cytoplasm of the cell. [1]

(d) Outline the significance of amino-acyl tRNA synthetase in translation. [3]

[Total: 10]

4 Fig. 4.1 shows actively dividing cells at various stages of the mitotic cell cycle.

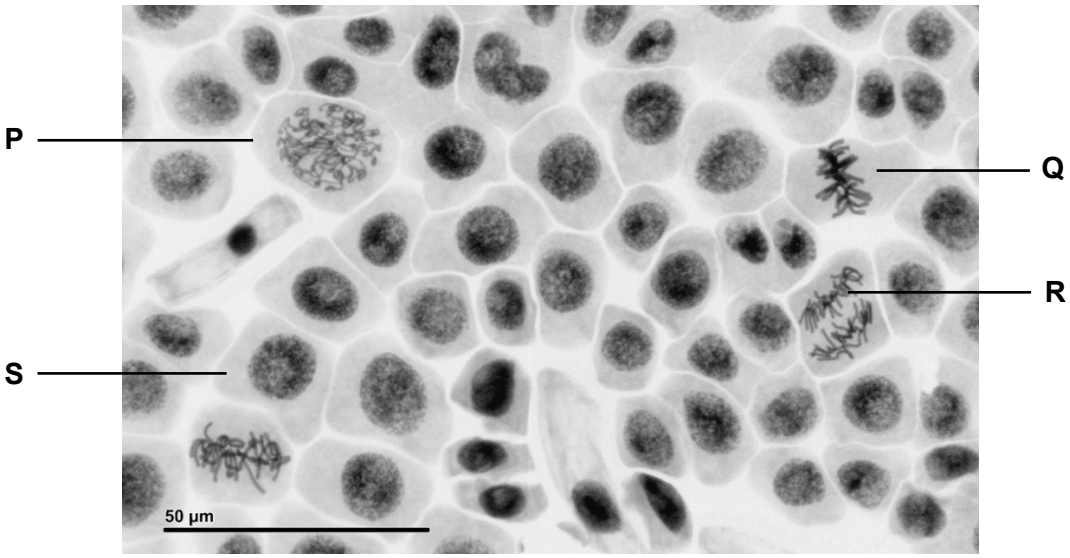


Fig. 4.1

(a) (i) Complete Table 4.1 below by:

- identifying the stages shown in Fig 4.1, and
- describe the behaviour of chromosomes at the identified stages. [3]

Table 4.1

stage	name of stage	behaviour of chromosomes
P		
Q		

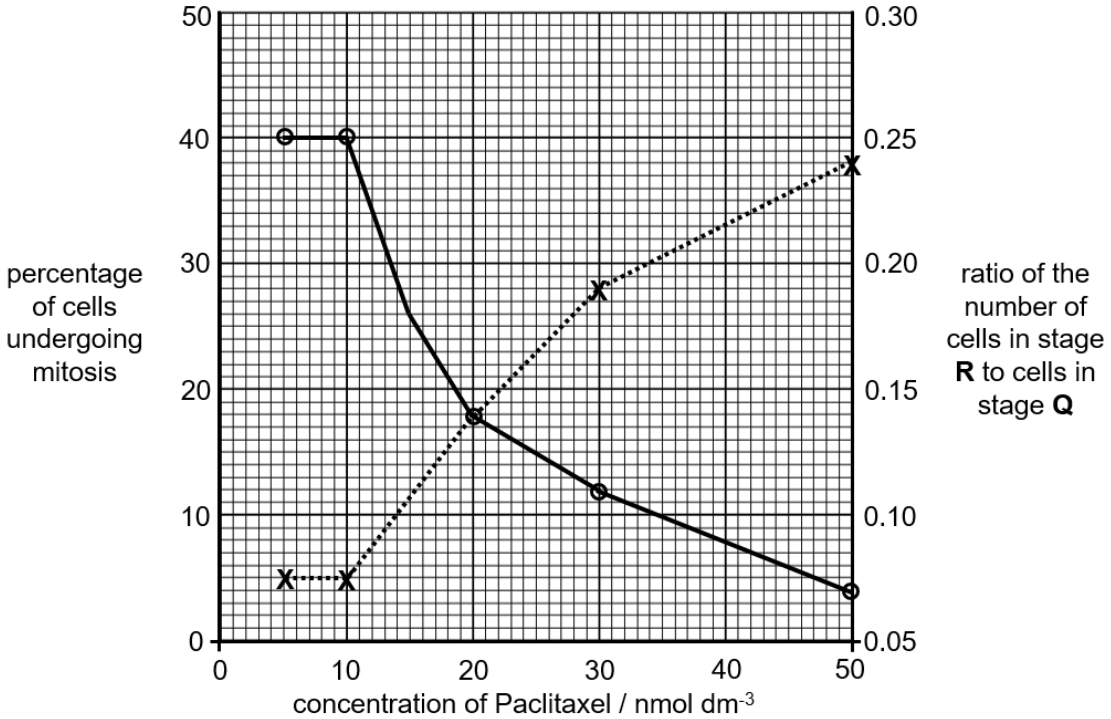
(ii) Describe how the lagging strand is synthesised during DNA replication in stage **S**. [3]

Paclitaxel is a drug used in the treatment of uncontrolled mitosis in some forms of cancer.

Researchers investigated the effect of Paclitaxel on the mitotic cell cycle.

- Cells were grown for two days and divided into groups.
- Each group was treated with a different concentration of Paclitaxel.

The results of the investigation **after** one cell cycle (28 hours) are shown in Fig 4.2.



key

percentage of cells undergoing mitosis

ratio of the number of cells in stage **R** to cells in stage **Q**

Fig. 4.2

(b) **(i)** With reference to Fig. 4.2, account for the change in percentage of cells undergoing mitosis **and** the change in ratio of the number of cells beyond 10 nmol dm^{-3} of Paclitaxel. [3]

(ii) Paclitaxel is found to act on proteins involved in mitosis.

Suggest a mechanism in which paclitaxel can treat uncontrolled mitosis. [1]

[Total: 10]

5 In treatment of genetic diseases, scientists have developed vectors to introduce 'normal' genes into target cells that are malfunctioning. Of the different vectors, viral vectors offer the best possibility of success.

Fig. 5.1 shows a modified lentiviral vector which contains a single-stranded RNA genome. The vector can bind to cells lining the airways of the lungs.

The lentivirus is a form of retrovirus modified to contain glycoproteins which are also found on the influenza envelope.

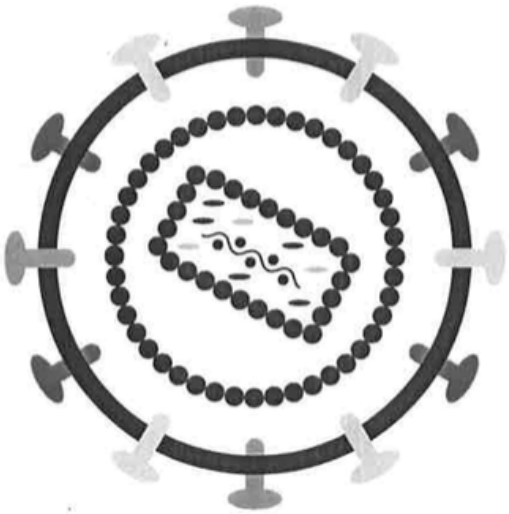


Fig. 5.1

(a) With reference to Fig. 5.1, compare **two** features of lentivirus and influenza and explain how these features promote rapid mutation in influenza. [4]

(b) Explain how 'normal' genes are delivered by lentivirus to target cells to result in stable gene expression. [4]

(c) Explain how influenza causes disease. [2]

[Total: 10]

6 A genetic marker is a DNA sequence with a known locus on a chromosome. It can be used in diagnosis of genetic diseases as the marker is inherited together with alleles located in close proximity.

An example of a genetic marker is the microsatellite and it is shown in Fig. 6.1. The two alleles of this marker can be used to identify a recessive disease due to gene **G/g**.

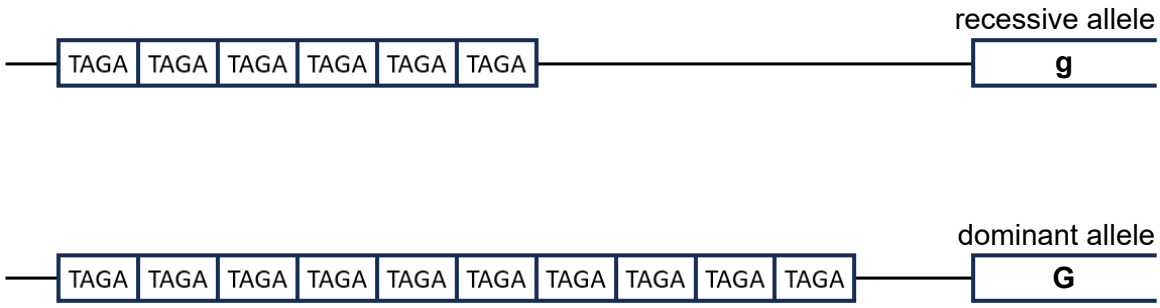


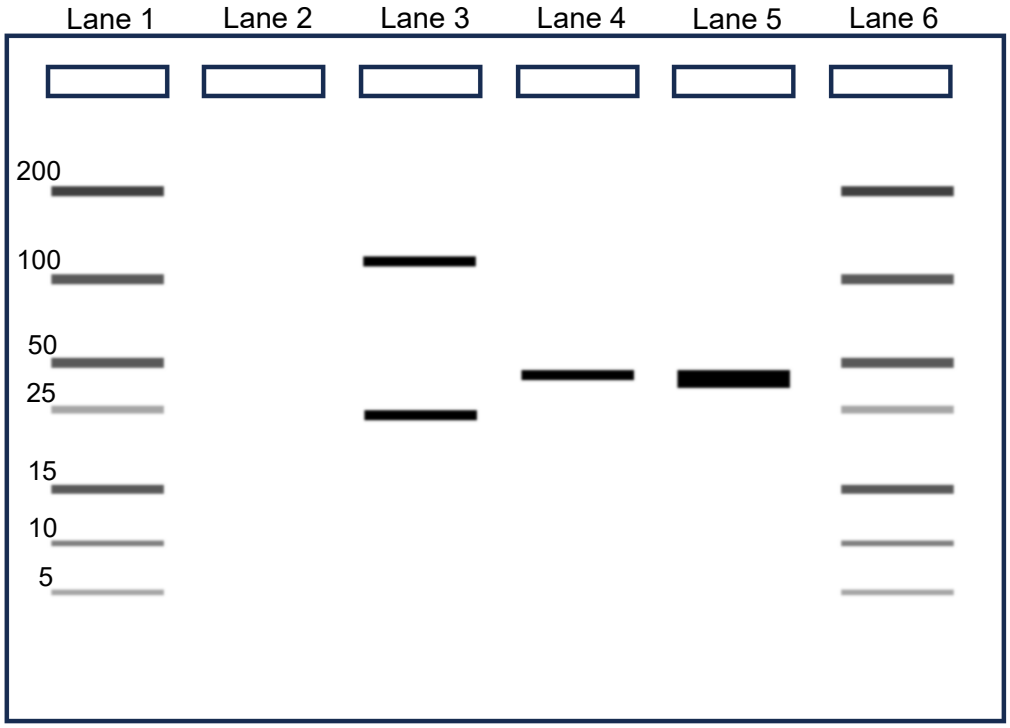
Fig. 6.1

(a) State the features of a microsatellite in this context. [2]

To diagnose the disease, DNA is first extracted from the individual.

(b) Outline how a carrier of the disease can be identified from extracted DNA **and** draw the expected results in Lane 2 on Fig. 6.2. [4]

Fig. 6.2 shows the diagnostic results of the disease on several individuals, using the microsatellite in Fig. 6.1. All individuals are carriers of the disease.



key

Lanes 1, 6: DNA ladder
Lane 2, 3, 4, 5: individuals who are carriers of the disease

Fig. 6.2

(c) Suggest what may have happened to result in each band pattern observed in lanes 3, 4 and 5. [3]

Microsatellites can also be used in DNA fingerprinting of individuals in a population.

Table 6.1 shows different types of microsatellites, their repeat motifs and the number of different alleles each has.

Table 6.1

microsatellite	repeat motif	number of alleles
D19S433	AAGG	9
CSF1PO	TAGA	10
TH01	TCAT	12
D18S51	AGAA	21
TPOX	GAAT	8

Adapted from Butler, Biotechniques, 43(4), 2018

(d) In 2023, Singapore has an estimated population of 6,014,723.

Using the data in Table 6.1, explain which microsatellites should be used so that the **fewest** microsatellites are needed to DNA fingerprint the whole of Singapore's population. [1]

[Total: 10]

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

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

- a dominant allele, **B**, coding for a full band
- a recessive allele, **b**, coding for a broken band.

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

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

Scientists conducted a few crosses on butterflies of different phenotypes as shown in Fig 7.1.

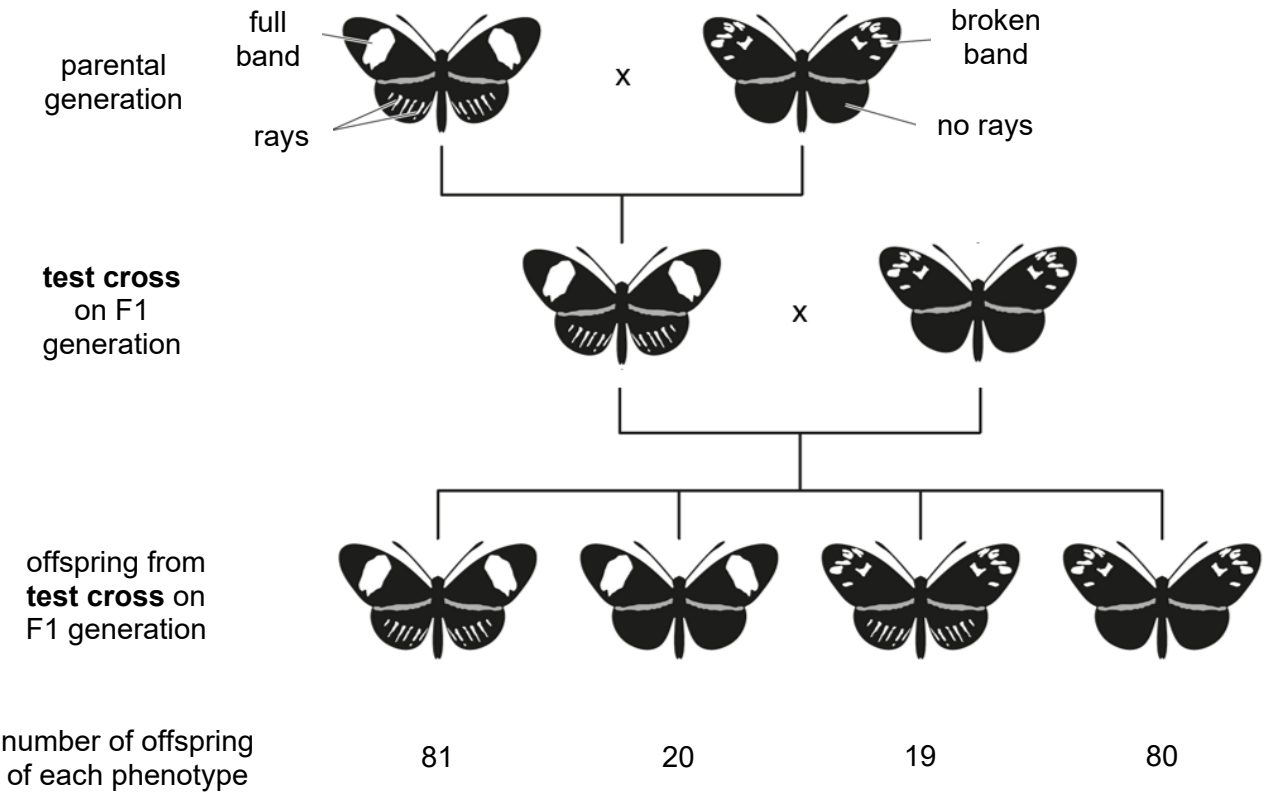


Fig. 7.1

(a) Explain what is meant by the terms

(i) homozygous, [1]

(ii) allele. [1]

(b) State the expected phenotypic ratio from the test cross on F1 generation. [1]

(c) Draw a genetic diagram to explain the results of the test cross. [4]

(d) Explain why there are more parental phenotypes than recombinant phenotypes among the offspring of the test cross. [3]

[Total: 10]

8 (a) Explain the role of NAD in aerobic respiration. [3]

To investigate respiration in mammalian cells, the following steps were carried out:

- mitochondria were extracted and incubated in a buffer solution
- pyruvate and inorganic phosphate (Pi) were added at 0 minute
- ADP was added one minute later
- the oxygen concentration of the buffer solution containing mitochondria was monitored throughout the investigation
- all other variables were in excess throughout the investigation

The results of the investigation are shown in Fig. 8.2.

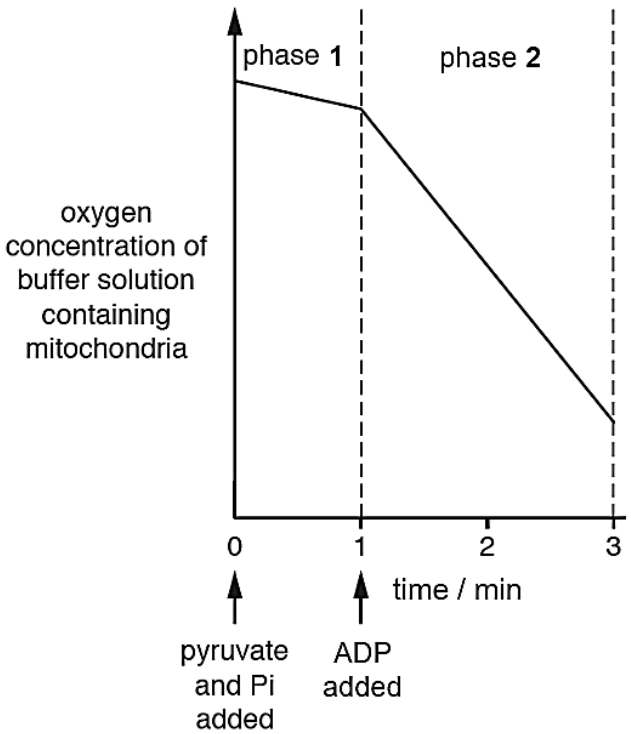


Fig. 8.2

(b) **(i)** Describe the immediate fate of pyruvate after it is added at 0 minute. [2]

(ii) Explain why the graph shows a steeper decrease during phase **2** than during phase **1**. [3]

(c) Other than carbohydrates, fats can also be used during cellular respiration.

In an investigation, the total oxygen consumption by cellular respiration of the same mass of fats and carbohydrates were measured.

Put a tick (✓) in one box to indicate the total oxygen consumption for fats as compared to carbohydrates.

Explain your answer. [2]

lower ☐ same ☐ higher ☐

[Total: 10]

9 **(a)** Explain why genetic variation is important to the survival of a species. [2]

(b) Suggest why a small, isolated population is less able to preserve its genetic variation. [1]

Mimulus is a plant genus containing a diverse range of species that have colourful flowers to attract pollinators. The role of pollinators is to transfer pollen between flowers for plant sexual reproduction.

Table 9.1 compares features of two closely-related species of *Mimulus* that both grow in the same region of North America. These features include:

- the year the species was first discovered
- the altitude at which the two species grow
- the distance from the opening of the flower to the nectar on which the pollinators feed
- the percentages of pollinator visits that they receive and successful pollination

Table 9.1

species of *Mimulus*	year first discovered	altitude / m	distance to nectar / mm	percentage of visits (and successful pollination) from pollinator type	
				hummingbird	bee
M. lewisii	1876	1500 – 3200	15	0	100 (79)
M. cardinalis	1838	0 – 2100	29	95 (58)	5 (0)

Adapted from Nelson et al, PLOS Genetics, 17(2), 2021

(c) Using the data in Table 9.1, explain how the two species were formed. [4]

(d) Describe one limitation for each of the following species concepts: [3]

(i) biological species concept

(ii) ecological species concept

(iii) morphological species concept

[Total: 10]

10 Antibiotics, such as penicillin, affects bacterial cells in the gut of mosquitoes.

(a) Outline the effect of penicillin on bacterial cells. [3]

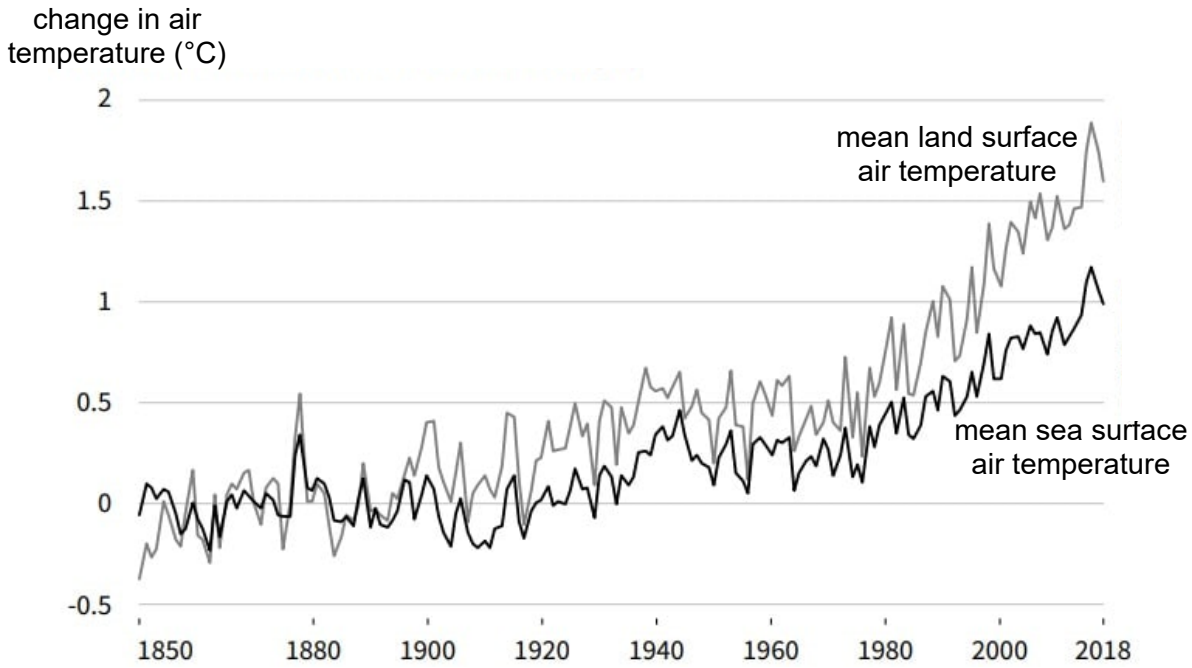
The female *Anopheles* mosquito is the vector of the *Plasmodium* pathogen that causes malaria. Research has shown that *Plasmodium* is not always transmitted to uninfected people, due to two main reasons:

- Individuals in the human population may be vaccinated against *Plasmodium*.
- Bacteria living in the gut of mosquitoes compete with *Plasmodium* so it does not survive to continue its life cycle.

(b) Using the information provided, explain why vaccination and antibiotics have different effects on the transmission of malaria. [2]

[Total: 5]

11 Climate change results in global warming which affects both land and water masses. Scientists measured the change in mean land surface air temperature and mean sea surface air temperature, shown in Fig. 11.1.



Adapted from IPCC Special Report on Climate Change and Land, 2019

Fig. 11.1

(a) Other than heat capacity, explain the difference between the change in the two mean surface air temperatures from 1980. [2]

(b) Climate change also results in more extreme weather conditions.

Describe the effects of such environmental stress on food chains and niche occupation. [3]

[Total: 5]