RIVER VALLEY HIGH SCHOOL
JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME											
CENTRE NUMBER	S					CLASS	21J	INDEX NUMBER			

H2 BIOLOGY **9744/01**

Paper 1 Multiple Choice **23 September 2022**

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, Centre number and index number on the Answer Sheet in the spaces provided unless this has been done for you.
DO **NOT** WRITE IN ANY BARCODES.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C**, and **D**.
Choose the **one** you consider correct and record your choice **in soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer. Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This Question Paper consists of **18** printed pages and **2** blank pages.

1 The electron micrograph shows part of several eukaryotic cells.

Which of the following statements are correct?

1 Both P and Q contain templates for transcription.

2 Q contains ribosomal RNA which is involved in peptide bond synthesis.

3 R has a fluid mosaic structure and regulates the movement of substances between the two cells.

4 S is the site of pyruvate synthesis.

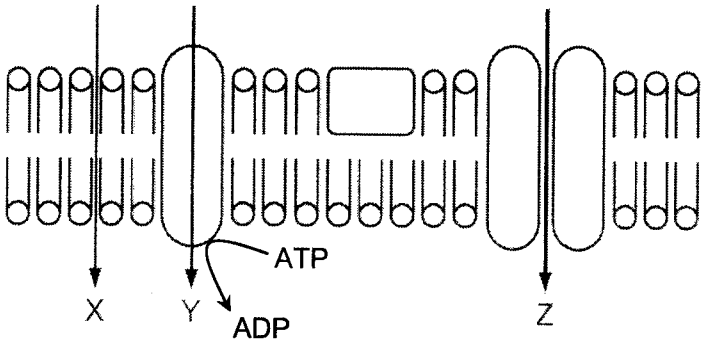
A 1, 2, 3 and 4

B 1, 2 and 4 only

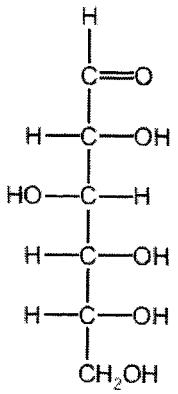
C 1 and 3 only

D 2 and 4 only

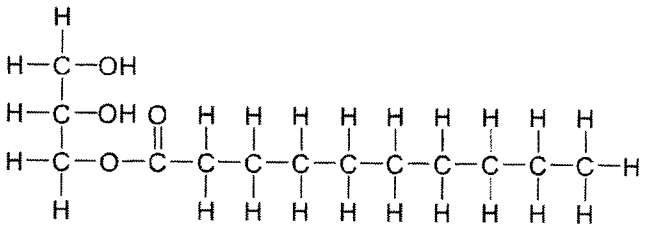
2 The diagram shows three pathways, X, Y and Z, through which substances can move across a cell surface membrane.



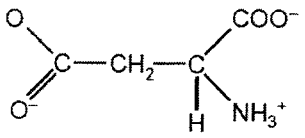
Which row correctly identifies all possible pathways through which substances 1, 2, 3 and 4 could use to enter the cell?



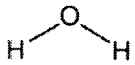
1



2



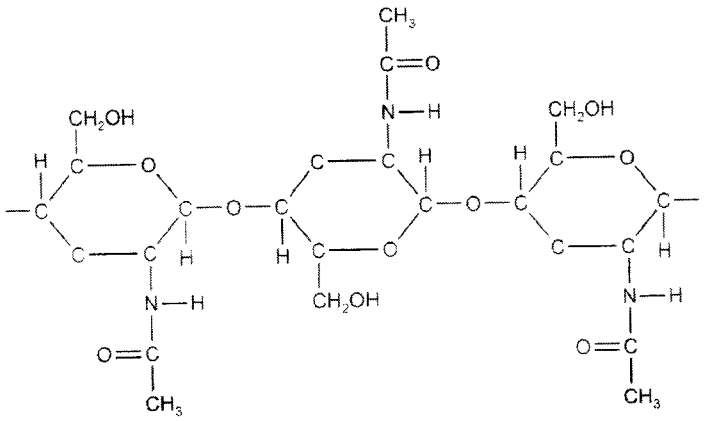
3



4

	X	Y	Z
A	2, 4	3	1, 3, 4
B	2, 4	1, 3	1, 3
C	2	1, 3	1, 3
D	2	3	1, 3, 4

3 The diagram shows the structure of part of a polysaccharide, chitin, found in the cell walls of certain fungi.



Which statements are true for **both** chitin and cellulose?

1 Each polysaccharide is composed of two different monosaccharides.

2 Each polysaccharide can form cross linkages via hydrogen bonds between chains.

3 Their monosaccharides are joined by 1,4-glycosidic bonds.

4 Every second monosaccharide in the polysaccharide chain is rotated by 180°.

A 1, 2 and 3

B 2, 3 and 4

C 2 and 4 only

D 3 and 4 only

4 Which row about the structure of proteins is correct?

	primary structure	secondary structure	quaternary structure
A	is the result of translation of an mRNA molecule by a ribosome into a chain of amino acids	occurs because of attraction between R groups of amino acid residues	is the sub-unit polypeptides that link together to form a protein
B	is the number of amino acids present in a protein	is the coiling of a chain of amino acids to form a β-pleated sheet or α-helix	contains two types of polypeptide that interact forming the shape of a protein
C	is synthesised by ribosomes in the cytoplasm	is the left-handed spiral formed by the primary structure	is formed by four polypeptides and an additional prosthetic group attached to the protein
D	is the sequence of amino acids in a protein coded by DNA	is formed by hydrogen bonding at intervals along the polypeptide backbone	is formed by the linking together of more than one polypeptide to form a protein

5 Hydrogenated vegetable oils are unsaturated fats that have been converted to saturated fats.

Which property of the fats will have changed?

1 Their melting point has increased.

2 There will be an increase in the ratio of carbon to hydrogen atoms.

3 Their hydrocarbon chains will fit together more closely.

A 1, 2 and 3

B 1 and 2 only

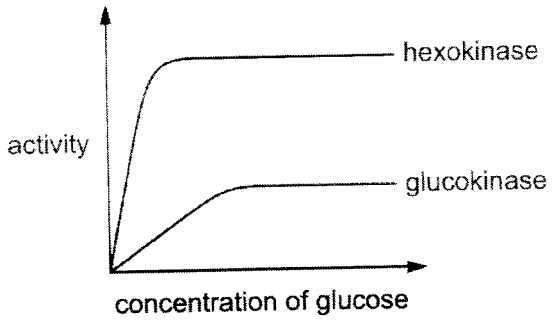
C 1 and 3 only

D 2 and 3 only

6 The enzymes glucokinase in the liver and hexokinase in the brain both catalyse the phosphorylation of glucose during glycolysis:

Glucose + ATP → glucose phosphate + ADP

The graph shows the activity of each enzyme measured at different concentrations of glucose.



Which statements correctly describe the differences between the two enzymes?

1 At low concentrations of glucose, temperature is limiting the activity of glucokinase only.

2 At high concentrations of glucose, the difference between the total amount of products formed by hexokinase and glucokinase remains constant.

3 Contact residues at the active site of hexokinase bind to glucose with greater affinity than that of glucokinase.

4 Hexokinase becomes saturated with glucose at a lower concentration of glucose than glucokinase.

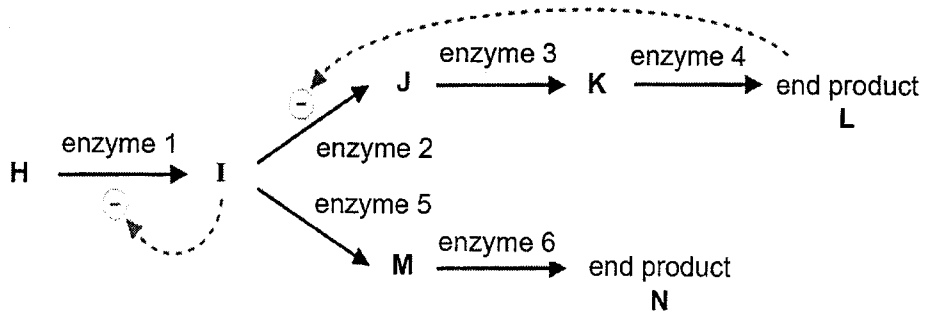
A 1, 3 and 4

B 2 and 3 only

C 2 and 4 only

D 3 and 4 only

7 The diagram shows a biosynthesis pathway.



The addition of substance **X** resulted in the following:

- no change in the concentration of metabolite **H**
- accumulation of metabolite **I**
- low concentrations of metabolite **J** and **K** and end product **N**

Further addition of metabolite **I** results in the formation of more end product **N**, but not end product **L**.

What does the information indicate about substance **X**?

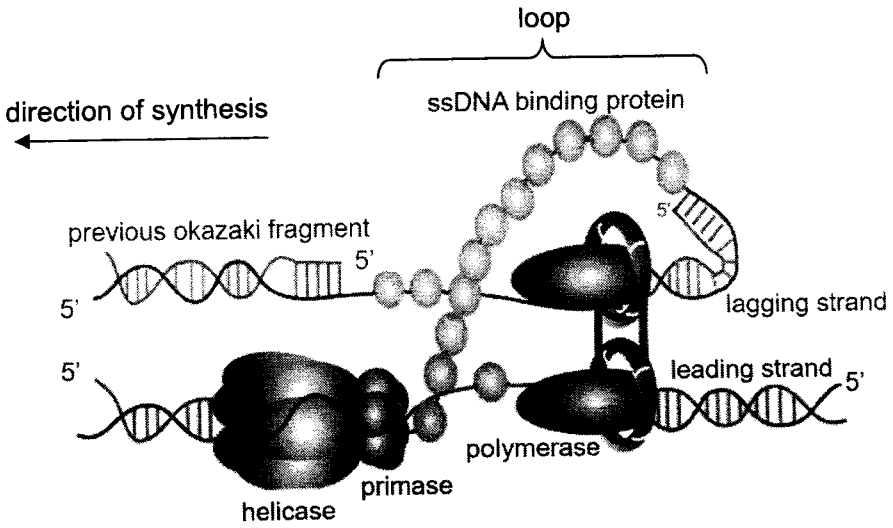
A It reacts with metabolite **J** to form metabolite **K**.

B It is an allosteric activator of enzyme 1.

C It is a non-competitive inhibitor of enzyme 3.

D It is a competitive inhibitor of enzyme 5.

8 The diagram shows the synthesis of the leading and lagging strands during DNA replication. The lagging strand template forms a loop at the replication fork.



Which statements explain why looping is needed during DNA replication?

1 The anti-parallel nature of the DNA strands.

2 DNA polymerase joins new nucleotides to the 3' end of the growing strand.

3 Single stranded DNA can be maintained to act as templates for polymerases.

4 Both DNA polymerases can then synthesise daughter strands in the same overall direction.

A 1, 2 and 3

B 1, 2 and 4

C 1 and 2 only

D 2 and 3 only

9 The DNA sequence CCAAGAAGTCGACAAACA was transcribed and translated to synthesise the polypeptide chain gly-ser-ser-ala-val-cys.

A mutation in the sequence resulted in a polypeptide chain that was shortened from six to two amino acids.

Which mutations might have occurred to result in the outcome observed?

1 A single base pair substitution from G to T.

2 A single base pair substitution from G to C.

3 Addition of a base pair at the 3rd mRNA codon.

A 1, 2 and 3

B 1 and 2 only

C 1 and 3 only

D 2 and 3 only

10 The following statements describe non-coding DNA in eukaryotes.

1 Presence of repeating sequences.
2 Number of nucleotides varies in different cells.
3 May be bound by proteins.

Which statement(s) apply **only** to non-coding DNA present outside of genes?

A 1 and 3 only

B 2 and 3 only

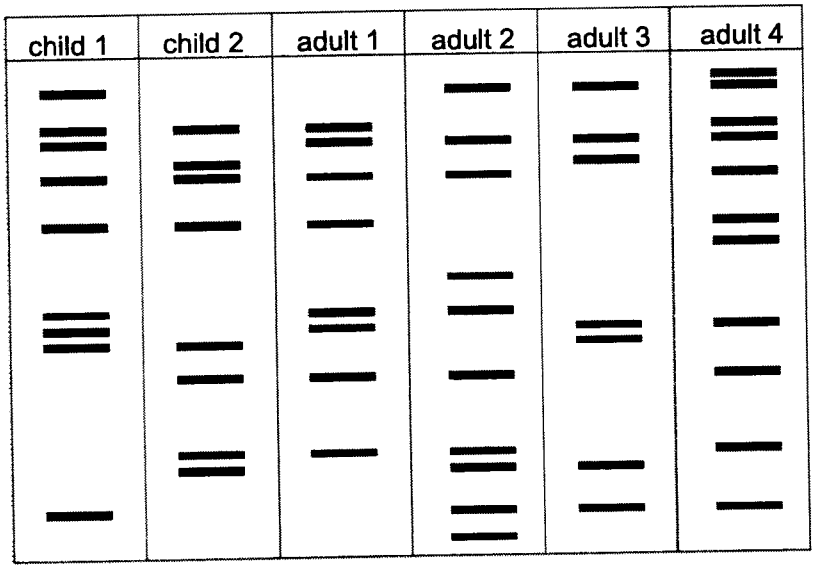
C 1 only

D 2 only

11 Which row describing the effect of a modification to the regulation of gene expression in eukaryotes is correct?

	modification	effect
A	mutation of intron splice sites	aggregation of misfolded proteins in cytoplasm
B	inactivation of poly-A-polymerase	accumulation of mRNAs in nucleus
C	loss-of-function mutation in eukaryotic initiation factors	inability to synthesise mRNA
D	over-expression of histone methyltransferase	upregulation of expression for a large variety of genes

12 DNA fingerprinting was used to identify the parents of two children. Short tandem repeats of a particular locus were selectively amplified using polymerase chain reaction and the products subsequently underwent gel electrophoresis. The results are shown below.



Given that both the children have the same pair of parents, which two adults may be their parents?

A adults 1 and 2

B adults 1 and 3

C adults 2 and 4

D adults 3 and 4

13 The mitotic cell cycle is carefully controlled by a cell-cycle control system.

Which of these statements explain why the mitotic cell cycle requires control?

1 To ensure sufficient time for DNA errors to be repaired.

2 To allow for genetic variation in daughter cells.

3 To induce apoptosis upon detection of any DNA damage.

4 To ensure that cells grow to an appropriate size for cell division.

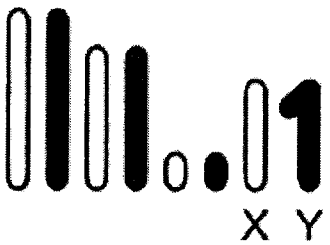
A 1 and 2 only

B 1 and 4 only

C 2 and 3 only

D 3 and 4 only

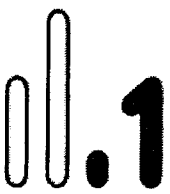
14 The diagram shows the four pairs of homologous chromosomes present in the germ cell of a male fruit fly, *Drosophila melanogaster.*



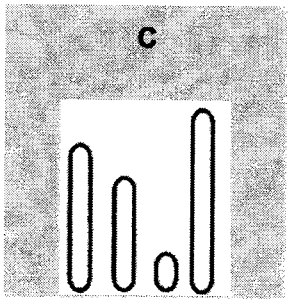
Given that crossing over does not occur during prophase I, which set of chromosomes shows the genetic variation resulting from independent assortment in the nucleus of a sperm cell?

A

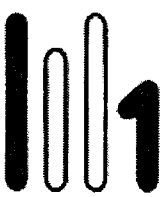
B



C



D



15 The Philadelphia chromosome is associated with the development of several forms of leukaemia. The Philadelphia chromosome is formed when:

- one end of chromosome 9 and one end of chromosome 22 breaks
- part of the *BCR* gene that lies at broken end of chromosome 22 fuses with the *ABL1* gene that is part of the fragment of chromosome 9

When the *BCR-ABL1* fused gene is expressed, a protein that exhibits high tyrosine kinase activity is produced.

Which statement(s) cannot be concluded with the information above?

1 *BCR-ABL1* gene is a proto-oncogene as the gene product stimulates cell division.

2 Multiple copies of *BCR* gene results in the development of cancer.

3 The Philadelphia chromosome is an example of chromosomal translocation.

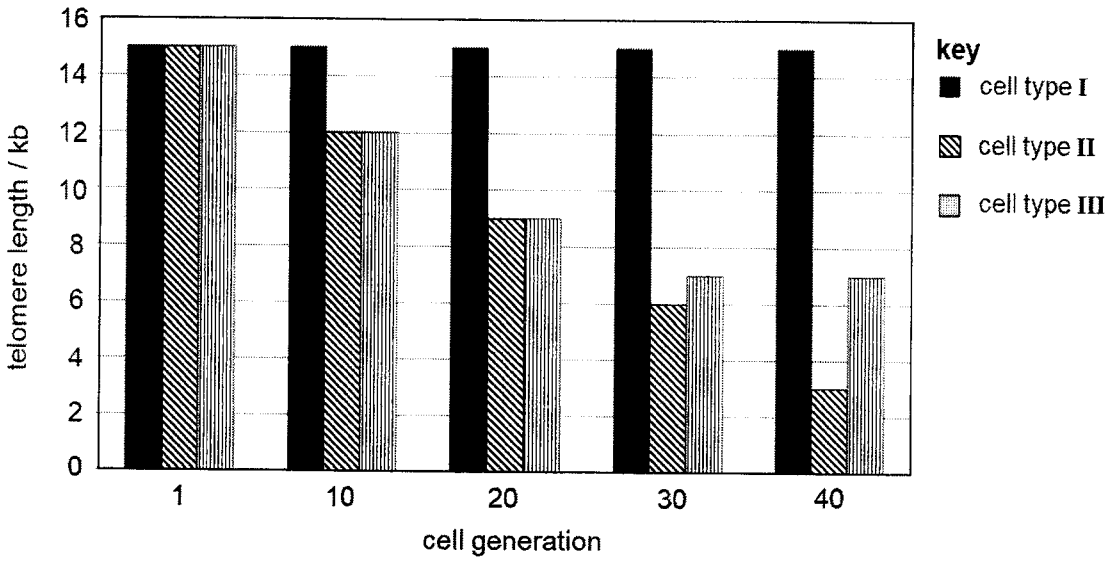
A 1, 2 and 3

B 1 and 2 only

C 1 and 3 only

D 2 only

16 The graph shows the telomere length of three different cell types I to III.



What may be concluded from the graph above?

1 Cells of type I and III are capable of long term self-renewal.

2 Cells of type II do not contain mutations in tumour suppressor genes.

3 Cells of type I can be induced to differentiate by environmental signals.

4 Cells of type III can proliferate uncontrollably.

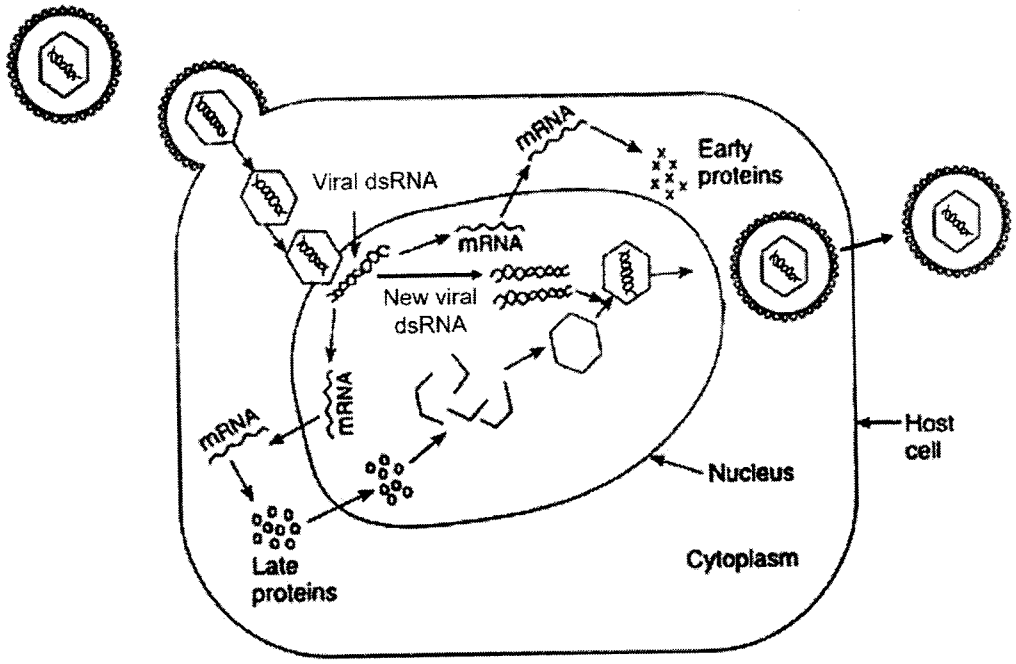
A 1, 2 and 3

B 1, 3 and 4

C 1 and 3 only

D 2 and 4 only

17 The diagram shows the reproductive cycle of a virus in a host cell.



Which statement correctly describes the reproductive cycle of this virus?

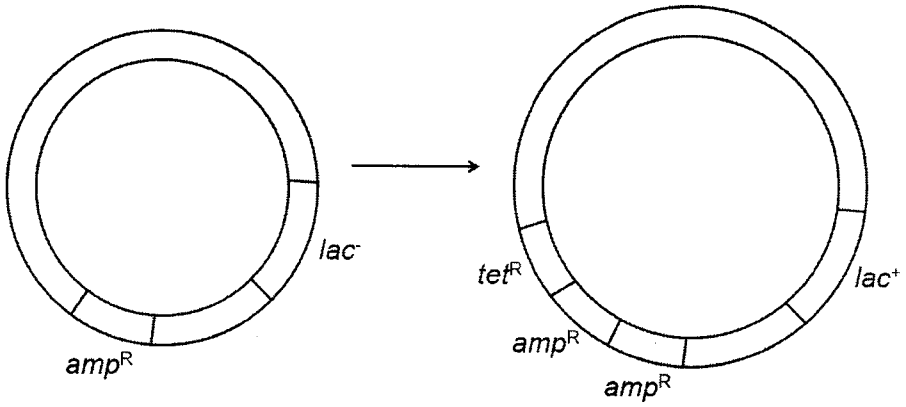
A It is an enveloped virus that enters the host cell via receptor-mediated endocytosis.

B The viral genes serve as templates to form RNA molecules with negative configuration to synthesise early and late proteins.

C Synthesis of new viral genome is carried out by the same enzyme as in the influenza virus.

D The viral progeny is released via budding.

18 Which environment could account for the changes in the bacterial chromosome as shown in the diagram?



key

amp^R – ampicillin resistance gene

tet^R – tetracycline resistance gene

lac$^+$ – lac operon present

lac$^-$ – lac operon absent

A Exposure of actively dividing bacteria to mutagens.

B A single bacterial colony grown in culture medium containing lambda phages.

C Bacteria grown in culture medium with other strains of heat-killed bacteria.

D Bacteria grown in culture medium containing tetracycline.

19 The activities of the *lac* operon in four different *E. coli* strains, cultured in different nutrient media, were investigated. The results are shown in the table below.

E. coli strain	nutrient present in media	conformational state of *lac* repressor	β-galactosidase
1 (normal)	glucose	active	absent
	lactose	inactive	present
2 (mutant)	glucose	active	present
3 (mutant)	lactose	active	absent
4 (mutant)	lactose	inactive	absent

Which statements could explain these results?

1 A mutation in the *lac I* gene in strain 3.

2 A mutation in the operator of the *lac* operon in strain 2.

3 A mutation in the promoter of the *lac* operon in strain 4.

4 A mutation that swapped the positions of the promoter and operator in the *lac* operon in strain 2.

A 1, 2, 3 and 4

B 1, 2 and 3 only

C 1 and 2 only

D 3 and 4 only

20 Coat colour in domestic cats is controlled by two genes. Information of these genes are given in the table below.

gene location	symbol	phenotype
chromosome 2	**B**	black coat colour
	b	brown coat colour
X chromosome	$\mathbf{X^G}$	ginger coat colour
	$\mathbf{X^g}$	absence of ginger colour $\mathbf{X^G}$ is expressed even in the presence of the **B** allele

During the development of female cats, one X chromosome in each cell is inactivated at random. Consequently, in female cats that are heterozygous at both gene loci, skin cells may be in a patch of ginger fur or black fur depending on whether they have developed from a cell with an active $\mathbf{X^G}$ allele or $\mathbf{X^g}$ allele. Cats with this form of colouring are called tortoiseshell cats.

A male cat heterozygous for black coat is mated with a female cat with tortoiseshell coat.

What proportion of their kittens would be expected to have the tortoiseshell colouring?

A 0.125

B 0.25

C 0.5

D 0.75

21 In domestic poultry, the gene for white feathers is dominant to the gene for dark feathers and the gene for frizzled feathers is dominant to normal feathers. Pure-breeding poultry which were homozygous for dark, frizzled feathers were crossed with pure-breeding poultry bearing white, normal feathers. The F1 were test-crossed and the phenotypes of offspring were recorded. The results are shown.

white frizzled	39
dark frizzled	79
white normal	68
dark normal	46

The chi-squared test can be used to determine the probability that offspring ratio fits the expected ratio.

The formula for the chi-squared test is:

$$\chi^2 = \Sigma \frac{(O-E)^2}{E} \qquad v = c - 1$$

Part of the probability table for chi-squared values is shown below.

degrees of freedom	probability, p			
	0.10	0.05	0.01	0.001
1	2.71	3.84	6.64	10.83
2	4.61	5.99	9.21	13.82
3	6.25	7.82	11.35	16.27
4	7.78	9.49	13.28	18.47

Which combination correctly describes the conclusion of the χ^2 test?

	probability	loci of genes
A	< 0.05	different chromosomes
B	< 0.05	same chromosomes
C	> 0.05	different chromosome
D	> 0.05	same chromosome

22 Which statement concerning chrysanthemum plants, of the genus *Dendranthema*, is a valid example of how the environment may affect the phenotype?

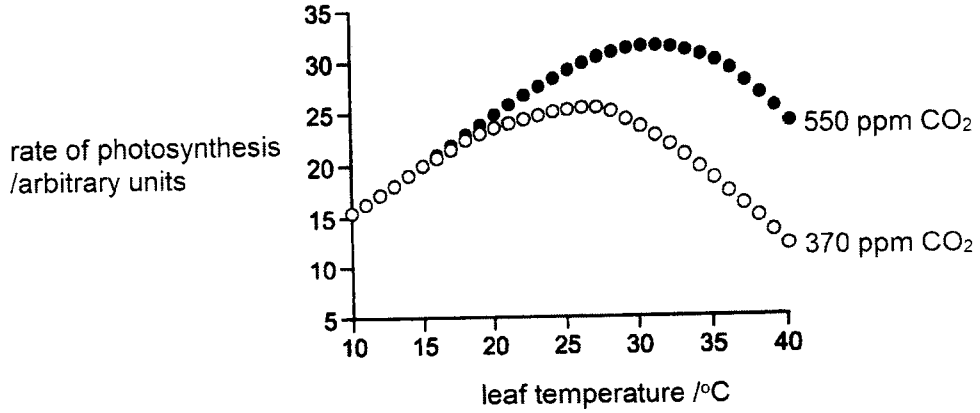
A Identical genetic crosses performed between varieties of *Dendranthema* result in a greater proportion of offspring plants with plastids exhibiting a yellow colour when grown in a field and a greater proportion of offspring plants with colourless plastids when grown in a glass house.

B Anthocyanins and anthoxanthins are vacuolar pigments, whereas xanthophylls and carotenes are pigments found in membrane-bound organelles known as plastids. These, together with molecules known as co-pigments, are responsible for the variation observed in petal colour in *Dendranthema*.

C The seeds of a cross between *Dendranthema weyrichii* and *Dendranthema grandiflora* produce plants that are far more frost-tolerant and exhibit an extended flowering season compared with both parent plants.

D The seeds of a cross between *Dendranthema weyrichii* (height varying between 12.5 – 15.0 cm) and *Dendranthema grandiflora* (height varying between 8.0 – 25.0 cm) produce plants, when grown in natural day length, of a height varying between 55.0 – 71.0 cm.

23 The graph shows the results of increased concentration of carbon dioxide on soy bean photosynthesis at various leaf temperatures. Carbon dioxide concentration is measured in ppm (parts per million). Light intensity was at an optimum level.



Which statement(s) concerning the data in the graph is valid?

1 When temperature is limiting, increased carbon dioxide concentration increases the rate of photosynthesis.

2 At all temperatures up to 27.5 °C, temperature is the only limiting factor for both carbon dioxide concentrations.

3 At all temperatures, carbon dioxide concentration is the main limiting factor.

4 The photosynthetic rate obtained at the optimum temperature for 370 ppm CO_2 could be achieved at a temperature around 7.5 °C lower using an increased concentration of 550 ppm CO_2.

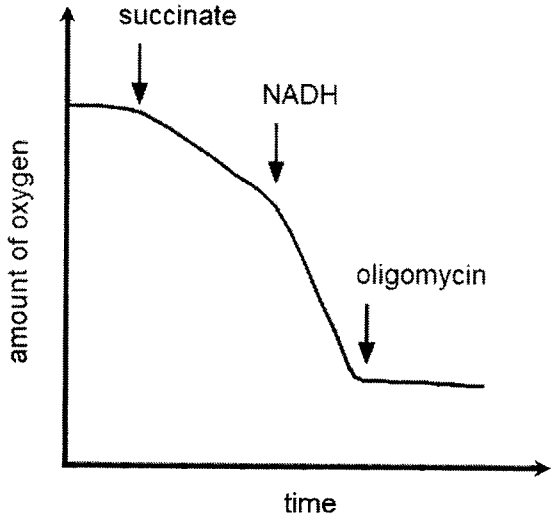
A 1 and 2 only

B 1 and 4 only

C 2 and 3 only

D 4 only

24 A suspension of mitochondria was prepared in a buffer containing ADP and inorganic phosphate (Pi). The oxygen concentration in the buffer was monitored carefully and recorded as shown below. At the times indicated, a specific reagent was added to the buffer. Throughout the experiment, the concentrations of ADP and Pi were in excess.



Which one of the following shows correctly from the highest to the lowest, the rate of ATP production after the addition of the three chemicals?

	highest rate → lowest rate		
A	succinate	NADH	oligomycin
B	NADH	succinate	oligomycin
C	succinate	oligomycin	NADH
D	oligomycin	NADH	succinate

25 The steps involved in a cell-signalling pathway are listed.

- binding of ligand to receptor binding site
- phosphorylation of receptor
- synthesis of second messengers
- activation of the enzyme adenyl cyclase
- initiation of a protein kinase cascade
- binding of protein to DNA sequences

What is the 3rd common step that occurs during **both** insulin and glucagon signalling?

A synthesis of second messengers

B activation of the enzyme adenyl cyclase

C initiation of a protein kinase cascade

D binding of protein to DNA sequence

26 Before the settlement of California in the 1800s, the elk population was very large. By about 1900, there were only a few dozen elk left due to hunting.

Owing to protection, there are now about 3000 elk living in a small number of isolated herds.

Unfortunately, some of the elk in all the herds have difficulty grazing due to a shortened lower jaw, as a result of having one copy of a mutated allele. These elk can be observed in subsequent generations.

Which statements best explain the observations?

1 There was a mutation affecting jaw size in some of the herds.

2 There was random mating within each herd.

3 The mutated allele is preserved in the population due to heterozygote protection.

4 The current elk distribution demonstrates a founder effect.

A 1 and 2

B 1 and 3

C 2 and 4

D 3 and 4

27 Lord Howe Island is relatively small, volcanic island that formed approximately 6.4 – 6.9 million years ago. Two species of palm, *H. forsteriana* and *H. belmoreana*, are found on this island and had descended from one ancestor species.

To investigate speciation of the two palm species, the following findings are listed.

1 Two populations from the ancestral species develop variation in soil tolerance. One population grows in neutral to acidic soil while the other grows in soils rich in calcarenite which has a more basic pH.

2 Calcarenite soils are poor in nutrients which will delay the physiological development of palm.

3 The soils on most parts of Lord Howe Island are mainly neutral to acidic, except at low lying areas where alkaline soils are found.

4 The peak flowering of each species is separated by approximately six weeks and has limited overlap.

What is the correct sequence to explain this speciation?

A 1 → 2 → 3 → 4

B 2 → 4 → 3 → 1

C 3 → 1 → 2 → 4

D 4 → 2 → 1 → 3

28 Which statement about immunity is correct?

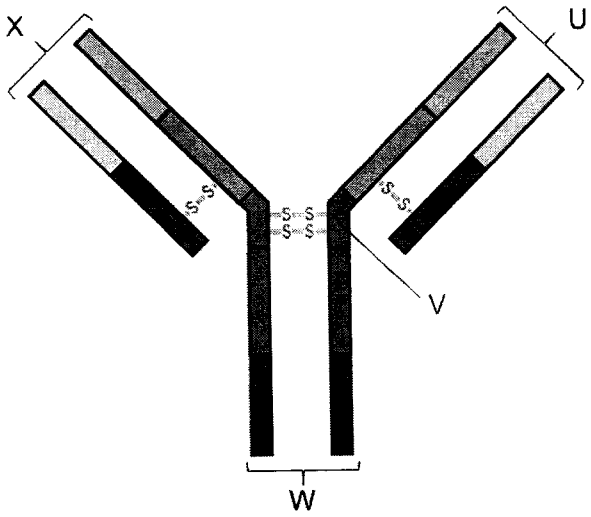
A Immunity following a vaccination lasts for a greater length of time than natural passive immunity.

B Antibody injection results in artificial active and artificial passive immunity.

C Natural active immunity provides a faster response to infection than artificial active immunity.

D Antigen presentation by specific B lymphocytes only occurs with natural immunity.

29 The diagram shows the simplified structure of an antibody.



Which statement is correct?

A U and X are unique antigen-binding sites that allow the antibody to bind to two different antigens.

B V allows for flexibility of the antibody to bind to antigens.

C W varies across different classes of antibodies due to alternative splicing of heavy chain mRNA.

D X undergoes somatic hypermutation during B lymphocyte development in bone marrow.

30 Dengue disease is spread by *Aedes aegypti* and *Aedes albopictus* mosquitoes.

Which of these risk factors increases the probability of developing severe dengue disease following infection?

A increased resistance of the vector to insecticides

B exposure to different mosquito species

C people living in more crowded conditions due to an increase in human populations

D having a chronic disease such as diabetes

Answer Key

1	**B**	11	**A**	21	**B**
2	**A**	12	**B**	22	**A**
3	**B**	13	**B**	23	**D**
4	**D**	14	**C**	24	**B**
5	**C**	15	**B**	25	**D**
6	**D**	16	**C**	26	**C**
7	**D**	17	**C**	27	**C**
8	**B**	18	**C**	28	**A**
9	**B**	19	**A**	29	**B**
10	**D**	20	**A**	30	**D**

BLANK PAGE

RIVER VALLEY HIGH SCHOOL

JC 2 PRELIMINARY EXAMINATION

CANDIDATE NAME									
CENTRE NUMBER	S					CLASS	21J	INDEX NUMBER	

BIOLOGY **9744/02**

Paper 2 Structured Questions **12 September 2022**

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	15
2	8
3	9
4	10
5	10
6	10
7	8
8	11
9	9
10	5
11	5
Total	100

This document consists of **26** printed pages.

Answer **all** questions.

1 In the lung, epithelial cells have a thin layer of watery mucus on their surface to trap particles.

Fig. 1.1 shows a series of processes that occur at the cell surface membrane of an epithelial cell, involving a channel protein called the Cystic Fibrosis Transmembrane conductance Regulator (CFTR).

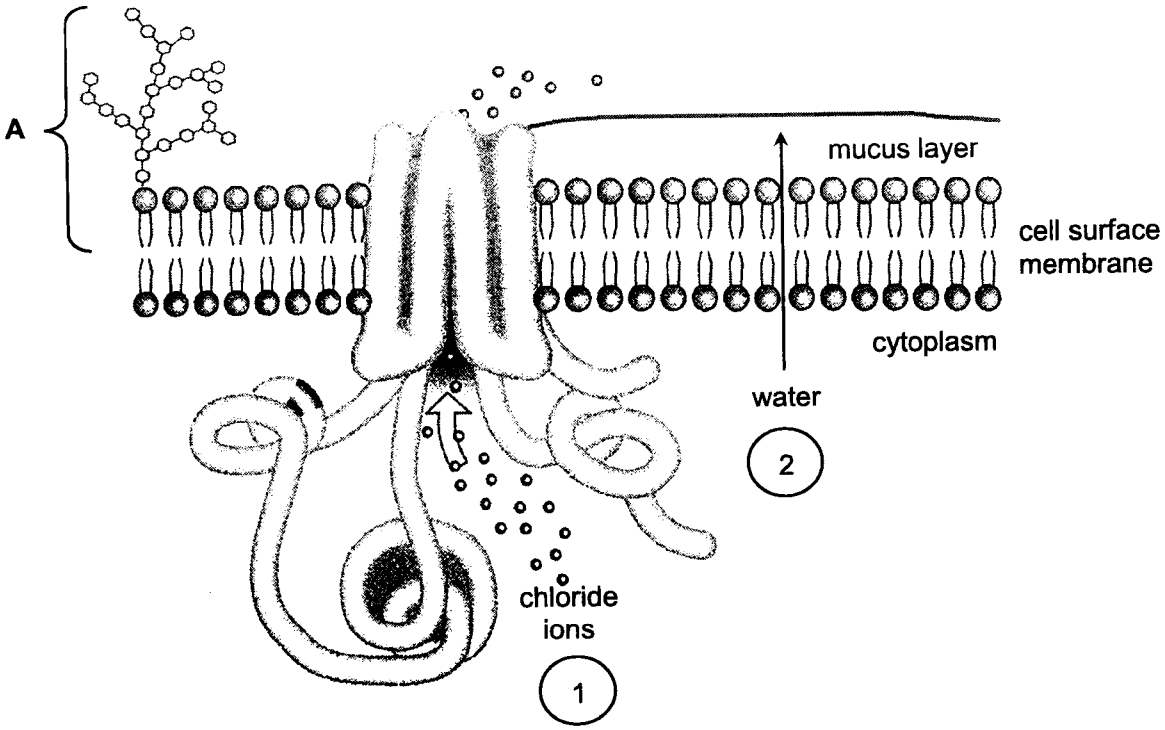


Fig. 1.1

(a) Identify the structure labelled **A** and state its role. [2]

AOA

structure **glycolipid;;**

role **Cell surface marker for cell-cell recognition / cell-cell adhesion to form tissues;;**

(b) (i) Explain why chloride ions can only cross cell surface membranes via CFTR. [3]

1. **chloride ions are charged;;**
2. **cannot diffuse through hydrophobic core of cell surface membrane;**
3. **CFTR provides a hydrophilic channel that that shields Cl^- from the hydrophobic core;**

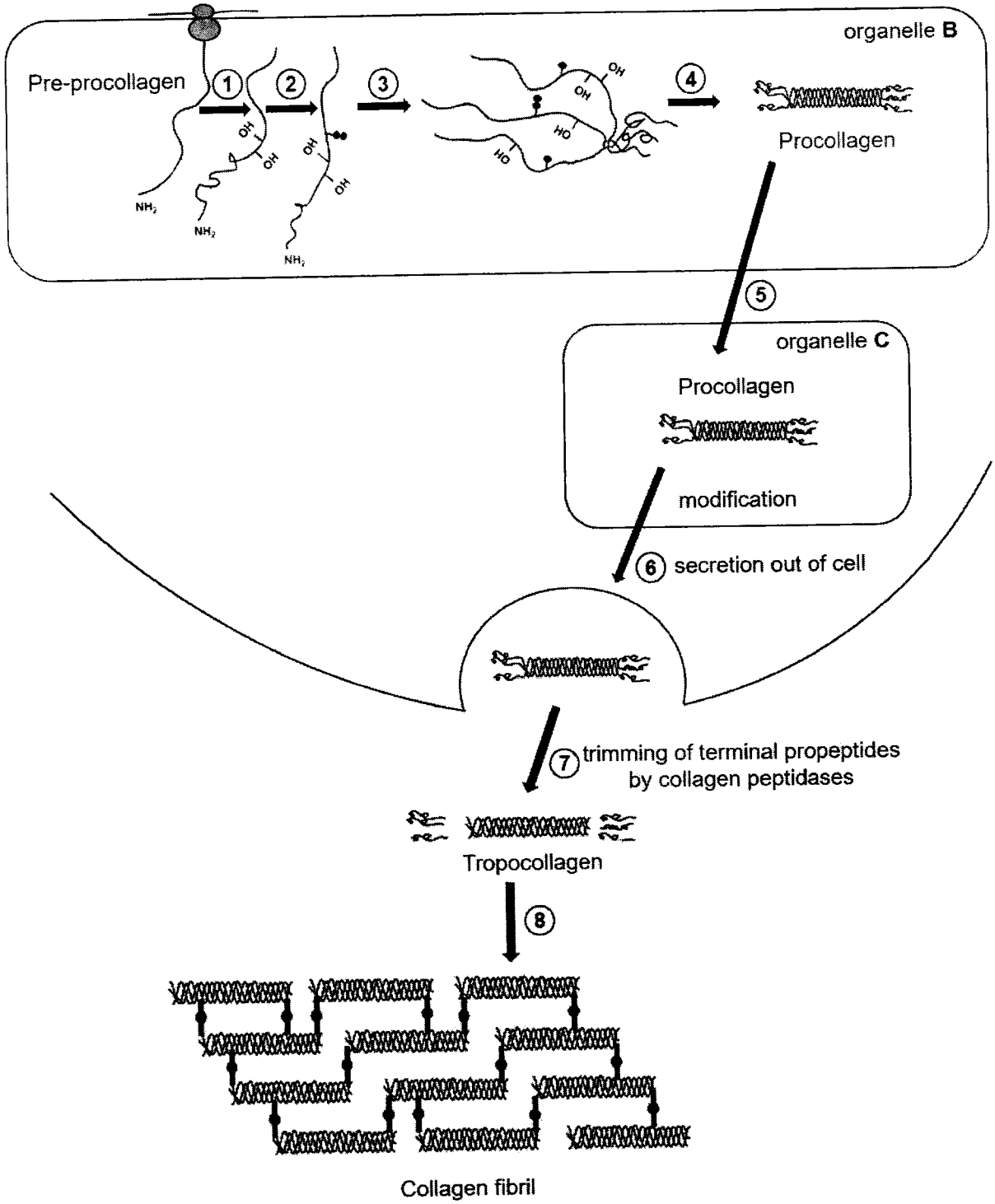
4. **the channel is specific to the transport of chloride ions as it has a specific binding site complementary to the shape of chloride ions;;**

(ii) Explain why absence of CFTR results in more viscous mucus. [2]

1. **chloride ions remain inside epithelial cell;**
2. **water potential inside the cell is more negative than outside the cell;;**
3. **water enters the cell via osmosis;**

   resulting in more viscous mucus

Fig. 1.2 shows the stages during the synthesis of collagen.



key
OH: hydroxyl group
: sugar

Fig. 1.2

(c) (i) Identify organelles **B** and **C** in Fig. 1.2. [2]

organelle **B** **Rough endoplasmic reticulum;;**

organelle **C** **Golgi apparatus;;**

(ii) With reference to Fig. 1.2, describe how tropocollagen is synthesised from pre-procollagen. [3]

1. **Addition of OH groups / hydroxylation;**
2. **Addition of sugars / glycosylation;**
3. **Three pre-procollagen chains joined together to form procollagen in organelle B (RER);**
4. **Procollagen transported to organelle C (GA) to be modified;**
5. **secreted out of the cell;**

   A: released via exocytosis
6. **Terminal propeptides are cleaved / removed / trimmed by collagen peptidases;**

(iii) The feet of elephants are covered in padding to support the mass of the elephant. This padding is made up of a large number of cells surrounded by connective tissue containing many fibres of collagen.

Explain how **stage 8** contributes to the function of the padding. [2]

1. **Tropocollagen molecules lie parallel to each other in a staggered arrangement;**
2. **joined by covalent bonds between carboxyl and amino ends / cross-linked;**
3. **bundling of fibrils to form fibres;**
4. **contribute to high tensile strength (to support the mass of the elephant);**

(iv) Suggest why collagen fibril is assembled outside the cell. [1]

1. **Enzymes involved In the removal of propeptides are found outside the cell;;**
2. **Tropocollagen is too large to pass through the cell surface membrane;;**

Any one

[Total: 15]

2 Enzymes can be immobilised in alginate beads to improve their physical and biochemical properties. A study was carried out to investigate the effect of pH on the activity of free GH and immobilised GH. Equal concentrations of free GH and immobilised GH were used.

Fig. 2.1 shows the results of this study.

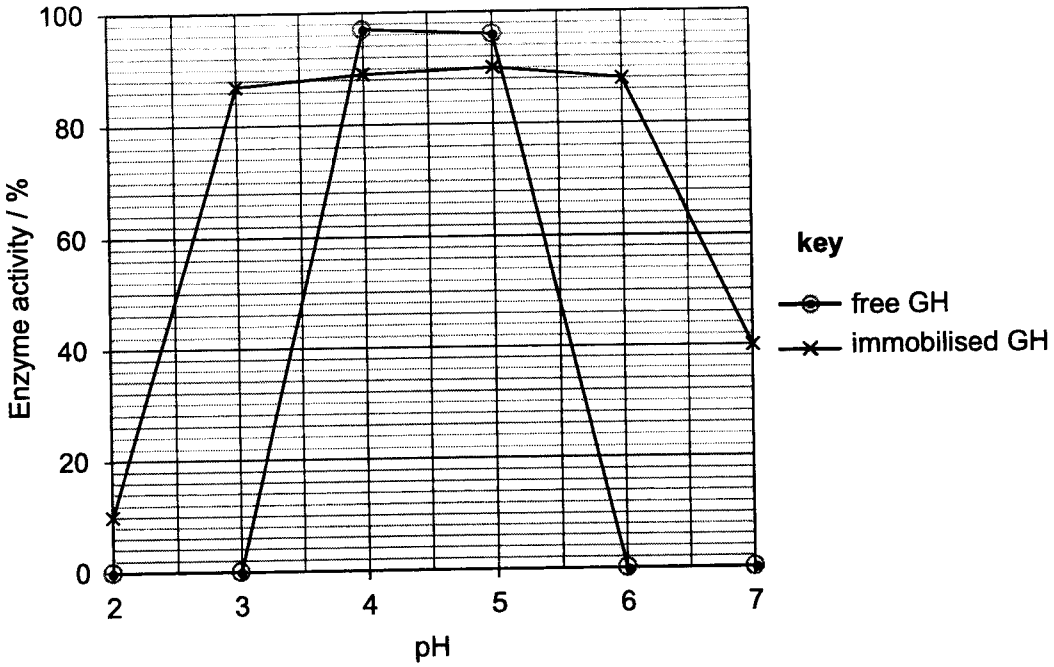


Fig. 2.1

(a) With reference to Fig. 2.1, describe **two** differences between the activity of free GH and immobilised GH.

Suggest an explanation for each of the two differences. [4]

difference 1 and explanation:

difference 2 and explanation:

Description

1. **immobilised GH has a wider range of optimum pH than free GH;**
2. **QV: optimum pH of immobilised GH is 3-6 but that of free GH is 4-5;**

or

3. **immobilised GH is functional over a wider range of pH than free GH;**
4. **QV: immobilised GH is 2 to 7 but that of free GH is >3 to <6;**

Explanation

5. **Immobilised GH less exposed to H^+;**

6. **Less change in charge of acidic and basic R group of amino acid residues / fewer breakage of hydrogen bonds and ionic bonds;**

or

7. **immobilisation restricts change in shape / unfolding of polypeptide chain;**
8. **despite breakage of ionic and hydrogen bonds;**

Description

9. **free GH has higher maximum activity than immobilised GH;**
10. **QV: max activity of free GH is 96-97% but that of immobilised GH is 87-90%;**

Explanation

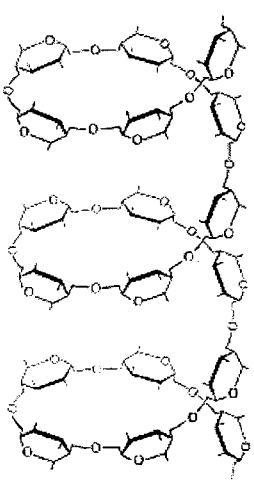
11. **Increase accessibility;**
12. **Higher frequency of effective collision between active site of free GH and substrate / higher number of enzyme-substrate complex formed per unit time;**

Glucoside hydrolase (GH) is an enzyme responsible for hydrolysing α-1,4-glycosidic bonds in carbohydrates, such as amylose and amylopectin.

(a) Using GH as an example, explain induced-fit hypothesis. [2]

1. **Active site of glucosidase has a shape complementary to that of α-1,4 glycosidic bond;**
2. **initial shape of enzyme active site may not be completely complementary to the shape of substrate;**
3. **Binding of the substrate to the active site induces a conformational change in the enzyme;**
4. **This enables the substrate to fit more snugly into the active site (to form enzyme-substrate complex);**

Fig. 2.2 shows a molecule of amylose and a molecule of RNA (not drawn to scale).



Amylose

RNA

Fig. 2.2

(c) Describe in what ways the helical structures in both amylose and RNA differ. [2]

Feature	Amylose	RNA
1: Helical structure;;	Single helix	Double helix
2: Formation of helical structure;;	Folding / coiling within <u>one polysaccharide</u> chain	<u>Two segments of RNA</u> molecule folds back on itself
3: Bond forming helical structure;;	α-1,4-glycosidic bonds	H bonds <u>between RNA nucleotides</u> (complementary base pairing)
4: Regularity of helical structure;;	Regular (coils throughout molecule)	Irregular (helix formed at some parts of the molecule)

[Total: 8]

3 Fig. 3.1 shows a diagram of RNA polymerase during transcription of the β-globin gene.

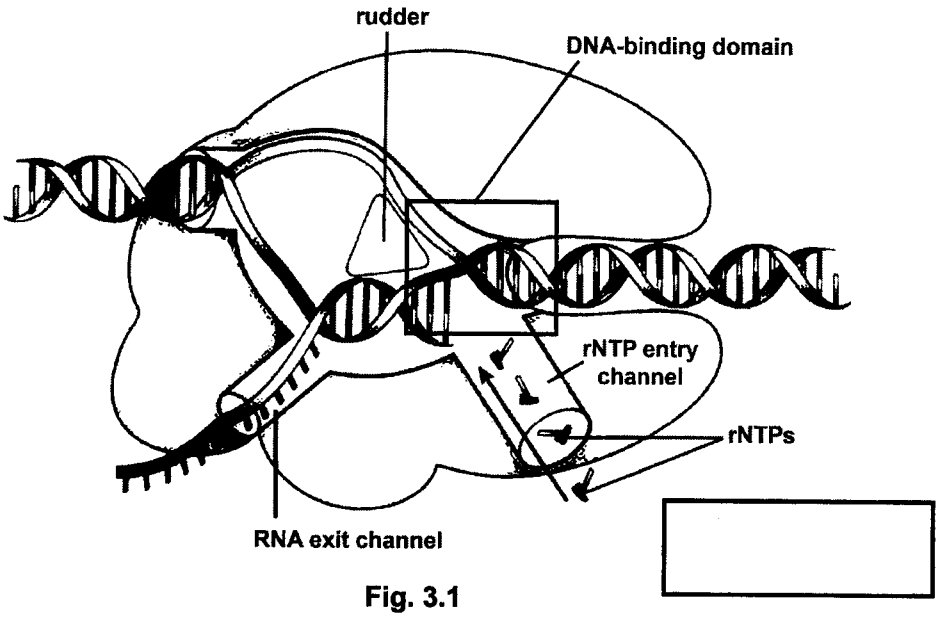


Fig. 3.1

(a) (i) In the box on Fig. 3.1, label with an arrow the direction of transcription. [1]

(ii) With reference to Fig. 3.1, describe how the structure of RNA polymerase allows it to perform its function. [2]

1. **(S) DNA binding domain has a specific 3-dimensional conformation (P) complementary to the shape of DNA;**

   (F) allows RNA polymerase to bind to DNA / bind to promoter to initiate transcription;

2. **(S) Presence of rudder;**

   (F) to separate the two DNA strands so as to expose template strand;

3. **(S) Presence of rNTP channel (P) that is complementary to shape of rNTP;**
   (F) allows incoming ribonucleoside triphosphate (rNTP) to enter RNA polymerase for elongation;

4. **(S) Presence of RNA exit channel;**

   (F) allows RNA strand to leave the RNA polymerase as it elongates;

Any two

Actinomycin D and cycloheximide are drugs used in the treatment of chronic leukemia, and are involved in the inhibition of β-globin synthesis.

Fig. 3.2 shows the results obtained when each drug is added to immature red blood cells in separate experiments. The thickness and intensity of the bands are an indication of the amount of β-globin mRNA or β-globin protein present. Results have been adjusted to allow for direct comparison.

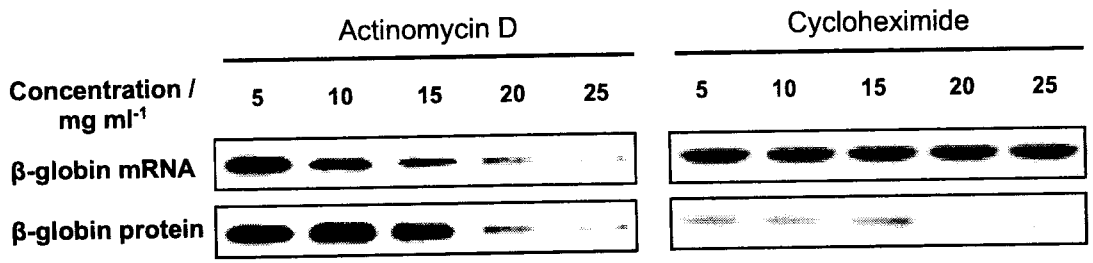


Fig. 3.2

(b) (i) State the drug that inhibits the following processes in β-globin synthesis. [1]

transcription **Actinomycin D**

translation **Cycloheximide**

(ii) Justify your answer to **(b)(i)**. [3]

1. (Evidence) **As concentration of actinomycin D added increases from 5 mg ml^{-1} to 25 mg ml^{-1}, <u>both</u> the amount of β-globin mRNA and β-globin protein decreases;;**
2. **therefore showing that <u>less mRNA templates were produced for translation</u>;**
3. (Evidence) **As concentration of cycloheximide added increases from 5 mg ml^{-1} to 25 mg ml^{-1}, amount of β-globin mRNA remains the same; but amount of β-globin protein decreases;**
4. **therefore showing that the <u>available mRNA templates were not used for translation</u>;**

(c) Describe **two** features of the genetic code. [2]

1. **consists of a triplet of bases (codons);;**
2. **universal;;**
3. **non-overlapping / mRNA sequence can be read continuously in a series of triplets without skipping any nucleotides;;**
4. **degenerate / more than 1 codons may code for the same amino acid;;**

Any two

[Total: 9]

4 Cancer is a genetic disease. Despite this, only around 10% of all cancers are inherited.

(a) Suggest **two** reasons why a cancer that occurs in a parent does not always occur in the offspring. [2]

1. **Mutations that result in the cancer occurs in somatic cells and not in germline cells, therefore absent in gametes;;**
2. **Mutations that result in the cancer may only occur after offspring has been born;;**
3. **Inheriting mutated gene only increases risk of developing the cancer;;**
4. **The cancer type is due to recessive alleles, may skip generation;;**
5. **AVP;;**

Max 2

Acute myeloid leukemia (AML) is a rare and extremely rapid developing cancer in human. AML results from aberrant proliferation and differentiation of mutated myeloid cells in the bone marrow. Large numbers of malfunctioning differentiated cells then result in symptoms such as fatigue, unusual bruising, and a high number of infections.

Patients with AML display mutations in many genes but mutations in *FLT3* and *DNMT3A* genes are most prevalent. FLT3 and DNMT3A are a type of receptor tyrosine kinase and DNA methyltransferase respectively.

Fig. 4.1 shows the development of AML in the bone marrow.

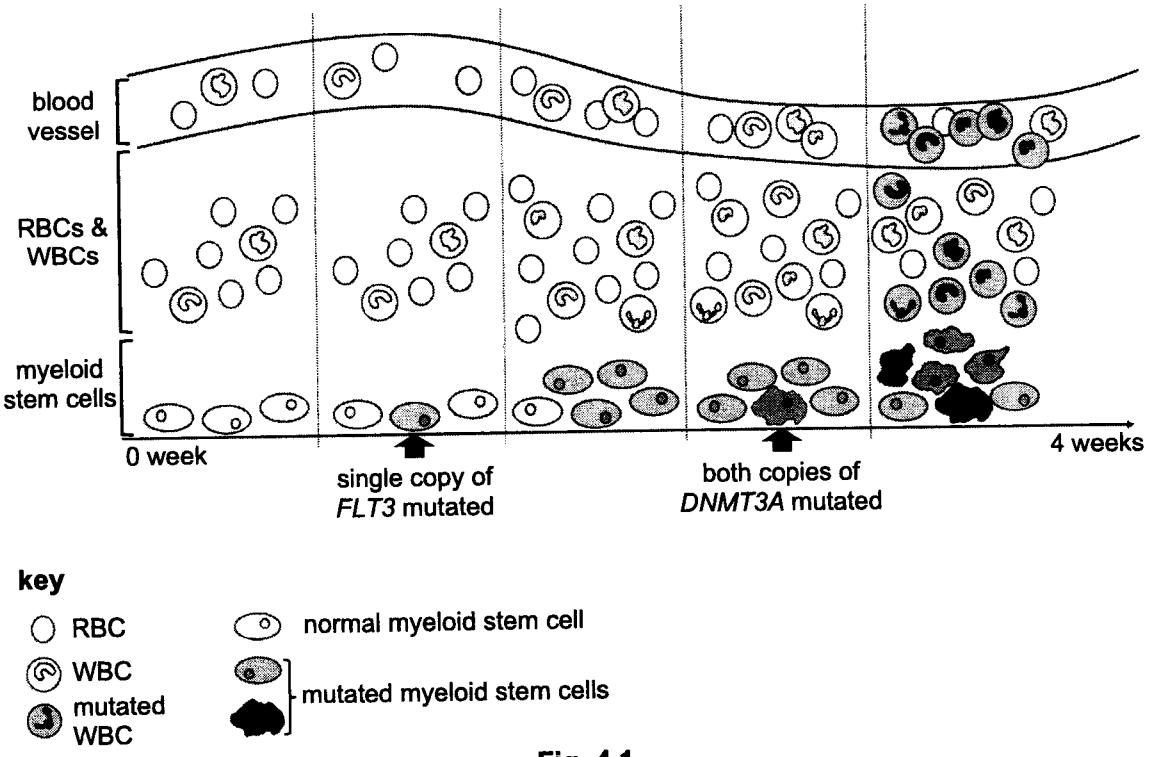


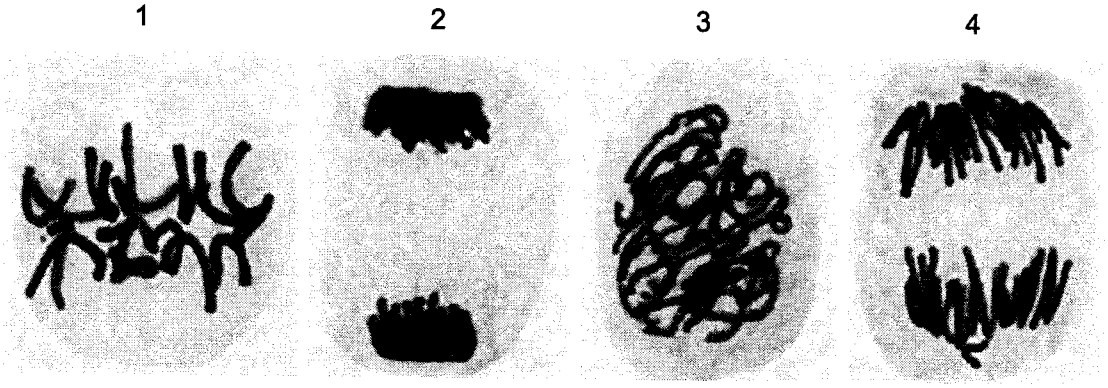
Fig. 4.1

(b) Outline how the mutations in myeloid stem cells result in the changes visible in Fig. 4.1 and the formation of multiple secondary sites of tumour development. [4]

1. ***FLT3* (proto-oncogene) undergoes gain-of-function mutation;**
2. **RTK becomes hyperactive / stimulates excessive cell division (to form more mutated myeloid cells);**
3. ***DNMT3A* (tumor suppressor gene) undergoes loss-of-function mutation;**
4. **Unable to inactivate gene expression of multiple genes / over-expression of many genes;**
5. **Results in uncontrolled cell division;**
6. **Differentiation (of mutated myeloid stem cells) to form more; malfunctioning WBCs than RBCs;**
7. **Metastasised via blood vessel to other parts of body;**
8. **mutated WBCs invade tissue and proliferate excessively;**

Max 4

Myeloid stem cells were obtained from a patient at 0 week. The photomicrographs below show the myeloid stem cells in various stages of nuclear division.



(c) **(i)** State which cell(s) contain twice as many chromosomes as a cell in resting phase from the same patient. [1]

2 and 4;;

(ii) With reference to cells 1, 2 and 4, describe in correct order the behaviour of chromosomes in these stages of nuclear division. [3]

1. **(in cell 1) chromosomes line up in a single row;**
2. **At the metaphase plate;**
3. **(in cell 4) separation of centromeres;**
4. **Sister chromatids separate to form daughter chromosomes;**
5. **Move to opposite poles of the cell;**

6. **(in cell 2) decondensation/uncoiling of chromosome to chromatin;**

[Total: 10]

5 Haemagglutinin (HA) protein of influenza virus is a homotrimeric protein complex. Each subunit is coded for by the *HA* gene present on one of its eight genomic segments.

Fig. 5.1 shows one of the subunits.

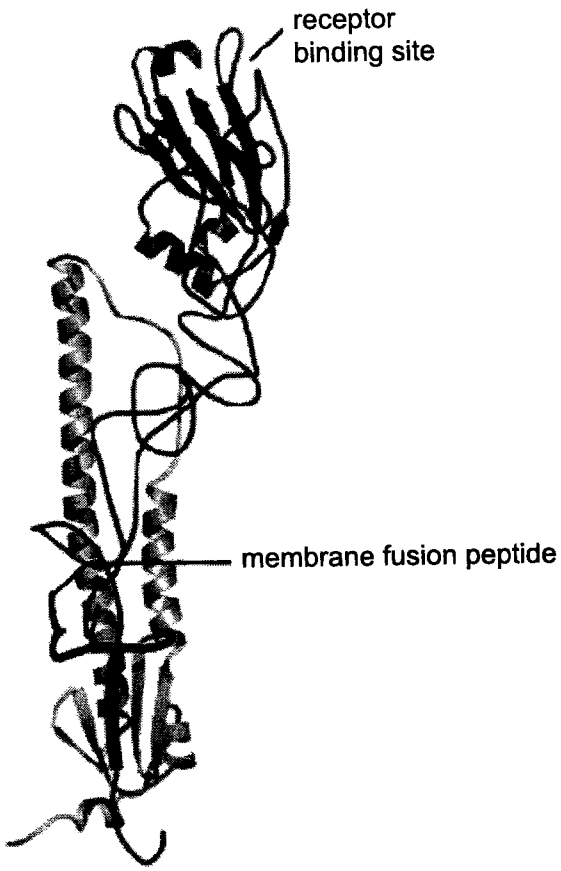


Fig. 5.1

(a) Outline how the identified features in Fig. 5.1 facilitate influenza infection. [3]

1. **Receptor binding site of HA binds to specific glycoprotein receptors/sialic-acid receptors;**
2. **on <u>cell surface membrane</u> of host cell;**
3. **Membrane fusion peptide helps <u>viral envelope</u> to <u>fuse</u>;**
4. **With <u>membrane of endosome</u> (when pH decreases);**
5. **Results in release of ssRNA (-) genome (and viral RNA-dependent RNA polymerase);**
6. **into host cell cytoplasm;**

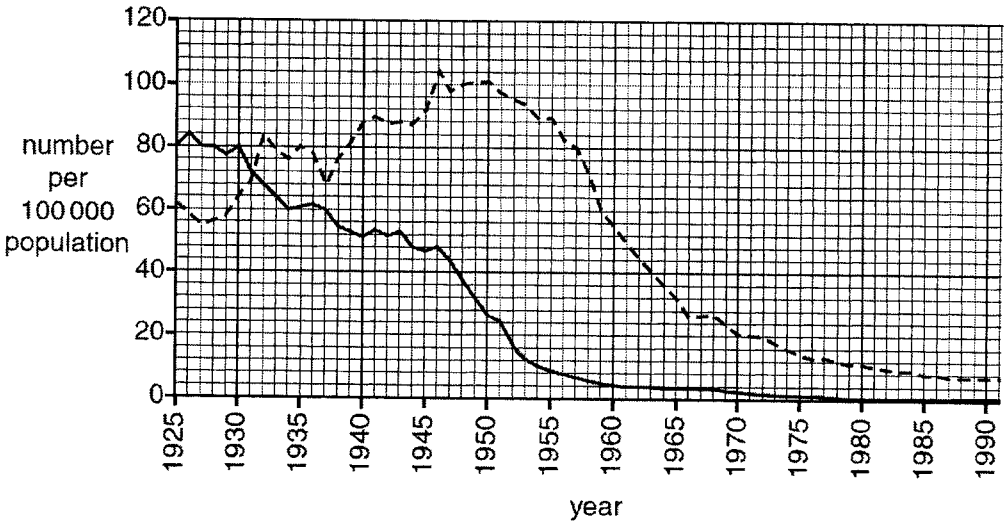
(b) Explain how influenza virus with eight genomic segments can result in a pandemic. [2]

1. **Antigenic shift;**
2. **When two different strains infect <u>same</u> host cell;**
3. **Genetic recombination of RNA segments / rearrangement of genes;**
4. **During viral assembly;**
5. **Emergence of novel strain;**

Max 2

Fig. 5.2 shows the number of deaths from influenza and the number of new cases of influenza from 1925 to 1991 in Country K.

An antiviral drug for influenza was introduced in Country K for widespread use in 1930. The antiviral drug specifically targets non-envelope viral proteins to reduce the influenza's ability to multiply.



key

—— deaths from influenza
------ new cases of influenza

Fig. 5.2

(c) Using the information provided, account for the difference in the ten-year effect of the introduction of the antiviral drug on the number of deaths and number of new cases of influenza. [5]

The introduction of antiviral for influenza, from 1930 to 1940,

1. **Results in a <u>decrease</u> in number of deaths from 80 to 52 per 100 000 population;;**
2. **but an <u>increase</u> in number of new cases from 64 to 88 per 100 000 population;;**

Reduces number of deaths by

3. **targeting RNA-dependent RNA polymerase;**
4. **prevents use of ssRNA (-) as template;**
5. **To synthesise complementary ssRNA (+);**
6. **Reduces/no <u>mRNAs</u> for translation to form viral proteins;**
7. **No <u>templates</u> to make new copies of ssRNA (-) genome;**
8. **to prevent death of epithelial cells/apoptosis in respiratory tract/lungs;**

9. **But does not prevent influenza spread / infection;**
10. **Through respiratory droplets between individuals;**

Max 5

[Total: 10]

6 Gene expression in eukaryotic cells is regulated at multiple levels.

Fig. 6.1 shows the regulation of transferrin receptor (TfR) expression using Iron Response Element-Binding Proteins (IRE-BP). IRE-BP binds to IREs which are loop structures found on the mRNA.

TfRs are present on the cell surface and are involved in the uptake of extracellular iron.

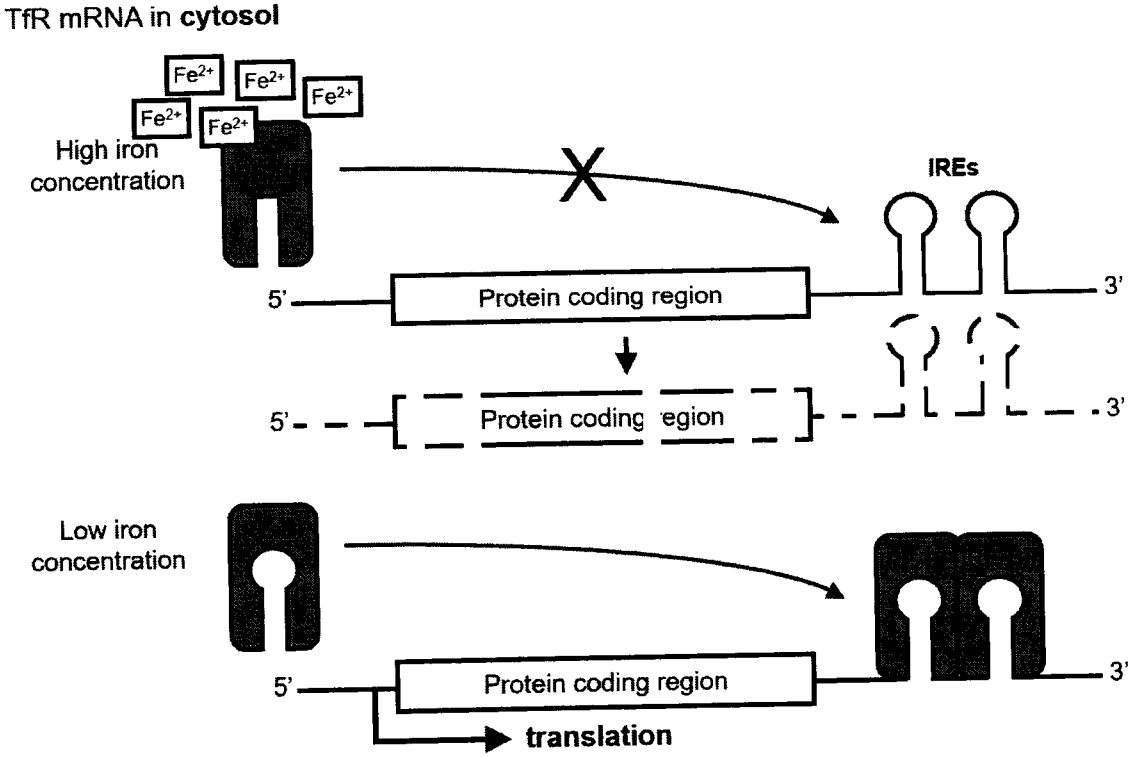


Fig. 6.1

(a) (i) State the level of regulation shown in Fig. 6.1. [1]

Translational level of regulation;;

(ii) Explain how a change in cytosolic iron concentration results in an increased uptake of extracellular iron. [4]

1. **When there is a decrease / low cytosolic iron concentration;**
2. **IRE-BP (is not bound by iron and therefore) is active;**
3. **Recognise and bind to IRE;**
4. **At 3' untranslated region;**
5. **Increases transferrin receptor mRNA stability / half-life;**
6. **mRNA is translated more frequently;**
7. **More transferrin receptor polypeptides synthesised**
8. **TfR proteins are brought to cell surface membrane;**
9. **via secretory vesicles;**

Max 4

Ferritin proteins are involved in the storage of iron taken into the cell by TfRs.

The regulation of ferritin expression is shown in Fig. 6.2.

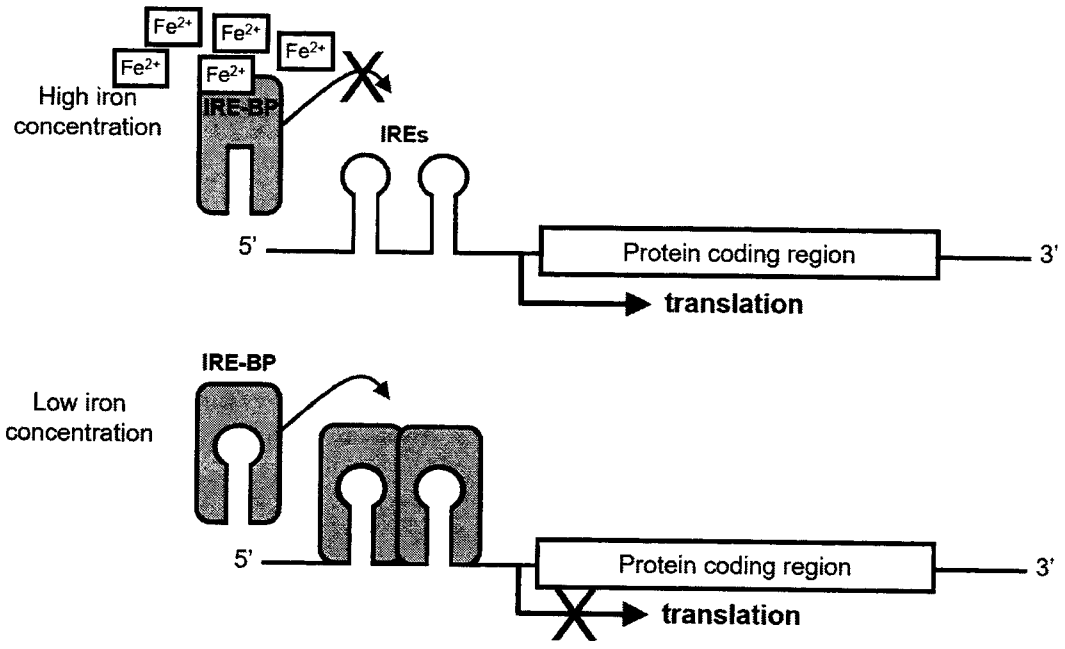


Fig. 6.2

(b) Outline two differences in the regulation of ferritin and TfR expression. [2]

Comparison Feature	Regulation of expression of	
	Ferritin	Transferrin receptor (TfR)
1. effect of cytosolic iron conc. on expression	High [iron] results in increased expression of ferritin / translation of ferritin mRNA	High [iron] results in decreased expression of TfR / translation of TfR mRNA;; A: reverse argument
2. Effect of IRE-BP binding to IRE	Results in translational repression	Results in translational activation;; A: reverse argument
3. Effect on mRNA when no translation occurs	mRNA remains intact	mRNA is hydrolysed / broken down;;
4. Location where IRE-BP binds	In 5' UTR	In 3' UTR;;
5. AVP;;		

Accept any two

At a different level of regulation, activators and repressors act on distal elements to control the rate of transcription.

(c) Describe how activators alter the expression of a gene. [3]

1. **Activators bind to <u>enhancers</u>;**
2. **Recruit DNA bending proteins;**
3. **Resulting in <u>bending of DNA</u>;**
4. **Activators also facilitates transcription initiation complex (TIC) assembly / RNA polymerase & transcription factors binding;**
5. **And facilitates correct positioning of TIC at <u>promoter</u>;**
6. **Leading to increased transcription rate;**

[Total: 10]

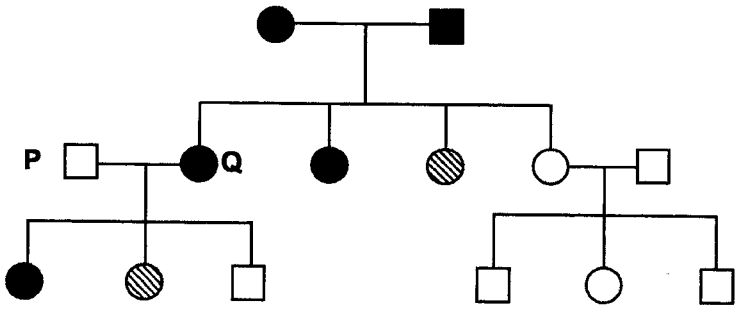
7 Dachshunds have three basic coat types: wire-, smooth- or long-haired. These are affected by two genes, **H/h** and **G/g**. The presence of **H** always results in wire hair. When long-haired dogs are crossed amongst themselves, they always produce long-haired puppies.

Two groups of dogs heterozygous for both genes are crossed and the results from this cross are shown in Table 7.1.

Table 7.1

phenotype	number of offspring
wire-haired	90
smooth-haired	22
long-haired	8

Fig. 7.1 shows the pedigree for inheritance of coat type in Dachshunds.



key

wire-haired female
wire-haired male
smooth-haired female
smooth-haired male
long-haired female
long-haired male

Fig. 7.1

(a) Draw a genetic diagram in the space below showing the cross between **P** and **Q**.

Use the symbols given above and show all possible genotypes and phenotypes for the offspring of these parents. [4]

Parental phenotypes	**wire-haired female dog**	**x**	**long-haired male dog**	
Parental genotypes	**HhGg**	**x**	**hhgg**	;;
Gametes	(HG) (Hg) (hG) (hg)	**x**	(hg)	;;

Punnett square	(HG)	(Hg)	(hG)	(hg)
(hg)	**HhGg**	**Hhgg**	**hhGg**	**hhgg**

	wire-haired	wire-haired	smooth-haired	long-haired
Offspring phenotypic ratio	2:		1:	1

offspring genotypes;;

offspring phenotypes;;

minus ½ for each mistakes

(b) In any genetic cross, the observed results are usually different from the expected results.

Suggest **one** reason why such a difference may occur, referring only to events after meiosis. [1]

1. **random fusion of gametes;;**
2. **differential survival of sperm/ ova (with particular genotypes);;**
3. **differential survival rate of zygotes (with particular genotypes);;**

any one

Other than variation in coat type, dogs also display variation in their coat colours.

Table 7.2 shows the colour scale and number of dogs showing each of the phenotypes.

Table 7.2

colour						
colour scale	1	2	3	4	5	6
number of dogs	114	216	305	350	288	133

(c) Distinguish between the two types of variation shown in coat type and coat colour in dogs. [3]

	Discontinuous variation (coat type)	Continuous variation (coat colour)
1	**discrete phenotypic classes ;;**	**a range of phenotypes** **R: no discrete class**
2	**Phenotype is controlled by one or two major genes;;**	**Phenotype is controlled by many genes (>2)**

3	**The environment has a small effect on the phenotype;;**	**The environment has a large effect on the phenotype**
4	**Effect of individual genes can be observed;;**	**Effect of individual polygenes cannot be observed**

[Total: 8]

8 (a) (i) Using the *trp* operon as an example, explain what is meant by negative gene regulation. [1]

1. active form of the *trp* repressor;

2. turns *trp* operon off;

(ii) Explain why a single base-pair insertion in the regulatory gene of the *trp* operon may lead to an over-production of tryptophan. [5]

1. leads to frameshift / alteration of reading frame;

2. change in mRNA codon sequence from point of insertion;

3. change in amino acid sequence;

4. polypeptide folds differently;

5. change in 3-dimensional conformation of *trp* repressor;

OR

1. leads to frameshift / alteration of reading frame;

2. resulting in a stop codon;

3. leads to premature termination of translation;

4. producing truncated polypeptide;

5. results in non-functional *trp* repressor / no *trp* repressor produced;

OR

1. (insertion at promoter leads to) change in promoter sequence;

2. change in shape of promoter sequence;

3. shape of promoter sequence no longer complementary to DNA binding site of RNA polymerase / RNA polymerase cannot bind to promoter sequence;

4. no transcription initiation complex assembled;

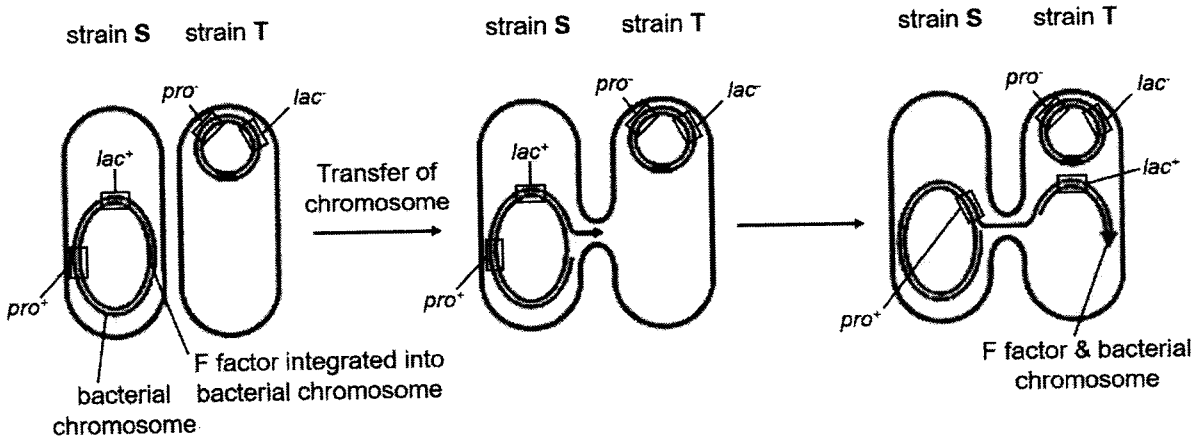
5. no transcription of regulatory gene;

6. **tryptophan unable to bind to allosteric site of *trp* repressor;**
7. ***trp* repressor always in the inactive form;**
8. ***trp* operon always switched on;**

   A: *trp* repressor cannot bind to the operator
9. **RNA polymerase binds to promoter continually;**
10. **for transcription and translation of structural genes to produce more enzymes involved in tryptophan synthesis;**

An investigation was conducted to study gene transfer between two strains of *E. coli*, **S** and **T**. Bacterial cells of strain **S** are able to synthesise proline and metabolise lactose, while bacterial cells of strain **T** are unable to carry out both processes.

Fig. 8.1 shows the process of gene transfer during the investigation.



key

pro$^+$: gene for proline synthesis present

lac$^+$: gene for lactose metabolism present

pro$^-$: gene for proline synthesis absent

lac$^-$: gene for lactose metabolism absent

Fig. 8.1

(b) (i) With reference to Fig. 8.1, describe the gene transfer process between *E. coli* strains **S** and **T**. [3]

1. **Bacterial conjugation;**
2. **strain S (F^+ cell) synthesises a <u>sex pilus</u>;**
3. **and <u>makes contact</u> with recipient F^- cell from strain T;**
4. **forming a <u>temporary mating bridge</u> between the two cells;**
5. **transfer of <u>bacterial chromosome containing F factor</u>;**

6. including *pro*$^+$ and *lac*$^+$ genes to recipient cell;

The two strains were mixed together in suspension in two separate experiments, for an incubation period of 10 minutes and 60 minutes respectively. At the end of the incubation, bacterial cells were then plated on an agar medium containing lactose and deficient in proline.

Table 8.1 shows the results of the two experiments.

Table 8.1

E. coli strain	colonies present in nutrient agar	
	after 10 minutes incubation	after 60 minutes incubation
S	94	95
T	42	93

(ii) Explain why there is a larger number of *E. coli* strain **T** colonies when the two strains were incubated together for 60 minutes as compared to 10 minutes. [2]

1. *lac*$^+$ gene is transferred followed by *pro*$^+$ gene;

2. Longer time for conjugation process;

3. recipient cell can acquire the *pro*$^+$ gene;

4. to synthesise proline for protein synthesis;

[Total: 11]

9 Fig. 9.1 shows the phylogenetic relationship of four different species of snapping shrimps obtained based on comparison of nucleotide sequence.

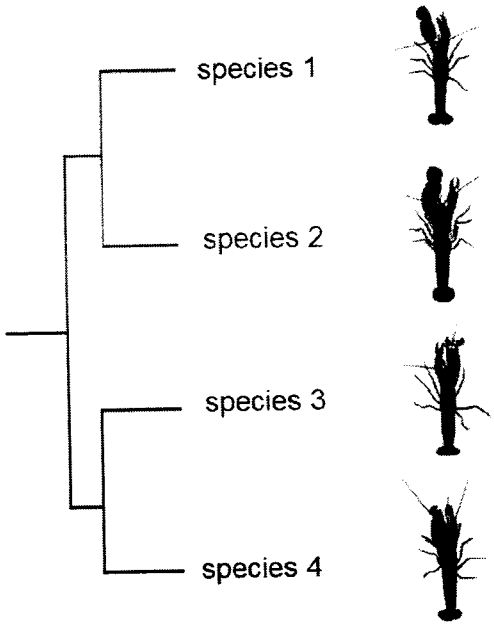


Fig. 9.1

(a) Describe how molecular data was used to construct the phylogenetic tree. [2]

1. **Comparison of DNA sequences of the same gene / homologous region;**
2. **from the different species of snapping shrimps;**
3. **High homology indicates that they are more closely related / share a more recent common ancestor (vice versa);**
4. **Indicated by a closer distance on phylogenetic tree;**

Twenty million years ago, there was a gap between the continents of North America and South America through which the waters of the Caribbean Sea and Pacific Ocean flowed freely.

The snapping shrimps lived in this area between North America and South America.

About 3 million years ago, volcanic activity and sedimentation formed a narrow strip of land, Isthmus of Panama, joining North America and South America.

Fig. 9.2 shows the current distribution these four species.

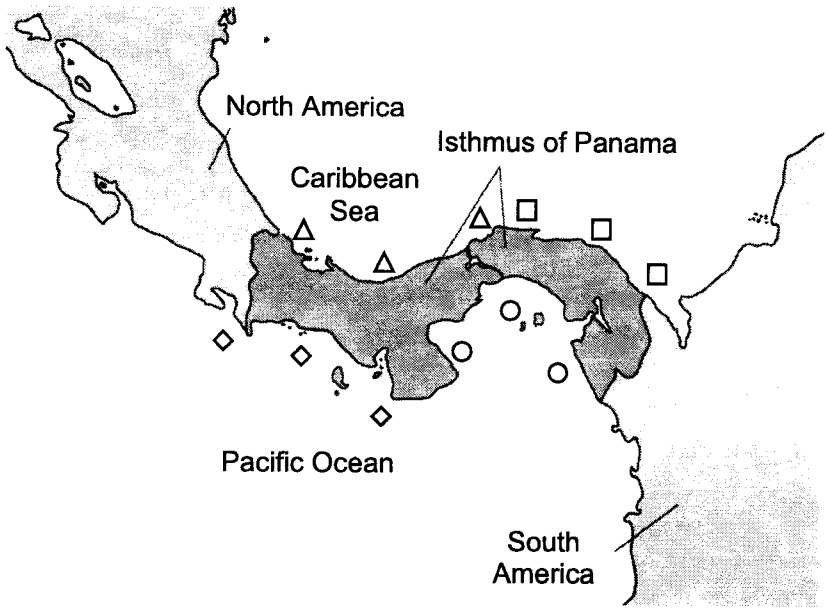


Fig. 9.2

Using information from Fig. 9.1 and Fig. 9.2,

(b) **(i)** explain how biogeography and anatomical homology of snapping shrimps support Darwin's theory of evolution. [4]

1. **(Fig. 9.2) more closely related species are found closer together;**
2. **compared with other species living in different areas;**
3. **evidence: species 1 and 2 are more closely related than with species 3 or 4;**
4. **(Fig. 9.1) similar phenotype shows common ancestry;**
5. **variations in phenotypes of snapping shrimps;**
6. **different selection pressures favouring different phenotypes;**
7. **evidence: variation in the claws;**
8. **(Fig. 9.2) allopatric speciation;**
9. **Due to no interbreeding between species 1 and 2 with species 3 and 4, and no gene flow;**
10. **evidence: separation by Isthmus of Panama**

(ii) suggest why breeding between species 1 and species 2 is possible. [1]

1. **The habitat of species 1 and 2 overlaps / proximity (Fig 9.2);;**
2. **Species 1 and 2 are phenotypically similar (Fig 9.1);;**

Any one

(c) Explain how fossil records can also be used as evidence for evolutionary change of species. [2]

1. **fossils show progressive changes in structure of organisms over time**
2. **showing intermediate forms;**
3. **fossils can be dated in chronological order;**
4. **some species disappeared showing extinction (as selected against);**
5. **new species appeared at a later stratigraphic level indicating speciation occurs;**

[Total: 9]

10 (a) Describe the role of T lymphocytes in the immune response against *Mycobacterium tuberculosis* infection. [3]

1. **Receptors on naïve helper T lymphocytes; in the lymph node**
2. **recognise antigens displayed by antigen presenting cell;**
3. **and are activated;**
4. **undergo clonal expansion;**
5. **migrate to the site of infection;**
6. **proliferate and surround tubercle bacilli;**
7. **forming a granuloma;**

(b) Explain **two** ways in which immunoglobulin differ from penicillin in response to infections by pathogen. [2]

Feature	Immunoglobulin	Penicillin
D1: Origin;;	Produced naturally by body's immune system	Produced by *Penicillium* mould
D2: Target;;	Effective against bacteria and viruses	Effective only against bacteria
D2: Function;;	Binds to specific pathogens to neutralise them / bring about opsonisation	Interferes with interpeptide linking of peptidoglycan, preventing cell wall synthesis

[Total: 5]

11 El Niño phenomenon is characterised by increased temperatures in the oceans.

(a) Explain how El Niño affects the corals. [2]

1. **El Niño events trigger coral bleaching;**
2. **Rise in temperature causes the coral to expel the zooxanthellae / cause death of zooxanthellae;**
3. **Without nutrients and oxygen provided by zooxanthellae;**
4. **causing death of corals;**

(b) **(i)** Describe how **one** human activity increases global sea temperatures. [1]

1. **burning of fossil fuels/ deforestation /increase consumption of meat;**
2. **increased CO_2 /greenhouse gas emissions;**

(ii) Suggest how reduction in the diversity of coral reefs reduces biodiversity. [2]

1. **loss of habitat / refuge / spawning & nursing ground, for other marine species;;**

   or

   loss of food source, affecting food chain;;
2. **predation/death, leading to extinction of species;;**

[Total: 5]

RIVER VALLEY HIGH SCHOOL

JC 2 PRELIMINARY EXAMINATION

CANDIDATE NAME									
CENTRE NUMBER	S					CLASS	21J	INDEX NUMBER	

BIOLOGY **9744/03**

Paper 3 Long Structured and Free-response Questions **13 September 2022**

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.

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.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	**25**
2	**15**
3	**10**
Section B	**25**
Total	

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

Section A

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

1 In plants, photosynthesis takes place in chloroplasts, which contain different types of photosynthetic pigments.

(a) Describe the role of different types of photosynthetic pigments in the photoactivation of chlorophyll. [3]

1. Accessory pigments;
2. absorb photons of light;
3. relay energy by resonance to reaction centre;
4. increase the range of wavelength of light absorbed;
5. special pair of chlorophyll a;
6. pass electrons to primary electron acceptor;
7. to initiate electron flow down ETC to drive photophosphorylation;

Scientists suggested that chloroplasts may have originated from prokaryotic cells that continue to function after becoming engulfed by primitive eukaryotic cells.

(b) Other than genomic features, describe **two** evidence that support this hypothesis. [2]

1. Possesses 70S ribosomes;;
2. Chloroplast multiply by binary fission;;
3. Chloroplast surrounded by double membrane;;

Any two

Saline soils, with high concentration of sodium ions (Na^+), are a major problem in many parts of the world. Most plant crop species are unable to tolerate high concentrations of sodium ions.

An experiment was conducted to determine the effect of salt (NaCl) concentration on the overall light-dependent reactions and separately on photophosphorylation activities involving photosystem I and photosystem II.

Table 1.1 shows the results of this experiment on a plant crop species.

Table 1.1

concentration of NaCl / mol dm^{-3}	photosynthetic activity / % activity relative to activity at 0 mol dm^{-3} of NaCl		
	photosystem I	photosystem II	overall light-dependent reactions
0.0	100	100	100
0.1	100	58	80
0.2	98	51	59
0.3	101	35	57
0.4	99	32	39
0.5	100	17	35

Adapted from El-Sheekh MM, Journal of Plant Physiology, 2004

(c) With reference to activities involving the photosystems, predict and explain what will happen to the growth of the plant as salt concentration continues to increase above 0.5 mol dm^{-3}. [3]

1. reduced/no growth;
2. (PSI) cyclic photophosphorylation produces only ATP;
3. reduced non-cyclic photophosphorylation (due to low PSII activity);
4. insufficient NADPH production;
5. for reduction of bisphosphoglylcerate;
6. reduced production of glucose/carbohydrates;
7. no energy for cell division/DNA replication/transcription/translation;

max 3

Recently one group of Na^+ transporters, HKT1, in root cells was found to be important for salt tolerance in plants. HKT1 actively removes Na^+ from the xylem sap. This prevents transport to and accumulation of Na^+ in the shoot.

Scientists have successfully isolated *HKT1* gene from salt-tolerant plants to create a *HKT1* gene construct as shown in Fig. 1.1.

key

pro – root cell-specific promoter

ter – termination sequence

HKT1 – gene from salt-tolerant plant

Fig. 1.1

HKT1 gene construct was then used to produce salt-tolerant transgenic plant. A transgenic plant refers to a plant whose DNA is modified by inserting a gene from another source.

Fig. 1.2 shows the process of how salt-tolerant transgenic plants is formed.

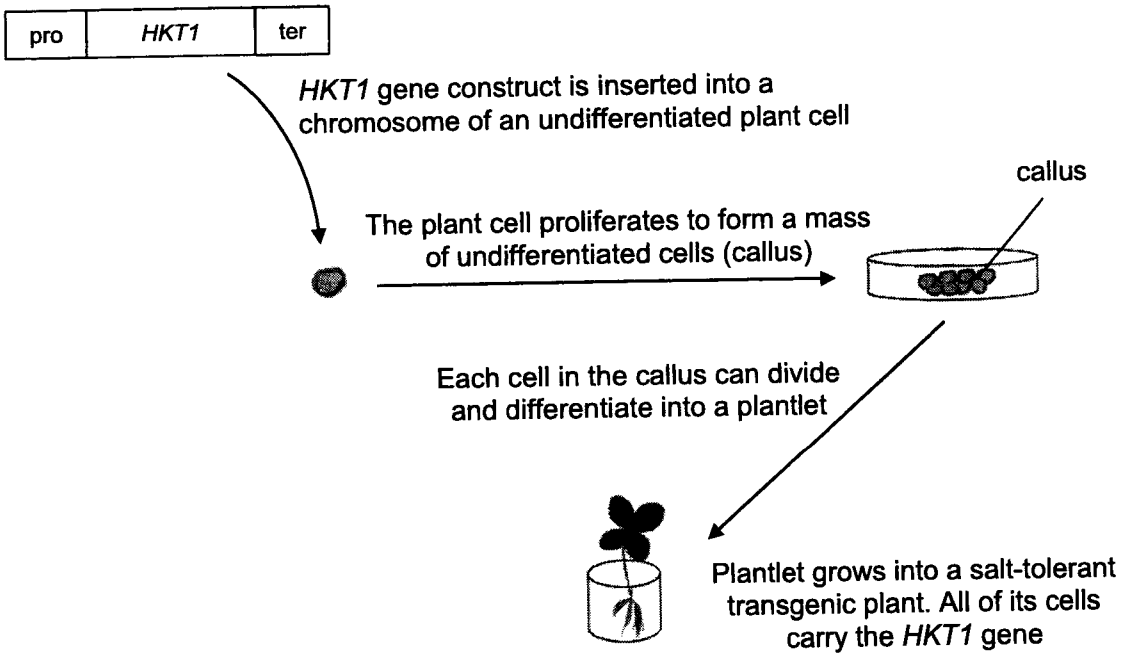


Fig. 1.2

(d) (i) Explain why the root cell-specific promoter was included in the *HKT1* gene construct. [2]

1. role of promoter is for binding of RNA polymerase/transcription factors;
2. to initiate transcription <u>*HKT 1* gene</u>;
3. (expression is) only;
4. in the root cells; *Reject: plant cell*

(ii) Cells from the callus in Fig. 1.2 are similar to zygotic stem cells in humans. [2]
Explain why these callus cells can be used to produce the entire plant.

1. The cell contains all the DNA/genes/genetic material of the plant;
2. The cell is totipotent;
3. Can divide to form more cells;
4. the cells can differentiate into any cell types;
5. under appropriate condition to form a whole plant;
6. selective gene expression;

Screening was conducted to verify that the 1.7 kb *HKT1* gene has been inserted into the transgenic plant's chromosome. The screening consisted of the following stages:

- DNA was isolated from the transgenic plant.
- The DNA was cut with restriction enzyme and the fragments produced were separated by gel electrophoresis.
- Detection of *HKT1* gene was then carried out.
- Fig. 1.3 shows the region where the radioactive probe binds to on the plant chromosome. The location of restriction site is indicated by *.

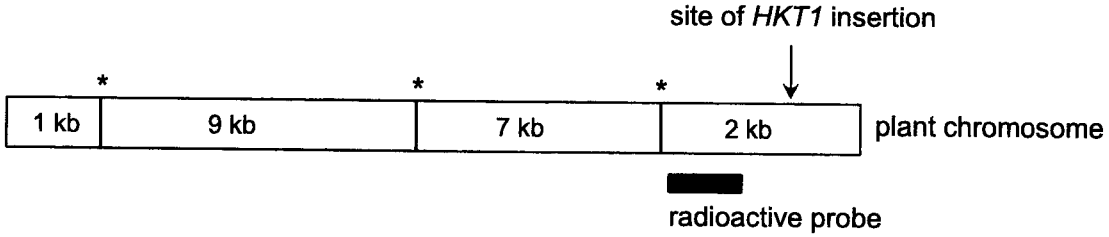


Fig. 1.3

(e) Outline how detection of *HKT1* gene was carried out. [3]

In Southern blotting

1. DNA becomes single stranded;
2. it is denatured by alkaline solution;
3. DNA bands on gel is transferred to nitrocellulose membrane by blotting;

In nucleic acid hybridisation

4. membrane is incubated with radioactive probe;
5. membrane exposed to X-ray film;
6. the size of band correspond to 3.7kb;

An experiment was performed on three groups of transgenic plants (T1, T2 and C) to investigate the effect of *HKT1* gene on plant growth in soils of different salinity. The three groups of plants were as follows:

T1	Transgenic plants containing one copy of the *HKT1* gene
T2	Transgenic plants containing two copies of the *HKT1* gene
C	Control plants without *HKT1* gene

The fresh weight of the plants was determined one week after growing in soils containing different concentrations of NaCl and is shown in Fig.1.4.

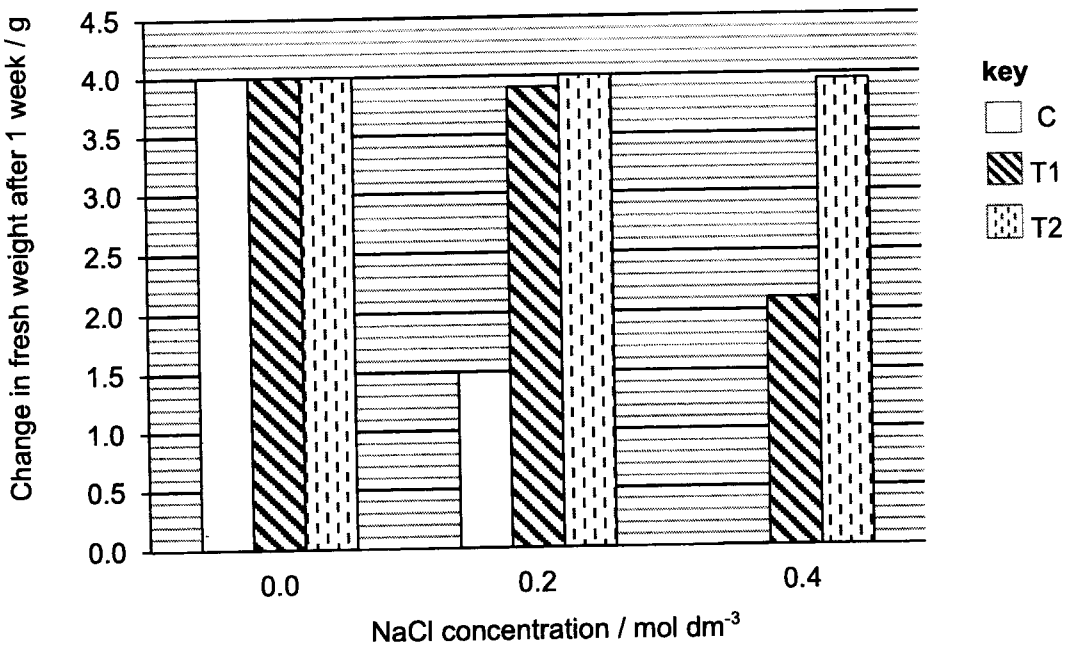


Fig. 1.4

(f) (i) With reference to Fig. 1.4, describe the effect of *HKT1* gene on the change in fresh weight of plants at each concentration of NaCl. [3]

At 0 mol dm^{-3} NaCl,

1. Presence of HKT1 gene and increase in number of copies of HKT1 gene has the same change in fresh weight at 4g;;

At 0.2 mol dm^{-3} NaCl,

2. increase in number of copies of HKT1 gene from 1 to 2, similar change in fresh weight at 4g;
3. which is higher than 0 copy of HKT1 at 2g;

At 0.4 moldm^{-3} of NaCl,

4. increase in number of copies of HKT1 gene from 1 to 2, change in fresh weight increases from 2g to 4g;
5. which is higher than 0 copy of HKT1 at 0g;

(ii) explain the difference in the change in fresh weight of T1 and T2 plants. [1]

1. More copies of *HKT1* gene for transcription in T2 than T1;
2. More transporters to remove Na^+;

Fig. 1.5 is a schematic representation of the regions present in the HKT1 transporter, a membrane bound protein.

key

transmembrane (hydrophobic) regions

hydrophilic regions

ATP-binding site

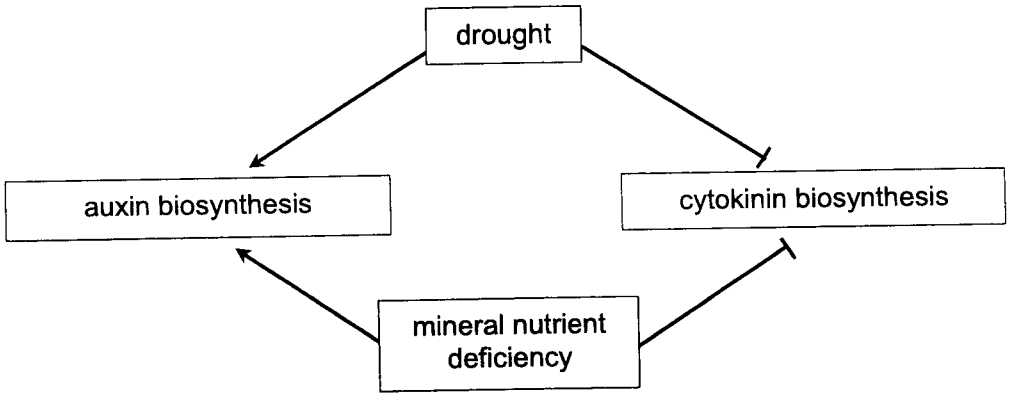
Fig. 1.5

(g) Explain how the different regions shown in Fig. 1.5 allow HKT1 transporter to perform its function. [3]

Structure	Function
Eight transmembrane regions are hydrophobic	form hydrophobic interactions to hold the receptor in the membrane;;
Hydrophilic regions	form the hydrophilic pathway for charged Na^+;;
ATP-binding site	for hydrolysis of ATP to provide energy for active transport/ change shape of transporter;;

Certain plants can adapt to changes in environment by changing the amount of plant hormones, auxin and cytokinin, produced.

Fig. 1.6 shows the effect of drought and mineral nutrient deficiency on auxin and cytokinin biosynthesis in these plants.



key

→ stimulates

⊣ inhibits

Fig. 1.6

The effects of various ratios of auxin to cytokinin on plant growth are summarised in Table 1.2. The extent of growth is shown on a scale increasing from + to +++.

Table 1.2

ratio of auxin to cytokinin	growth of shoot	growth of root
10:0	no growth	+++
8:2	no growth	++
6:4	no growth	+
5:5	no growth	no growth
4:6	+	no growth
2:8	++	no growth
0:10	+++	no growth

(h) Using Table 1.2 and Fig. 1.6, explain how these plants can survive under conditions of drought and mineral nutrient deficiency. [3]

1. Both inhibit cytokinin biosynthesis;
2. less resources used;
3. no shoot growth;
4. activate auxin biosynthesis;
5. trigger root growth;
6. longer roots to increase water and mineral nutrients absorption from the soil;

[Total: 25]

2 An open reading frame (ORF) is the DNA sequence between a start and stop codon. ORFs are commonly used to predict the presence of genes.

Fig. 2.1 shows the same sample sequence and three possible ORFs due to different possible reading frames. Start codons are underlined and bolded, and stop codons are underlined and italicised.

1 **ATG** CAA TGG GGA AAT GTT ACC CTT ATT GAG GTA AGA CAG ATT *TAA*
2 A TGC ATT GGG GAA **ATG** TTA CCC TTA TTG AGG *TAA* GAC AGA TTT AA
3 AT GCA **ATG** GGG AAA TGT TAC CCT TAT *TGA* GGT AAG ACA GAT TTA A

Fig. 2.1

(a) Using your knowledge of genomic organisation, explain why the use of ORF is more effective in predicting genes in prokaryotic genome than in eukaryotic genome. [1]

In prokaryotic genome

1. Absence of introns;
2. which may contain the triplets coding for start or stop codon;

Accept reverse argument

(b) Outline how the ORF region of sequence **2** may be amplified from a colony of bacteria cells. [4]

1. Extract DNA from cells via homogeniser / lysis;

Perform Polymerase Chain Reaction:

2. At 94°C; denaturation of dsDNA / separation of dsDNA to single-strands;
3. At 65°C; annealing of primers 3'-AAGGGGTTAGC-5'; and 5'-TTAAATCTGTC-3';

   [A: longer primer but within given seq., and also opp. strands]
4. At 72°C; *Taq* polymerase synthesises complementary DNA strand / extension of primers;

max 4

Researchers investigated the possible relationships of ORFs and non-coding sequences with the prokaryote genome size.

Fig. 2.2 shows the relationship between **number of ORFs** and genome size.

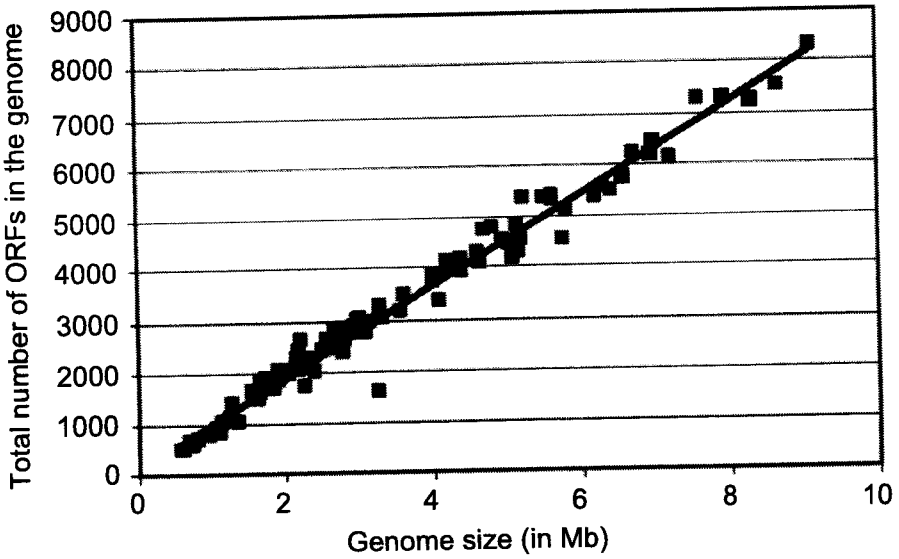


Fig. 2.2

Fig. 2.3 shows the relationship between the **size of non-coding DNA** and genome size.

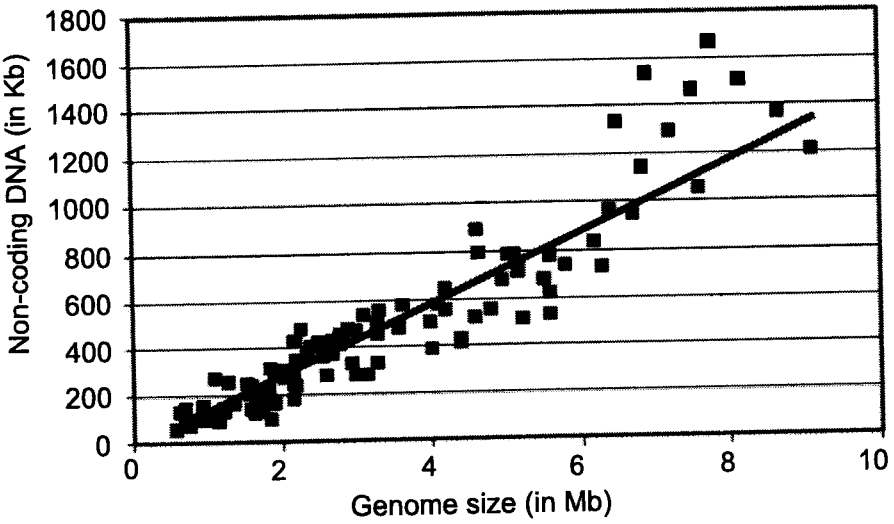


Fig. 2.3

Adapted from Konstantinidis and Tiedje, PNAS, 2004

(c) (i) Put a tick (✓) in one box to indicate which relationship shows a weaker correlation between the two variables investigated. [1]

Fig. 2.2 ☐ Fig. 2.3 ☑

(ii) With reference to your answer in **(c)(i)**, evaluate the extent to which the variable investigated can predict the genome size of the prokaryote. [3]

1. When size of non-coding DNA increases, the genome size increases / reference positive correlation;
2. Prediction at smaller genome size possible due to strong correlation;
3. As data clustered around trendline;
4. But cannot be used to predict genome size for larger genome size / weak correlation for larger genome size;
5. Many data points above trendline;
6. Quote data from Fig. 2.3;;

   e.g. to predict for genome size 8 Mb, should be 1200 Kb non-coding DNA but instead 1500 Kb was present

max 3

Obligate endocellular parasites are one of the smallest genome-sized prokaryotic species.

Fig. 2.4 shows how symbiotic relationship with their host affected genome size in terms of the number of genes and non-coding sequences.

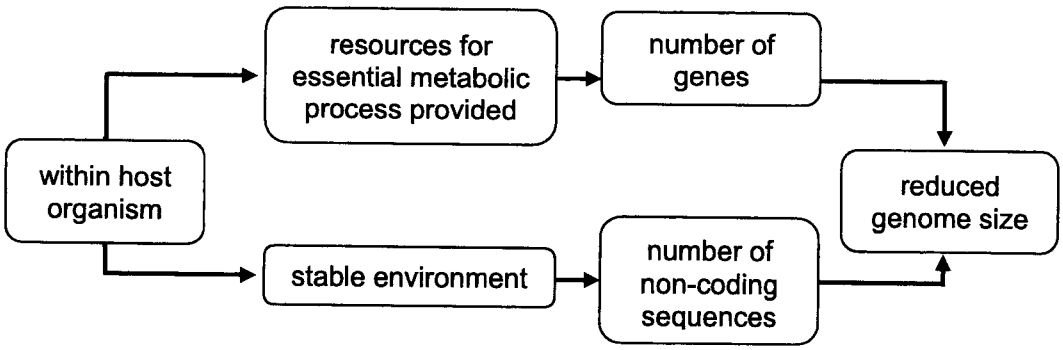


Fig. 2.4

(d) With reference to Fig. 2.4, explain how symbiotic relationship of obligate endocellular prokaryotes with host organisms results in a reduced genome size. [3]

Within the host organism, the prokaryotes

1. Loses genes coding for biosynthesis of resources;
2. Ref resources eg. amino acids, nucleotides etc.;
3. As can be taken up from host;
4. Loses non-coding sequences;
5. Such as (extensive) regulatory sequences;

6. Due to reduced need to respond to changes in environment;

Compared with RNA viruses, prokaryotes have a lower mutation rate.

(e) **(i)** Name an RNA virus. [1]

Influenza virus / Human immunodeficiency virus;;

(ii) Explain why prokaryotes have a lower mutation rate compared to RNA viruses. [2]

1. Prokaryotes have <u>double-stranded DNA</u>;
2. Able to use other strand as template to repair DNA sequence;
3. DNA polymerase has proof-reading ability;
4. Able to excise and replace incorrect nucleotide added at 3' end;

[Total: 15]

3 Rattlesnakes contain a tailshaker muscle which causes a rattling sound upon contraction.

(a) Explain how oxygen uptake by muscle cells changes when the tailshaker muscle contracts. [3]

1. Oxygen uptake increases;
2. More oxygen needed as final electron acceptor of ETC;
3. to maintain electron flow along ETC;
4. more free energy released to pump proton (from matrix to intermembrane space);
5. generate steeper proton gradient across inner mitochondrial membrane;
6. movement of H^+ coupled to increased phosphorylation of ADP to ATP (producing more ATP for muscle contraction);

An investigation was conducted to study the tailshaker muscle and a mammalian muscle.

Fig. 3.1 shows the rate and sources of ATP supply in the tailshaker muscle and the mammalian muscle during contraction.

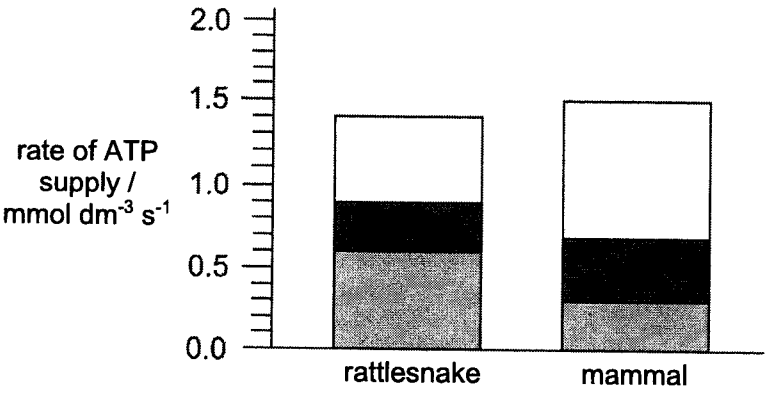


Fig. 3.1

(b) Using Fig. 3.1, calculate the amount of ATP supplied by anaerobic respiration in the tailshaker muscle in 1 minute.

Show your working clearly. [2]

Amount of ATP supplied in tailshaker muscle = 0.6 x 60;;

= 36 mmol dm^{-3};;

Table 3.1 shows the changes in activities in the two muscles during contraction, relative to when the muscles are at rest.

Table 3.1

	change in blood flow / ml min^{-1}	change in O_2 uptake by muscle cells / µmol g^{-1}	change in lactate content in blood / mmol dm^{-3}
tailshaker muscle during rattling	+9.2	+0.148	+2.0
mammalian muscle during contraction	+5.0	+0.180	+5.0

Adapted from Kemper et al., PNAS, 2001

(c) Using the data from Table 3.1, explain why the tailshaker muscle is able to rely on anaerobic respiration for a longer time during rattling as compared to the mammalian muscle. [2]

1. Greater increase in blood flow in tailshaker muscle (+9.2 ml min^{-1}) as compared to that in mammalian muscle (+5.0 ml min^{-1});
2. Lactate produced via lactate fermentation can be transported away quickly;
3. smaller increase in blood lactate content in tailshaker muscle (+2.0 mmol dm^{-3}) as compared to that in mammalian muscle (+5.0 mmol dm^{-3})
4. reduced accumulation of lactate prevents muscle fatigue;

Over the years, climate change has resulted in a rise in mean global temperatures. In Southwestern Europe, scientists collected data on the long-term population trends of a snake species and the rise in temperature in the region from 1980 to 2020, as shown in Fig. 3.2.

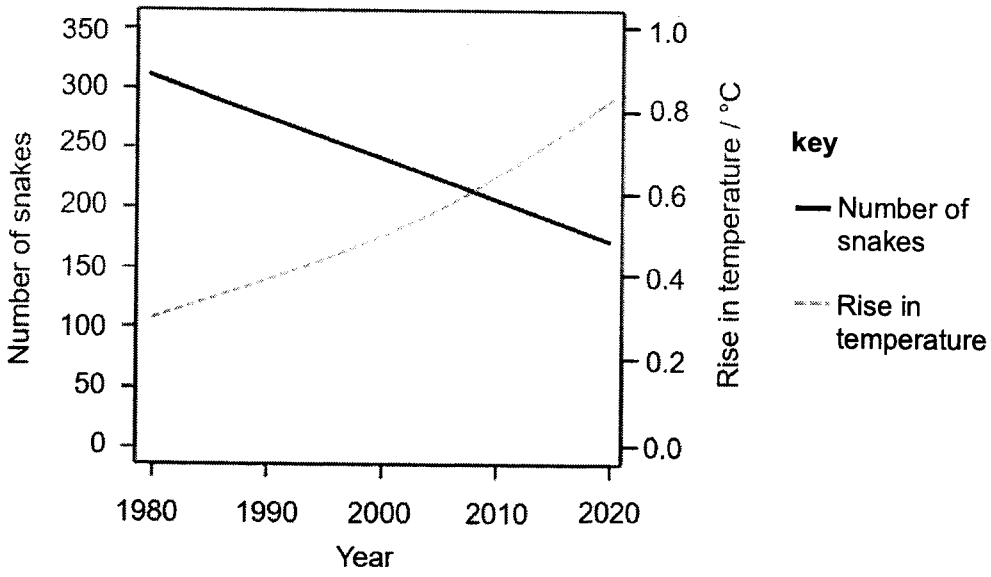


Fig. 3.2

(d) (i) With reference to Fig. 3.2, describe the impact of the rise in temperatures in Southwestern Europe on the number of the snake species. [1]

1. As the rise in temperature increases from 0.3°C to 0.82°C (from 1980 to 2020);
2. the relative number of snakes decreased from 310 to 175;

(ii) Suggest reasons for the change in number of snakes from 1980 to 2020. [2]

1. Migration of snakes towards cooler environments where temperatures are optimal for metabolism and survival;;
2. Death of snakes due to high temperatures which denature enzymes essential for survival;;
3. AVP;;

[Total: 10]

Section B

4 (a) Outline the functions of proteins involved in DNA replication and DNA condensation to form a chromosome in eukaryotes. [15]

Roles of proteins in DNA replication

1. Helicase;
2. catalyses the breakage of hydrogen bonds between complementary bases;
3. causing the 2 parental DNA strands to separate;
4. single-strand DNA binding proteins;
5. bind to the 2 separated parental DNA strands;
6. to stabilise the single-stranded DNA formed / replication fork;
7. Topoisomerase;
8. creates transient break by nicking a strand of DNA;
9. helps to unwind double helix ahead of replication fork;
10. prevents supercoiling of DNA;
11. Primase;
12. catalyses synthesis of RNA primer in the 5' to 3' direction;
13. DNA polymerase (III);
14. adds nucleotides to the free 3' end of the RNA primer/existing strand;
15. catalyses the formation of phosphodiester bonds between the nucleotides;
16. another DNA polymerase (I);
17. replaces RNA nucleotides of all the RNA primers with DNA nucleotides;
18. DNA ligase;
19. seals the gaps between DNA fragments;

Roles of proteins in packing of DNA to form chromosome

20. Histone proteins;
21. e.g. H2A, H2B, H3 and H4;
22. assemble to form histone octamer / core;
23. upon which DNA is wound around;
24. to form nucleosome;
25. Histone H1;
26. involved in coiling of 10 nm nucleosome fibre;
27. to produce 30 nm chromatin fibre / solenoid;
28. non-histone chromosomal proteins;
29. form scaffold involved in condensing 30 nm chromatin;
30. into looped domains, forming 300 nm fibre;

QWC: Describes roles of at least 2 proteins in DNA replication and 2 proteins in packing of DNA to form chromosomes;;

(b) Describe the structure of viruses and explain the significance of viruses in evolution. [10]

Structure of viruses

1. Contains viral genome;
2. DNA or RNA;
3. linear or circular;
4. single-stranded or double-stranded;
5. can be of positive (+) or negative (-) configuration;
6. Contains capsid (protein coat);
7. comprises large number of protein molecules called capsomeres;
8. arranged in a precise, highly repetitive and highly symmetrical pattern around nucleic acid;
9. helical / icosahedral / more complex shapes;
10. Some viruses contain viral envelope;
11. phospholipid bilayer with embedded glycoproteins;

Significance of viruses in evolution

12. Viruses can causes diseases;
13. e.g. influenza / AIDS / Covid-19 / cancer;
14. **hence act as a selection pressure;**
15. individuals with viral diseases are at a selective disadvantage;
16. will be selected against;
17. healthy individuals are at a selective advantage;
18. will be selected for;
19. can survive and reproduce;
20. and pass on alleles to offspring;
21. increasing allele frequency of normal genes in the population;

22. **Viruses introduce genetic variation;**
23. via bacterial transduction;
24. e.g. generalised / specialised transduction;
25. bacteriophages are transducing phages;
26. carry bacterial genes from one host cell to recipient cell;
27. allow for genetic recombination;

28. **Viruses can cause rapid genetic changes to organisms;**
29. increasing rate of accumulation of mutations;
30. increasing rate at which evolutionary changes occur;

QWC: Describes at least 2 structures of viruses and explains the significance of viruses in evolution;;

[Total: 25]

5 (a) Outline the functions of proteins involved in processes which lower high blood glucose concentration. [15]

1. Insulin;
2. as ligand secreted by β-cell of iset of Langerhans;
3. to transmit messages between cells;
4. to activate responses in liver cell/muscle cells;

5. Tyrosine kinase receptor (RTK);
6. as receptor on cell surface membrane;
7. for ligand binding to activate signaling pathway;
8. only allow complementary shape ligand to bind to binding site on receptor;
9. determines specificity of signaling pathway;

10. Tyrosine kinase;
11. as enzymes to catalyse phosphorylation / to activate receptor;
12. to phosphorylate tyrosine residues on receptor;

13. kinases;
14. to phosphorylate other kinases in signal transduction;

15. IRS (insulin receptor substrate);
16. as relay protein;
17. to activate other relay proteins;

18. (for kinases and IRS) to trigger phosphorylation cascade;
19. to transduce signal from activated receptors to other proteins in the cell;
20. can result in signal amplification;

21. glucose synthase to convert glucose to glycogen for storage in liver;
22. glucokinase which phosphorylate glucose;
23. glycolytic enzymes to increase rate of glycolysis/ ATP production;
24. enzymes to convert glucose to lipids;
25. enzymes involved in transcription & translation;

26. Glucose transporter;
27. as transport protein;
28. for uptake of glucose;
29. to increase glucose absorption in liver/muscle cells;

30. to lower of blood glucose concentration back to set point;

QWC: Describes at least 3 different functions of proteins;;

(b) Describe how the structure of antibody is related to its function and explain the significance of cell signaling in immune response. [10]

Structure relates to function of antibody

1. (S) Shape of antigen binding sites of antibody is complementary to that of antigen
   (F) bind to and block the interaction of pathogens with the host cell or neutralise their toxins;;
2. (S) Antibody has constant regions on heavy chains

(F) that allows for binding to specific group of effector molecules for antigen elimination;;

3. (S) Antibodies have two antigen binding sites

   (F) for binding to 2 identical structures;;

4. (S) Antibody comprises of antigen binding sites and constant region

   (F) for interactions with antigen and effector cells;;

5. (S) Antibody has variable regions on both heavy and light chains that give rise to a huge variety of antigen binding sites
   (F) for attachment to various antigenic determinant sites;;
6. (S) Antibody has variable heavy chains
7. (F) that gives rise to the 5 classes of antibodies (IgG, IgM, IgA, IgD, IgE) to trigger different effector functions;;

Role of cell signaling in human immune system

1. To activate multiple cells at once;
2. APC activate helper T lymphocyte (via release of interleukin-1);
3. helper T lymphocytes activate B lymphocytes and cytotoxic T lymphocytes (via the release of interleukin-2);

4. To trigger responses of cells;
5. Helper T lymphocytes/B lymphocytes divide by mitosis/clonal expansion;
6. cytotoxic T lymphocytes to kill infected cells;

7. To trigger responses within a cell;
8. helper T lymphocytes to synthesise and secrete cytokinin;
9. plasma cells to synthesise and secrete antibodies (to remove pathogen);

10. Coordination between cells;
11. To integrate and coordinate activities between innate and adaptive immunity;
12. Can attract cells to site of infection through release of cytokinin;

13. To remove pathogen;

QWC: describe at least 2 S-F relationship of antibody and explain the significance of cell signaling in human response;;

[Total: 25]