Class Adm No

Candidate Name: _____

H

millennia institute

2017 Preliminary Examination 2
Pre-University 3

H2 Biology **9648/01**

Paper 1 Multiple Choice **21 September 2017**

1 hour 15 min

Additional material: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name and Admission No. on the Answer Sheet in the spaces provided unless this has been done for you.

There are **forty** 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.

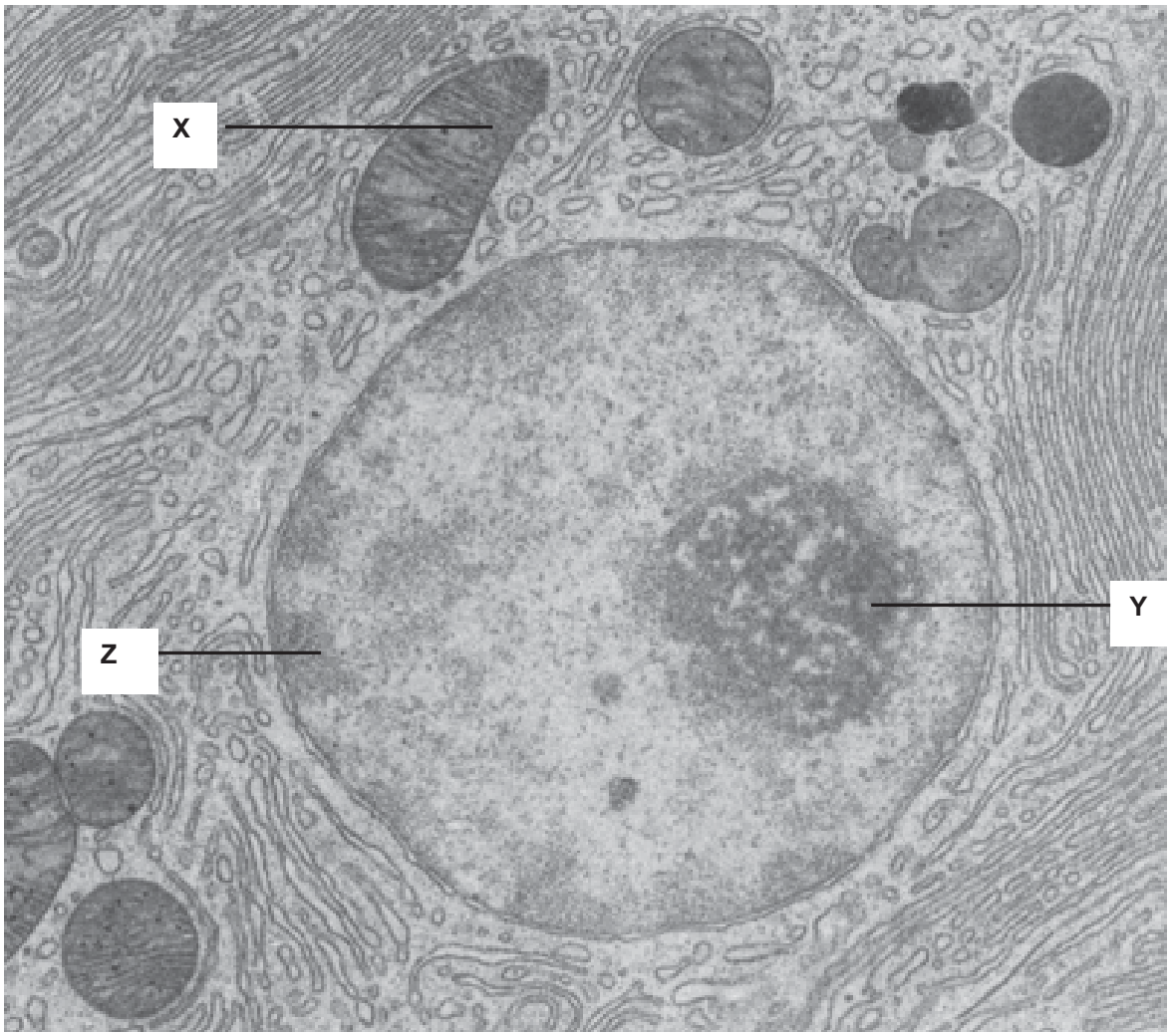
Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

The use of an approved scientific calculator is expected, where appropriate

This question paper consists of 35 printed pages.

[Turn over

1. The electron micrograph below shows the structures found in a cell.

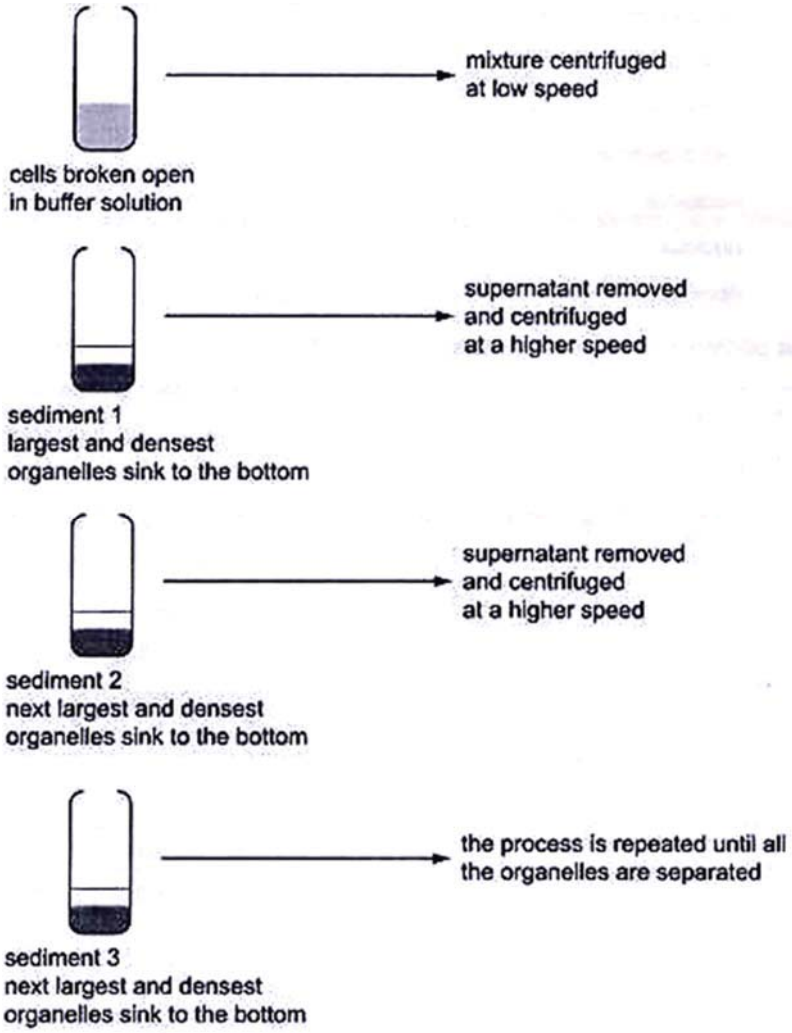


Which of the following statements is true for structures **X**, **Y** and **Z**?

	X	Y	Z
A	Contains reduced NAD^+ and reduced FAD	Transcription of gene coding for ribosomal RNA	Contains heterochromatin which is transcriptionally inactive
B	Involved in oxidative phosphorylation	Transcription of gene coding for ribosomal protein	Contains heterochromatin which is transcriptionally active
C	Contains reduced NAD^+ and reduced FAD	Involved in assembly of ribosomal subunits	Contains euchromatin which is transcriptionally inactive
D	Involved in oxidative phosphorylation	Involved in synthesis of ribosomal subunits	Contains euchromatin which is transcriptionally active

2. Fractionation is a process used to separate cell components according to their size and density.

The diagram shows the main stages in fractionation of a plant cell.

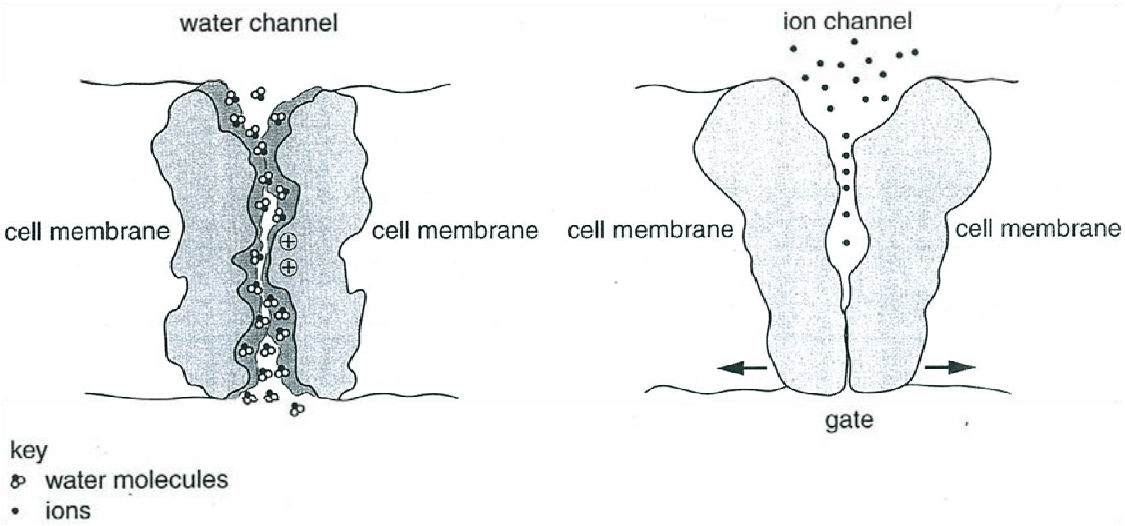


DCPIP and buffer solution (containing glucose, fructose, sodium bicarbonate) were added to each of the sediments, and the mixtures were left in the dark for fifteen minutes. Sediment 2 caused the DCPIP to be reduced.

Which organelle present in Sediment 2 caused reduction of DCPIP?

A Chloroplast
B Mitochondrion
C Nucleus
D Ribosome

3. The figure shows water and ion channels that are found in the cell surface membrane of all cells.



Which of the following statements is true?

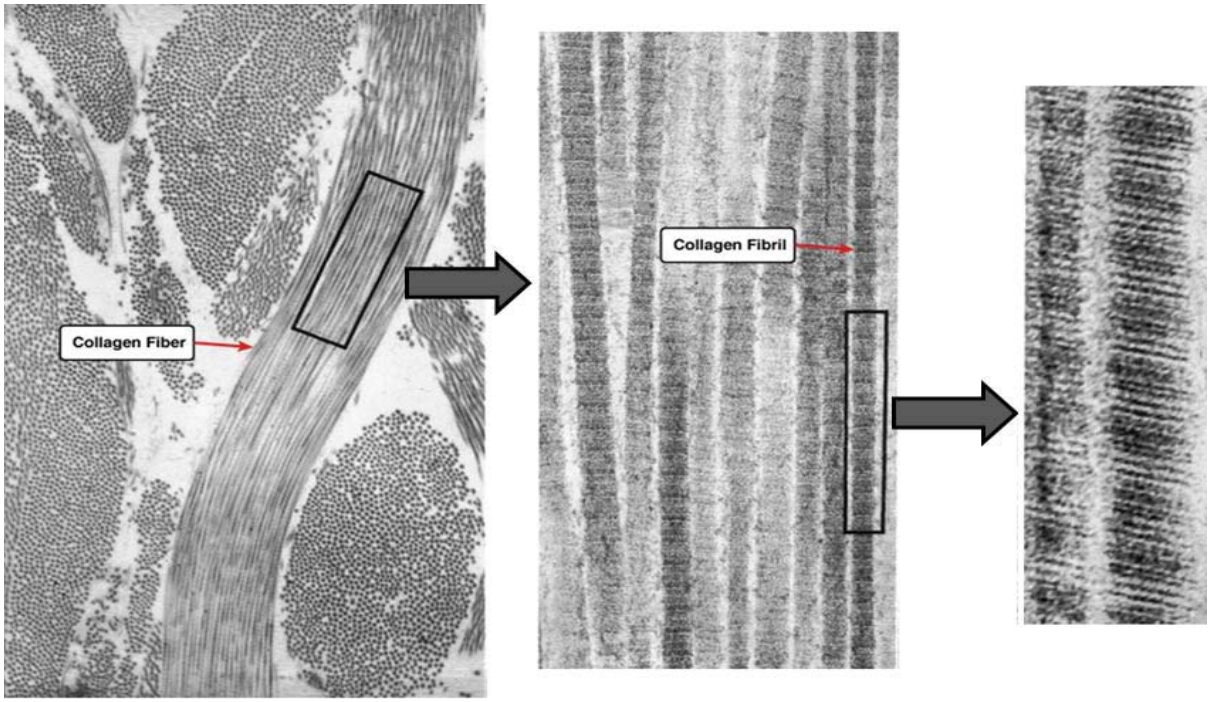
A Movement of water molecules through the water channel requires energy provided by the hydrolysis of ATP as water molecules are polar while the phospholipid bilayer of the membrane is hydrophobic.

B Common amino acid residues found on the protein surface surrounding the pores of both channels include valine and phenylalanine.

C Only the ion channel allows for the regulation of ion movement across the cell surface membrane.

D The ion channel is an example of a carrier protein as it is able to switch between two different conformations to allow the movement of ions.

4. Collagen is the main structural protein of the various connective tissues in animals. As the main component of connective tissue, it is the most abundant protein in mammal, making up from 25% to 35% of the whole-body protein content. The diagram below shows the structure of a collagen fibre and collagen fibrils.



Which of the following correctly accounts for the banded appearance of collagen fibril?

A Intermolecular hydrogen bonds between polypeptide chains within tropocollagen.
B Covalent cross-linkages between tropocollagen chains.
C Staggered arrangement of collagen fibres.
D Sequence motif of Gly-X-Y where Gly is glycine, X is proline and Y is hydroxypoline or hydroxylysine.

5. Some foods contain 'hydrogenated vegetable oils'. These are unsaturated fats that have been converted to saturated fats.

Which property of the fats will have changed?

A Their hydrocarbon chains will pack together more closely.
B Their solubility in water will increase.
C They will have more double bonds in their molecules.
D They will remain liquid at room temperature.

6. Most wild plants contain toxins that deter animals from eating them. A scientist discovered that a toxin produced by a certain plant was also toxic to the same plant if it as applied to the roots of the plant. As the first step on finding out why the plant was not normally killed by its own toxin, he fractionated some plant cells and found that the toxin was in the fraction that contained the largest cell organelle. He also found that the toxin was no longer toxic after it was heated.

Which of the following statements are consistent with the scientist's observations?

I The toxin was stored in the central vacuole.

II The toxin cannot cross the membrane of the organelle in which it is stored.

III The toxin was stored in chloroplast.

IV The toxin is likely to be lipid-soluble.

V The toxin may be an enzyme.

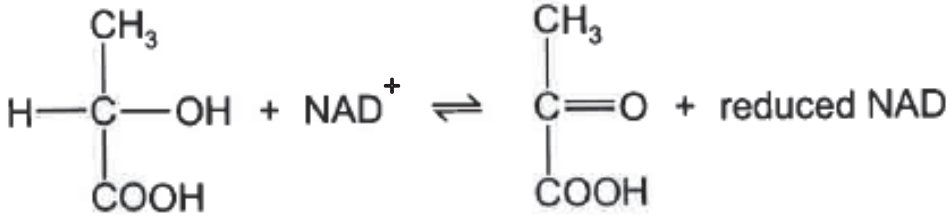
A I, II and V

B I, IV and V

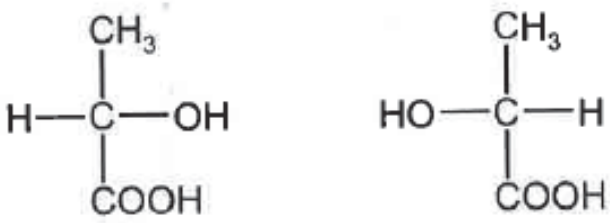
C II, III and IV

D III, IV and V

7. Lactic dehydrogenase catalyses the conversion of lactic acid as shown in the following equation.

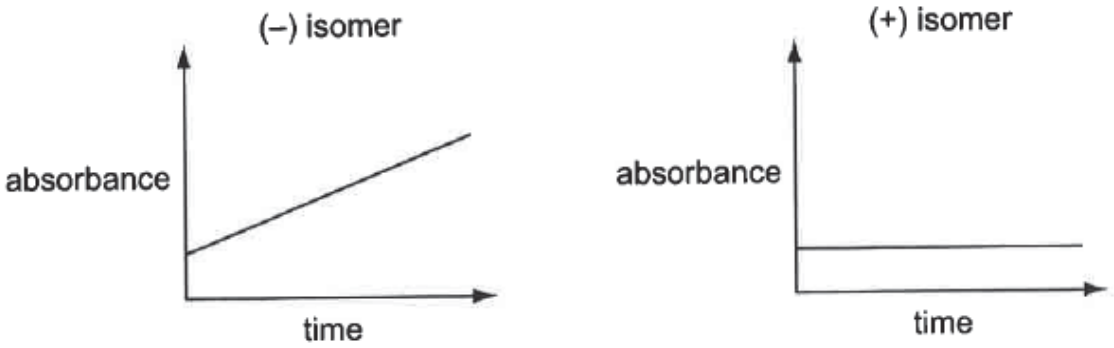


Two forms (isomers) of lactic acid exist, (-) and (+), as shown below.



(–) (+)

Reduced NAD absorbs ultraviolet light. NAD^+ does not. The activity of bacterial lactic dehydrogenase on two different isomers of lactic acid was compared. The absorbance of ultraviolet light was measured using an ultraviolet spectrophotometer. The graphs show the results.



What can be concluded about bacterial lactic dehydrogenase?

A Molecules of both isomers fit the active site.

B Molecules of neither isomer fit the active site.

C The enzyme is specific to the (-) isomer.

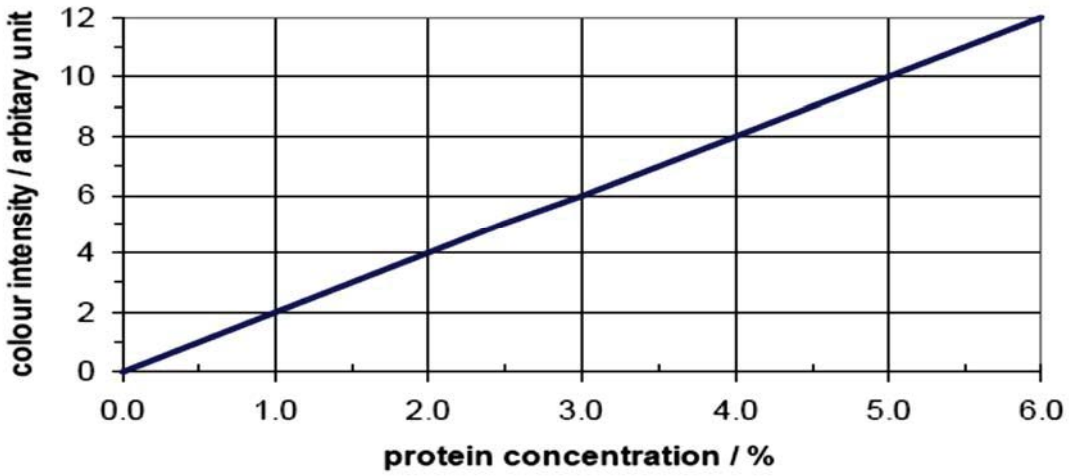
D The enzyme is specific to the (+) isomer.

8. In an experiment to study the effect of heat treatment on the digestibility of protein substrate and the effect of raw bean extract on protease activity, various reaction mixtures were prepared and were incubated for 30 minutes.

The protein concentration of each reaction mixture at the beginning and at the end of the incubation period was determined by the colorimetric method which measures colour intensity of these reaction mixtures. The results were shown in the table below.

Incubation period /min	**Colour intensity of the reaction mixture / arbitrary unit**			
	Tube A	**Tube B**	**Tube C**	**Tube D**
	Protease + heated protein substrate	**Protease + unheated protein substrate**	**Protease + unheated protein substrate + heated raw bean extract**	**Protease + unheated protein substrate + raw bean extract**
0	10	10	10	10
30	4	6	7	9

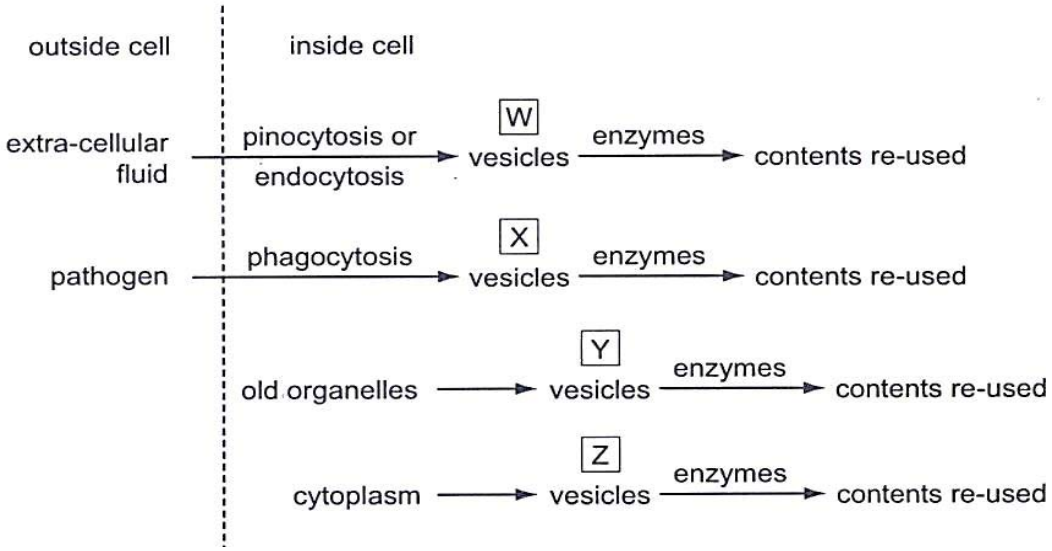
The standard graph obtained by using colorimetric method for determining concentration of protein solutions is shown below.



Which of the following combinations is correct?

	Test tube	**Decrease in protein concentration / %**
A	Tube A	4.0
B	Tube B	2.0
C	Tube C	3.0
D	Tube D	4.5

9. The flow chart shows processes which takes place inside animal cells.



Which processes require the activity of lysosomes?

A **W** and **X** only

B **X** and **Y** only

C **Y** and **Z** only

D All of the above

10. A student obtained a sample of DNA molecule. mRNA was transcribed from this DNA molecule. He then separated the two strands of the DNA sample by adding sodium hydroxide. The base compositions of each strand, that of the mRNA and a foreign DNA strand were analysed. The results of the analysis are shown in the table below.

	A	**G**	**C**	**T**	**U**
DNA strand 1	19.1	26.0	31.0	23.9	0.0
DNA strand 2	24.2	30.8	25.7	19.3	0.0
DNA strand 3	20.5	25.2	29.8	24.5	0.0
mRNA	19.0	25.9	30.8	0.0	24.3

Which strand of DNA serves as a template for mRNA synthesis?

A Strand 1

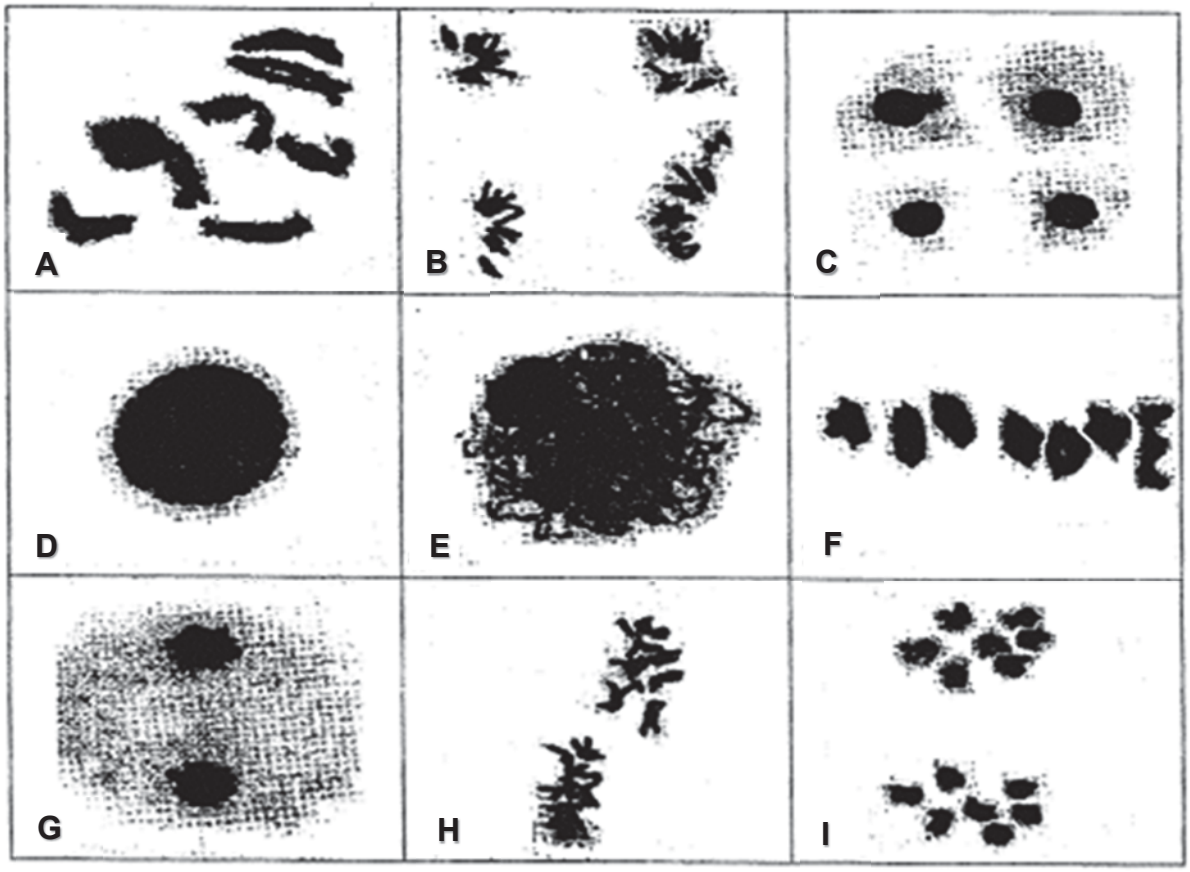
B Strand 2

C Strand 3

D Strand 2 and 3

Use the diagram below to answer Questions 11 and 12

The micrographs below show nuclei of cells at various stages during nuclear division in a flowering plant.



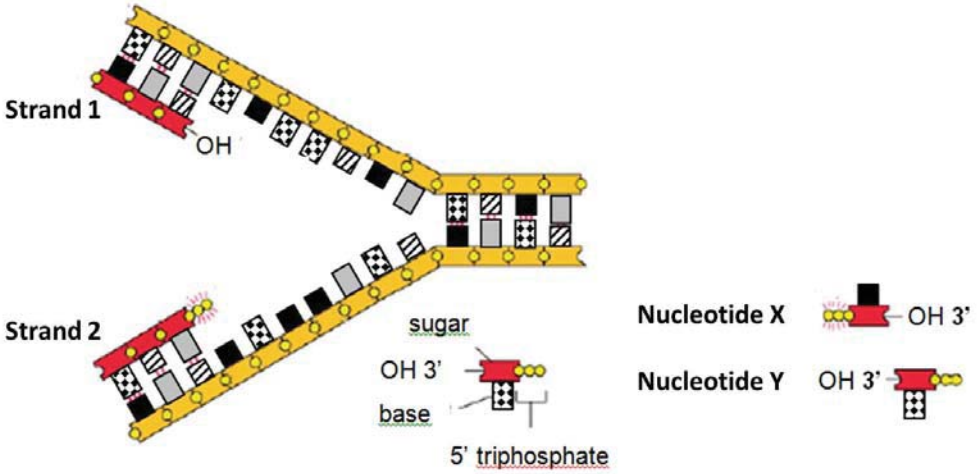
11. Which of the following combinations is the correct arrangement of letters in accordance with the chronological sequence of events for the above nuclear division process?

A	**D**	**E**	**B**	**C**	**I**	**G**	**H**	**A**	**F**
B	**E**	**D**	**A**	**H**	**I**	**F**	**G**	**B**	**C**
C	**D**	**E**	**A**	**F**	**I**	**G**	**H**	**B**	**C**
D	**C**	**B**	**H**	**G**	**I**	**F**	**A**	**E**	**D**

12. With reference to micrograph **F**, which of the following combinations is correct?

	Number of sets of chromosomes	Number of centromeres	Number of chromatids	Number of DNA strands
A	2	14	28	56
B	7	7	14	28
C	2	7	28	28
D	7	14	14	56

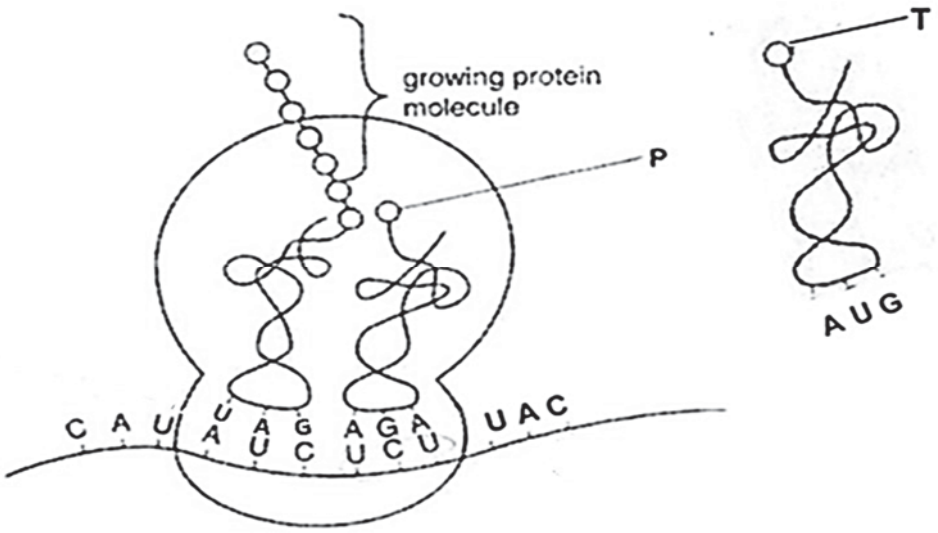
13. DNA replication is illustrated in the figure below.



Which of the following correctly describes the addition of the next nucleotide(s) to the DNA strands undergoing replication?

A Nucleotide **X** will be added to the leading strand, which is strand 1.
B Nucleotide **Y** will be added to the leading strand, which is strand 1.
C Nucleotide **X** will be added to the lagging strand, which is strand 2.
D Nucleotide **Y** will be added to the leading strand, which is strand 2.

14. The figure below shows a diagram of a ribosome bound to a mRNA strand during translation.



First Base		Second Base					Third Base
		U	C	A	G		
U		phenyalanine	serine	tyrosine	cysteine	U	
		phenyalanine	serine	tyrosine	cysteine	C	
		leucine	serine	(stop)	(stop)	A	
		leucine	serine	(stop)	tryptophan	G	
C		leucine	proline	histidine	arginine	U	
		leucine	proline	histidine	arginine	C	
		leucine	proline	glutamine	arginine	A	
		leucine	proline	glutamine	arginine	G	
A		isoleucine	threonine	asparagine	serine	U	
		isoleucine	threonine	asparagine	serine	C	
		isoleucine	threonine	lysine	arginine	A	
		(start) methionine	threonine	lysine	arginine	G	
G		valine	alanine	aspartate	glycine	U	
		valine	alanine	aspartate	glycine	C	
		valine	alanine	glutamate	glycine	A	
		valine	alanine	glutamate	glycine	G	

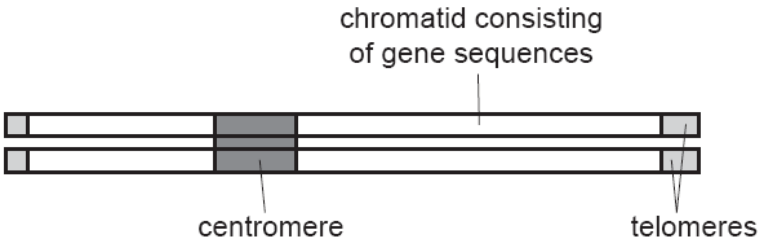
Using the codon table provided, which of the following options correctly identifies amino acids **P** and **T**?

	P	**T**
A	Serine	Histidine
B	Serine	Tyrosine
C	Arginine	Methionine
D	Arginine	Leucine

15. The ends of eukaryotic chromosome contain a special sequence of DNA called a telomere. Human telomeres consist of repeating TTAGGG sequences which extend from the ends of the chromosomal DNA.

When cells undergo mitotic division, some of these repeating sequences are lost. This results in a shortening of the telomeres.

The diagram shows a eukaryotic chromosome.



What is a consequence of the loss of repeating DNA sequences from the telomeres?

A The cell will begin the synthesis of different proteins.

B The cell will begin to differentiate as a result of the altered DNA.

C The number of mitotic divisions the cell can make will be limited.

D The production of mRNA will be reduced.

16. The table shows a comparison of some aspects of the genomes and protein-coding genes between the prokaryote *Escherichia coli* and the eukaryote fungus *Saccharomyces cerevisiae.*

	E.coli	*S.cerevisiae*
Genome length/base pairs	4 640 000	12 068 000
Number of protein-coding genes	4300	5800
Proteins with roles in:		
Metabolism	650	650
Energy release/storage	240	175
Membrane transport	280	250
Transcription	240	400
Translation	180	350
Cell structure	180	250

What could not account for the differences in the number of protein-coding genes?

A Many catabolic pathways for using carbon compounds in prokaryotes.

B The presence of introns in the DNA of eukaryotes.

C The presence of membrane-bound organelles in eukaryotes.

D The use of histones to package DNA in eukaryotes.

17. The following are characteristics of eukaryote transcription.

- Promoters are activated by transcription factors that recognise specific DNA sequences and other sequences that are very similar.
- Within a promoter, there may be recognition sites for more than one transcription factor.
- Similar specific DNA sequences can be recognised by more than one transcription factor.
- Each transcription factor may be capable of recognising a number of promoter recognition sites.

What explains the different levels of expression of a eukaryotic gene?

A Competition between recognition sites present in the promoter for transcription factors.

B Competition between transcription factors that recognise the same sites of a promoter.

C The number of transcription factors that recognise the same sites of a promoter.

D The number of different types of transcription factors.

18. The figure below shows a human karyotype.

What can be concluded from the karyotype provided?

A There was non-disjunction during meiosis I in the mother.

B There was non-disjunction during meiosis II in the father.

C One contributory gamete to the zygote is an egg with an X and a Y chromosome.

D One contributory gamete to the zygote is a sperm containing two X chromosomes.

19. Below are some statements related to cancer:

I. Oncogenes can be detected by introducing fragmented DNA from cancer cells into suitable cell lines and isolating colonies that display cancerous properties.

II. Individuals who inherit one inactive copy of tumour suppressor gene are more likely to develop cancer than individuals with two non-mutant copies.

III. Viruses and other infectious agents play no role in human cancers.

IV. In the cellular regulatory pathways that control cell growth and proliferation, the products of oncogenes are inhibitory components and the products of tumour suppressor genes are stimulatory components.

V. When analysed, cancer cells are often found to have only one mutation in a regulatory pathway that controls cell proliferation.

Which of the following statements are true?

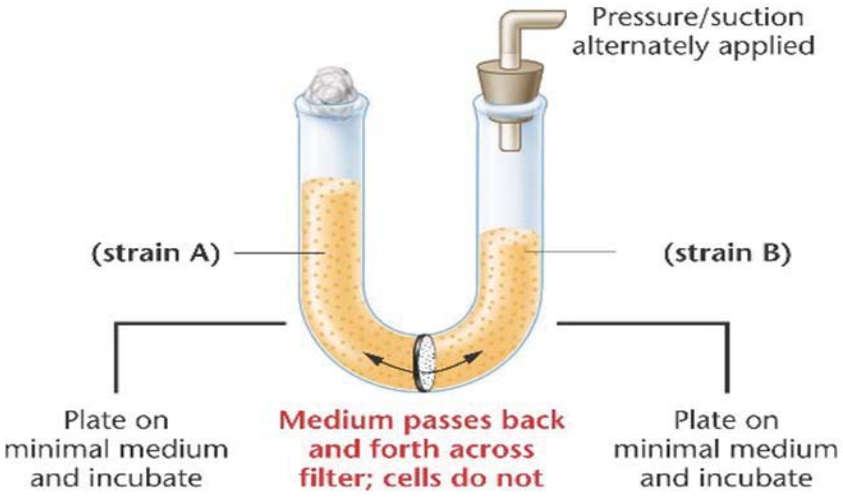
A I and II only.

B I, II and III only.

C I, III and V only.

D I, II, IV and V only.

20. Bacteria can undergo genetic recombination, a process by which genetic information from one bacterium is transferred to, and then recombined with, that of another bacterium.



The Davis U-tube, shown above is an apparatus used to investigate possible genetic recombination between bacteria. In the experiment, researchers placed *Salmonella typhimurium* **strains A** and **B** in the U-tube separated by a filter, thus preventing direct cell contact but allowing growth to occur in a common medium. When samples were removed from both sides of the filter, recombinants (containing genetic material from both **strain A** and **B**) were recovered only from the side of the tube containing **strain A** bacteria. Researchers postulated that a filterable agent was released by the **strain B** cells and was responsible for transferring the new genetic information.

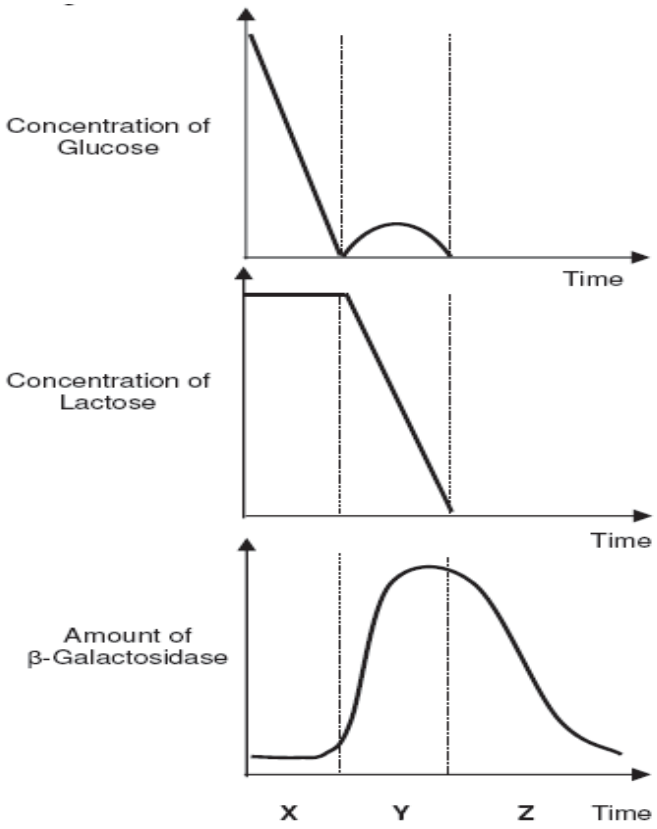
Three subsequent observations were useful in identifying the filterable agent:

1. The filterable agent was released by the **strain B** cells only when they were grown in association with **strain A** cells.
2. The addition of DNase, which enzymatically digests naked DNA, did not render the filterable agent ineffective.
3. The filterable agent could not pass across the filter of the Davis U-tube when the pore size was reduced below the size of bacteriophages.

Which process has occurred?

A Transduction
B Conjugation
C Transformation
D Binary fission

21. An experiment was conducted to examine the effects of glucose and lactose on the levels of β-galactosidase in *E.coli*. Lactose and glucose were added to a culture of bacteria at the start of the experiment and the levels of each were measured at specific time intervals. The results are shown in graphs below.



Which of the following statements could possibly account for period **X** to **Z**?

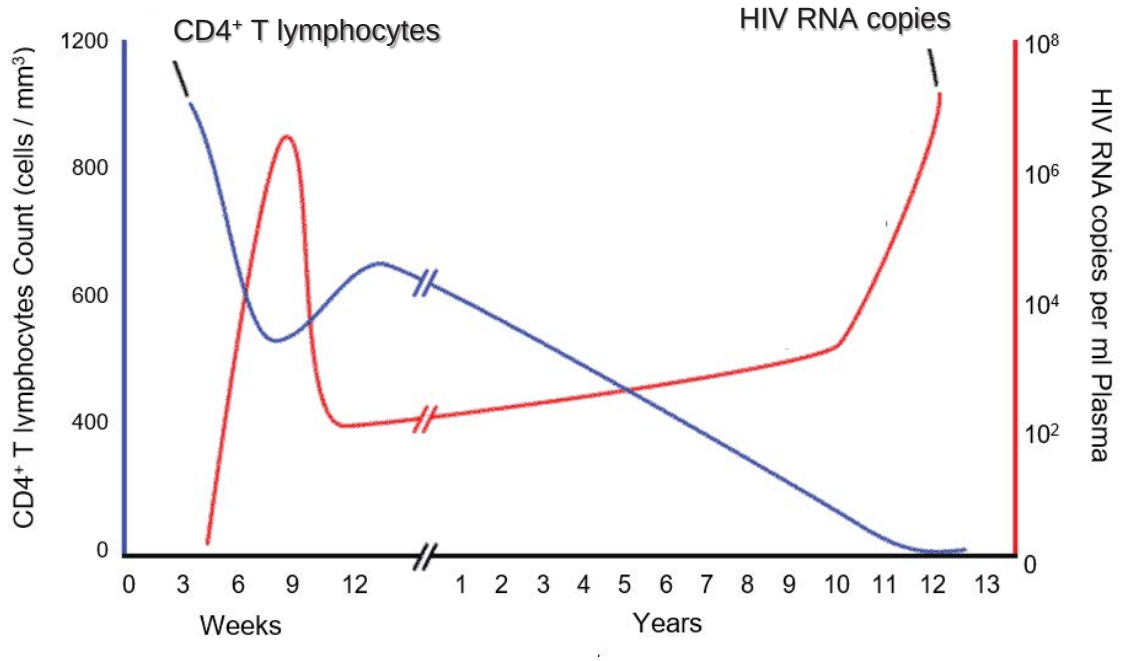
A Binding of cAMP to the CAP-binding site enhances binding of RNA polymerase to the promoter for gene transcription in period **Y**.

B Allolactose binds to the lac repressor, allowing it to assume an active configuration such that it can bind to the operator in period **X**.

C CAP is inactive and disengages from the CAP binding site, hence increasing the affinity of RNA polymerase to the promoter for gene transcription in period **Y**.

D mRNA of β-galactosidase has been degraded by nucleases in period **Z**.

22. The graph below shows HIV copies and $CD4^+$ T lymphocytes counts over the course of a typical HIV infection.



Which of the following statements are false about how HIV infects the cell?

I Complementary binding of the gp120 to specific $CD4^+$ receptors on the T cells and HIV enters the host cell via receptor-mediated endocytosis.

II RNA released into cytoplasm where reverse transcriptase uses negative-sense viral RNA as a template to synthesise a strand of cDNA and then form a double stranded viral DNA.

III The DNA enters the nucleus and ligase catalyses the integration into the chromosome DNA to form a provirus.

IV The provirus DNA is transcribed to form viral mRNA which are used as a template for translation of viral proteins such as nucleocapsids, viral envelope and viral enzymes.

V Neuraminidase cleaves the long chains of polyproteins when newly assembled HIV bud out of host cells.

A I and III only

B I, II and III only

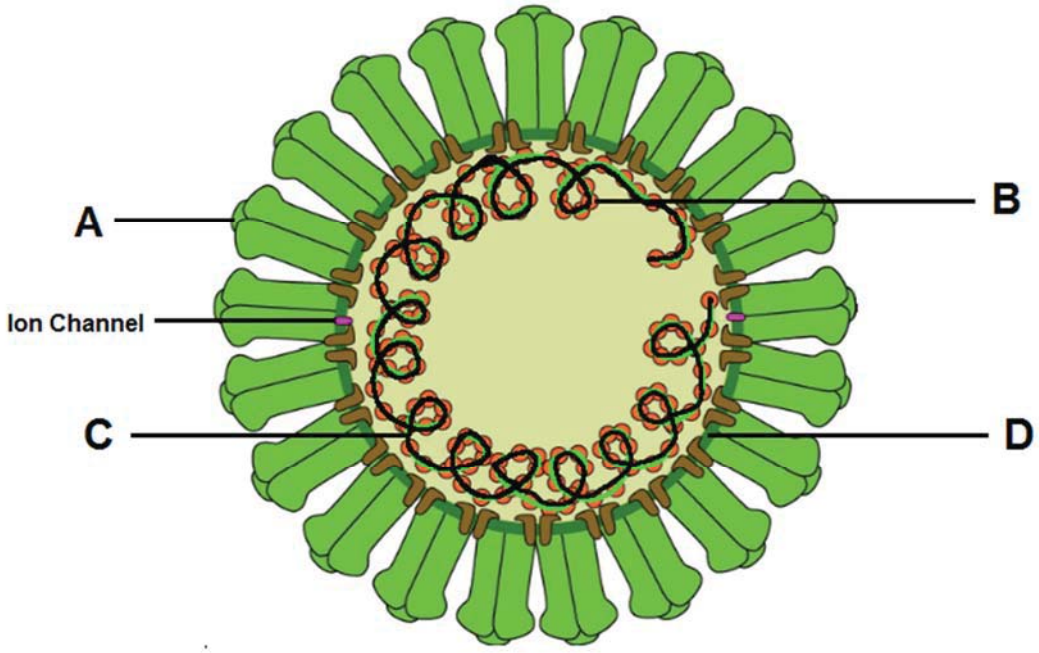
C I, IV and V only

D All of the above

23. Middle East respiratory syndrome (MERS) is a viral respiratory illness that was first reported in Saudi Arabia in 2012. Symptoms may range from fever, cough to shortness of breath.

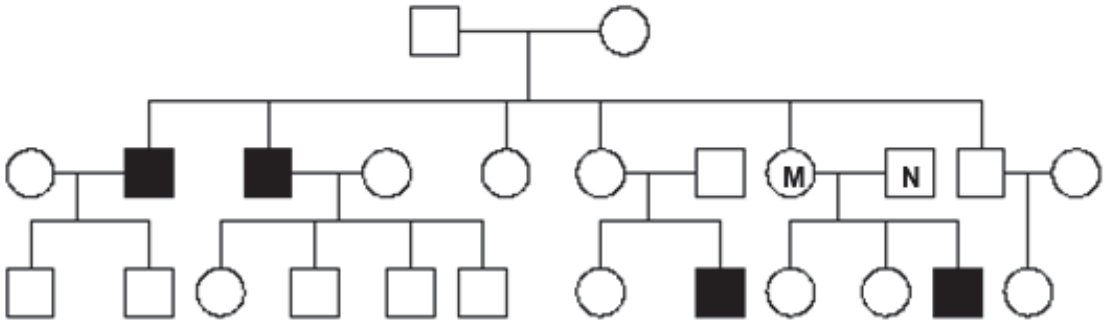
This infection is caused by the MERS-coronavirus (MERS-CoV) shown in the diagram below.

Which of the following components of MERS-CoV is not present in *Escherichia coli* bacterium?



Use the diagram below to answer Questions 24 and 25.

Hunter's syndrome is a serious genetic disorder. It interferes with the body's ability to break down and recycle specific mucopolysaccharides, also known as glycosaminoglycans or GAG. The visible signs and symptoms of Hunter syndrome in younger people are usually the first clues leading to a diagnosis. In general, the time of diagnosis usually occurs from about 2 to 4 years of age.



24. With reference to the pedigree diagram, which of the following is the correct mode of inheritance for Hunter's syndrome?

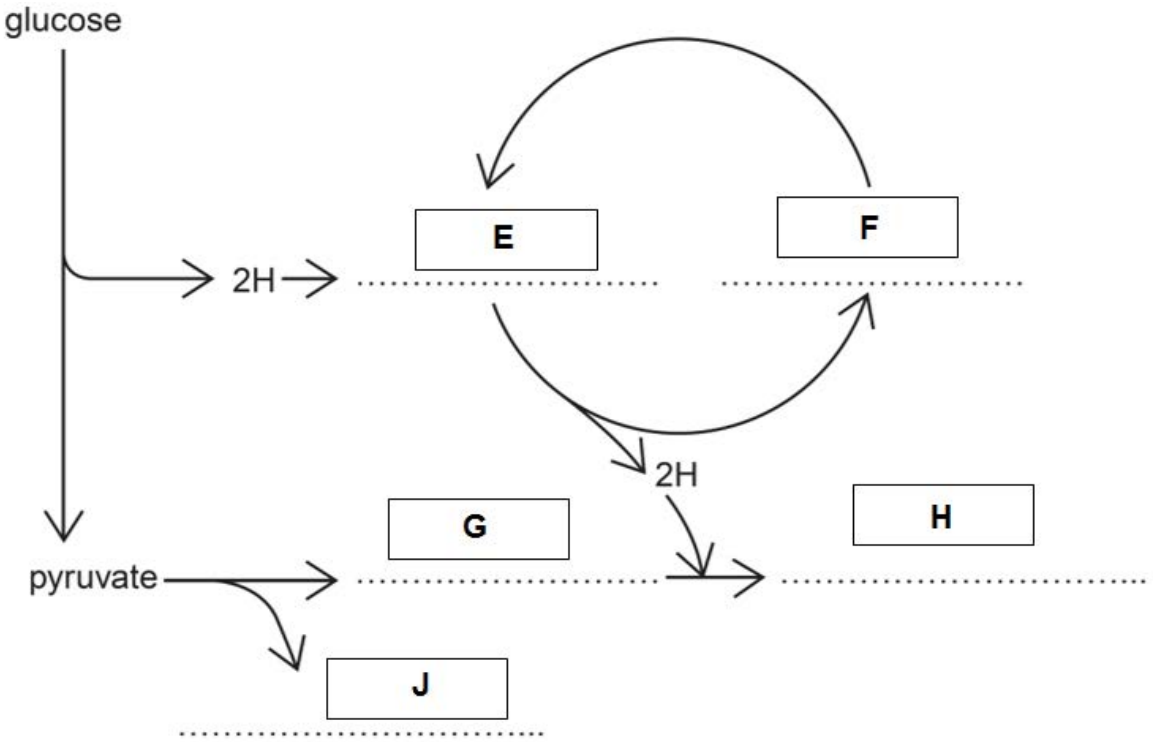
A Autosomal recessive
B Incomplete dominance
C Sex-linked recessive
D Codominance

25. Mariah (**M**) married Nick (**N**) and had three children. One of the children had Hunter's syndrome.

What is the probability of their next child being an affected son?

A 0.5
B 0.375
C 0.25
D 0.125

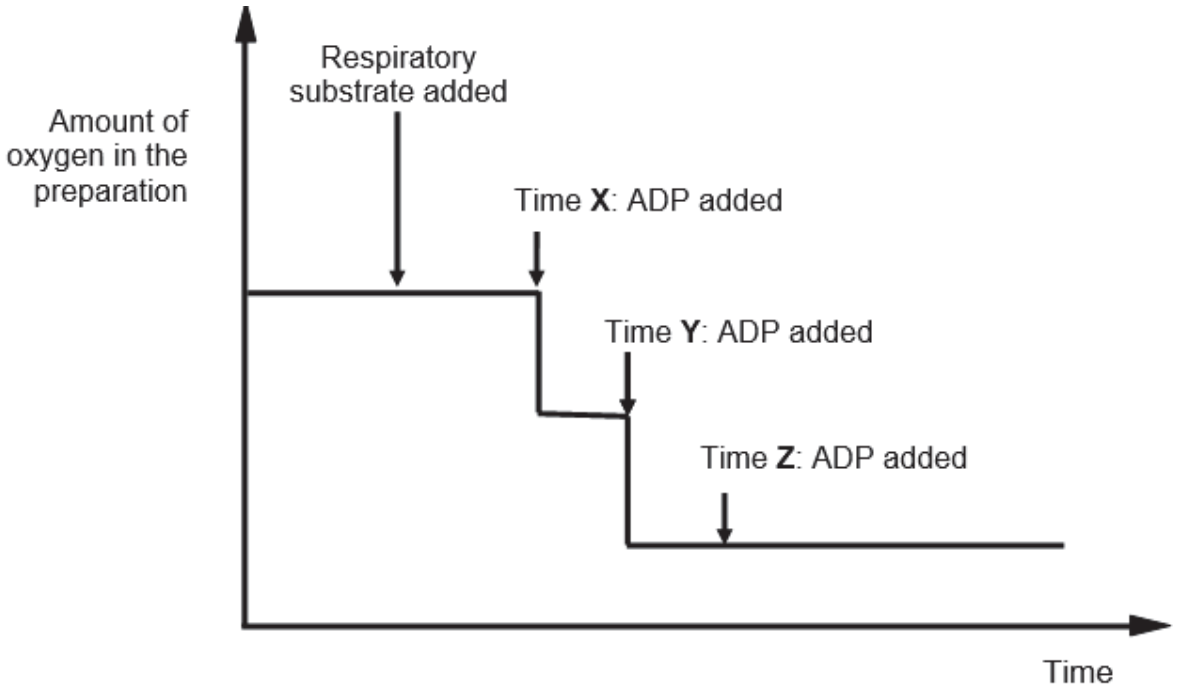
26. The figure below outlines a process that occurs in plant cells.



Which of the following combinations is correct?

	E	F	G	H	J
A	NADH	NAD^+	Ethanal	Ethanol	CO_2
B	NAD^+	NADH	Ethanol	Ethanal	CO_2
C	NADPH	$NADP^+$	Lactate	Lactose	O_2
D	$NADP^+$	NADPH	Lactate	Lactose	O_2

27. A suspension of mitochondria was isolated from liver tissue. Various substances were added to the suspension at different time intervals and the amount of oxygen remaining in the preparation was monitored over some time. The graph below shows the results as well as the times at which different substances were added.



Which of the following statement(s) could possibly be true?

I Glucose is the respiratory substrate added.

II Between **X** and **Y**, oxidative phosphorylation occurred and oxygen acted as the final electron acceptor.

III Between **Y** and **Z**, chemiosmosis occurred where ATP synthase utilizes the proton-motive force to phosphorylate ADP to form ATP.

IV After **Z**, anaerobic respiration occurred as oxygen levels did not decrease even though ADP is added.

V After **Z**, inorganic phosphates, NADH and $FADH_2$ have been depleted.

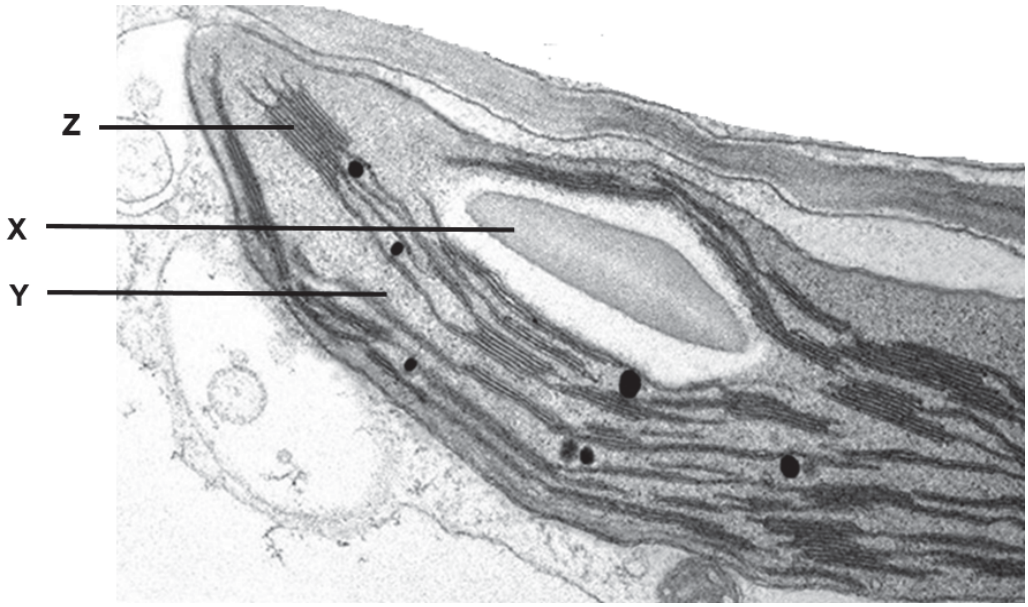
A I, III and IV only

B II, IV and V only

C II, III and V only

D All of the above

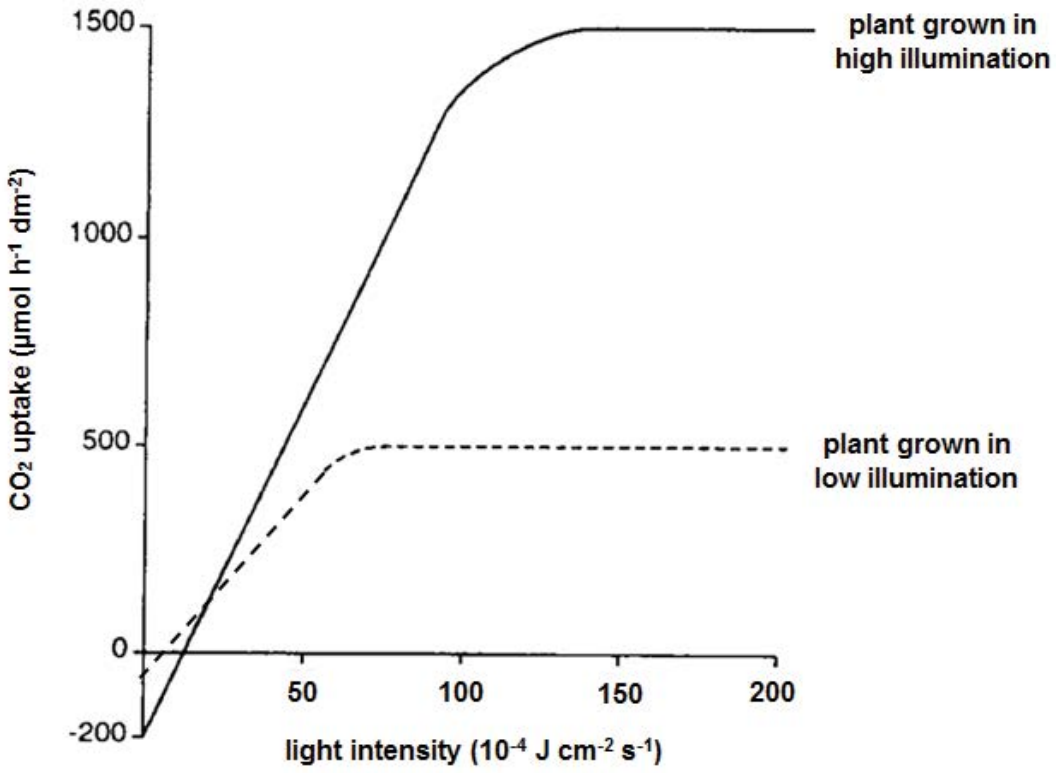
28. The diagram below is a transmission electron micrograph of a labelled organelle.



Which of the following combinations is correct?

	X	Y	Z
A	Consists of more amylopectin branches than amylose chains.	Contains low concentrations of protons and has an alkaline pH.	Site of non-cyclic and cyclic photophosphorylation.
B	Large central vacuole surrounded by a tonoplast and contains cell sap.	Site of Calvin cycle processes of carbon fixation, reduction and RuBP regeneration.	Site of ATP and NADPH synthesis.
C	Insoluble in water as hydroxyl groups are projected inwards into helical structures and unable to form hydrogen bonds with water.	Site of oxidation of NADPH to form NADP+ as well as expenditure of ATP.	Photolysis of water occurs to generate protons, oxygen and electrons.
D	Consists of monomers joined together by β(1→4) and β(1→6) glycosidic bonds.	Consists of chlorophyll pigments with photosystems to facilitate light-dependent reactions.	Consists of cristae that increases surface area to volume ratio for more efficient ATP production.

29. Two groups of white mustard plants, *Sinapis alba*, were grown, one group under high illumination, the other under low illumination. When fully grown, the effect of increasing light intensity on the rate of photosynthesis in the two groups of plants was measured.



Which of the following statements can be concluded from the graph?

A Below the compensation point, plants grown at high illumination give out less carbon dioxide than plants grown in low illumination.

B The compensation point for plants grown in high illumination occurs at a lower light intensity than those grown in low illumination.

C Light intensity is no longer a limiting factor for photosynthesis for light intensity above $150x10^{-4}$ Jcm^{-2} s^{-1} for plants grown in high illumination.

D For light intensity from 20×10^{-4} Jcm^{-2} s^{-1} to 50×10^{-4} Jcm^{-2} s^{-1}, carbon fixation for the plants grown in high illumination is similar to that grown in low illumination.

30. Four proteins isolated from a human cell were investigated for their involvement in cell signalling pathways.

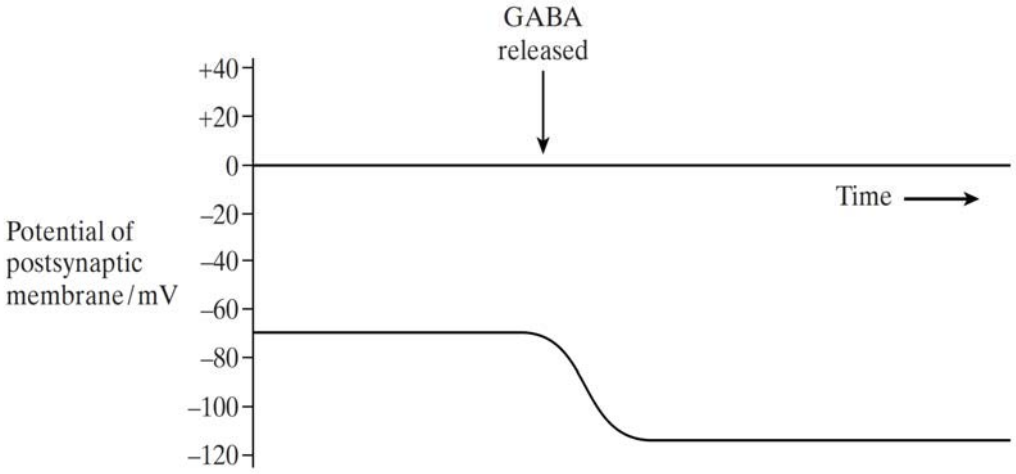
	Protein A	**Protein B**	**Protein C**	**Protein D**
Transmembrane domain	-	+	+	-
DNA binding domain	-	-	-	+
Enzymatic domain	+	-	+	-

Key: (+) = present , (-) = absent

Which of the following shows the correct identity of these four proteins?

	Protein A	**Protein B**	**Protein C**	**Protein D**
A	GPCR	Ras protein	RTK	Testosterone receptor
B	Ras protein	RTK	GPCR	Testosterone receptor
C	Testosterone receptor	GPCR	RTK	Ras protein
D	Ras protein	GPCR	RTK	Testosterone receptor

31. GABA is a neurotransmitter which inhibits the production of action potential. The figure below shows how the release of GABA from a pre-synaptic neurone affects the membrane potential of a post-synaptic membrane.



Which of the following options correctly explains why an action potential is less likely to occur if GABA is released?

A GABA opens ligand-gated K^+ ion channels in the post-synaptic membrane, allowing K^+ to diffuse out of post-synaptic neuron, causing hyperpolarization.

B GABA closes voltage-gated Na^+ ion channels in the pre-synaptic membrane, allowing K^+ to diffuse out of pre-synaptic neuron, causing repolarization.

C GABA opens voltage-gated K^+ ion channels in the post-synaptic membrane, allowing K^+ to diffuse into the post-synaptic neuron, causing repolarization.

D GABA opens voltage-gated Na^+ ion channels in the post-synaptic membrane, allowing Na^+ to diffuse out of post-synaptic neuron, causing hyperpolarization.

32. The resting potential of a nerve axon is essential for action potential generation.

Which of the following, when instantaneously removed, would most rapidly bring the resting potential of a nerve axon close to 0 mV?

A Active transport of K^+ ions into the cell

B Active transport of Na^+ ions out of the cell

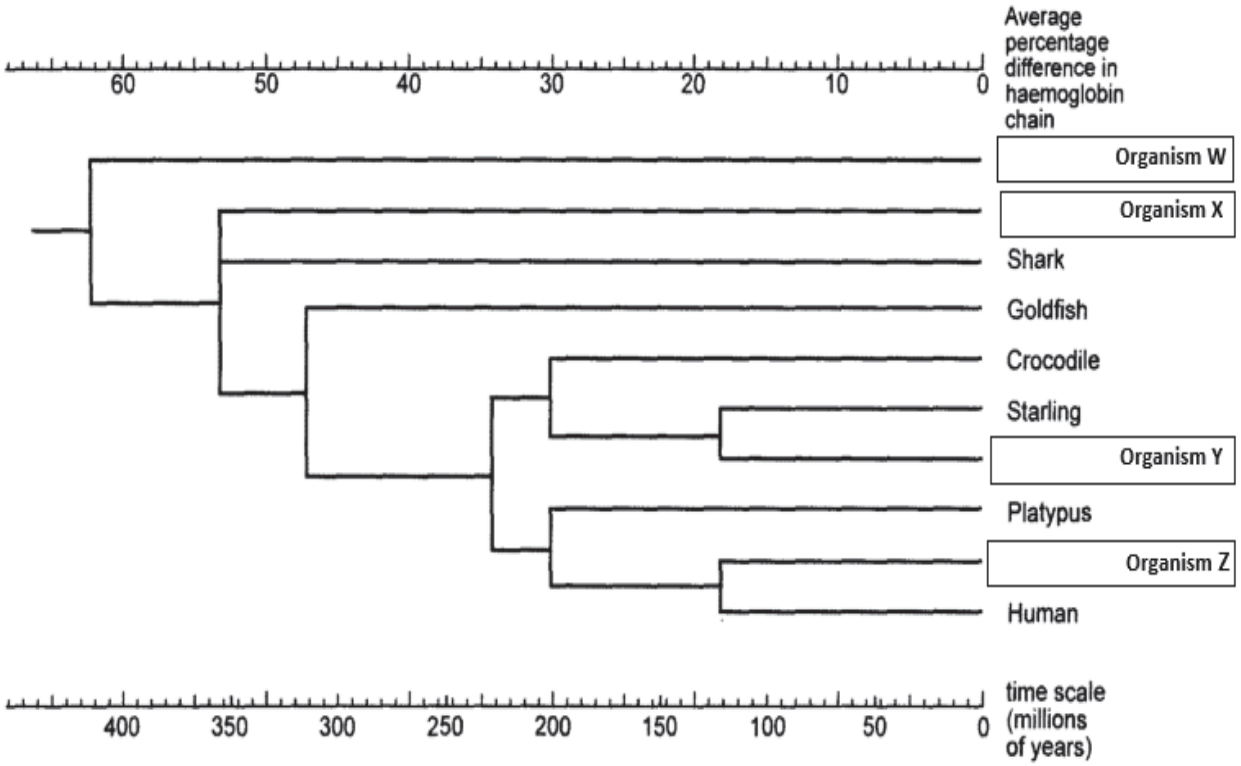
C High membrane permeability to Na^+ ions

D High membrane permeability to K^+ ions

33. The table shows the amino acid differences in the cytochrome b protein between various vertebrates.

	Human	Elephant	Platypus	Ostrich	Starling	Crocodile	Lungfish	Coelacanth	Goldfish	Shark
Human		26	40	43	41	47	83	70	68	71
Elephant			45	45	48	50	84	72	63	74
Platypus				54	52	51	89	74	70	76
Ostrich					26	36	91	75	68	73
Starling						47	91	77	67	70
Crocodile							85	78	70	77
Lungfish								90	94	86
Coelacanth									83	78
Goldfish										88
Shark										

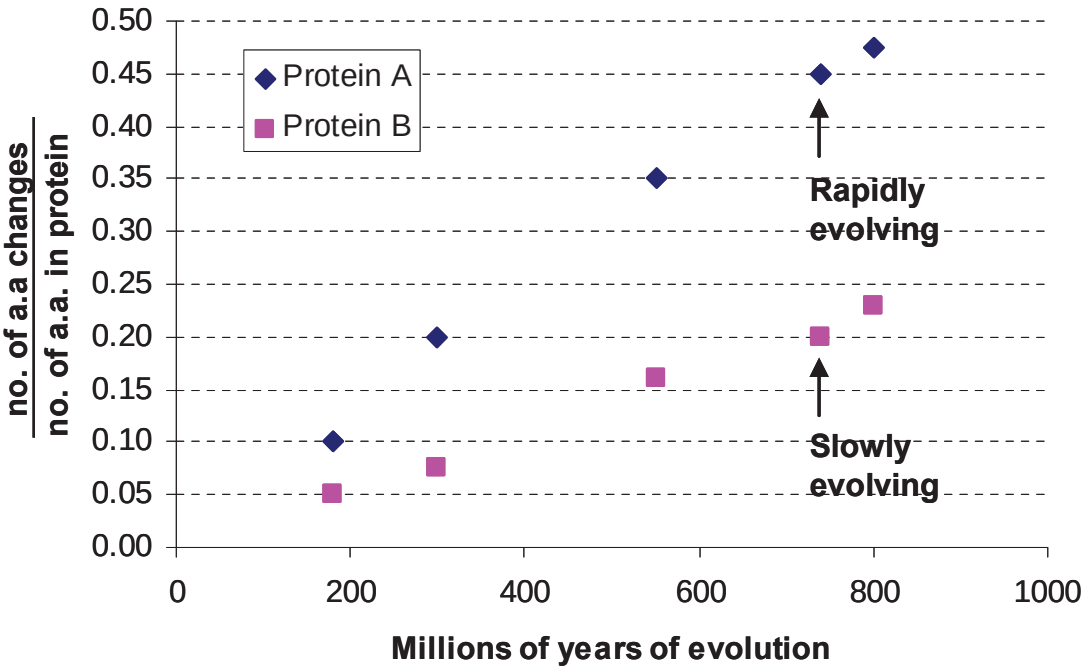
The phylogenetic tree below is based on differences between the cytochrome b proteins.



Which of the following combinations are correct?

	W	X	Y	Z
A	Lungfish	Coelacanth	Ostrich	Elephant
B	Lungfish	Ostrich	Coelacanth	Elephant
C	Coalacanth	Lungfish	Ostrich	Elephant
D	Coalacanth	Lungfish	Elephant	Ostrich

34. The graph below shows the evolution of two different proteins against the evolutionary time that has passed.



Which of the following statements can be deduced from the graphical data?

A The difference between the amino acid sequences of protein A and protein B shows how much evolution has happened in the 800 million years.

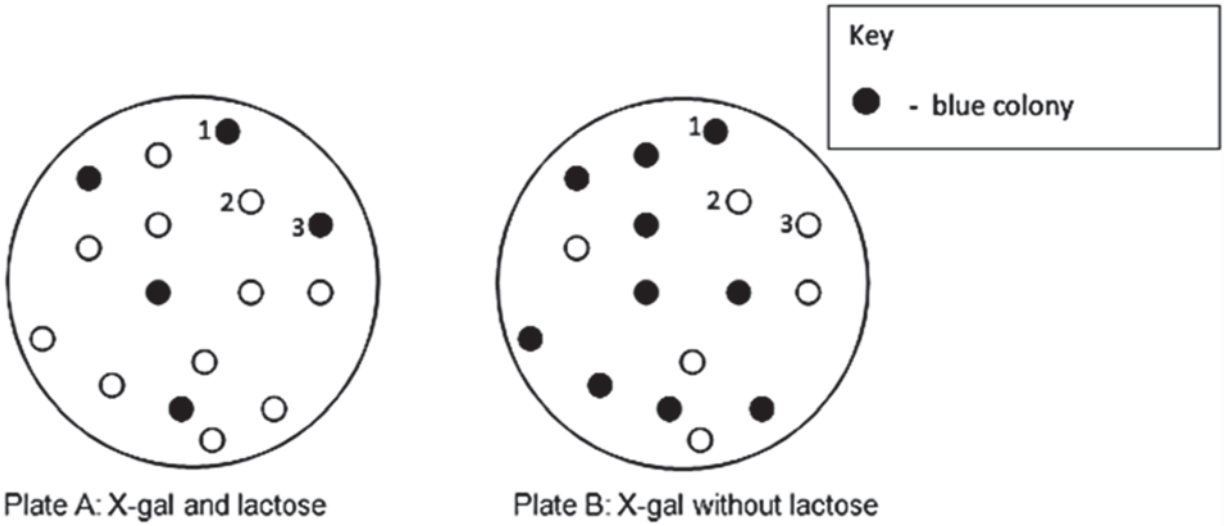
B The evolution of protein A is by natural selection while that of protein B is mostly neutral changes that make no difference to how the protein works.

C Protein A has a higher proportion of possible changes that are neutral and hence evolved at a higher rate.

D Protein B has a higher proportion of possible changes that are neutral and hence evolved at a slower rate.

35. *Escherichia coli.* bacteria are infected with laboratory-cultured lambda phage. The bacteria are initially cultured in a nutrient medium without X-gal. The bacteria colonies produced are replica plated onto two agar plates, one containing X-gal and lactose and the other containing X-gal without lactose.

There is no glucose in either plates. The agar plates below show the results of this experiment.



Which of the following explanations for colonies 1, 2 and 3 are correct?

A Colony 1 is blue in both plates because transcription of Lac Z gene is turned on all the time so β galactosidase is continuously translated to break down X-gal into a blue compound.

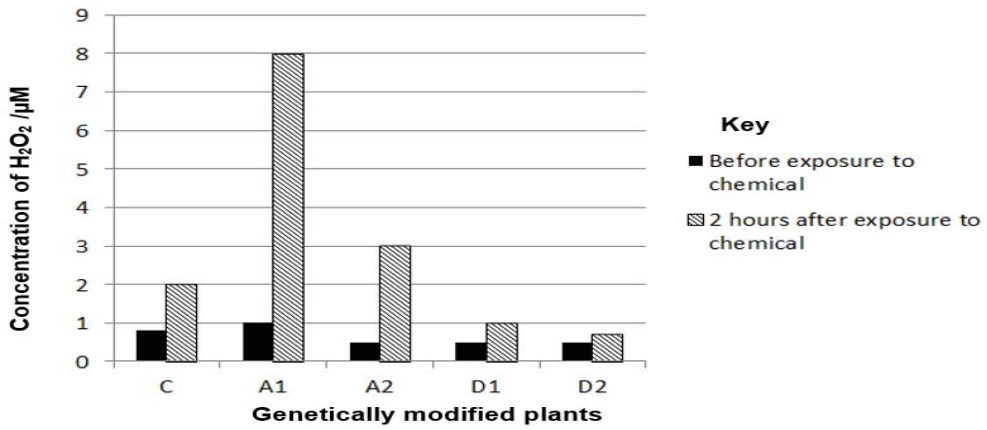
B Colony 2 is white in both plates because transcription of lac Z gene results in β galactosidase being produced to break down X-gal into a white compound.

C Colony 3 is blue in plate A and white in plate B because viral DNA is integrated into lac Z gene and lac Z gene is disrupted leading to insertional inactivation.

D Colony 3 is blue in plate A and white in plate B because phage DNA is integrated into the operator by transduction and repressor cannot find to operator.

36. Plants have developed defence mechanisms against pathogens such as bacteria, fungi and viruses. Chemicals released by these pathogens can trigger a defence response in infected plant cells. For example, the production of hydrogen peroxide (H_2O_2) which reacts with pathogen membranes and cellular chemicals eventually kills both the cell and pathogen.

The *OSRac1* gene from another plant species was isolated and introduced into a number of rice plant (*Oryza spp.*) lines to study its role in disease resistance of plants to blast fungus. Experiments were carried out to see if the *OSRac1* gene was part of the signalling pathway for hydrogen peroxide production. A control (**C**) and four other genetically modified rice plant lines (**A1**, **A2**, **D1** and **D2**) grown *in vitro* from calluses were exposed to chemicals known to initiate a defence response by producing hydrogen peroxide. **A1** and **A2** are rice plants with the *OSRac1* gene always turned on. **D1** and **D2** are rice plants with the *OSRac1* gene suppressed. The results are shown in the graph below.



Which of the following statements can be concluded from the graph?

A *OSRac1* gene is not involved in disease resistance as both D2 showed a lower increase in H_2O_2 production by 40% as compared to control which showed an increase in H_2O_2 production of 150%.

B *OSRac1* gene is involved in disease resistance as A2 showed a higher increase in H_2O_2 production by 300% as compared to control which showed an increase in H_2O_2 production of 50%.

C *OSRac1* gene is not involved in disease resistance as both A1 and A2 genetically modified plants showed lesser change in the number of times of H_2O_2 production.

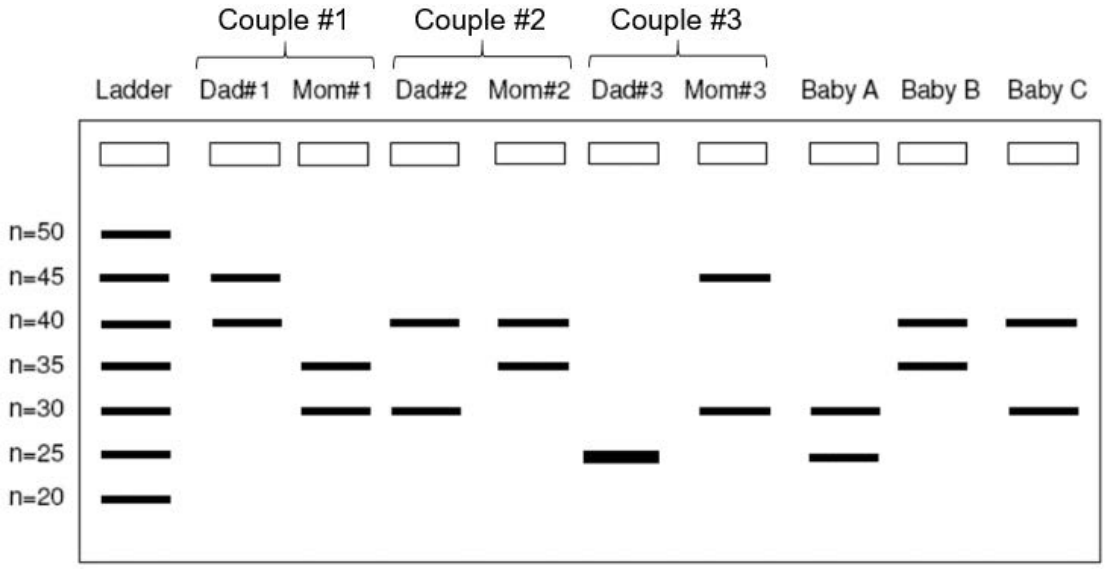
D *OSRac1* gene is involved in disease resistance as both D1 and D2 genetically modified plants with *OSRac1* gene suppressed showed smaller change in the number of times of H_2O_2 production.

37. In a maternity ward at a local hospital, a mix-up involving three couples and three babies caused a lot of confusion. Based on phenotypic characteristics, the nurses were unable to correctly identify the parents of the babies. In order to solve the case, a scientist was called in to carry out a DNA test to identify the parents of the babies. The test was based on the principle that different individuals have a different number of repeating units at a particular locus in a chromosome.

Chromosome 13 was isolated from the DNA samples that were obtained from the three couples and three babies and used for further analysis. The sequence below shows a segment of chromosome 13, which was used in the analysis where (TTAGGAT) is the repeating unit and n is the number of repeats.

5' …GCTAAGTATTGCTCAAGA… (TTAGGAT)n…GATAAATAACTGGCTAGTA…-3'
3' …CGATTCATAACGAGTTCT… (AATCCTA)n… CTATTTATTGACCGATCAT…-5'

The diagram below shows the results of the DNA test obtained from each individual.



Based on the results above, which couple does Baby B belong to?

A Couple 1
B Couple 2
C Couple 3
D Not enough information

38. The DNA sequences of the normal and mutated versions of a gene are shown below.

Normal DNA sequence:

GAGAATCCTTGAGCTCTTAAGCTTATT

Mutated DNA sequence:

GAGAATCCTTGAGGTCTTAAGCTTATT

The table below shows the recognition sequences of four restriction endonucleases.

Restriction endonuclease	Recognition site
*Bam*HI	GGATCC
*Eco*RI	GAATTC
*Hin*dIII	AAGCTT
*Sac*I	GAGCTC

Which of the restriction endonucleases would produce different number of fragments when used to digest normal and mutant DNA?

A *BamHI*

B *EcoRI*

C *HindIII*

D *SacI*

39. Which of the following is not true of adult stem cells during tissue repair?

A The stem cells must have active telomerase.

B The different checkpoints in the cell cycle of the stem cells are activated.

C Mitosis of the stem cells is induced without any stimulus.

D The stem cells will stop dividing after the damaged cells are replaced.

40. Equal masses of tobacco plant callus were cultured for four weeks on media containing different concentrations of two plant growth regulators: auxin and cytokinin.

Which of the following combinations is not possible?

Treatment	Concentration of plant growth regulators / $mgdm^{-3}$		Effect of plant growth regulators on callus growth
	Auxin	Cytokinin	
A	2.00	0.00	No growth
B	2.00	0.50	Growth of roots
C	2.00	2.00	Increased growth of callus with no differentiation
D	2.00	3.50	Growth of roots

End of Paper

Candidate Name: _____

Class	Adm No

H

millennia institute

2017 Preliminary Examination 2
Pre-University 3

H2 Biology **9648/02**

Paper 2 Core Paper **13 September 2017**

2 hours

Additional Materials: Writing paper

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your Admission number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

The use of an approved scientific calculator is expected, where appropriate. You will lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	
2	
3	
4	
5	
6	
7	
Section B	
Total	

Section A

Answer **all** questions in this section.

1. Fig. 1.1 shows a series of micrographs of animal cells undergoing cell and nuclear division.

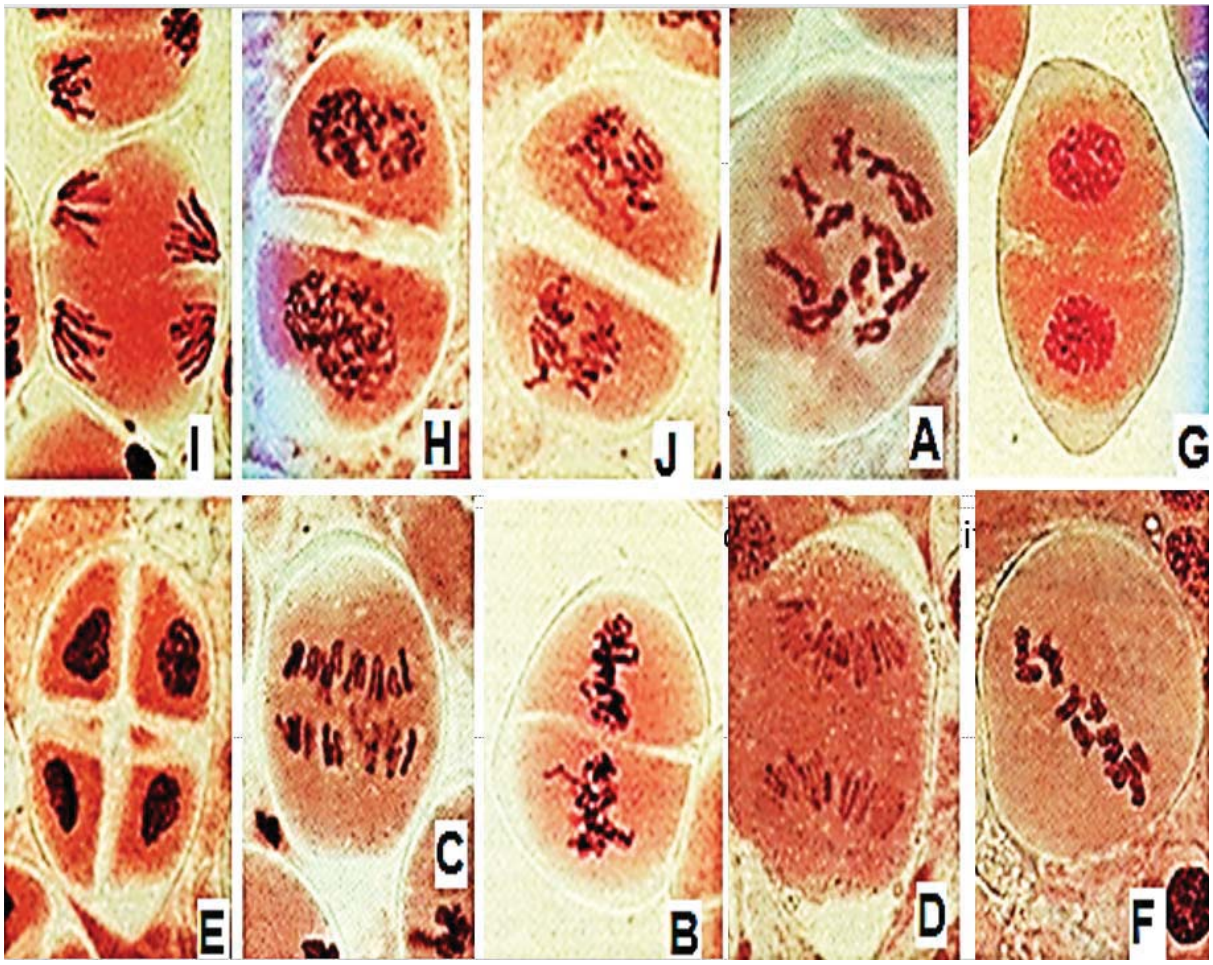


Fig. 1.1

(a) Arrange the letters in Fig. 1.1 in a correct sequence to show the events occurring in the cell and nuclear division process.

.....[2]

(b) Describe the processes occurring in **A**.

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.....[2]

(c) State one similarity and one difference between process **C** and **J**.

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……**[2]**

(d) Explain the significance of process **H**.

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……**[2]**

(e) Suggest how the cell and nuclear division process would be affected if centromeric DNA is deleted from a chromosome.

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……**[2]**

[Total 10]

2. In bacteria, the production of the amino acid tryptophan is catalyzed by five specific enzymes (simply named as **E, D, C, B** and **A** in this question) encoded by specific genes *trpE, trpD, trpC, trpB and trpA*. The *trp* operon is transcriptionally regulated by a repressor protein, (named **R** in this question), encoded by the *trpR* gene. Expression of the *trpE, trpD, trpC, trpB* and *trpA* genes is controlled by a promoter region and an operator region.

When levels of tryptophan are high, tryptophan binds to the repressor protein, **R**. The tryptophan-repressor protein complex binds to the operator region and prevents expression of the *trpE, trpD, trpC, trpB* and *trpA* genes.

(a) Draw a simple diagram to show the *trp* operon.

[1]

(b) Explain why it is useful for a bacterial cell to decrease expression of the *trp* genes when tryptophan is present.

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.....**[2]**

Table 2.1 below indicates the activity levels of the functional enzymes E, D, C, B and A in wild type bacterial cells in the presence and absence of tryptophan (Trp).

Table. 2.1

	Activity level of enzymes/units	
Enzyme	**Trp absent**	**Trp present**
E	700	0
D	700	0
C	700	0
B	700	0
A	700	0

Researchers have managed to obtain several bacterial mutants. Each mutant is the result of a single base-pair substitution in a single component of the *trp* operon. The activity level of functional enzymes E, D, C, B and A in the bacterial cells having these individual mutations is shown in Table 2.2.

Table. 2.2

	Activity level of enzymes/units					
	Mutant 1		**Mutant 2**		**Mutant 3**	
Enzymes	**Trp absent**	**Trp present**	**Trp absent**	**Trp present**	**Trp absent**	**Trp present**
E	700	700	700	0	0	0
D	700	700	0	0	0	0
C	700	700	700	0	0	0
B	700	700	700	0	0	0
A	700	700	700	0	0	0

(c) With reference to Table 2.1 and Table 2.2, identify the mutant bacteria that has a phenotype that is consistent with a loss-of-function mutation in the *trpR* gene and explain your choice.

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…….[2]

(d) Assuming mutant 3 experienced a loss-of-function mutation, account for its phenotype.

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.....**[2]**

(e) If the phenotype of mutant 3 is caused by a mutation in the *trpR* gene, explain how this mutation would affect the structure and function of the repressor protein.

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.....**[2]**

[Total: 9]

3. Researchers are constantly investigating the effects of limiting factors on the rate of photosynthesis on various plants. Fig. 3.1 show how three main limiting factors, carbon dioxide concentration, light intensity and temperature can affect the rate of photosynthesis in cactus plants.

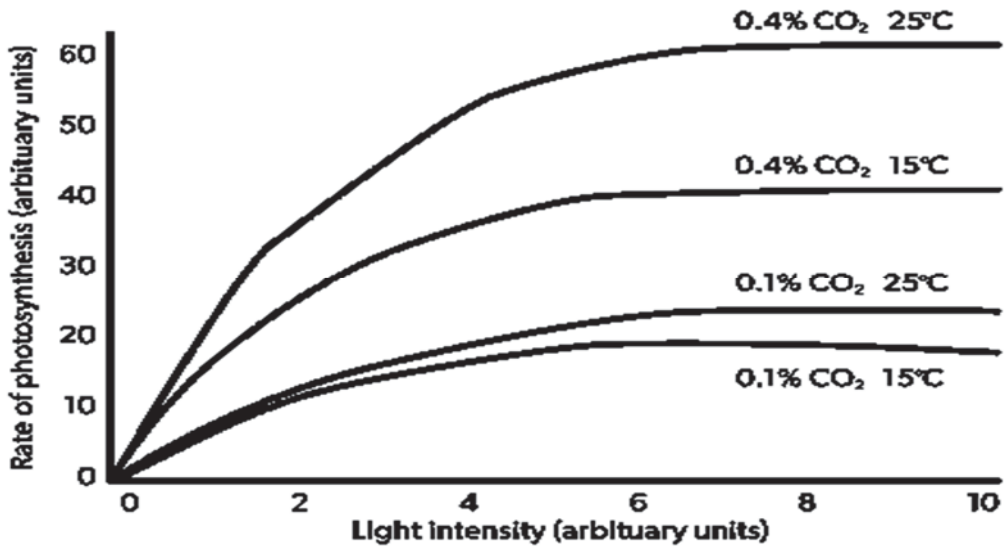

Fig. 3.1

(a) Define the term 'limiting factor'.

.....

.....**[1]**

(b) With reference to Fig. 3.1,

(i) explain for the effect of light intensity on rate of photosynthesis.

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.....**[5]**

[Turn over

(ii) justify if carbon dioxide concentration or temperature is a greater limiting factor on the rate of photosynthesis.

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.....**[3]**

(c) Suggest why water is not considered a limiting factor for the rate of photosynthesis.

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.....**[1]**

Fig. 3.2 illustrates a graph showing how varying light intensity affects the net carbon dioxide uptake and release in sun and shade plants.

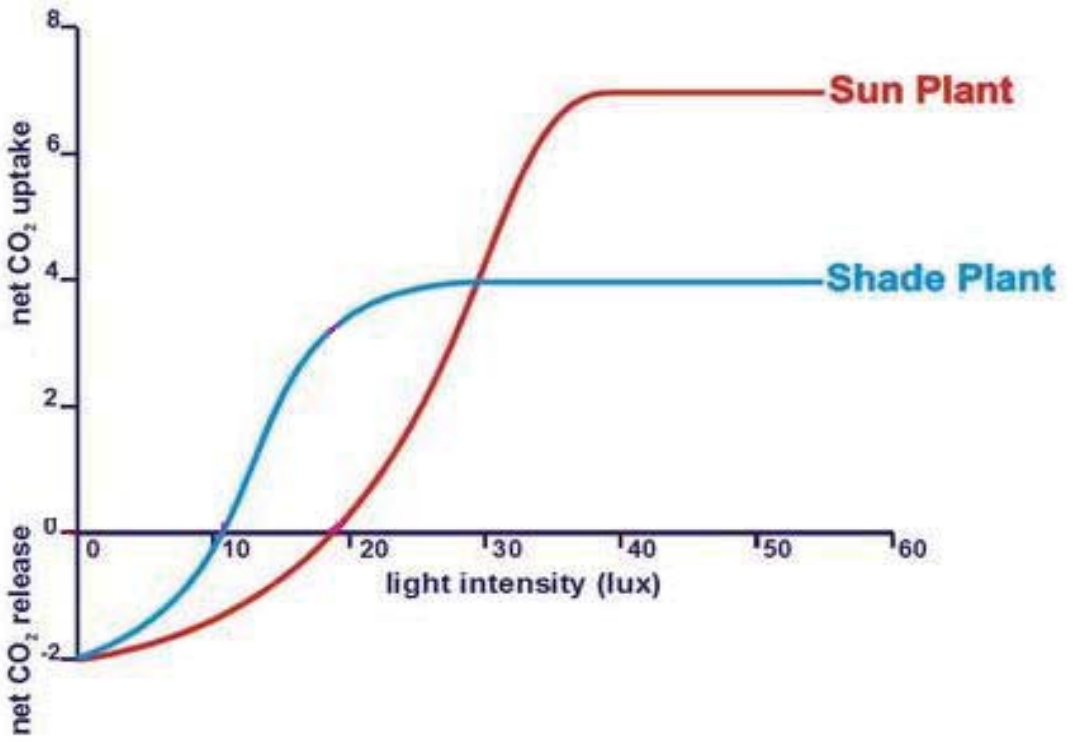

Fig. 3.2

(d) With reference to Fig. 3.2,

(i) state the compensation points of sun and shade plants.

.....

.....**[1]**

(ii) account for the graph differences between sun and shade plants.

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.....**[4]**

[Total: 15]

4. A study was conducted to study the inheritance of coat colour in mice, in which one of the allele is also known to affect normal embryonic development. A cross between agouti mouse (with agouti coat colour) and yellow mouse (with yellow coat colour) resulted in half of the F1 progeny being agouti mice and the other half being yellow. Mating of F1 yellow mice resulted in the following F2 generation.

Agouti mice	98
Yellow mice	202

(a) Using the symbols **A** and **a** for the two alleles involved, draw a genetic diagram in the space below to show how the F1 cross resulted in the F2 progeny.

[3]

In another experiment involving deer mouse, pure breeding pink-eyed mice with wild-type fur was crossed with pure breeding dark-eyed albino mice. The resulting progeny all had wild-type fur and dark eyes. These F1 mice were then crossed with pink-eyed albino mice. The results are shown in Table 4.1. It was difficult to distinguish between mice that are dark-eyed albino and pink-eyed albino, so these two phenotypes were counted together.

Table 4.1

Phenotype	**Number of progeny**
Wild-type fur, dark-eyed	12
Wild-type fur, pink-eyed	62
Albino, dark-eyed Albino, pink-eyed	78
Total	152

(b) In the blank space below, calculate the chi-square value.

[2]

Table 4.2 shows a portion of the chi-square table.

Table 4.2

distribution of X^2			
number of degrees of freedom (v)	**probability**		
	0.1	**0.05**	**0.01**
1	2.71	3.84	6.64
2	4.60	5.99	9.21
3	6.25	7.82	11.34
4	7.78	9.49	13.28

(c) Using the values in Table 4.2, draw appropriate conclusions as to whether the results of the cross followed the expected ratio you have predicted in **(b)**.

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.....**[2]**

(d) Using **E/e** to represent alleles for eye colour and **A/a** to represent alleles for fur coat colour, explain the result of the F1 cross in the deer mouse experiment using a genetic diagram.

[4]

[Total: 11]

5. *Bungarus multicinctus*, also known as the Taiwanese Krait, is a species of venomous snake endemic to Asia and is predominantly found in forests from Taiwan to Southeast Asia. In order to better understand the venomous snake's physiological pathways, researchers have been conducting extensive research on the mechanism of action of Taiwanese Krait venom which consists primarily of neurotoxins.

Fig. 5.1 shows a diagram of the kappa-bungarotoxin, a neurotoxin found in the venom of the Taiwanese Krait. Kappa-bungarotoxin is a highly stable protein molecule that is capable of withstanding harsh chemical reactions.

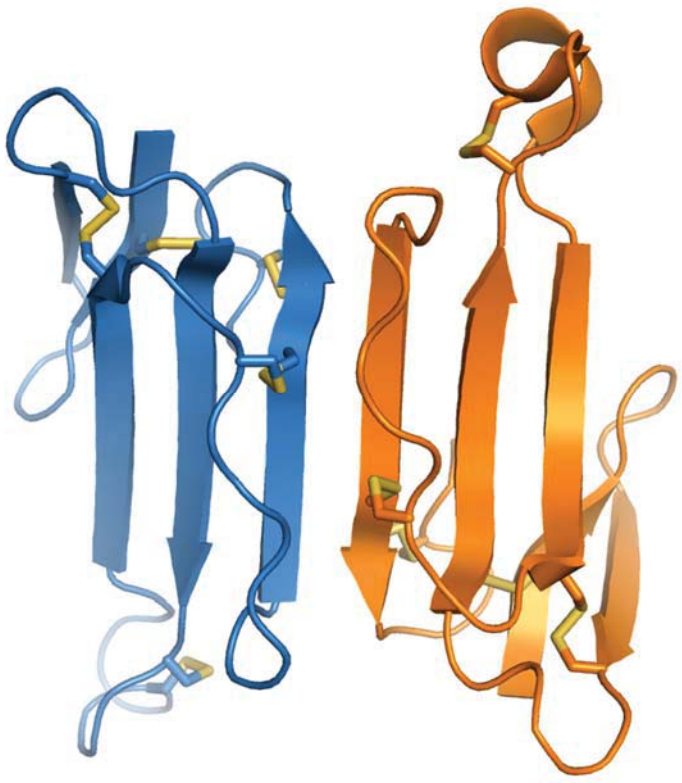

Fig. 5.1

(a) Explain how the protein structure of kappa-bungarotoxin is maintained.

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.....**[3]**

People bitten by *Bungarus multicinctus* suffer from neuromuscular paralysis and respiratory failure. Research shows that the venom causes serious health complications due to the effects of kappa-bungarotoxin at the neuromuscular junctions at the muscle cells of the lungs as shown in Fig. 5.2.

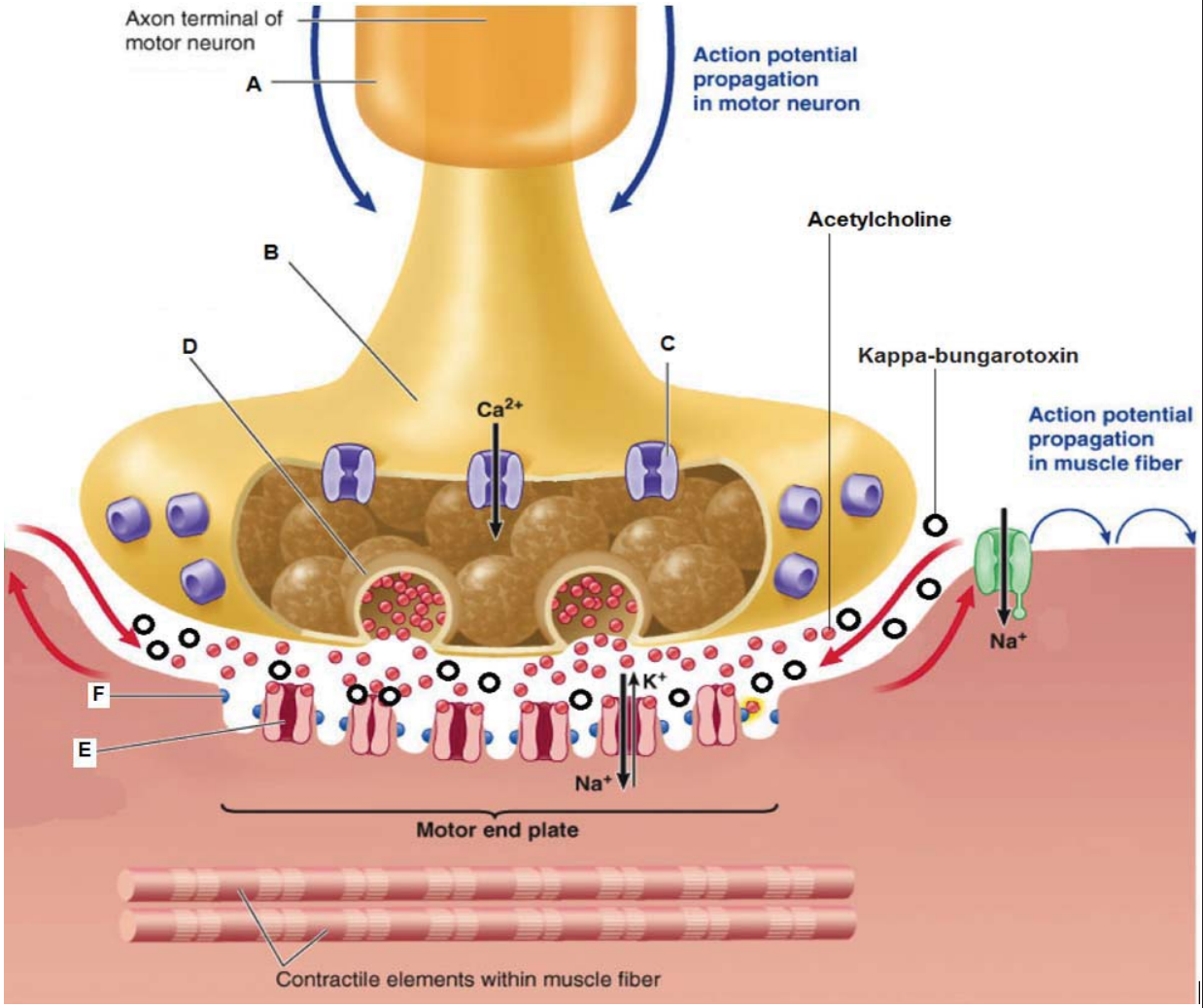

Fig. 5.2

(b) Name the parts of the neuromuscular junction shown in Fig 5.2 labelled **A**, **B**, **C, D** and **E**.

A: .....

B: .....

C: .....

D: .....

E: .....

[2]

In Fig. 5.2, **F** is an enzyme important in synaptic signalling.

(c) Describe the function of **F**.

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.....**[1]**

(d) Explain how the transmission of nervous impulse shown in Fig. 5.2 differs from electrical transmission of action potentials.

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.....**[2]**

(e) Explain how kappa-bungarotoxin causes respiratory failure among humans bitten by *Bungarus multicinctus.*

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.....**[4]**

Antivenom is a medication used to treat venomous bites and is recommended for use via injection if the venom from the snake is of high risk of toxicity.

(f) Suggest how antivenom can alleviate the effects of kappa-bungarotoxin.

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.....**[1]**

[Total: 13]

6. Fig. 6.1 shows a tyrosine kinase receptor. The effect of insulin binding to this complementary receptor is shown in Fig. 6.2. The boxed regions in Fig. 6.1 and Fig. 6.2 are cysteine-rich domains.

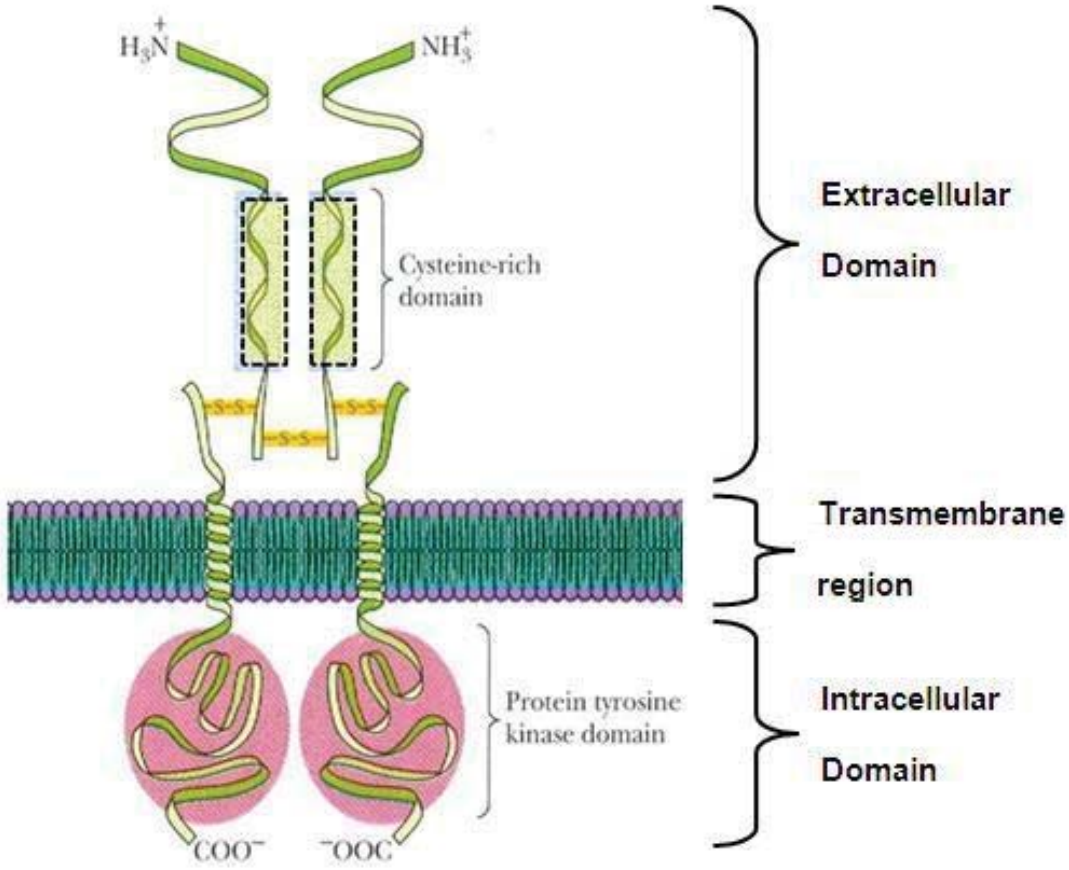

Fig. 6.1

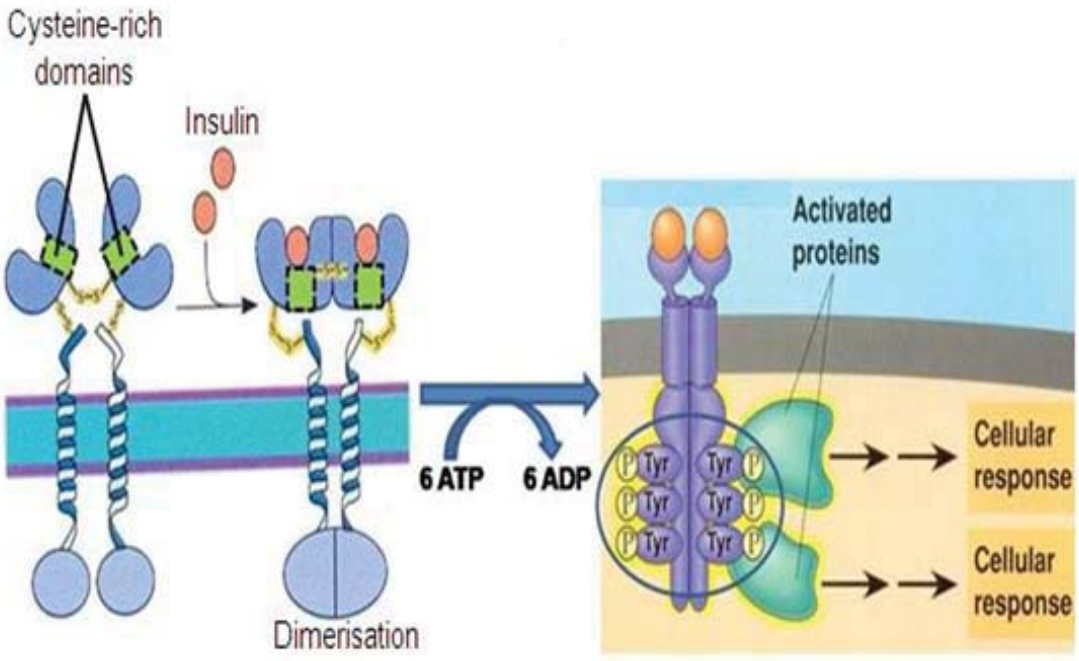

Fig. 6.2

(a) Explain how the structure of the tyrosine kinase receptor is suited for its role in insulin mediated cell signalling.

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.....**[2]**

Fig. 6.3 shows how blood levels of glucose, insulin and glucagon change after a meal.

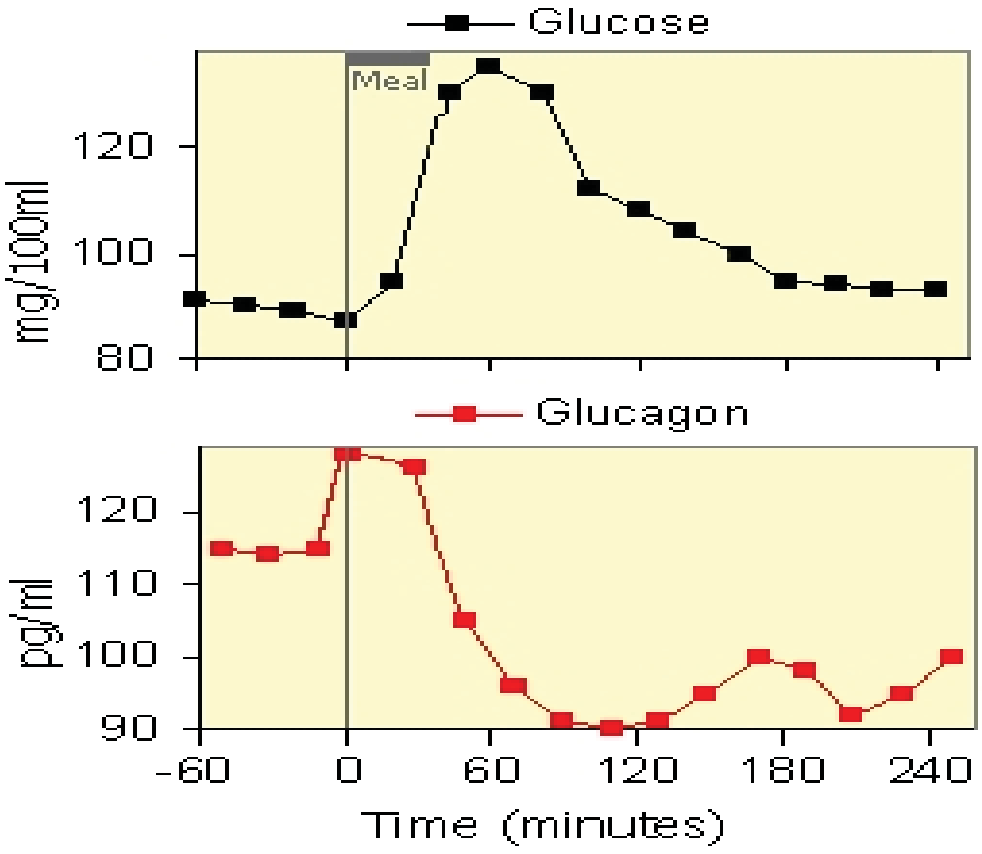

Fig. 6.3

(b) Describe the components of a homeostatic control system and explain the principles of homeostasis.

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.....**[3]**

(c) With reference to Fig. 6.3, explain the relationship between glucose and glucagon levels from 0 to 120 minutes.

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.....**[4]**

Diabetes mellitus is a disease in which high blood glucose cannot be regulated back to normal set point within the body. The hormone insulin is commonly used in the treatment of diabetes. There are two forms of diabetes mellitus: Type 1 and Type 2. Type 2 diabetes mellitus is characterized by insulin resistance whereby the body tissues do not respond effectively to insulin.

(d) Suggest why the body tissue is insensitive to insulin in Type 2 diabetes mellitus.

.....

.....**[1]**

Glucagonoma is a rare tumour of the α-cells of the islet of Langerhans which results in an overproduction and secretion of glucagon.

(e) Suggest how glucose metabolism is affected when an individual has a glucagonoma.

.....

.....**[1]**

Cancer development occurs in stages. The advanced stage of cancer is characterized by the spread of cancer development to other parts of the body via the circulatory system to form secondary tumours by a process known as metastasis.

(f) Explain the properties of cancer cells required for metastasis.

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.....**[2]**

[Total: 13]

7. In New Zealand, there are two species and three sub-species of native bush robins. It is believed that the robins evolved from a common ancestral stock, members of which flew from Australia across the Tasman Sea and became established in New Zealand over a million years ago. This ancestral form is considered to be similar to the present day Australian flame robin, *Petroica multicolor*, a bird with a brightly coloured red breast. The New Zealand birds do not have this red colour. Some characteristics of the birds and their distributions are shown in Fig. 7.1.

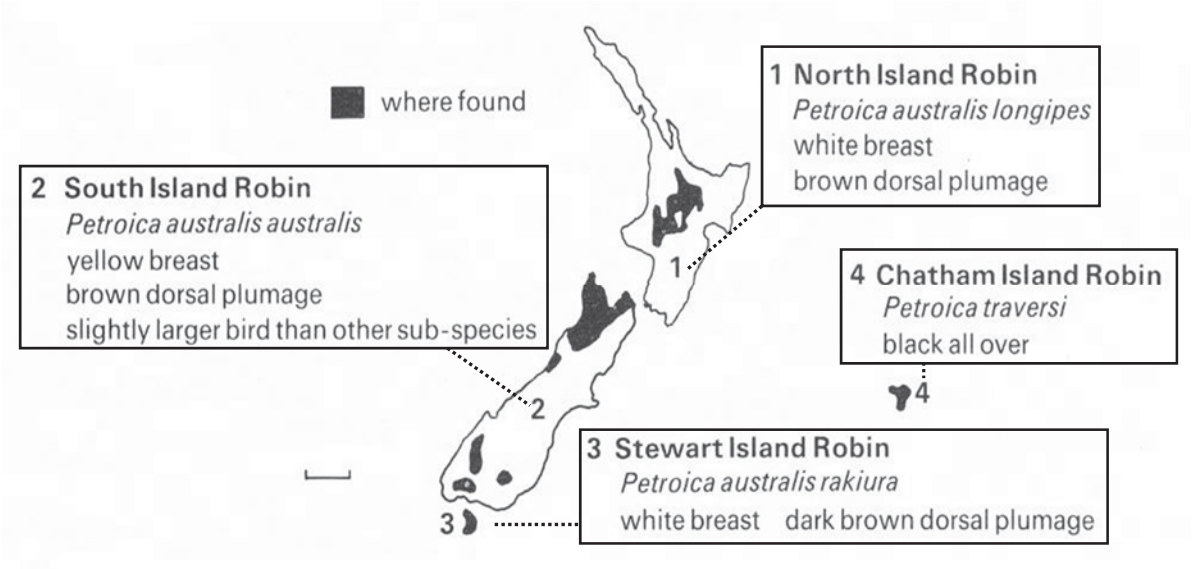

Fig. 7.1

(a) State the scientific name of the two species of native bush robins in New Zealand.

..... **[1]**

(b) Explain why the robins in locations **1**, **2** and **3** are similar but different from those in location **4**.

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.....**[3]**

Based on earlier research, the native bush robin species and subspecies were distinguished based on a number of phenotypic differences such as plumage and breast colour. However, with modern technology, researchers have been using molecular methods such as direct DNA and amino acid comparison to further determine the phylogeny between the native bush robin species.

(c) Explain why molecular homology is better than anatomical homology in determining evolutionary relationship between species of native bush robins.

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.....**[2]**

Differences in the *cytochrome b* DNA sequence of several native bush robins from different regions of New Zealand were measured and plotted against time since divergence from the primitive ancestor as seen in Fig. 7.2.

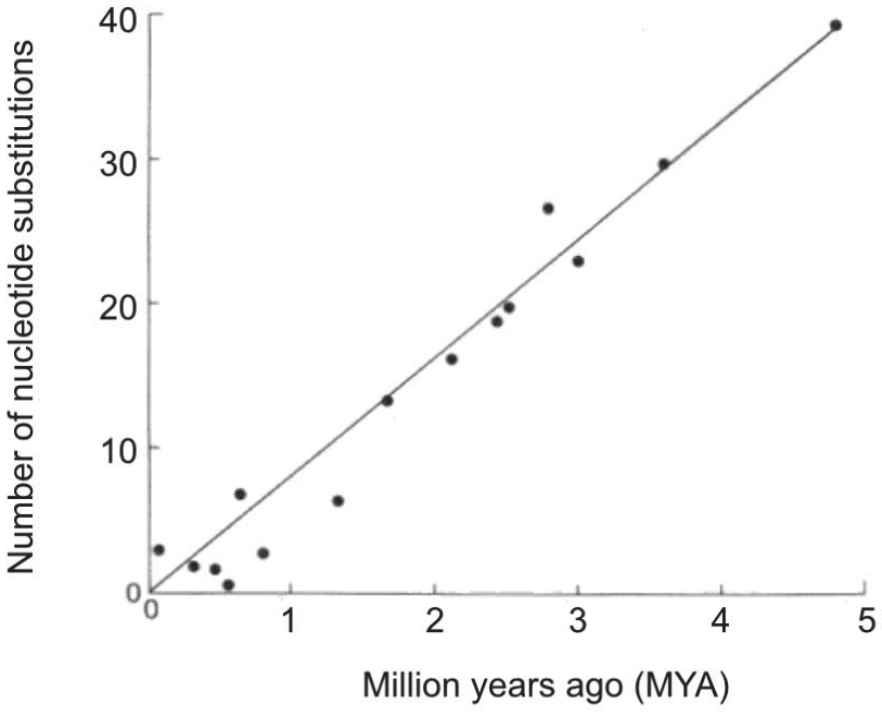

Fig. 7.2

(d) Describe how the differences in the number of nucleotide substitutions support the neutral theory of molecular evolution.

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.....**[2]**

(e) Suggest why New Zealand robins do not have the red breast trait even though it is present in its Australian robin ancestors.

.....

.....**[1]**

[Total: 9]

Section B

Answer **one** question.

Write your answers on the separate answer paper provided.
Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.
Your answers must be in continuous prose, where appropriate.
Your answers must be set out in sections **(a), (b)** etc., as indicated in the question.

8.

(a) Compare between DNA replication and transcription. **[6]**

(b) Describe how differences in the structure and organization of prokaryotic and eukaryotic genomes affect their control of gene expression. **[7]**

(c) Outline the viral reproduction cycle of HIV. **[7]**

[Total: 20]

9.

(a) Contrast the structures of viral, prokaryotic and eukaryotic genome. **[5]**

(b) Relate the structure of ribosome to its role in protein synthesis. **[7]**

(c) Outline the processes involved in oxidative phosphorylation. **[8]**

[Total: 20]

End of Paper

Class Adm No

Candidate Name: _____

H

millennia institute

2017 Preliminary Examination 2
Pre-University 3

H2 Biology **9648/03**

Applications Paper and Planning Question **19 September 2017**

2 hours

Additional Materials: Writing paper

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your Admission number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

The use of an approved scientific calculator is expected, where appropriate.
You will lose marks if you do not show your working or if you do not use appropriate units.
At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
Total	

This question paper consists of 20 printed pages

[Turn over

Answer **all** questions.

1. The ability to model human diseases using cultured pluripotent stem cells (PSCs) has revolutionized the ways in which we study monogenic, complex and epigenetic disorders, as well as early- and late-onset diseases. Several strategies are used to generate such disease models using either embryonic stem cells (ES cells) or patient-specific induced PSCs (iPSCs), creating new possibilities for the establishment of models and their use in drug screening. Fig. 1.1 shows strategies for generating human pluripotent stem cells (hPSCs) carrying a genetic disorder for research purposes. Disease-specific ES cells can be identified during the in-vitro fertilization (IVF) process by pre-implantation genetic diagnosis (PGD) or pre-implantation genetic screening (PGS).

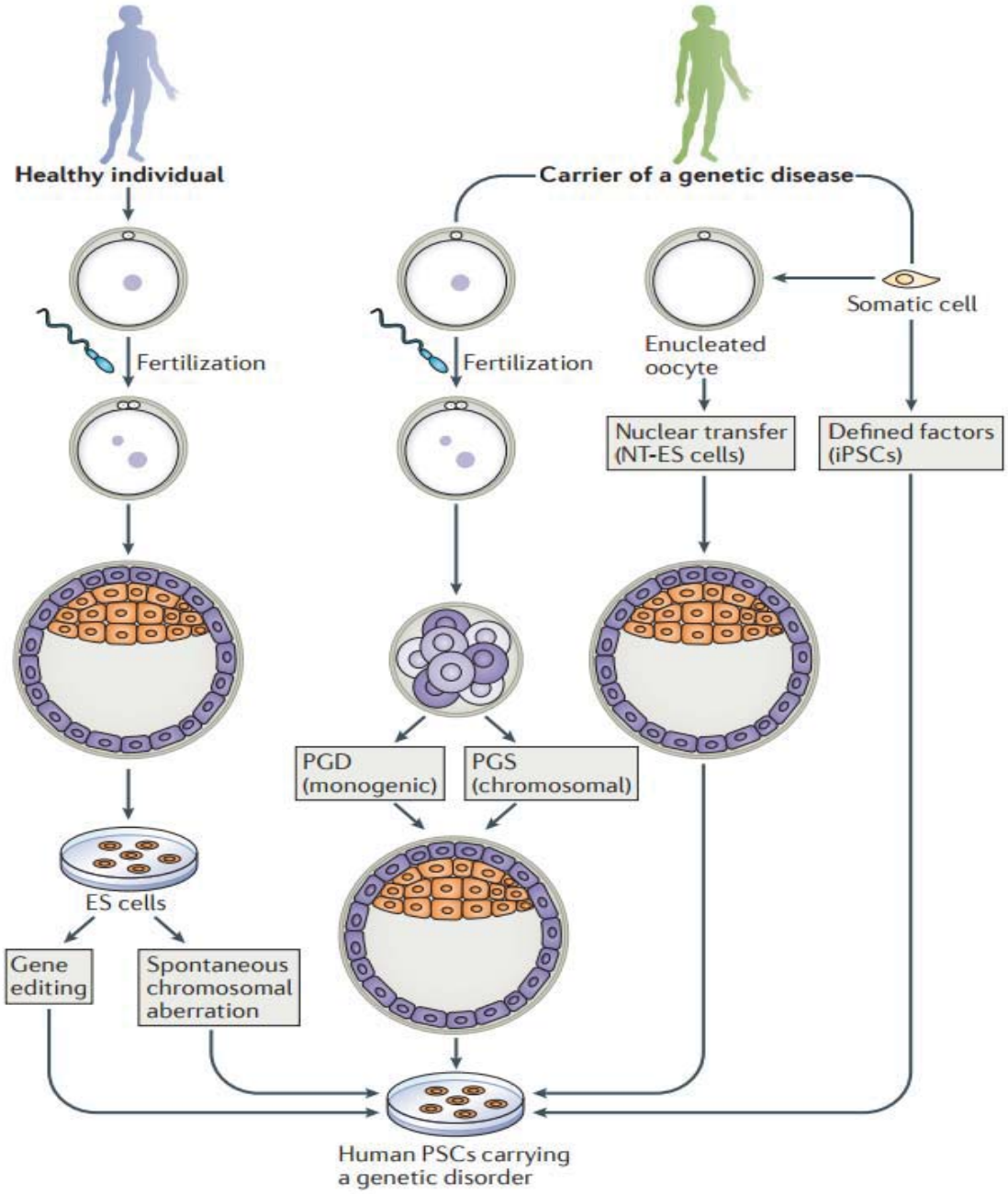

Fig. 1.1

(a) Describe one similarity and one difference between a blastocyst and embryo.

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.....

.....

.....**[2]**

(b) Describe one advantage and one limitation of using somatic cell nuclear transfer (SCNT) to generate human PSCs carrying a genetic disorder.

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.....**[2]**

In order to optimise the conditions and increase the chances of creating iPSCs from somatic cells, extensive research has been conducted on 4 main genes, *Oct4*, *Sox2*, *Nanog* and *Lin28* using M4 cell cultures. Fig. 1.2 shows the effect of different combinations of genes in the reprogramming mixture on the number of induced-pluripotent stem cell colonies formed.

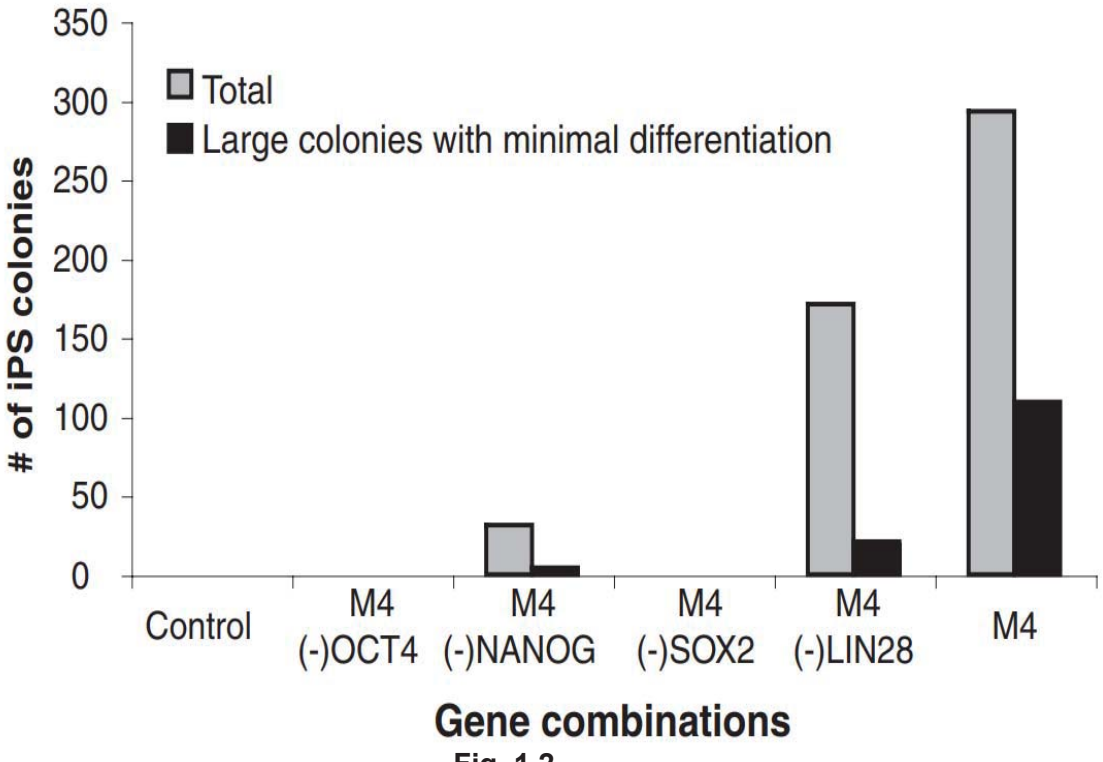

Fig. 1.2

[Turn over

(c) With reference to Fig. 1.2,

(i) explain the purpose of the control.

……

……**[1]**

(ii) describe the results produced from varying gene combinations in the reprogramming mixture.

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……

……**[2]**

(d) Describe one possible regulatory process at the chromosomal level that could increase the expression of *Oct4*, *Sox2*, *Nanog* and *Lin28* genes.

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……**[2]**

(e) Suggest one reason why the number of cell colonies with minimal differentiation differs from the total number of cell colonies produced.

……

……**[1]**

X-linked Severe Combined Immunodeficiency (SCID) is a rare congenital disorder characterised by improper development of immune cells which has been treated by gene therapy. The ability to generate iPS cells that have similar characteristics with embryonic stem cells has provided a promising alternative to the use of haematopoietic stem cells for gene therapy to treat X-linked SCID.

Fig 1.3 shows a possible process of using iPS cells for gene therapy.

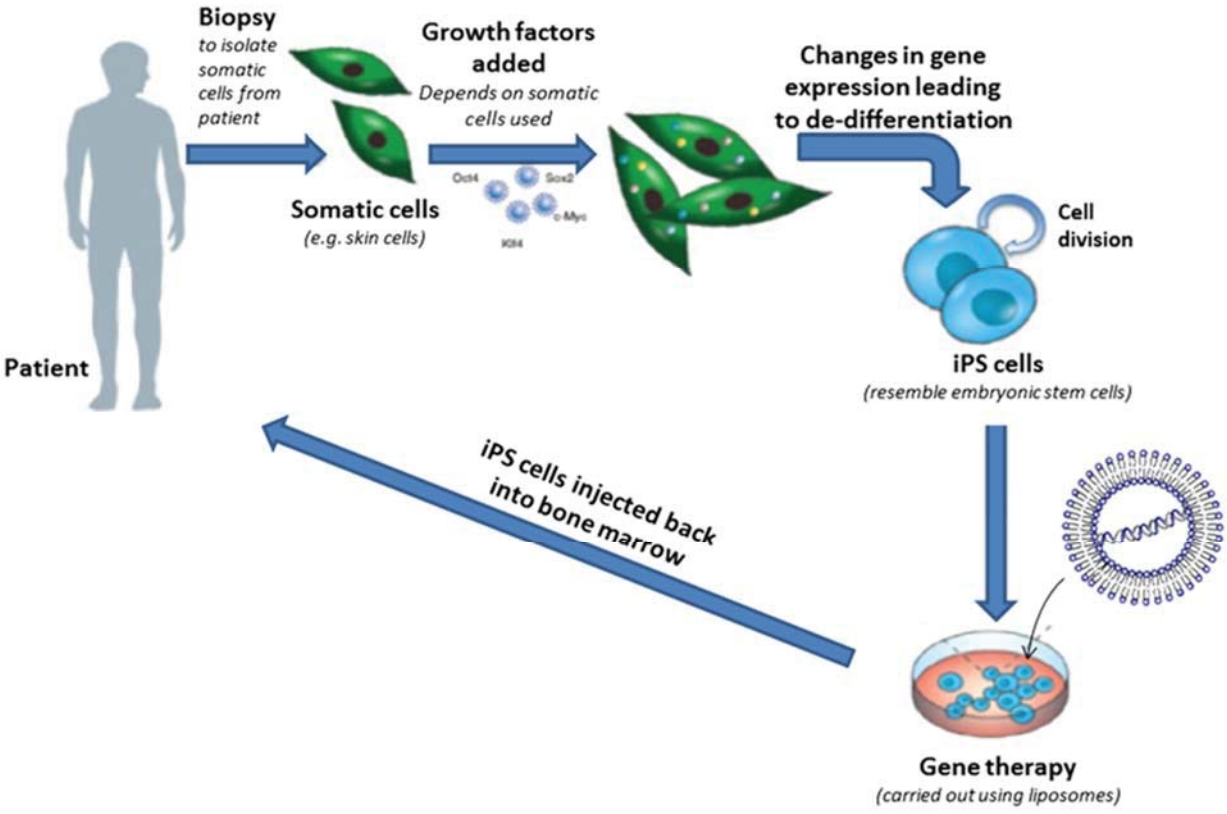

Fig. 1.3

(f) Besides difficulties with de-differentiating somatic cells to iPS cells, explain one other factor that could prevent this method of gene therapy for X-linked SCID from becoming an effective treatment.

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.....**[2]**

(g) Justify if you agree or disagree that use of iPS cells can address the ethical concerns of using embryonic stem cells for treatment of genetic diseases.

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.....**[2]**

[Total: 14]

2. Conventional DNA ladders are traditional molecular weight standards used for sizing and approximate quantification of linear double-stranded DNA fragments in agarose and non-denaturing polyacrylamide gels for research purposes. The markers are composed of lambda phage DNA digested to completion with the appropriate restriction enzyme(s), purified and dissolved in storage buffer. The DNA fragments contain blunt or sticky ends depending on the restriction enzyme used for the marker's preparation. Fig. 2.1 shows the genome of Lambda DNA with the restriction sites corresponding to six different restriction enzymes.

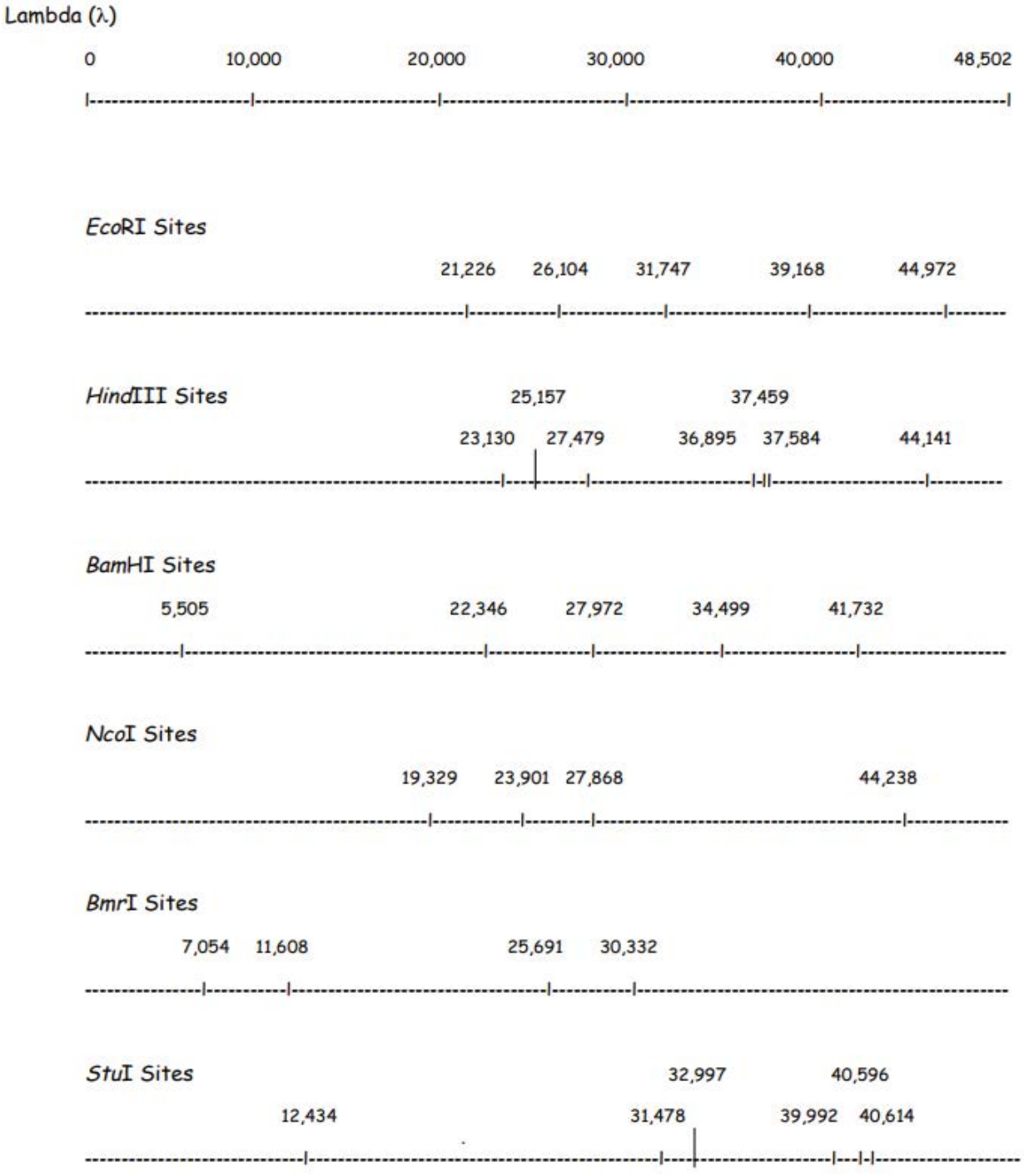

Fig. 2.1

Table 2.1

EcoRI	HindIII	NcoI	BmrI

(a) With reference to Fig. 2.1, fill in the columns of Table 2.1 with the respective DNA fragments generated from their corresponding restriction enzymes. List each fragment from the largest to the smallest. **[2]**

(b) Explain two factors that would influence a researcher's decision in choosing a restriction enzyme for the restriction digest step of the gene cloning experiment.

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…….**[2]**

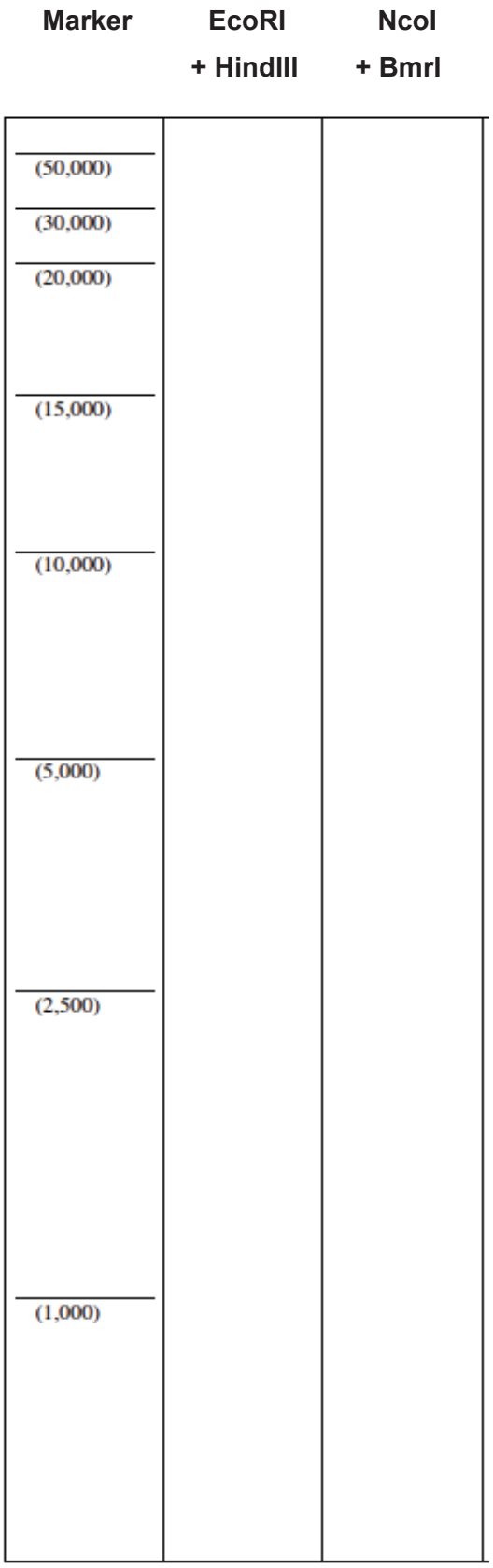

Fig. 2.2

(c) Complete Fig. 2.2 below by drawing the DNA band patterns after gel electrophoresis. **[2]**

(d) Explain how DNA bands can be visualized after gel electrophoresis.

…….

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…….

…….**[2]**

(e) Suggest a method to improve the separation of DNA bands during gel electrophoresis.

…….

…….**[1]**

Besides being used for DNA fragment separation, gel electrophoresis can also be conducted to separate protein fragments for agricultural research purposes in order to study relationships between polypeptide band patterns and phenotypic traits.

Barley (*Hordeum vulgare)* is an important crop in southern Brazil where its production is used in the brewing industry. Hence, the malting quality of different barley plant cultivars must be continuously researched and improved upon. Cultivars are new plant species obtained via artificial selecting breeding processes.

Malt is germinated cereal grains that have been dried via malting. Malting grains develop the enzymes required for modifying the starch in the grains into various types of sugars such as maltose and glucose. Characteristics of importance for malting quality, which can differ considerably among barley cultivars, include grain size, grain protein concentration and nitrogen content in the seeds.

Recently, researchers are researching on how the quality of a particular storage protein named hordein could affect the malting quality of barley plants. Barley is highly polymorphic regarding the hordein polypeptide composition. Electrophoresis is used as a screening test to differentiate barley plant cultivars and to determine malting quality of each variety. By comparing the total hordein pattern from barley cultivars of different malting quality, researchers can investigate the relationship between malting quality and band patterns and to explore the feasibility of using hordein protein electrophoresis to assist in the selection of barley plant cultivars for malting.

Fig. 2.3 shows the hordein polypeptide band patterns of 14 different barley plant species. On the right of the gel, a polypeptide fragment ladder showing the band positions of 26 different hordein polypeptide sizes serves as a reference point for comparison.

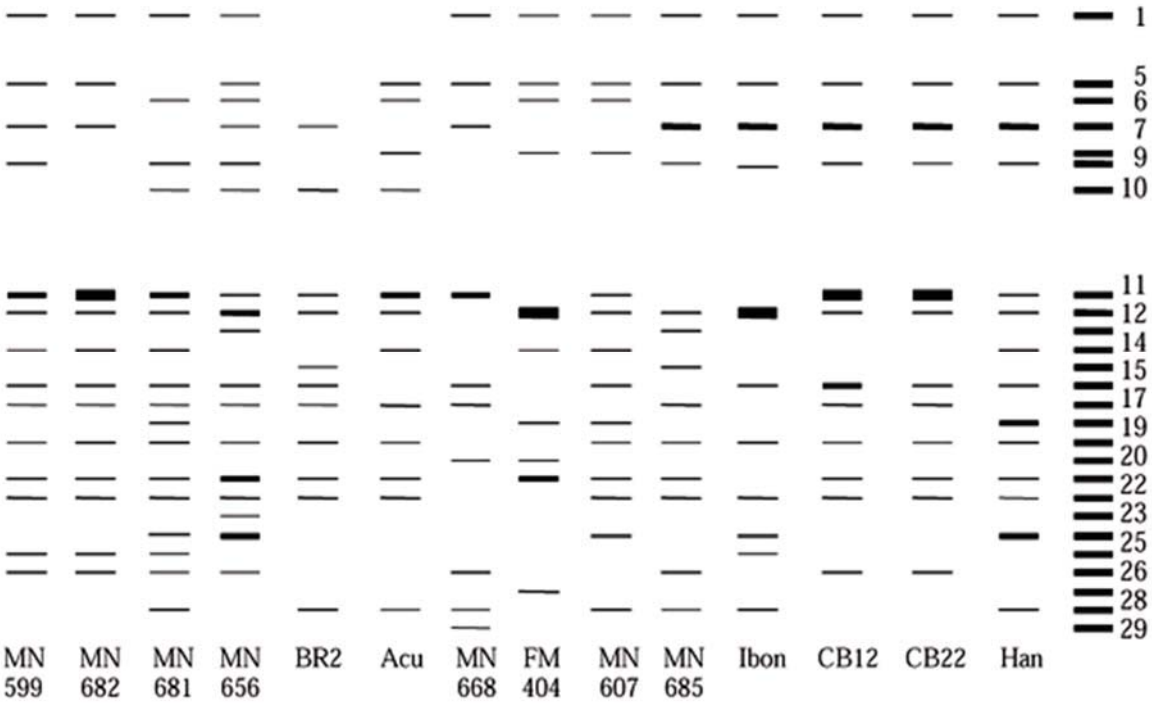

Fig. 2.3

(f) With reference to Fig. 2.3, complete the phylogenetic tree shown in Fig. 2.4.

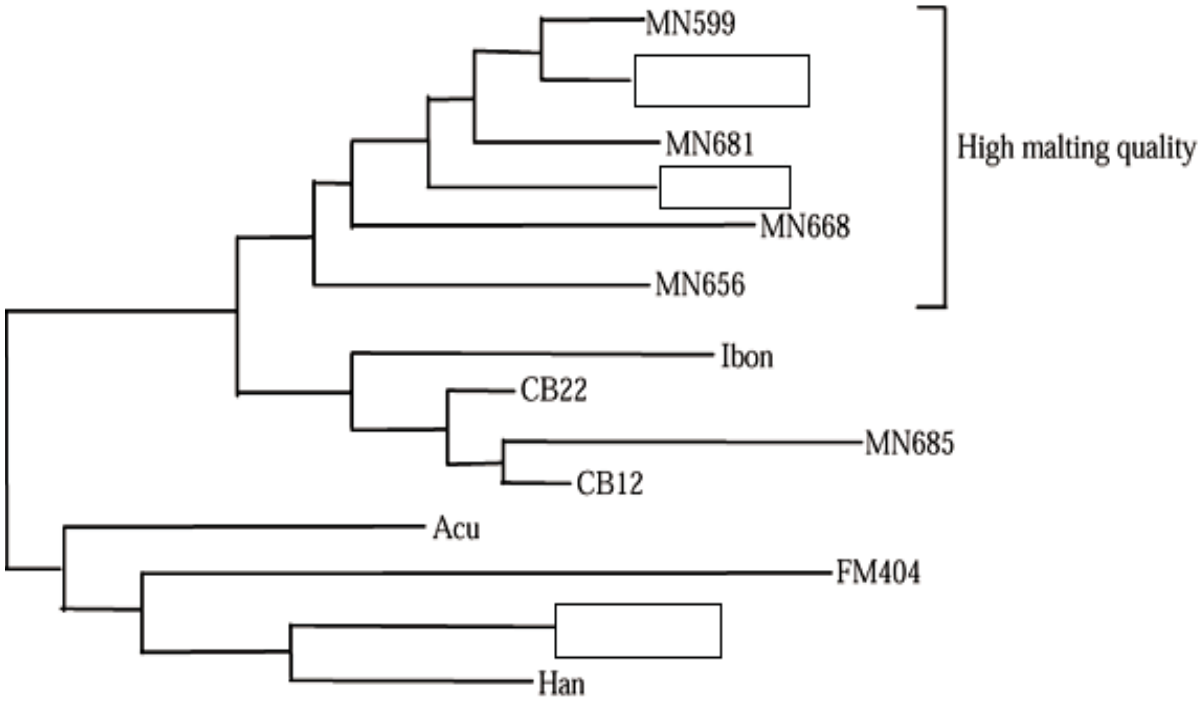

Fig. 2.4 **[2]**

Table 2.2 shows the correlation of each polypeptide band with the malting quality of barley varieties studied. The number of + / - in Table 2.2 indicates the strength of correlation between the polypeptide band and malting quality.

Table 2.2

Band	Correlation	Band	Correlation
1	-	17	-
5	- -	18	-
6	+	19	- - -
7	-	20	+
8	-	21	-
9	-	22	-
10	+	23	+
11	+	24	-
12	- -	25	+
13	+	26	+
14	-	27	+
15	+	28	-
16	+	29	+

Table 2.3 shows the frequency of the hordein polypeptide bands (in percentage) in each barley variety studied.

Table 2.3

Hordein band	Varieties[1]													
	MN 599	MN 682	MN 668	MN 681	MN 656	BR2	Acu	Han	FM 404	MN 607	MN 685	Ibon	CB12	CB22
1	20	20	27	27	38	0	0	78	100	70	100	90	100	100
5	20	10	18	0	8	0	91	71	100	70	100	90	100	90
6	0	0	0	9	8	0	75	0	100	70	0	0	0	0
7	20	20	27	0	31	13	0	78	0	0	100	90	100	100
8	0	0	0	0	0	0	75	0	100	50	0	0	0	0
9	20	0	0	27	8	0	0	64	0	0	100	70	100	90
10	0	0	0	9	8	33	8	0	0	0	0	0	0	0
11	100	100	100	100	54	100	100	100	0	100	0	0	100	100
12	100	70	0	64	92	40	100	100	100	100	100	100	100	100
13	0	0	0	0	46	0	0	0	0	0	100	0	0	0
14	30	30	0	27	0	0	100	100	100	100	0	0	0	0
15	0	0	0	0	0	60	0	0	0	0	100	0	0	0
16	100	100	100	100	54	100	0	100	0	30	0	100	100	100
17	50	60	100	73	23	60	91	0	0	0	100	0	100	100
18	0	0	0	18	0	0	0	100	100	100	0	0	0	0
19	20	20	0	36	54	66	100	100	0	90	100	100	100	100
20	0	0	9	0	0	0	0	0	100	0	0	0	0	0
21	100	100	0	100	46	100	42	100	100	100	100	0	100	100
22	100	100	0	100	46	100	91	36	0	100	100	100	100	100
23	0	0	0	0	23	0	0	0	0	0	0	0	0	0
24	0	0	0	27	54	0	0	100	0	100	0	90	0	0
25	50	30	0	45	0	0	0	0	0	0	0	20	0	0
26	40	40	100	9	23	0	0	0	0	0	100	0	100	100
27	0	0	0	0	0	0	0	0	100	0	0	0	0	0
28	0	0	64	9	0	6	8	93	0	100	50	100	0	0
29	0	0	27	0	0	0	0	0	0	0	0	0	0	0

[Turn over

(g) With reference to Fig. 2.4, Table 2.2 and Table 2.3, identify and explain which barley variant would have the best malting quality.

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……**[4]**

[Total: 15]

3. Rice is the staple diet in many parts of the world. It lacks a number of important nutrients, including β carotene, from which vitamin A is synthesised. Adequate concentrations of vitamin A give protection from night blindness. Higher concentrations act as an antioxidant that may give some protection from cancer and heart disease. Golden rice, which contains β carotene, was developed in Switzerland by genetically modifying rice using genes from a daffodil (a flowering plant) and a bacterium.

Fig. 3.1 shows an artificial DNA sequence used.

Key:

pro – promoter sequence for polymerase enzymes

ter – termination signal for polymerase enzymes

Hyg resist – Hygromycin B antibiotic resistance gene from a bacterium

Fig. 3.1

Fig. 3.2 shows the main events involved in obtaining a transgenic rice plant.

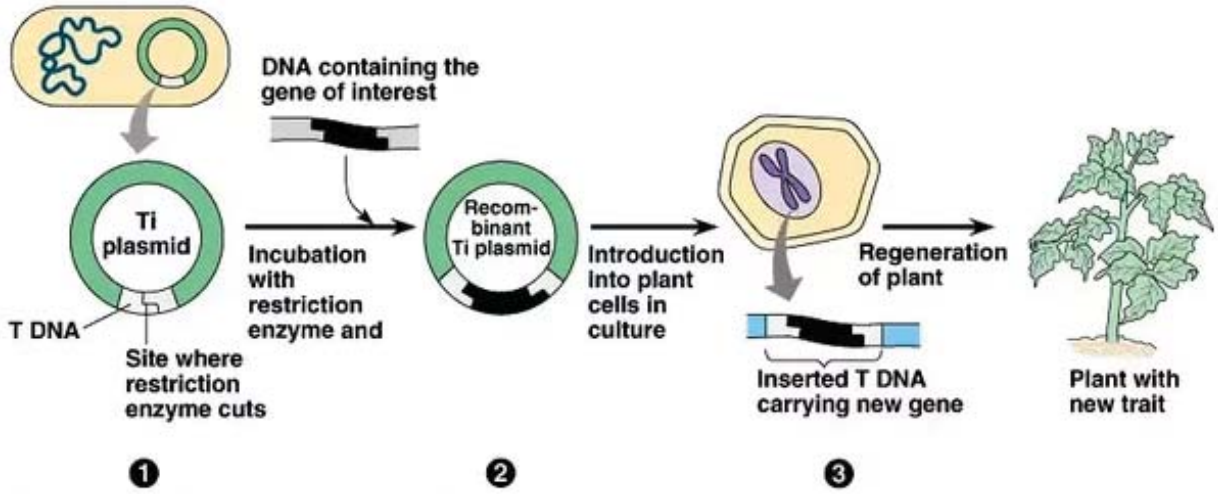

Fig. 3.2

(a) Define the term 'transgenic'.

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.....**[1]**

(b) Describe two unique and distinct regions found within the Ti plasmid.

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.....**[2]**

(c) With reference to Fig. 3.1 and Fig. 3.2,

(i) outline the processes involved from stage **2** to stage **3**.

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(ii) outline the processes involved from stage **3** to generate a full-grown transgenic plant.

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.....**[4]**

[Total: 11]

4. A pineapple plantation owner wants to find out the amount of ascorbic acid (vitamin C) in the pineapples cultivated in the plantation. He believes that his pineapples produce the most vitamin C compared to the standard pineapple breeds which typically contain 40.0 – 48.5 %.

The amount of ascorbic acid present in a sample can be determined using a bioassay method. At pH 7 and above, ascorbic acid reduces solutions of the dye dichlorophenol indophenol (DCPIP) from blue to colourless. For this experiment to work, the pH of the samples must be adjusted to pH 9. Ascorbic acid does not chemically change when neutralised by sodium hydroxide or when boiled.

Using this information and your own knowledge, design an experiment to determine the validity of the plantation owner's claim that the pineapples from his plantation contain higher concentrations of ascorbic acid.

Your planning must be based on the assumption that you have been provided with the following equipment and materials which you must use:

- 100 cm^3 of 5.0 % stock solution of ascorbic acid, adjusted to pH 7
- 100 cm^3 distilled water
- 100 cm^3 molten agar containing DCPIP
- Sterile petri dishes
- 1ml syringes
- Plastic straw to create wells in the agar plate
- Labels
- Stopwatch
- Forceps
- Normal laboratory glassware e.g. test tubes, beakers, graduated pipettes, droppers, glass rods etc
- 10 cm^3 pineapple juice, supplied by the plantation owner
- Sodium hydroxide
- pH meter

[Turn over

Your plan should:

- have a clear and helpful structure such that the method you use is able to be repeated by anyone reading it,
- be illustrated by relevant diagrams, if necessary,
- identify the independent and dependent variable,
- describe the method with the scientific reasoning used to decide the method so that results are as accurate and reliable as possible,
- show how you will record your results and the proposed layout of tables and graphs,
- use correct technical and scientific terms,
- include references to safety measures to minimize any risk associated with the proposed experiment.

[Total: 12]

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Free-response question

Write your answers to this question on the separate answer paper provided.

Your answer:

- should be illustrated by large, clearly labelled diagrams, where appropriate;
- must be in continuous prose, where appropriate;
- must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

5.

(a) Describe the use of restriction fragment length polymorphism analysis in creating a linkage map. **[6]**

(b) Outline the processes involved in PCR. **[6]**

(c) Discuss the goals and benefits of the Human Genome Project. **[8]**

[Total: 20]

End of Paper

Class Adm No

Candidate Name: _____

H

millennia institute

2017 Preliminary Examination 2
Pre-University 3

H2 Biology **9648/01**

Paper 1 Multiple Choice **21 September 2017**

1 hour 15 min

Additional material: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name and Admission No. on the Answer Sheet in the spaces provided unless this has been done for you.

There are **forty** 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.

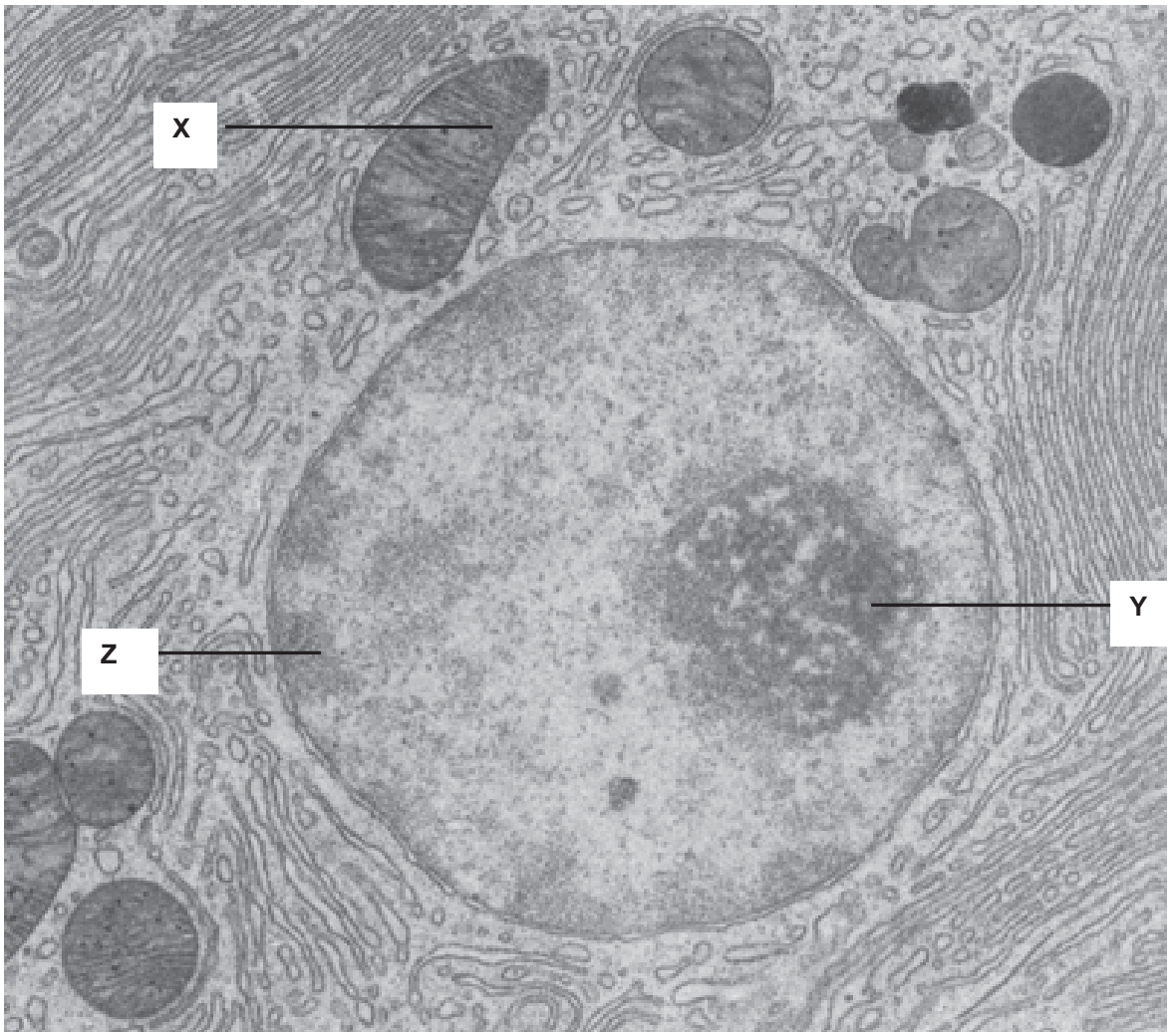
Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

The use of an approved scientific calculator is expected, where appropriate

This question paper consists of 35 printed pages.

[Turn over

1. The electron micrograph below shows the structures found in a cell.

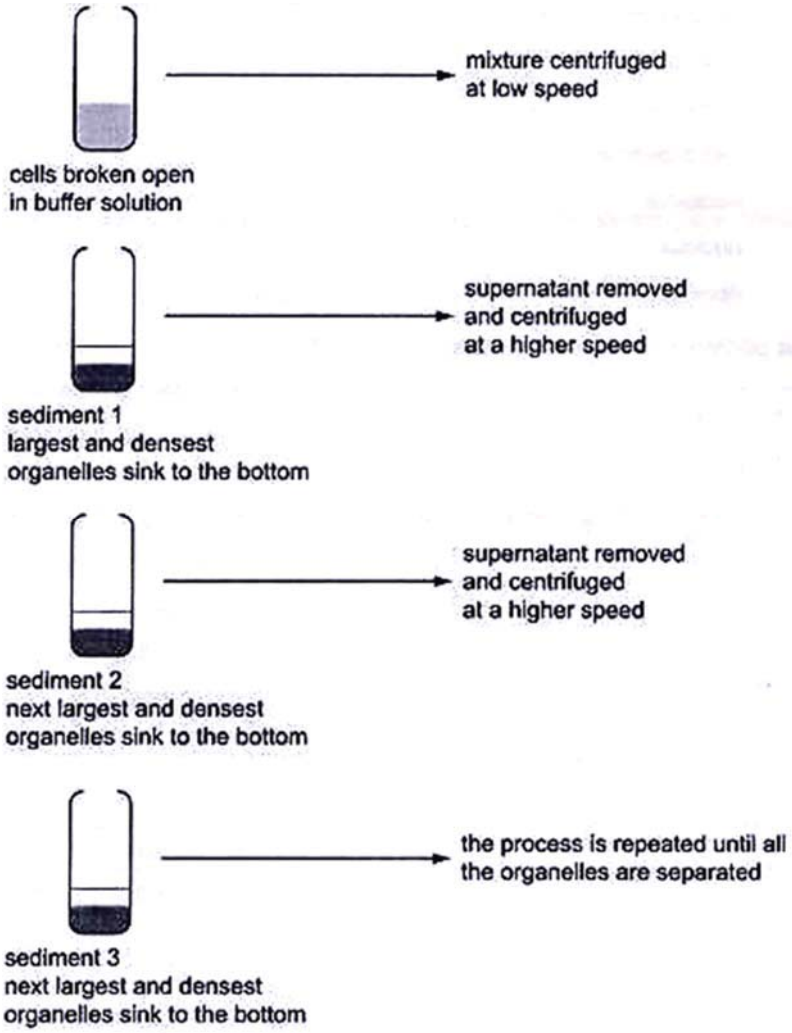


Which of the following statements is true for structures **X**, **Y** and **Z**?

	X	Y	Z
A	Contains reduced NAD^+ and reduced FAD	Transcription of gene coding for ribosomal RNA	Contains heterochromatin which is transcriptionally inactive
B	Involved in oxidative phosphorylation	Transcription of gene coding for ribosomal protein	Contains heterochromatin which is transcriptionally active
C	Contains reduced NAD^+ and reduced FAD	Involved in assembly of ribosomal subunits	Contains euchromatin which is transcriptionally inactive
D	Involved in oxidative phosphorylation	Involved in synthesis of ribosomal subunits	Contains euchromatin which is transcriptionally active

2. Fractionation is a process used to separate cell components according to their size and density.

The diagram shows the main stages in fractionation of a plant cell.

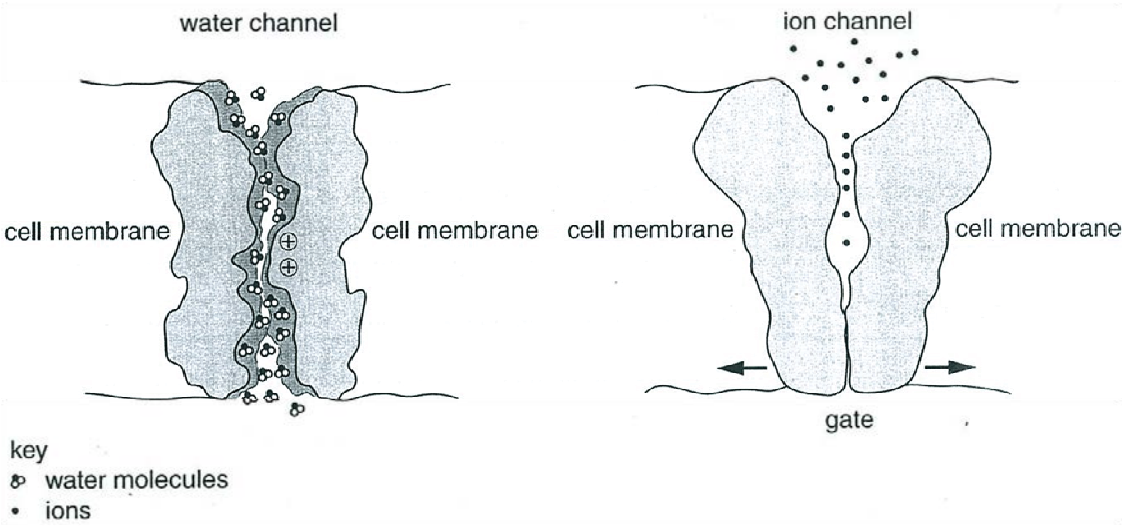


DCPIP and buffer solution (containing glucose, fructose, sodium bicarbonate) were added to each of the sediments, and the mixtures were left in the dark for fifteen minutes. Sediment 2 caused the DCPIP to be reduced.

Which organelle present in Sediment 2 caused reduction of DCPIP?

A Chloroplast
B Mitochondrion
C Nucleus
D Ribosome

3. The figure shows water and ion channels that are found in the cell surface membrane of all cells.



Which of the following statements is true?

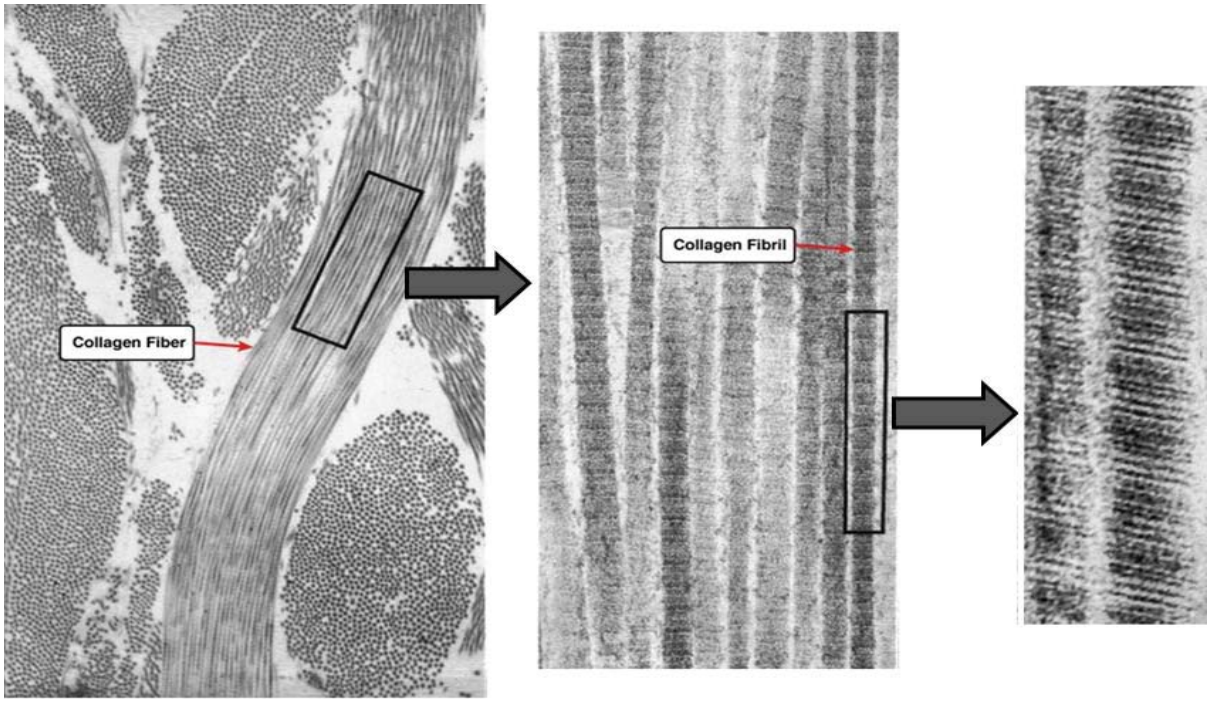
A Movement of water molecules through the water channel requires energy provided by the hydrolysis of ATP as water molecules are polar while the phospholipid bilayer of the membrane is hydrophobic.

B Common amino acid residues found on the protein surface surrounding the pores of both channels include valine and phenylalanine.

C Only the ion channel allows for the regulation of ion movement across the cell surface membrane.

D The ion channel is an example of a carrier protein as it is able to switch between two different conformations to allow the movement of ions.

4. Collagen is the main structural protein of the various connective tissues in animals. As the main component of connective tissue, it is the most abundant protein in mammal, making up from 25% to 35% of the whole-body protein content. The diagram below shows the structure of a collagen fibre and collagen fibrils.



Which of the following correctly accounts for the banded appearance of collagen fibril?

A Intermolecular hydrogen bonds between polypeptide chains within tropocollagen.
B Covalent cross-linkages between tropocollagen chains.
C Staggered arrangement of collagen fibres.
D Sequence motif of Gly-X-Y where Gly is glycine, X is proline and Y is hydroxypoline or hydroxylysine.

5. Some foods contain 'hydrogenated vegetable oils'. These are unsaturated fats that have been converted to saturated fats.

Which property of the fats will have changed?

A Their hydrocarbon chains will pack together more closely.
B Their solubility in water will increase.
C They will have more double bonds in their molecules.
D They will remain liquid at room temperature.

6. Most wild plants contain toxins that deter animals from eating them. A scientist discovered that a toxin produced by a certain plant was also toxic to the same plant if it as applied to the roots of the plant. As the first step on finding out why the plant was not normally killed by its own toxin, he fractionated some plant cells and found that the toxin was in the fraction that contained the largest cell organelle. He also found that the toxin was no longer toxic after it was heated.

Which of the following statements are consistent with the scientist's observations?

I The toxin was stored in the central vacuole.

II The toxin cannot cross the membrane of the organelle in which it is stored.

III The toxin was stored in chloroplast.

IV The toxin is likely to be lipid-soluble.

V The toxin may be an enzyme.

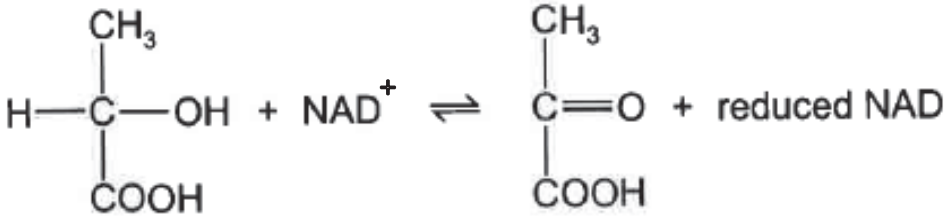
A I, II and V

B I, IV and V

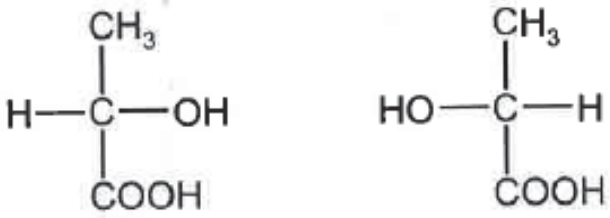
C II, III and IV

D III, IV and V

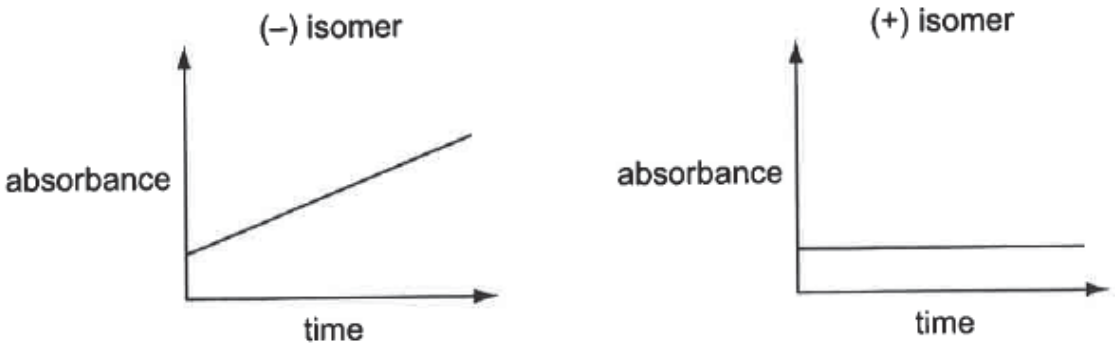
7. Lactic dehydrogenase catalyses the conversion of lactic acid as shown in the following equation.



Two forms (isomers) of lactic acid exist, (-) and (+), as shown below.



Reduced NAD absorbs ultraviolet light. NAD^+ does not. The activity of bacterial lactic dehydrogenase on two different isomers of lactic acid was compared. The absorbance of ultraviolet light was measured using an ultraviolet spectrophotometer. The graphs show the results.



What can be concluded about bacterial lactic dehydrogenase?

A Molecules of both isomers fit the active site.

B Molecules of neither isomer fit the active site.

C The enzyme is specific to the (-) isomer.

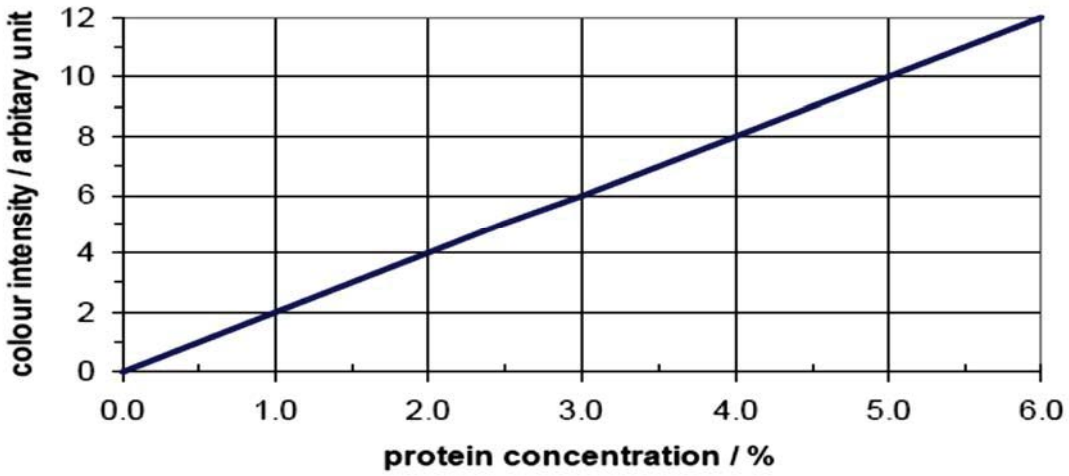
D The enzyme is specific to the (+) isomer.

8. In an experiment to study the effect of heat treatment on the digestibility of protein substrate and the effect of raw bean extract on protease activity, various reaction mixtures were prepared and were incubated for 30 minutes.

The protein concentration of each reaction mixture at the beginning and at the end of the incubation period was determined by the colorimetric method which measures colour intensity of these reaction mixtures. The results were shown in the table below.

Incubation period /min	Colour intensity of the reaction mixture / arbitrary unit			
	Tube A	Tube B	Tube C	Tube D
	Protease + heated protein substrate	Protease + unheated protein substrate	Protease + unheated protein substrate + heated raw bean extract	Protease + unheated protein substrate + raw bean extract
0	10	10	10	10
30	4	6	7	9

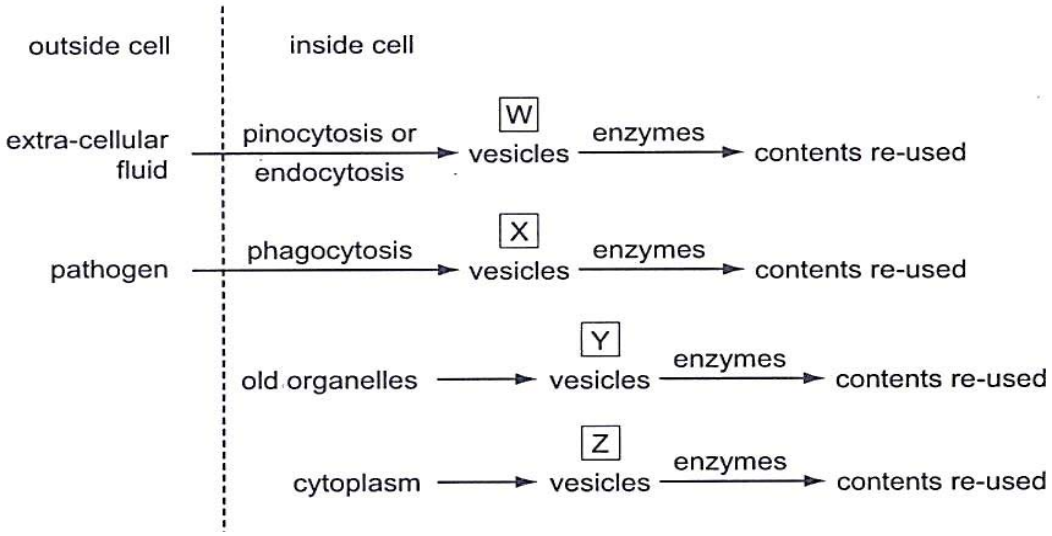
The standard graph obtained by using colorimetric method for determining concentration of protein solutions is shown below.



Which of the following combinations is correct?

	Test tube	Decrease in protein concentration / %
A	Tube A	4.0
B	Tube B	2.0
C	Tube C	3.0
D	Tube D	4.5

9. The flow chart shows processes which takes place inside animal cells.



Which processes require the activity of lysosomes?

A **W** and **X** only

B **X** and **Y** only

C **Y** and **Z** only

D All of the above

10. A student obtained a sample of DNA molecule. mRNA was transcribed from this DNA molecule. He then separated the two strands of the DNA sample by adding sodium hydroxide. The base compositions of each strand, that of the mRNA and a foreign DNA strand were analysed. The results of the analysis are shown in the table below.

	A	**G**	**C**	**T**	**U**
DNA strand 1	19.1	26.0	31.0	23.9	0.0
DNA strand 2	24.2	30.8	25.7	19.3	0.0
DNA strand 3	20.5	25.2	29.8	24.5	0.0
mRNA	19.0	25.9	30.8	0.0	24.3

Which strand of DNA serves as a template for mRNA synthesis?

A Strand 1

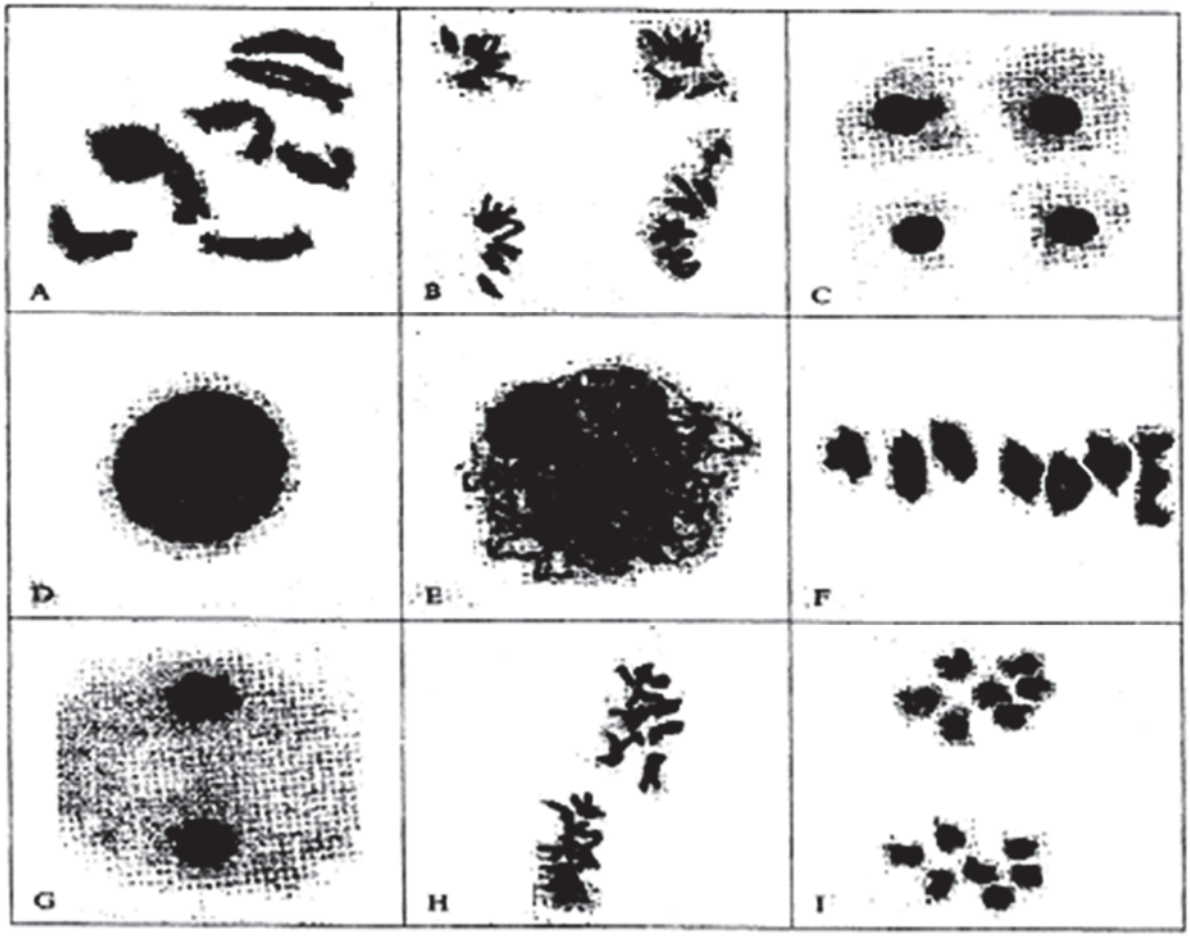
B Strand 2

C Strand 3

D Strand 2 and 3

Use the diagram below to answer Questions 11 and 12

The micrographs below show nuclei of cells at various stages during nuclear division in a flowering plant.



11. Which of the following combinations is the correct arrangement of letters in accordance with the chronological sequence of events for the above nuclear division process?

A

D	E	B	C	I	G	H	A	F

B

E	D	A	H	I	F	G	B	C

C

D	E	A	F	I	G	H	B	C

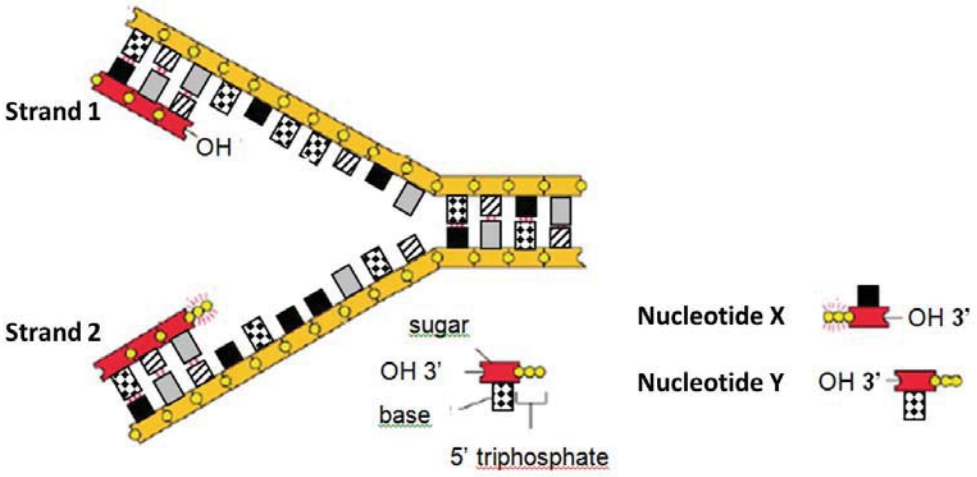
C	B	H	G	I	F	A	E	D

D

12. With reference to micrograph **F**, which of the following combinations is correct?

	Number of sets of chromosomes	Number of centromeres	Number of chromatids	Number of DNA strands
A	2	14	28	56
B	7	7	14	28
C	2	7	28	28
D	7	14	14	56

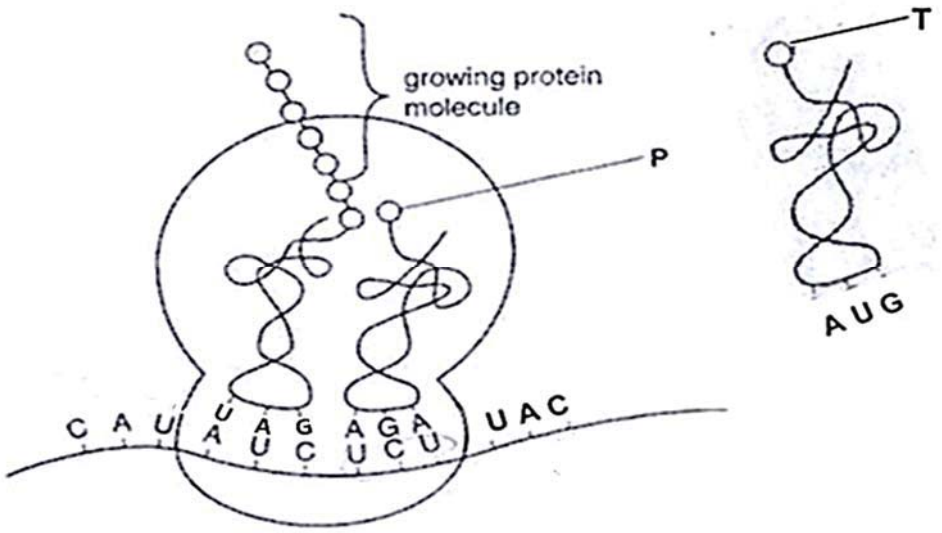
13. DNA replication is illustrated in the figure below.



Which of the following correctly describes the addition of the next nucleotide(s) to the DNA strands undergoing replication?

A Nucleotide **X** will be added to the leading strand, which is strand 1.
B Nucleotide **Y** will be added to the leading strand, which is strand 1.
C Nucleotide **X** will be added to the lagging strand, which is strand 2.
D Nucleotide **Y** will be added to the leading strand, which is strand 2.

14. The figure below shows a diagram of a ribosome bound to a mRNA strand during translation.



First Base		Second Base				Third Base
		U	C	A	G	
U		phenyalanine	serine	tyrosine	cysteine	U
		phenyalanine	serine	tyrosine	cysteine	C
		leucine	serine	(stop)	(stop)	A
		leucine	serine	(stop)	tryptophan	G
C		leucine	proline	histidine	arginine	U
		leucine	proline	histidine	arginine	C
		leucine	proline	glutamine	arginine	A
		leucine	proline	glutamine	arginine	G
A		isoleucine	threonine	asparagine	serine	U
		isoleucine	threonine	asparagine	serine	C
		isoleucine	threonine	lysine	arginine	A
		(start) methionine	threonine	lysine	arginine	G
G		valine	alanine	aspartate	glycine	U
		valine	alanine	aspartate	glycine	C
		valine	alanine	glutamate	glycine	A
		valine	alanine	glutamate	glycine	G

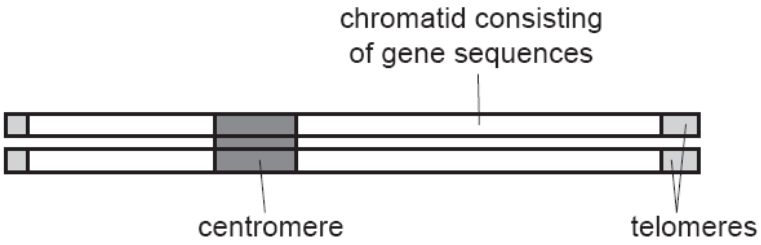
Using the codon table provided, which of the following options correctly identifies amino acids **P** and **T**?

	P	T
A	Serine	Histidine
B	Serine	Tyrosine
C	Arginine	Methionine
D	Arginine	Leucine

15. The ends of eukaryotic chromosome contain a special sequence of DNA called a telomere. Human telomeres consist of repeating TTAGGG sequences which extend from the ends of the chromosomal DNA.

When cells undergo mitotic division, some of these repeating sequences are lost. This results in a shortening of the telomeres.

The diagram shows a eukaryotic chromosome.



What is a consequence of the loss of repeating DNA sequences from the telomeres?

A The cell will begin the synthesis of different proteins.

B The cell will begin to differentiate as a result of the altered DNA.

C The number of mitotic divisions the cell can make will be limited.

D The production of mRNA will be reduced.

16. The table shows a comparison of some aspects of the genomes and protein-coding genes between the prokaryote *Escherichia coli* and the eukaryote fungus *Saccharomyces cerevisiae.*

	E.coli	*S.cerevisiae*
Genome length/base pairs	4 640 000	12 068 000
Number of protein-coding genes	4300	5800
Proteins with roles in:		
Metabolism	650	650
Energy release/storage	240	175
Membrane transport	280	250
Transcription	240	400
Translation	180	350
Cell structure	180	250

What could not account for the differences in the number of protein-coding genes?

A Many catabolic pathways for using carbon compounds in prokaryotes.

B The presence of introns in the DNA of eukaryotes.

C The presence of membrane-bound organelles in eukaryotes.

D The use of histones to package DNA in eukaryotes.

17. The following are characteristics of eukaryote transcription.

- Promoters are activated by transcription factors that recognise specific DNA sequences and other sequences that are very similar.
- Within a promoter, there may be recognition sites for more than one transcription factor.
- Similar specific DNA sequences can be recognised by more than one transcription factor.
- Each transcription factor may be capable of recognising a number of promoter recognition sites.

What explains the different levels of expression of a eukaryotic gene?

A Competition between recognition sites present in the promoter for transcription factors.

B Competition between transcription factors that recognise the same sites of a promoter.

C The number of transcription factors that recognise the same sites of a promoter.

D The number of different types of transcription factors.

18. The figure below shows a human karyotype.

What can be concluded from the karyotype provided?

A There was non-disjunction during meiosis I in the mother.

B There was non-disjunction during meiosis II in the father.

C One contributory gamete to the zygote is an egg with an X and a Y chromosome.

D One contributory gamete to the zygote is a sperm containing two X chromosomes.

19. Below are some statements related to cancer:

I. Oncogenes can be detected by introducing fragmented DNA from cancer cells into suitable cell lines and isolating colonies that display cancerous properties.

II. Individuals who inherit one inactive copy of tumour suppressor gene are more likely to develop cancer than individuals with two non-mutant copies.

III. Viruses and other infectious agents play no role in human cancers.

IV. In the cellular regulatory pathways that control cell growth and proliferation, the products of oncogenes are inhibitory components and the products of tumour suppressor genes are stimulatory components.

V. When analysed, cancer cells are often found to have only one mutation in a regulatory pathway that controls cell proliferation.

Which of the following statements are true?

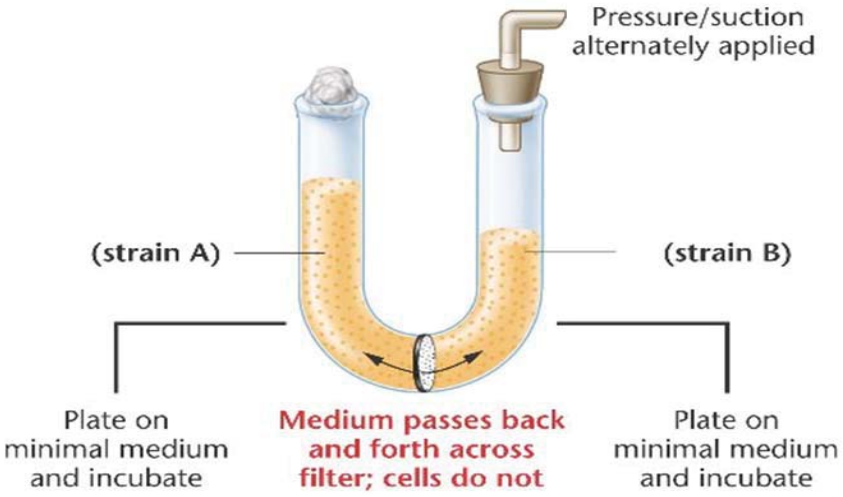
A I and II only.

B I, II and III only.

C I, III and V only.

D I, II, IV and V only.

20. Bacteria can undergo genetic recombination, a process by which genetic information from one bacterium is transferred to, and then recombined with, that of another bacterium.



The Davis U-tube, shown above is an apparatus used to investigate possible genetic recombination between bacteria. In the experiment, researchers placed *Salmonella typhimurium* **strains A** and **B** in the U-tube separated by a filter, thus preventing direct cell contact but allowing growth to occur in a common medium. When samples were removed from both sides of the filter, recombinants (containing genetic material from both **strain A** and **B**) were recovered only from the side of the tube containing **strain A** bacteria. Researchers postulated that a filterable agent was released by the **strain B** cells and was responsible for transferring the new genetic information.

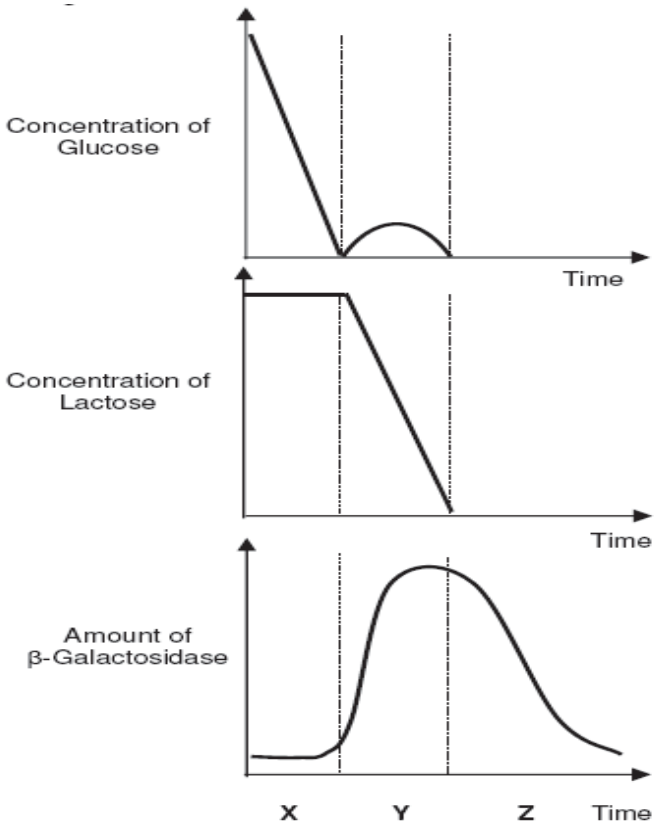
Three subsequent observations were useful in identifying the filterable agent:

1. The filterable agent was released by the **strain B** cells only when they were grown in association with **strain A** cells.
2. The addition of DNase, which enzymatically digests naked DNA, did not render the filterable agent ineffective.
3. The filterable agent could not pass across the filter of the Davis U-tube when the pore size was reduced below the size of bacteriophages.

Which process has occurred?

A Transduction
B Conjugation
C Transformation
D Binary fission

21. An experiment was conducted to examine the effects of glucose and lactose on the levels of β-galactosidase in *E.coli*. Lactose and glucose were added to a culture of bacteria at the start of the experiment and the levels of each were measured at specific time intervals. The results are shown in graphs below.



Which of the following statements could possibly account for period **X** to **Z**?

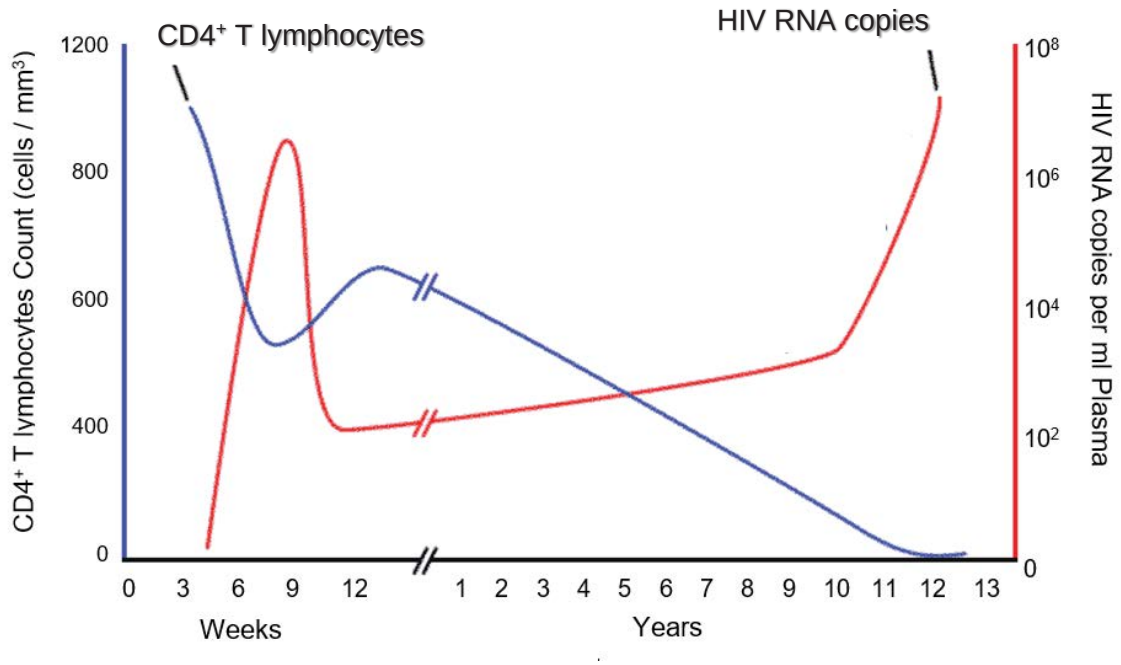
A Binding of cAMP to the CAP-binding site enhances binding of RNA polymerase to the promoter for gene transcription in period **Y**.

B Allolactose binds to the lac repressor, allowing it to assume an active configuration such that it can bind to the operator in period **X**.

C CAP is inactive and disengages from the CAP binding site, hence increasing the affinity of RNA polymerase to the promoter for gene transcription in period **Y**.

D mRNA of β-galactosidase has been degraded by nucleases in period **Z**.

22. The graph below shows HIV copies and $CD4^+$ T lymphocytes counts over the course of a typical HIV infection.



Which of the following statements are false about how HIV infects the cell?

I Complementary binding of the gp120 to specific $CD4^+$ receptors on the T cells and HIV enters the host cell via receptor-mediated endocytosis.

II RNA released into cytoplasm where reverse transcriptase uses negative-sense viral RNA as a template to synthesise a strand of cDNA and then form a double stranded viral DNA.

III The DNA enters the nucleus and ligase catalyses the integration into the chromosome DNA to form a provirus.

IV The provirus DNA is transcribed to form viral mRNA which are used as a template for translation of viral proteins such as nucleocapsids, viral envelope and viral enzymes.

V Neuraminidase cleaves the long chains of polyproteins when newly assembled HIV bud out of host cells.

A I and III only

B I, II and III only

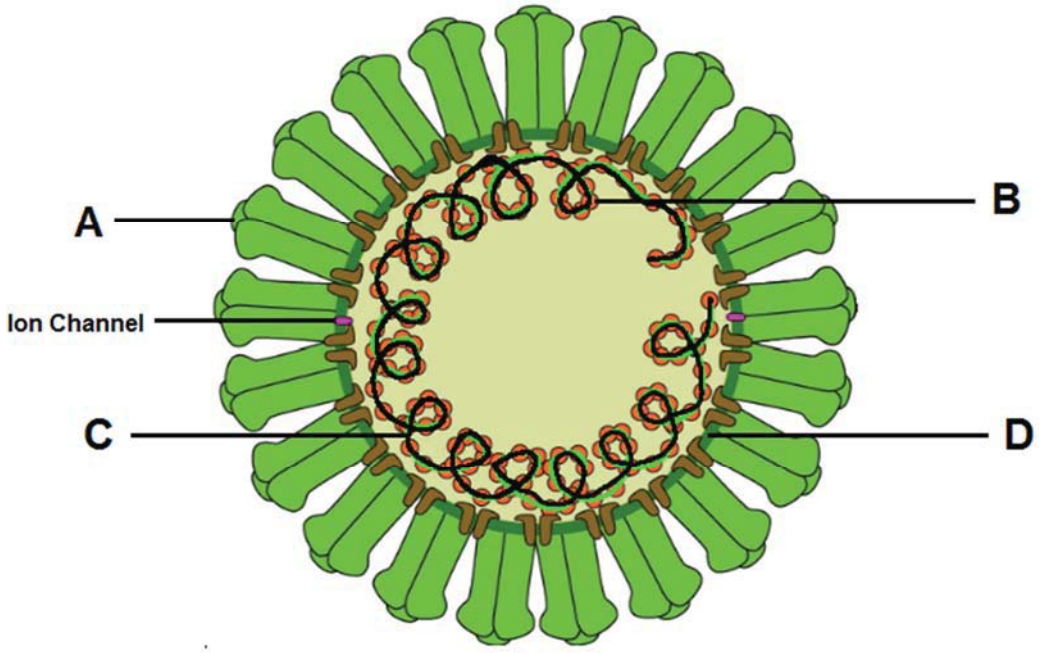
C I, IV and V only

D All of the above

23. Middle East respiratory syndrome (MERS) is a viral respiratory illness that was first reported in Saudi Arabia in 2012. Symptoms may range from fever, cough to shortness of breath.

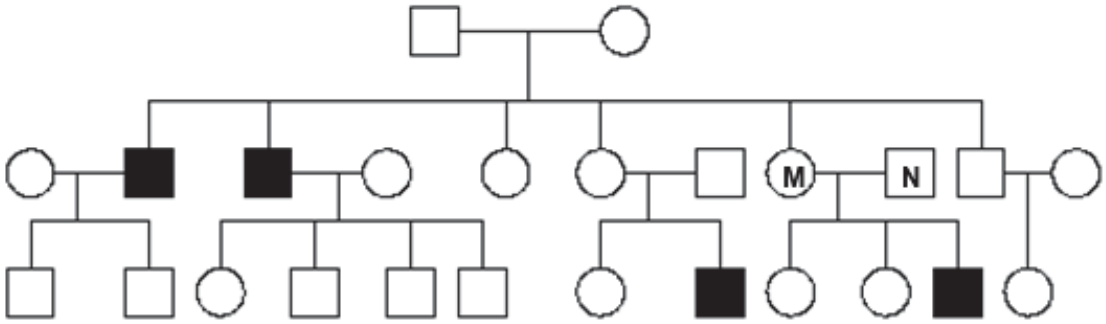
This infection is caused by the MERS-coronavirus (MERS-CoV) shown in the diagram below.

Which of the following components of MERS-CoV is not present in *Escherichia coli* bacterium?



Use the diagram below to answer Questions 24 and 25.

Hunter's syndrome is a serious genetic disorder. It interferes with the body's ability to break down and recycle specific mucopolysaccharides, also known as glycosaminoglycans or GAG. The visible signs and symptoms of Hunter syndrome in younger people are usually the first clues leading to a diagnosis. In general, the time of diagnosis usually occurs from about 2 to 4 years of age.



24. With reference to the pedigree diagram, which of the following is the correct mode of inheritance for Hunter's syndrome?

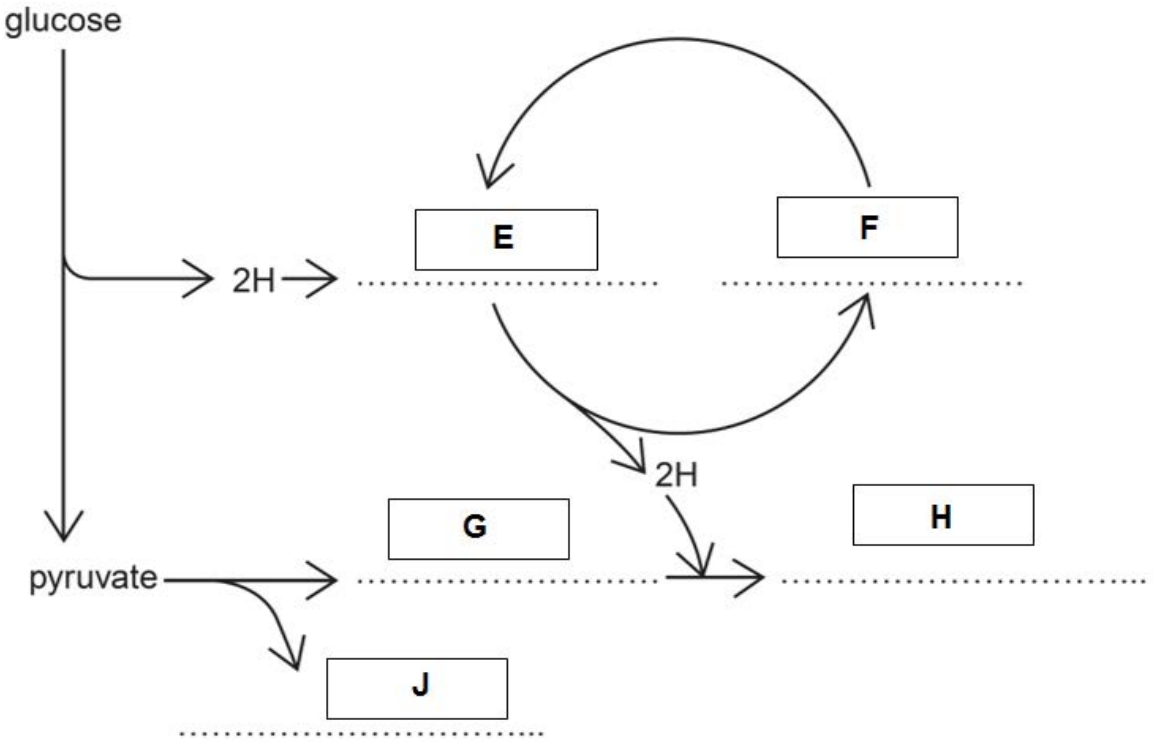
A Autosomal recessive
B Incomplete dominance
C Sex-linked recessive
D Codominance

25. Mariah (**M**) married Nick (**N**) and had three children. One of the children had Hunter's syndrome.

What is the probability of their next child being an affected son?

A 0.5
B 0.375
C 0.25
D 0.125

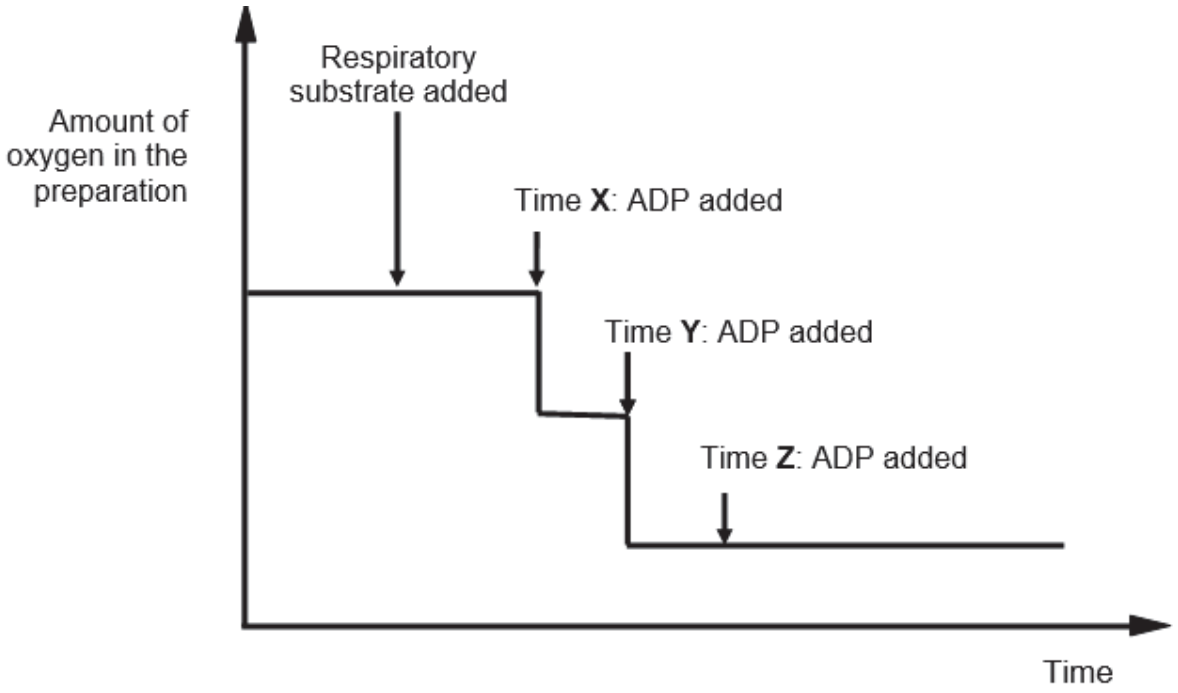
26. The figure below outlines a process that occurs in plant cells.



Which of the following combinations is correct?

	E	F	G	H	J
A	NADH	NAD^+	Ethanal	Ethanol	CO_2
B	NAD^+	NADH	Ethanol	Ethanal	CO_2
C	NADPH	$NADP^+$	Lactate	Lactose	O_2
D	$NADP^+$	NADPH	Lactate	Lactose	O_2

27. A suspension of mitochondria was isolated from liver tissue. Various substances were added to the suspension at different time intervals and the amount of oxygen remaining in the preparation was monitored over some time. The graph below shows the results as well as the times at which different substances were added.



Which of the following statement(s) could possibly be true?

I Glucose is the respiratory substrate added.

II Between **X** and **Y**, oxidative phosphorylation occurred and oxygen acted as the final electron acceptor.

III Between **Y** and **Z**, chemiosmosis occurred where ATP synthase utilizes the proton-motive force to phosphorylate ADP to form ATP.

IV After **Z**, anaerobic respiration occurred as oxygen levels did not decrease even though ADP is added.

V After **Z**, inorganic phosphates, NADH and $FADH_2$ have been depleted.

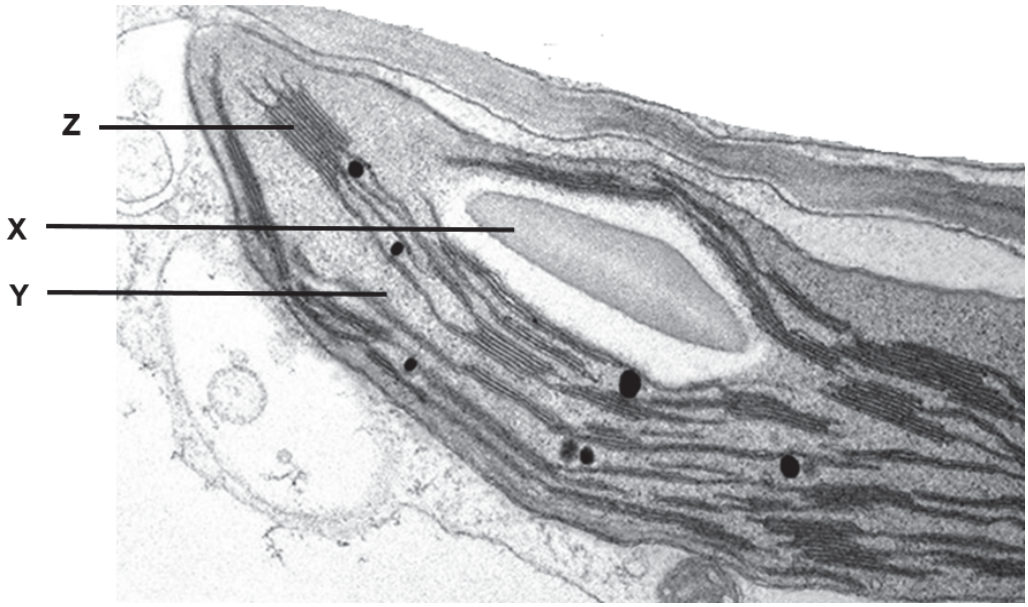
A I, III and IV only

B II, IV and V only

C II, III and V only

D All of the above

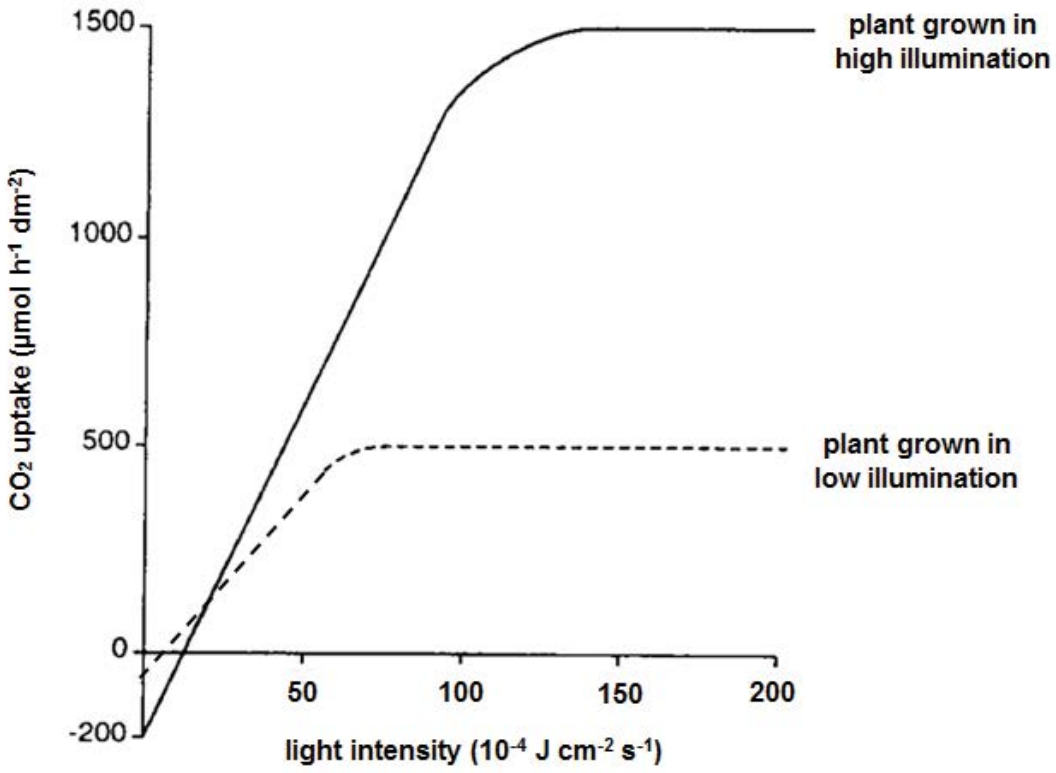
28. The diagram below is a transmission electron micrograph of a labelled organelle.



Which of the following combinations is correct?

	X	Y	Z
A	Consists of more amylopectin branches than amylose chains.	Contains low concentrations of protons and has an alkaline pH.	Site of non-cyclic and cyclic photophosphorylation.
B	Large central vacuole surrounded by a tonoplast and contains cell sap.	Site of Calvin cycle processes of carbon fixation, reduction and RuBP regeneration.	Site of ATP and NADPH synthesis.
C	Insoluble in water as hydroxyl groups are projected inwards into helical structures and unable to form hydrogen bonds with water.	Site of oxidation of NADPH to form NADP+ as well as expenditure of ATP.	Photolysis of water occurs to generate protons, oxygen and electrons.
D	Consists of monomers joined together by β(1→4) and β(1→6) glycosidic bonds.	Consists of chlorophyll pigments with photosystems to facilitate light-dependent reactions.	Consists of cristae that increases surface area to volume ratio for more efficient ATP production.

29. Two groups of white mustard plants, *Sinapis alba*, were grown, one group under high illumination, the other under low illumination. When fully grown, the effect of increasing light intensity on the rate of photosynthesis in the two groups of plants was measured.



Which of the following statements can be concluded from the graph?

A Below the compensation point, plants grown at high illumination give out less carbon dioxide than plants grown in low illumination.

B The compensation point for plants grown in high illumination occurs at a lower light intensity than those grown in low illumination.

C Light intensity is no longer a limiting factor for photosynthesis for light intensity above $150x10^{-4}$ Jcm^{-2} s^{-1} for plants grown in high illumination.

D For light intensity from 20×10^{-4} Jcm^{-2} s^{-1} to 50×10^{-4} Jcm^{-2} s^{-1}, carbon fixation for the plants grown in high illumination is similar to that grown in low illumination.

30. Four proteins isolated from a human cell were investigated for their involvement in cell signalling pathways.

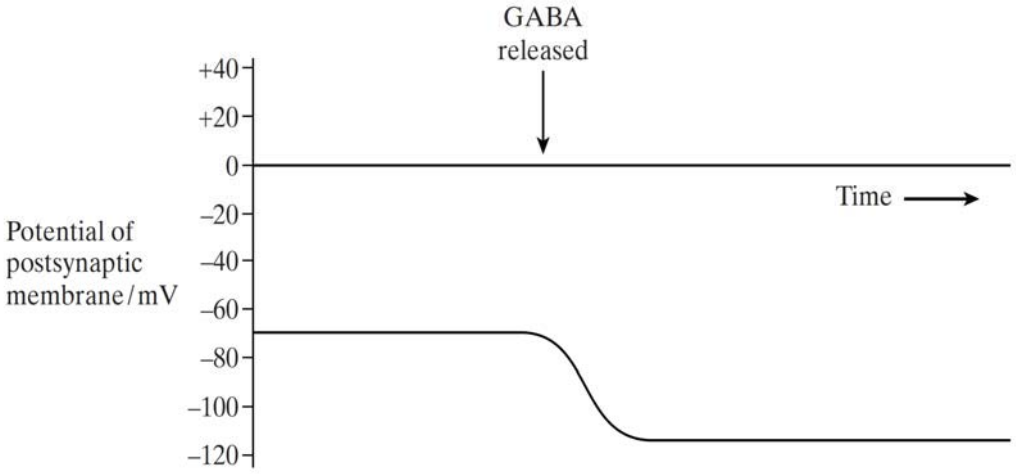
	Protein A	**Protein B**	**Protein C**	**Protein D**
Transmembrane domain	-	+	+	-
DNA binding domain	-	-	-	+
Enzymatic domain	+	-	+	-

Key: (+) = present , (-) = absent

Which of the following shows the correct identity of these four proteins?

	Protein A	**Protein B**	**Protein C**	**Protein D**
A	GPCR	Ras protein	RTK	Testosterone receptor
B	Ras protein	RTK	GPCR	Testosterone receptor
C	Testosterone receptor	GPCR	RTK	Ras protein
D	Ras protein	GPCR	RTK	Testosterone receptor

31. GABA is a neurotransmitter which inhibits the production of action potential. The figure below shows how the release of GABA from a pre-synaptic neurone affects the membrane potential of a post-synaptic membrane.



Which of the following options correctly explains why an action potential is less likely to occur if GABA is released?

A GABA opens ligand-gated K^+ ion channels in the post-synaptic membrane, allowing K^+ to diffuse out of post-synaptic neuron, causing hyperpolarization.

B GABA closes voltage-gated Na^+ ion channels in the pre-synaptic membrane, allowing K^+ to diffuse out of pre-synaptic neuron, causing repolarization.

C GABA opens voltage-gated K^+ ion channels in the post-synaptic membrane, allowing K^+ to diffuse into the post-synaptic neuron, causing repolarization.

D GABA opens voltage-gated Na^+ ion channels in the post-synaptic membrane, allowing Na^+ to diffuse out of post-synaptic neuron, causing hyperpolarization.

32. The resting potential of a nerve axon is essential for action potential generation.

Which of the following, when instantaneously removed, would most rapidly bring the resting potential of a nerve axon close to 0 mV?

A Active transport of K^+ ions into the cell

B Active transport of Na^+ ions out of the cell

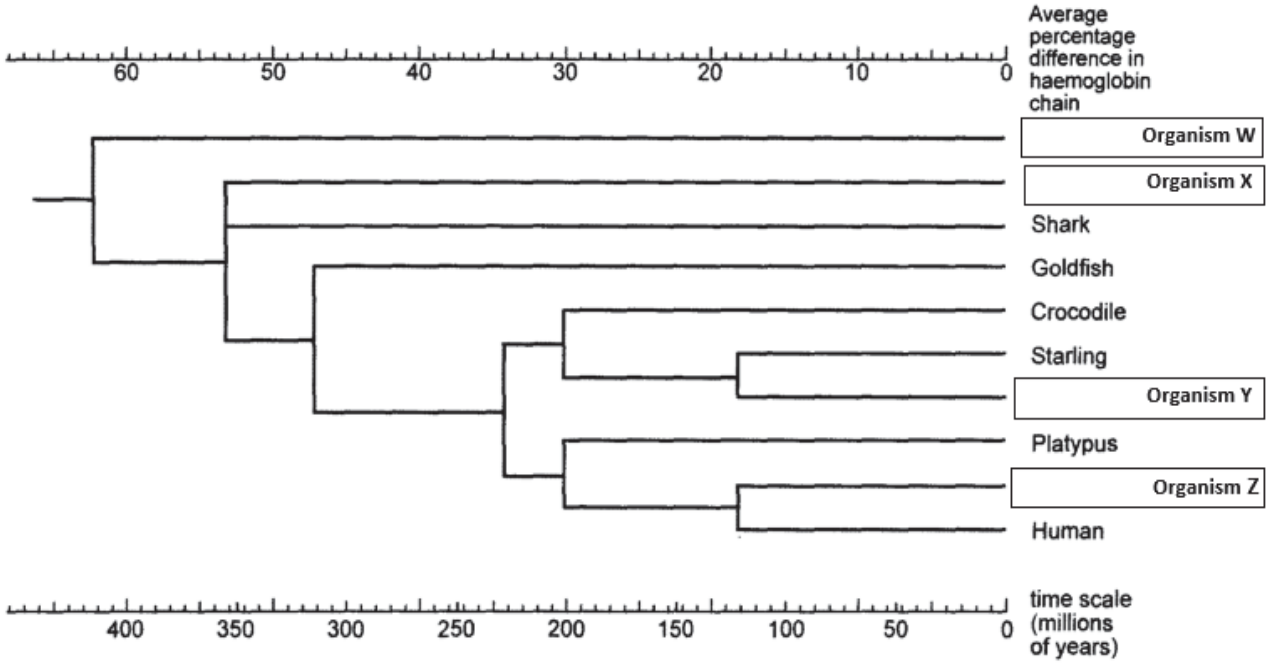
C High membrane permeability to Na^+ ions

D High membrane permeability to K^+ ions

33. The table shows the amino acid differences in the cytochrome b protein between various vertebrates.

	Human	Elephant	Platypus	Ostrich	Starling	Crocodile	Lungfish	Coelacanth	Goldfish	Shark
Human		26	40	43	41	47	83	70	68	71
Elephant			45	45	48	50	84	72	63	74
Platypus				54	52	51	89	74	70	76
Ostrich					26	36	91	75	68	73
Starling						47	91	77	67	70
Crocodile							85	78	70	77
Lungfish								90	94	86
Coelacanth									83	78
Goldfish										88
Shark										

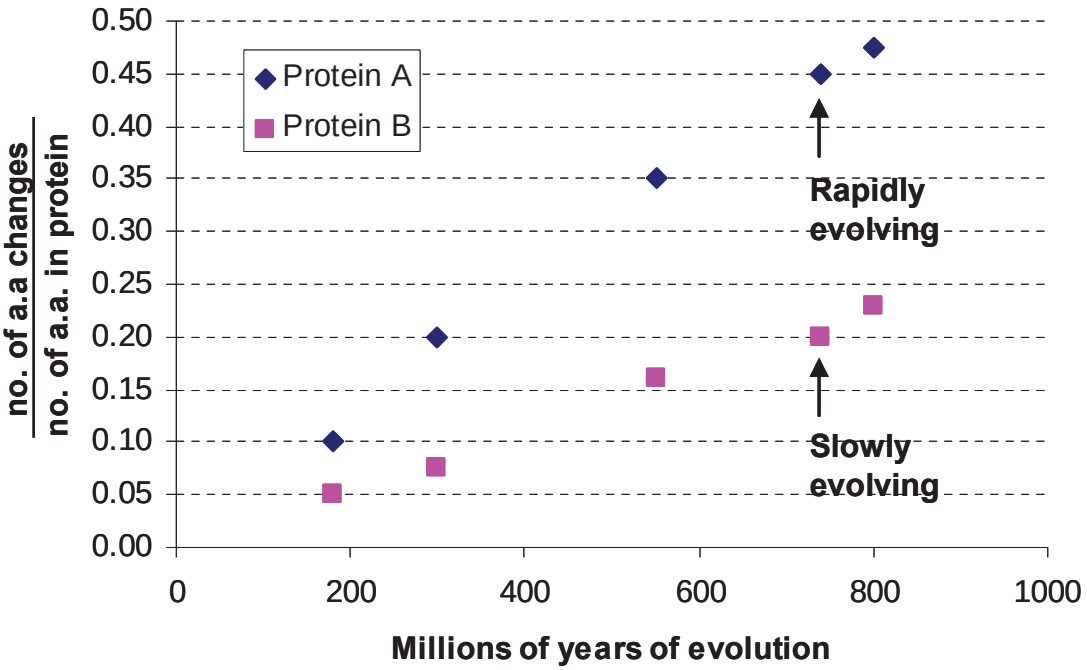
The phylogenetic tree below is based on differences between the cytochrome b proteins.



Which of the following combinations are correct?

	W	X	Y	Z
A	Lungfish	Coelacanth	Ostrich	Elephant
B	Lungfish	Ostrich	Coelacanth	Elephant
C	Coalacanth	Lungfish	Ostrich	Elephant
D	Coalacanth	Lungfish	Elephant	Ostrich

34. The graph below shows the evolution of two different proteins against the evolutionary time that has passed.



Which of the following statements can be deduced from the graphical data?

A The difference between the amino acid sequences of protein A and protein B shows how much evolution has happened in the 800 million years.

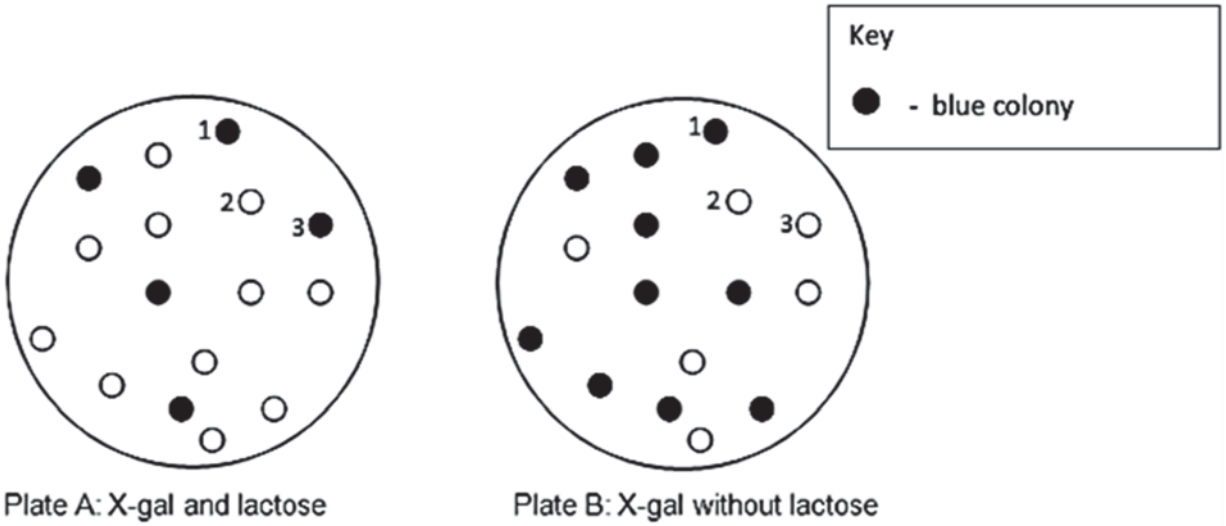
B The evolution of protein A is by natural selection while that of protein B is mostly neutral changes that make no difference to how the protein works.

C Protein A has a higher proportion of possible changes that are neutral and hence evolved at a higher rate.

D Protein B has a higher proportion of possible changes that are neutral and hence evolved at a slower rate.

35. *Escherichia coli.* bacteria are infected with laboratory-cultured lambda phage. The bacteria are initially cultured in a nutrient medium without X-gal. The bacteria colonies produced are replica plated onto two agar plates, one containing X-gal and lactose and the other containing X-gal without lactose.

There is no glucose in either plates. The agar plates below show the results of this experiment.



Which of the following explanations for colonies 1, 2 and 3 are correct?

A Colony 1 is blue in both plates because transcription of Lac Z gene is turned on all the time so β galactosidase is continuously translated to break down X-gal into a blue compound.

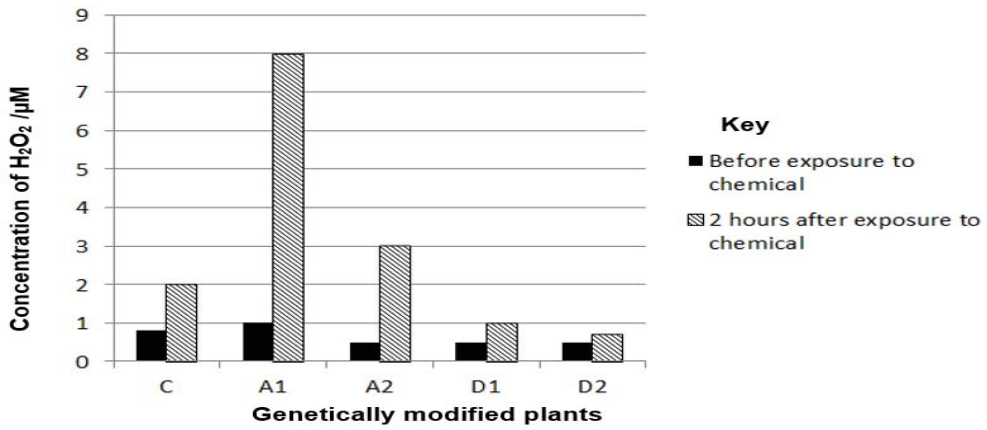
B Colony 2 is white in both plates because transcription of lac Z gene results in β galactosidase being produced to break down X-gal into a white compound.

C Colony 3 is blue in plate A and white in plate B because viral DNA is integrated into lac Z gene and lac Z gene is disrupted leading to insertional inactivation.

D Colony 3 is blue in plate A and white in plate B because phage DNA is integrated into the operator by transduction and repressor cannot find to operator.

36. Plants have developed defence mechanisms against pathogens such as bacteria, fungi and viruses. Chemicals released by these pathogens can trigger a defence response in infected plant cells. For example, the production of hydrogen peroxide (H_2O_2) which reacts with pathogen membranes and cellular chemicals eventually kills both the cell and pathogen.

The *OSRac1* gene from another plant species was isolated and introduced into a number of rice plant (*Oryza spp.*) lines to study its role in disease resistance of plants to blast fungus. Experiments were carried out to see if the *OSRac1* gene was part of the signalling pathway for hydrogen peroxide production. A control (**C**) and four other genetically modified rice plant lines (**A1**, **A2**, **D1** and **D2**) grown *in vitro* from calluses were exposed to chemicals known to initiate a defence response by producing hydrogen peroxide. **A1** and **A2** are rice plants with the *OSRac1* gene always turned on. **D1** and **D2** are rice plants with the *OSRac1* gene suppressed. The results are shown in the graph below.



Which of the following statements can be concluded from the graph?

A *OSRac1* gene is not involved in disease resistance as both D2 showed a lower increase in H_2O_2 production by 40% as compared to control which showed an increase in H_2O_2 production of 150%.

B *OSRac1* gene is involved in disease resistance as A2 showed a higher increase in H_2O_2 production by 300% as compared to control which showed an increase in H_2O_2 production of 50%.

C *OSRac1* gene is not involved in disease resistance as both A1 and A2 genetically modified plants showed lesser change in the number of times of H_2O_2 production.

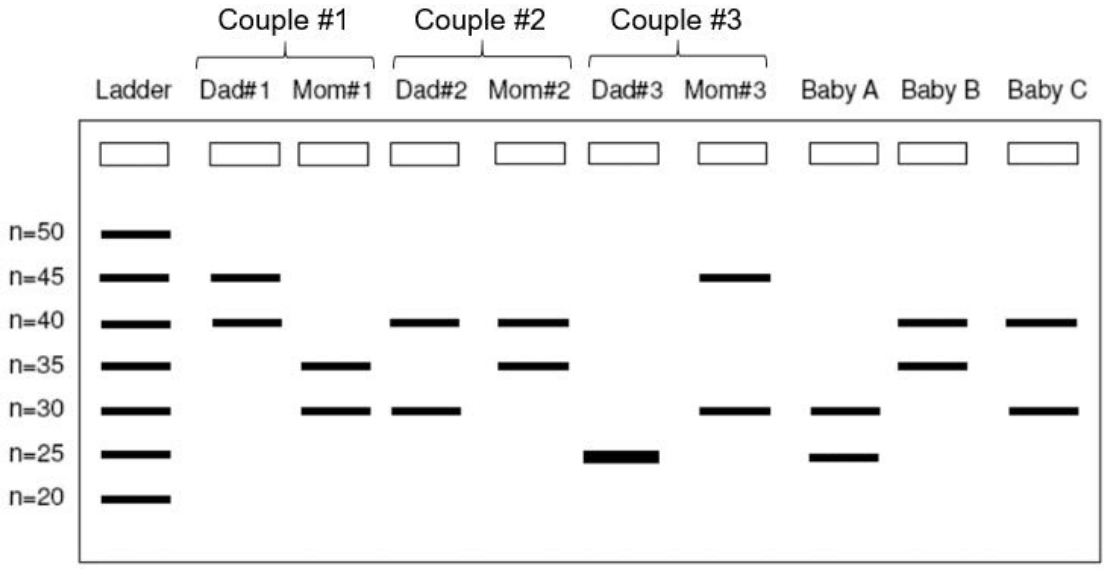
D *OSRac1* gene is involved in disease resistance as both D1 and D2 genetically modified plants with *OSRac1* gene suppressed showed smaller change in the number of times of H_2O_2 production.

37. In a maternity ward at a local hospital, a mix-up involving three couples and three babies caused a lot of confusion. Based on phenotypic characteristics, the nurses were unable to correctly identify the parents of the babies. In order to solve the case, a scientist was called in to carry out a DNA test to identify the parents of the babies. The test was based on the principle that different individuals have a different number of repeating units at a particular locus in a chromosome.

Chromosome 13 was isolated from the DNA samples that were obtained from the three couples and three babies and used for further analysis. The sequence below shows a segment of chromosome 13, which was used in the analysis where (TTAGGAT) is the repeating unit and n is the number of repeats.

5' …GCTAAGTATTGCTCAAGA… (TTAGGAT)n…GATAAATAACTGGCTAGTA…-3'
3' …CGATTCATAACGAGTTCT… (AATCCTA)n… CTATTTATTGACCGATCAT…-5'

The diagram below shows the results of the DNA test obtained from each individual.



Based on the results above, which couple does Baby B belong to?

A Couple 1
B Couple 2
C Couple 3
D Not enough information

38. The DNA sequences of the normal and mutated versions of a gene are shown below.

Normal DNA sequence:

GAGAATCCTTGAGCTCTTAAGCTTATT

Mutated DNA sequence:

GAGAATCCTTGAGGTCTTAAGCTTATT

The table below shows the recognition sequences of four restriction endonucleases.

Restriction endonuclease	Recognition site
*Bam*HI	GGATCC
*Eco*RI	GAATTC
*Hin*dIII	AAGCTT
*Sac*I	GAGCTC

Which of the restriction endonucleases would produce different number of fragments when used to digest normal and mutant DNA?

A *BamHI*

B *EcoRI*

C *HindIII*

D *SacI*

39. Which of the following is not true of adult stem cells during tissue repair?

A The stem cells must have active telomerase.

B The different checkpoints in the cell cycle of the stem cells are activated.

C Mitosis of the stem cells is induced without any stimulus.

D The stem cells will stop dividing after the damaged cells are replaced.

40. Equal masses of tobacco plant callus were cultured for four weeks on media containing different concentrations of two plant growth regulators: auxin and cytokinin.

Which of the following combinations is not possible?

Treatment	Concentration of plant growth regulators / $mgdm^{-3}$		Effect of plant growth regulators on callus growth
	Auxin	Cytokinin	
A	2.00	0.00	No growth
B	2.00	0.50	Growth of roots
C	2.00	2.00	Increased growth of callus with no differentiation
D	2.00	3.50	Growth of roots

End of Paper

Answers for Prelim 2 Exam

1	A	**21**	D
2	A	**22**	D
3	C	**23**	B
4	B	**24**	C
5	A	**25**	C
6	A	**26**	A
7	C	**27**	C
8	B	**28**	C
9	D	**29**	C
10	B	**30**	D
11	C	**31**	A
12	A	**32**	D
13	A	**33**	A
14	B	**34**	C
15	C	**35**	A
16	B	**36**	D
17	B	**37**	D
18	A	**38**	D
19	A	**39**	C
20	A	**40**	D

Candidate Name: _____

Class	Adm No

H

millennia institute

2017 Preliminary Examination 2
Pre-University 3

H2 Biology **9648/02**

Paper 2 Core Paper **13 September 2017**

2 hours

Additional Materials: Writing paper

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your Admission number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

The use of an approved scientific calculator is expected, where appropriate. You will lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	
2	
3	
4	
5	
6	
7	
Section B	
Total	

For Examiner's Use

Section A

Answer **all** questions in this section.

1. Fig. 1.1 shows a series of micrographs of animal cells undergoing cell and nuclear division.

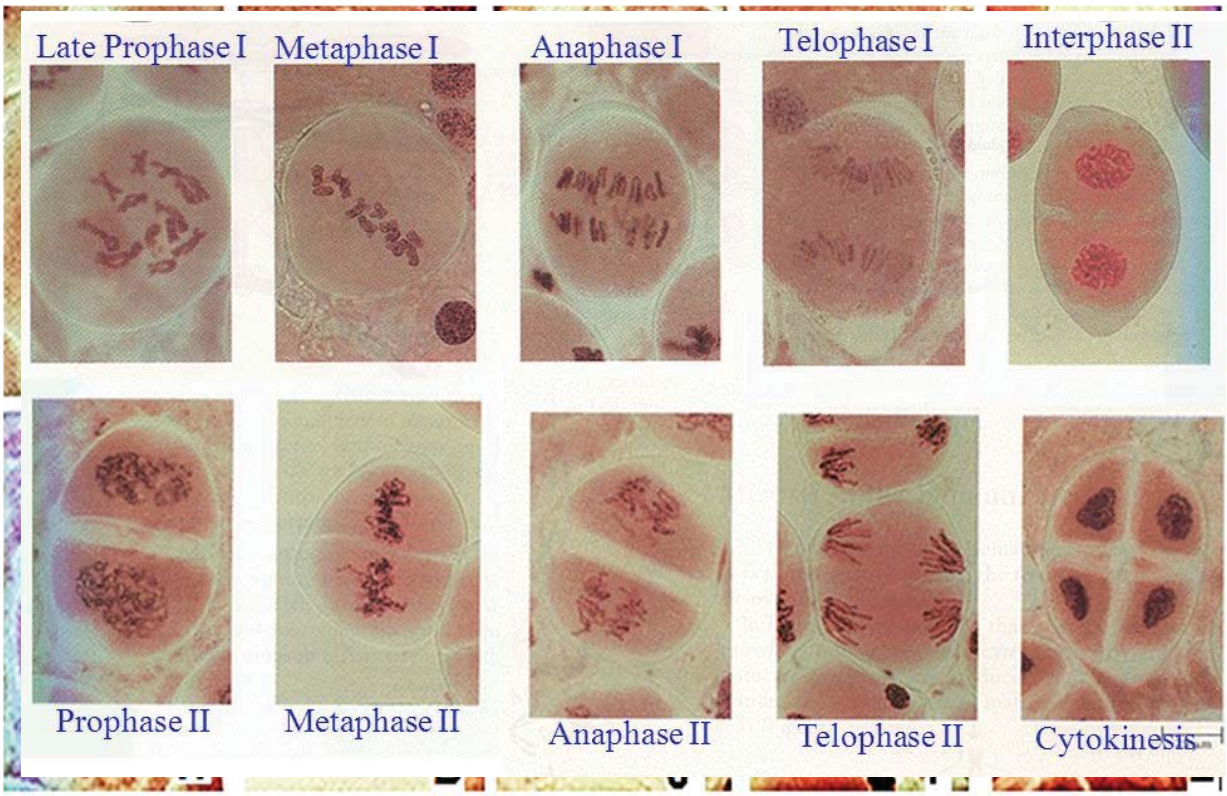


Fig. 1.1

(a) Arrange the letters in Fig. 1.1 in a correct sequence to show the events occurring in the cell and nuclear division process.

A, F, C, D, G, H, B, J, I, E.

; 5 letters in correct sequence for 1 mark, max is 2 mark

.....[2]

(b) Describe the processes occurring in **A**.

.....

- Pairing of homologous chromosomes to form bivalents / synapsis occurs;
- Crossing-over of alleles at chiasmata;
- between non-sister chromatids of the homologous chromosomes;
- creates new combination of alleles and giving rise to genetic variation in the gametes and hence offspring;
- The chromatids / euchromatin condense to form chromosomes;
- The nucleolus and nuclear envelope disintegrate;
- Centrioles migrated to poles and spindle forms;

.....

.....

...[2]

b

(c) State one similarity and one difference between process **C** and **J**.

- Similarity 1: Chromatids are separated;
- Similarity 2: Shortening of the microtubules / spindle fibres;
- Similarity 3: Genetic material migrate towards opposite poles of the cell / towards centrioles;

- Difference 1: The number of chromosomes in anaphase II is half of that in anaphase I;
- Difference 2: The centromeres in process C do not divide but the centromeres in process J divides;
- Difference 3: Homologous chromosomes separate during C but chromatids separate during J;

2]

(d) Explain the significance of process **H**.

- Prevent the doubling of chromosome number in the organism;
- Reduction of the number of chromosome number by half for gametes;
- So that when the gametes fuse, the original chromosome number of the cell will be restored;

R! Haploid

..[2]

(e) Suggest how the cell and nuclear division process would be affected if centromeric DNA is deleted from a chromosome.

- Chromatids are not held/joined together;
- Kinetochores cannot form on chromosome;
- Spindle fibres cannot attach/bind to chromosomes;
- chromosomes cannot align along equatorial plane / metaphase plate during metaphase;
- Ref. to random movement of sister chromatids / chromatids not separated to opposite poles *(idea of opposite poles is important)* ;
- Daughter cells will not have complete set of chromosomes/ have extra or less chromosomes / will not be genetically identical to parent cell / ref. to aneuploidy;
- mitosis may not proceed past metaphase / anaphase cannot occur;
- Non-disjunction can occur;

[2]

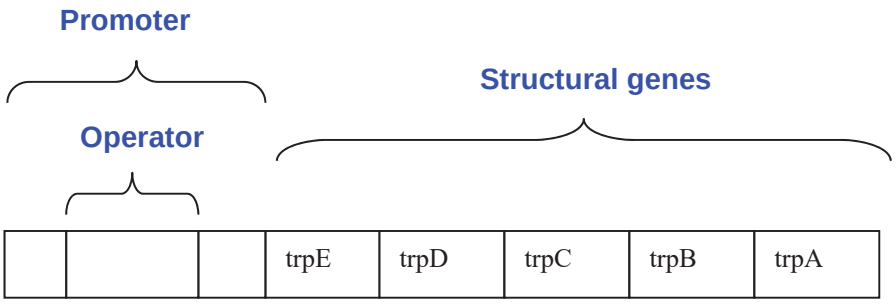
l 10]

For Examiner's Use

2. In bacteria, the production of the amino acid tryptophan is catalyzed by five specific enzymes (simply named as **E, D, C, B** and **A** in this question) encoded by specific genes *trpE, trpD, trpC, trpB and trpA*. The *trp* operon is transcriptionally regulated by a repressor protein, (named **R** in this question), encoded by the *trpR* gene. Expression of the *trpE, trpD, trpC, trpB* and *trpA* genes is controlled by a promoter region and an operator region.

When levels of tryptophan are high, tryptophan binds to the repressor protein, **R**. The tryptophan-repressor protein complex binds to the operator region and prevents expression of the *trpE, trpD, trpC, trpB* and *trpA* genes.

(a) Draw a simple diagram to show the *trp* operon. **[1]**



Reject: if operator not within promoter
Reject: if the structural genes are not in order of sequence; all or none

(b) Explain why it is useful for a bacterial cell to decrease expression of the *trp* genes when tryptophan is present.

- Trp genes code for enzymes (involved in/necessary for) (anabolism/synthesis) of tryptophan; .....
- Decreased expression helps to conserve resources that could be diverted for other uses; accept idea of preventing wastage of resource; .....

Reject: ONLY mention of energy and not resources .....

.....**[2]**

Table 2.1 below indicates the activity levels of the functional enzymes E, D, C, B and A in wild type bacterial cells in the presence and absence of tryptophan (Trp).

Table. 2.1

	Activity level of enzymes/units	
Enzyme	**Trp absent**	**Trp present**
E	700	0
D	700	0
C	700	0
B	700	0
A	700	0

Researchers have managed to obtain several bacterial mutants. Each mutant is the result of a single base-pair substitution in a single component of the *trp* operon. The activity level of functional enzymes E, D, C, B and A in the bacterial cells having these individual mutations is shown in Table 2.2.

Table. 2.2

	Activity level of enzymes/units					
	Mutant 1		**Mutant 2**		**Mutant 3**	
Enzymes	**Trp absent**	**Trp present**	**Trp absent**	**Trp present**	**Trp absent**	**Trp present**
E	700	700	700	0	0	0
D	700	700	0	0	0	0
C	700	700	700	0	0	0
B	700	700	700	0	0	0
A	700	700	700	0	0	0

(c) With reference to Table 2.1 and Table 2.2, identify the mutant bacteria that has a phenotype that is consistent with a loss-of-function mutation in the *trpR* gene and explain your choice.

- Mutant 1;
- The normal / wild type *trpR* activity is repression of the *trp* operon / codes for repressor protein (e.g. zero enzyme activity in the presence of tryptophan);
- A loss of the repression / lack of repressor will lead to constitutive expression of the *trp* genes (700 units of enzyme activity even in the presence of tryptophan);

[2]

For Examiner's Use

(d) Account for the phenotype of mutant 3 assuming that it experienced a loss-of-function mutation.

- A loss of function of the promoter;
- 0 units of enzyme activity regardless whether tryptophan is absent or present;
- Transcription factors are not able to the bind to the promoter to form transcription initiation complex;
- RNA polymerase is unable to bind to the promoter to initiate transcription and thus block / prevent expression of the *trp* operon;

Reject: operator as a loss of function in that component would not allow the repressor to bind, causing expression of the *trp* genes.
Reject *trpR* loss-of-function mutation since there would be no functional repressor and the phenotype would be the same as mutant 1.

.....
.....
.....
....[2]

(e) If the phenotype of mutant 3 is caused by a mutation in the *trpR* gene, explain how this mutation would affect the structure and function of the repressor protein.

- Gain of function mutation which causes a change in amino acid / Missense mutation in the *trpR* gene;
- which causes the protein to fold into the same conformation as the active repressor / trp-bound wild type R protein; (only awarded if it leads to correctly stated altered repressor function as stated below);
- trp repressor is always existing in an active conformation / constitutively active;
- Permanently bound to operator / binds to operator even in absence of tryptophan;
- Prevent binding of RNA polymerase to the promoter and inhibit transcription of genes;

.....
.....
.....
....[2]

[Total: 9]

3. Researchers are constantly investigating the effects of limiting factors on the rate of photosynthesis on various plants. Fig. 3.1 show how three main limiting factors, carbon dioxide concentration, light intensity and temperature can affect the rate of photosynthesis in cactus plants.

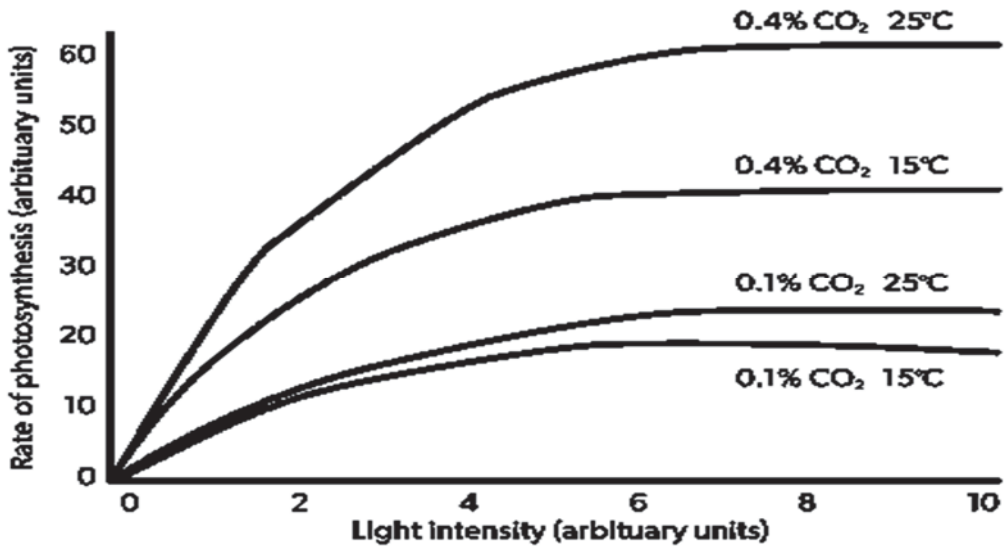


Fig. 3.1

(a) Define the term 'limiting factor'.

- Rate of photosynthesis is limited by the slowest reaction in the series and when the rate of photosynthesis is limited by more than one factors;
- the rate is limited by the factor which is in the shortest supply;
- This factor determines the rate of reaction, ie. when this factor is increased in concentration, the rate increases too;

[1]

(i) explain the effect of light intensity on rate of photosynthesis.

- As light intensity increases from 0 to 6 arbitrary units, rate of oxygen production increases / rate of photosynthesis increases proportionally with increasing light intensity;
- At low light intensities, light intensity is the limiting factor;
- Light is needed for photolysis of water to provide electrons for photophosphorylation;
- Light directly affects light-dependent stage / non-cyclic + cyclic photophosphorylation of photosynthesis which is responsible for synthesis of ATP and NADPH;
- More ATP and NADPH produced per unit time would lead to increase rate of Calvin cycle;
- More G3P converted to glucose per unit time;
- As light intensity increases above 6 arbitrary units, rate of oxygen production remains constant at the maximum rate;
- Light intensity is no longer a limiting factor, other environmental factors like carbon dioxide concentration or temperature or other factors may be limiting;
- When the light saturation point being reached, any further increase in light intensity will have no effect on the rate of light dependent reaction / rate of oxygen production;

[5]

(ii) justify if carbon dioxide concentration or temperature is a greater limiting

- Carbon dioxide;
- A 0.3% increase in carbon dioxide increases rate of photosynthesis by 25au at 15°C / 40au at 25°C but a 10°C increase in temperature increases rate of photosynthesis by 5au at 0.1% CO2 concentration / 20au at 0.4% CO2 concentration;
- Increasing the temperature to 25°C will increase rate of photosynthesis to 20au but increasing the carbon dioxide concentration to 0.4% will increase the rate of photosynthesis to 60au;
- Carbon dioxide is needed for carbon fixation during Calvin cycle when combining with RuBP;
- Temperature affects mainly light-independent stage and rate of photosynthesis doubles for each rise of 10°C until optimum temperature is reached;
- However, rate of photosynthesis decreases at higher temperature as enzymes start to denature; **[3]**

(c) Suggest why water is not considered a limiting factor for the rate of photosynthesis.

- Amount of water needed for photosynthesis is very little;
- When plants do not have enough water, stomata on leaves will close and limit amount of carbon dioxide entering the plant;
- Plants wilt when there is insufficient water;
- AVP; **[1]**

Fig. 3.2 illustrates a graph showing how varying light intensity affects the net carbon dioxide uptake and release in sun and shade plants.

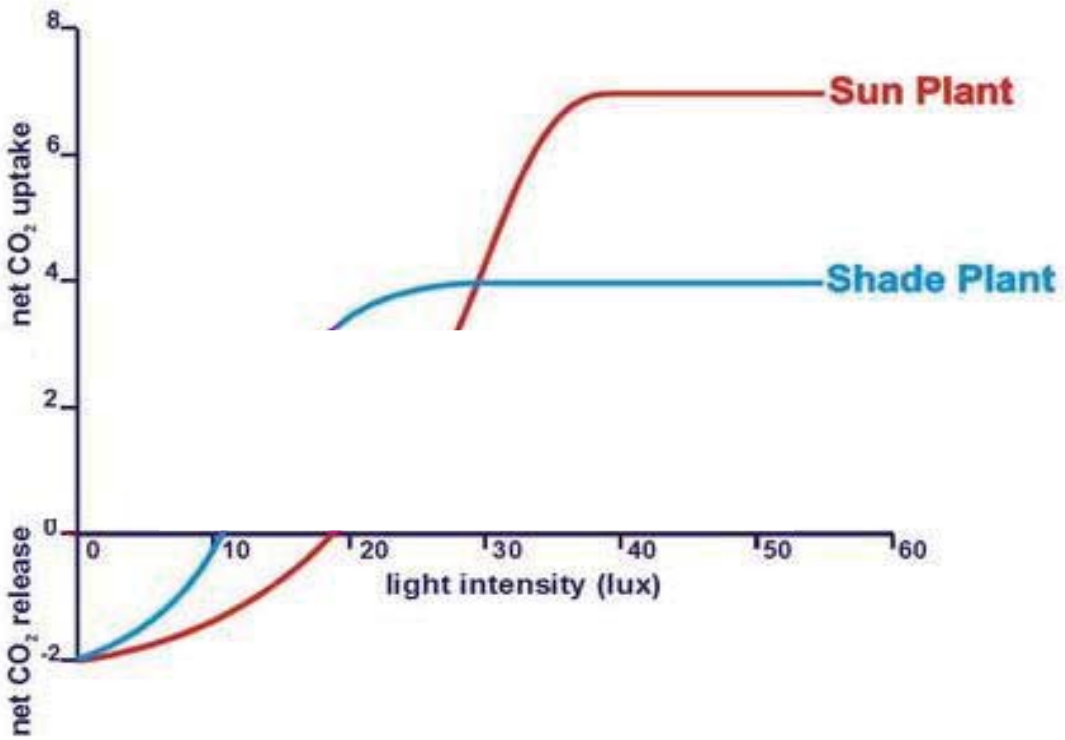


Fig. 3.2

(d) With reference to Fig. 3.2,

(i) state the compensation points of sun and shade plants.

- Sun plants: 19 lux;
- Shade plants: 11 lux;

[1]

(ii) account for the graph differences between sun and shade plants.

- Compensation point is lower for shade plants by 9 lux as compared to sun plants;
- Net carbon dioxide uptake is higher for sun plants than shade plants by 2.5 – 3 au;
- Shade plants reaches maximum net carbon dioxide uptake of 4 au at 28 lux whereas sun plants reaches maximum net carbon dioxide uptake of 7 au at 37 lux;

Max 2 marks

- Kreb cycle occurs more at low light intensities from 0 – 20 lux for sun plants;
- Carbon fixation during Calvin cycle occurs more at higher light intensities from 19 lux and above for sun plants;

OR

- Shade plants have more chloroplast;
- Can absorb light even at low light intensities;
- and light-dependent reactions can still occur at low-light intensities;
- Rate of photosynthesis is higher than rate of respiration at low light intensities from 10 lux and above;

[4]

[Total: 15]

2012 MJC Prelim 2 Q6

For Examiner's Use

4. A study was conducted to study the inheritance of coat colour in mice, in which one of the allele is also known to affect normal embryonic development. A cross between agouti mouse (with agouti coat colour) and yellow mouse (with yellow coat colour) resulted in half of the F1 progeny being agouti mice and the other half being yellow. Mating of F1 yellow mice resulted in the following F2 generation.

Agouti mice 98
Yellow mice 202

(a) Using the symbols **A** and **a** for the two alleles involved, draw a genetic diagram in the space below to show how the F1 cross resulted in the F2 progeny.

Key: **A represents the dominant allele for yellow coat colour.**
a represents the recessive allele for agouti coat colour.

F1 phenotypes	Yellow x Yellow
F1 genotypes	Aa x Aa
F1 gametes	A a x A a
F2 genotypes	AA Aa Aa aa
F2 phenotypic ratio	202 Yellow : 98 Agouti 2 Yellow : 1 Agouti
	AA died

[3]

In another experiment involving deer mouse, pure breeding pink-eyed mice with wild-type fur was crossed with pure breeding dark-eyed albino mice. The resulting progeny all had wild-type fur and dark eyes. These F1 mice were then crossed with pink-eyed albino mice. The results are shown in Table 4.1. It was difficult to distinguish between mice that are dark-eyed albino and pink-eyed albino, so these two phenotypes were counted together.

Table 4.1

Phenotype	**Number of progeny**
Wild-type fur, dark-eyed (recombinant)	12
Wild-type fur, pink-eyed (parental)	62
Albino, dark-eyed (parental) Albino, pink-eyed (recombinant)	78
Total	152

(b) In the blank space below, calculate the chi-square value. **[2]**

Phenotype	Observed (O)	Expected (E)	$(O-E)^2 / E$
Wild-type fur, dark-eyed	12	38	17.7
Wild-type fur, pink-eyed	62	38	15.2
Albino, dark-eyed Albino, pink-eyed	78	76	0.05
		Chi Square Value	32.95

Table 4.2 shows a portion of the chi-square table.

Table 4.2

distribution of X^2			
number of degrees of freedom (v)	**probability**		
	0.1	**0.05**	**0.01**
1	2.71	3.84	6.64
2	4.60	5.99	9.21
3	6.25	7.82	11.34
4	7.78	9.49	13.28

(c) Using the values in Table 4.2, draw appropriate conclusions as to whether the results of the cross followed the expected ratio you have predicted in **(b)**.

- P(difference occurring by chance) <0.05 for df of 2;
- Critical value < calculated chi-square value of 32.95;
- difference between observed and expected results is significant / not due to chance;
- Does not conform to the expected phenotypic ratio of 1:1:1:1 / 1:1:2;
- Hence the two genes do not segregate independently / the two genes are linked;

[2]

(d) Using **E/e** to represent alleles for eye colour and **A/a** to represent alleles for fur coat colour, explain the result of the F1 cross in the deer mouse experiment using a genetic diagram.

Key: E represents the dominant allele for dark-eyed.
e represents the recessive allele for pink-eyed.
A represents the dominant allele for wild-type fur.
a represents the recessive allele for albino

F1 Cross:

Phenotype of parents: dark-eyed, wild type fur x pink-eyed, albino

Genotype of parents: e A / E a x e a / e a

Gametes produced (n): e A, E a, e a, E A x e a, e a

Genotype of offspring: e A / e a; E a / e a; e a / e a; E A / e a

Phenotype of offspring: pinked-eyed, wild-type fur; dark-eyed, albino; pink-eyed, albino; dark-eyed, wild-type fur

Parental type; Recombinant type

Phenotypic ratio: 62 : 78 : 12

[4]

[Total: 11]

5. *Bungarus multicinctus*, also known as the Taiwanese Krait, is a species of venomous snake endemic to Asia and is predominantly found in forests from Taiwan to Southeast Asia. In order to better understand the venomous snake's physiological pathways, researchers have been conducting extensive research on the mechanism of action of Taiwanese Krait venom which consists primarily of neurotoxins.

Fig. 5.1 shows a diagram of the kappa-bungarotoxin, a neurotoxin found in the venom of the Taiwanese Krait. Kappa-bungarotoxin is a highly stable protein molecule that is capable of withstanding harsh chemical reactions.

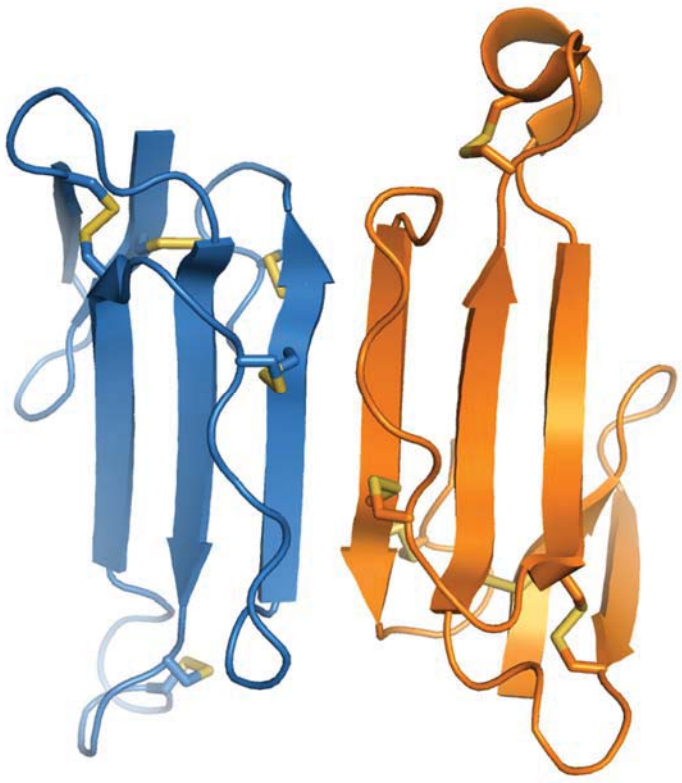


Fig. 5.1

(a) Explain how the protein structure of kappa-bungarotoxin is maintained.

- Secondary structures include beta-pleated sheets held together by intramolecular hydrogen bonds along the polypeptide backbone;
- Tertiary structure: 3D configuration held together by bonds such as hydrophobic interactions, disulphide bridges, ionic bonds and hydrogen bonds between R-groups;
- Quaternary structure: 2 subunits are held together by hydrophobic interactions / covalent bonds;

.....[3]

People bitten by *Bungarus multicinctus* suffer from neuromuscular paralysis and respiratory failure. Research shows that the venom causes serious health complications due to the effects of kappa-bungarotoxin at the neuromuscular junctions at the muscle cells of the lungs as shown in Fig. 5.2.

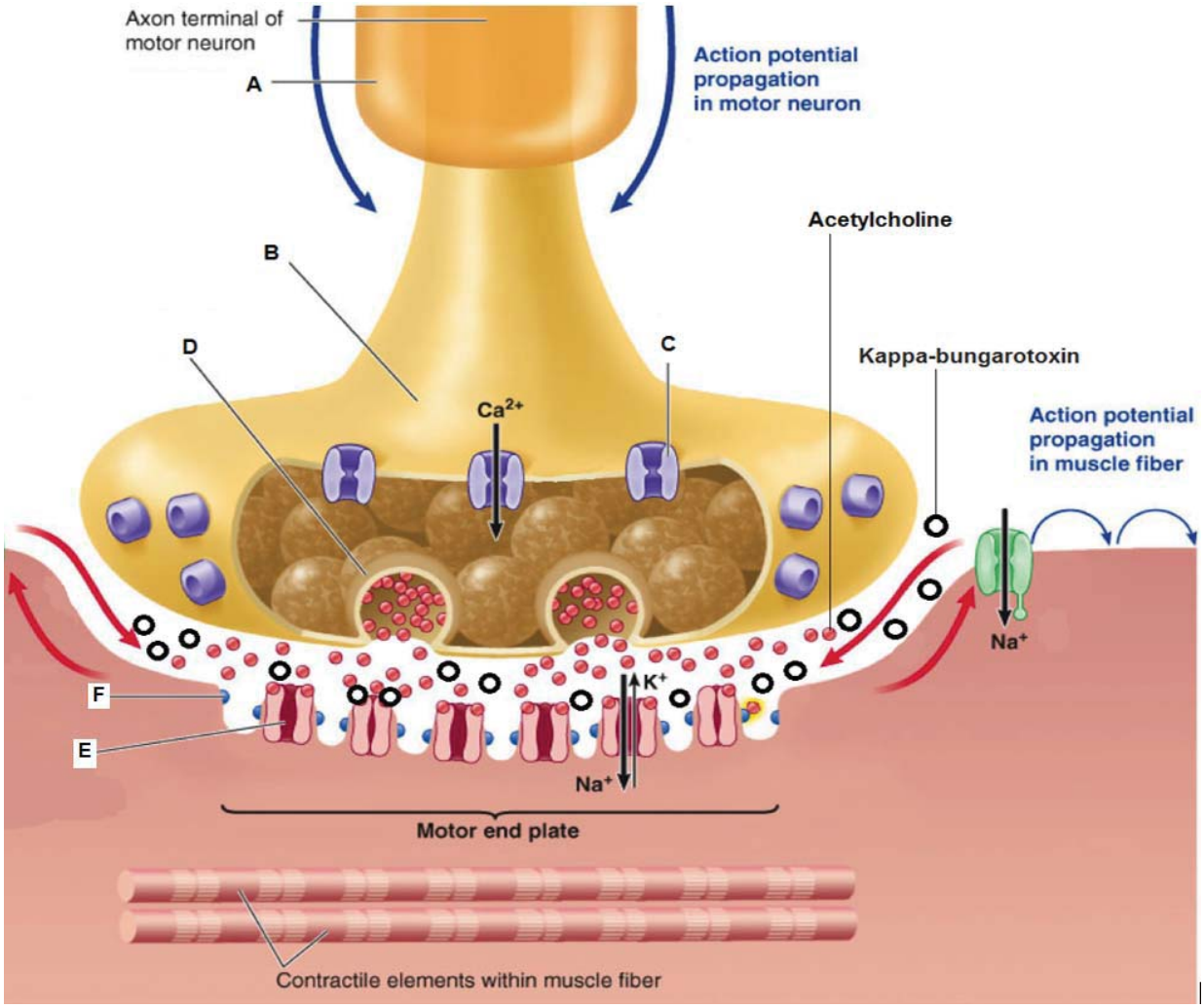


Fig. 5.2

(b) Name the parts of the neuromuscular junction shown in Fig 5.2 labelled **A**, **B**, **C, D** and **E**.

A: .....

B: .....

C: .....

D: .....

E: .....

A: Myelin sheath;
B: Presynaptic knob;
C: Voltage-gated calcium ion channels;
D: Secretory / Synaptic vesicles (containing acetylcholine);
E: Cholinergic receptors / Post-synaptic receptors / Ligand-gated ion channel;

2 correct – 1 mark
5 correct – 2 marks

[2]

In Fig. 5.2, **F** is an enzyme important in synaptic signalling.

(c) Describe the function of **F**.

- Aceylcholinesterase breaks down acetylcholine into acetyl group and choline;
- to prevent over-generation of action potentials at the post-synaptic terminal;

[1]

(d) Explain how the transmission of nervous impulse shown in Fig. 5.2 differs from electrical transmission of action potentials.

	Transmission of action potential along a neurone		Synaptic transmission
1	Electrical in nature.	1	Chemical in nature.
2	Action potential travels along one neurone.	2	Involves two adjacent neurones.
3	Calcium ion is not required.	3	Calcium ions are required for triggering the release of neurotransmitter into the synaptic cleft.
4	Only excitatory.	4	Synapses can be excitatory or inhibitory.
5	Depolarisation is due to an influx of sodium ions, resulting from an increase in the permeability of axon membrane to sodium ions.	5	In an excitatory synapse, the post-synaptic membrane becomes more permeable to both sodium ions and potassium ions. Depolarisation (or EPSP) is due to greater inward diffusion of sodium ions into the post-synaptic neurone than outward diffusion of potassium ions.
6	Action potential occurs immediately in response to a stimulus of adequate strength.	6	There is a synaptic delay. This is due to time taken for the release of the neurotransmitter from synaptic vesicles, and for the diffusion of the neurotransmitter across the synaptic cleft.
7	Action potential is an all-or-none response.	7	Several EPSP can be summated to reach the threshold potential.
8	Recovery is due to repolarisation (influx of sodium ions stops and efflux of potassium ions) and sodium-potassium pump.	8	Recovery requires acetylcholinesterase, which hydrolyses acetylcholine.
9	An absolute refractory period and a relative refractory period exist.	9	There is no refractory period but synapse can be fatigued due to a shortage of neurotransmitter.
10	Speed of transmission is affected by the diameter of axon, presence or absence of myelin sheath and temperature.	10	Synaptic transmission can be affected by drugs, eg curare. Curare binds to the receptor sites for acetylcholine.
11	Bi-directional; depolarisation waves sweep along both sides of stimulus.	11	Synaptic transmission is always unidirectional, from the pre-synaptic membrane to the post-synaptic membrane.
12	Information is transmitted over a distance of one metre.	12	Information is transmitted over a distance of 20 nm.

[2]

(e) Explain how kappa-bungarotoxin causes respiratory failure among humans bitten by *Bungarus multicinctus.*

- Kappa-bungarotoxin competes with acetylcholine for the binding site of the cholinergic receptor;
- Permanently binds to the binding site of the cholinergic receptor causes action potentials to be always generated at the post-synaptic membrane;
- Voltage-gated sodium ion channels are always opened and influx of sodium ions will always flux into the axon;
- Depolarization of the post-synaptic neuron will always occur;
- Hence, always triggering the contraction of contractile elements within the muscle fibers and causing respiratory failure as the muscle fibres cannot relax;

[4]

Antivenom is a medication used to treat venomous bites and is recommended for use via injection if the venom from the snake is of high risk of toxicity.

(f) Suggest how antivenom can alleviate the effects of kappa-bungarotoxin.

- It binds to the kappa-bungarotoxin and changes its conformation such that it can no longer bind to the binding site of the cholinergic receptor;
- It is an enzyme that degrades the kappa-bungarotoxin into simpler substances;
- AVP;

……

…[1]

[Total: 13]

2010 MJC Prelim 2 Q3
+ 2010 RI Prelim 2 Q5

For Examiner's Use

6. Fig. 6.1 shows a tyrosine kinase receptor. The effect of insulin binding to this complementary receptor is shown in Fig. 6.2. The boxed regions in Fig. 6.1 and Fig. 6.2 are cysteine-rich domains.

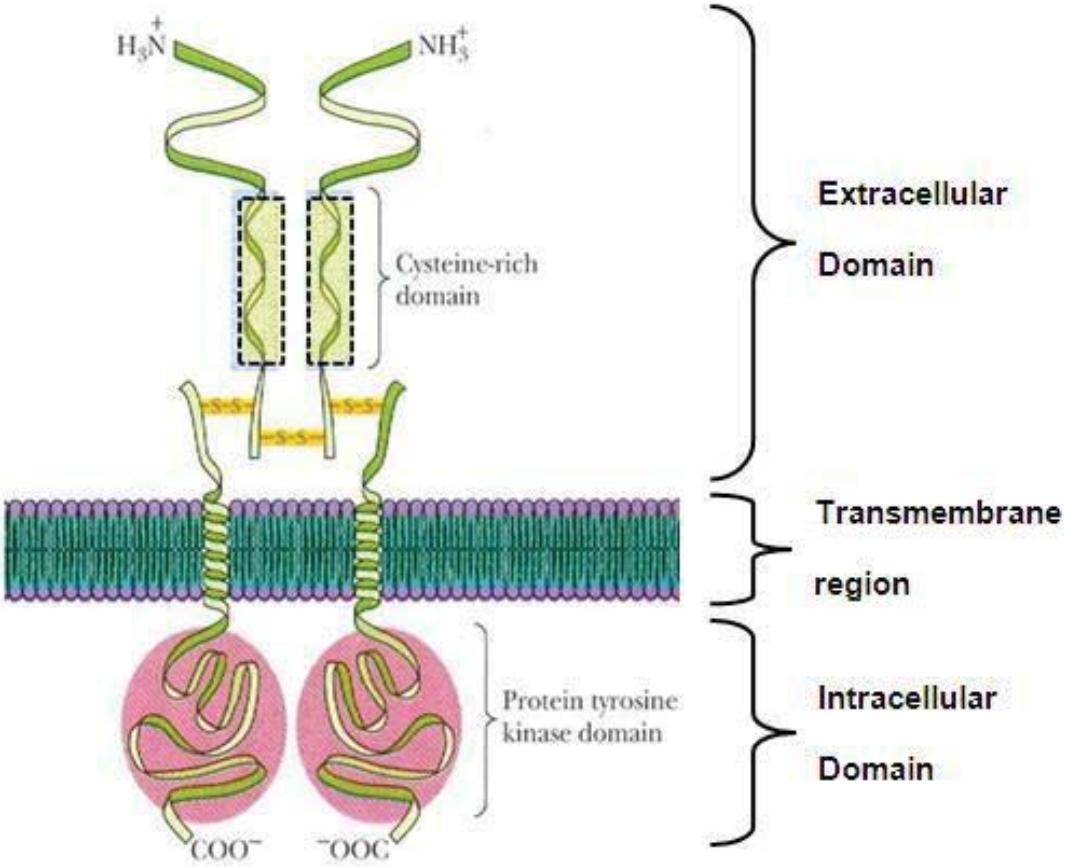
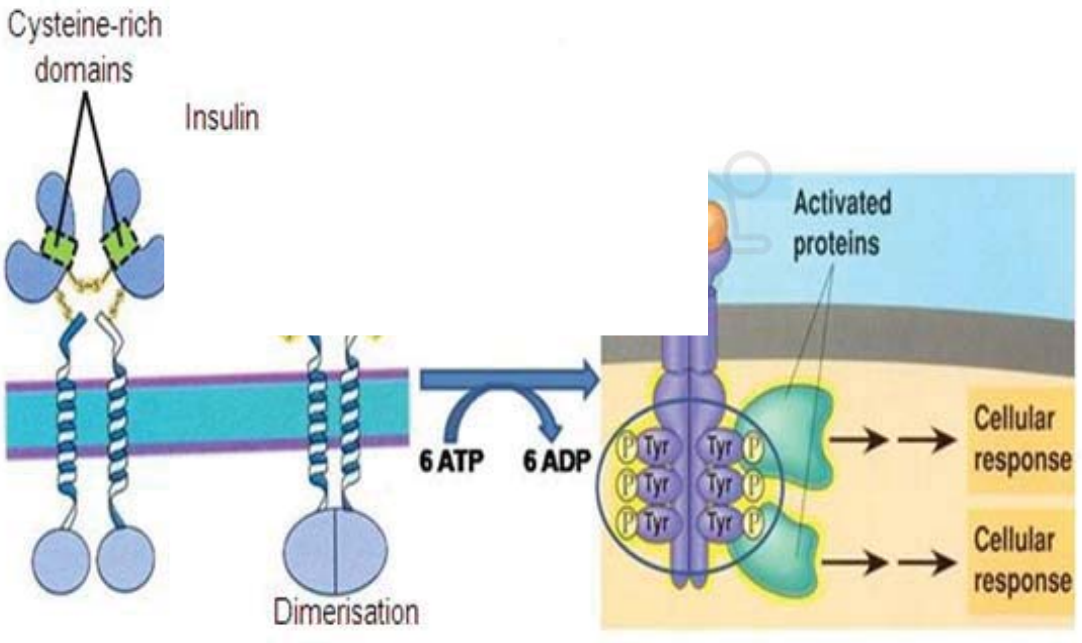


Fig. 6.1



[Turn over

Fig. 6.2

(a) Explain how the structure of the tyrosine kinase receptor is suited for its role in insulin mediated cell signalling.

- Cysteine-rich extracellular domain of receptor is complementary to insulin to facilitate binding;
- Transmembrane helices relays signal to cell interior;
- Dimerisation of intracellular tyrosine kinase domains results in phosphorylation of the tyrosine tails;
- which in turn activate specific relay proteins to elicit cellular responses;

.....

.....**[2]**

Fig. 6.3 shows how blood levels of glucose and glucagon change after a meal.

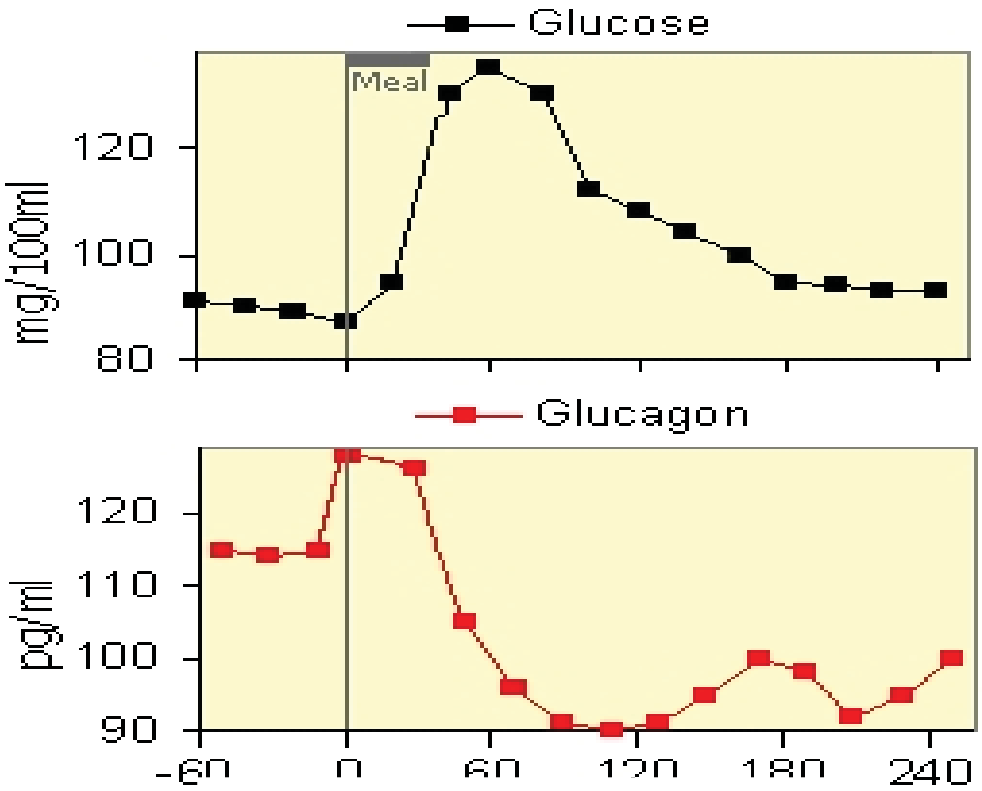


Fig. 6.3

(b) Describe the components of a homeostatic control system and explain the principles of homeostasis.

.....

- A homeostatic control system would include a receptor / detector to detect stimulus, a control centre to process information from the receptor and effector to carry out the response;
- Self-regulation which refers to the fact that the control mechanism is triggered by the very entity that it serves to regulate.
- Negative feedback - Any deviation from the reference point triggers mechanisms that serve to eliminate that deviation and return to the reference point.

.....[3]

(c) With reference to Fig. 6.3, explain the relationship between glucose and glucagon levels from 0 to 120 minutes.

- From 0 – 60 mins, glucagon levels decrease from above 120pg/ml to 95pg/ml as glucose levels increase from below 90mg/100ml to above 120mg/100ml;
- From 60 - 120mins, glucose levels gradually decreases from above 120mg/100ml to about 110mg/100ml as glucagon levels decrease from above 120pg/ml to 90pg/ml;

OR

- From 0 – 120 mins, glucagon levels decrease from above 120 pg/ml to 90 pg/ml as glucose levels increases from 85mg/100ml to above 120mg/100ml before dropping to 110mg/100ml; (2 marks)

Max 2 marks

- As glucose levels increase and deviate from set point reference, there is negative feedback due to diminished stimulus to alpha-cells of Islets of Langerhans of pancreas / alpha-cells of Islets of Langerhans of pancreas stops releasing glucagon;
- Decreased secretion of glucagon to blood stream would lead to less glucagon binding to GPCR;
- Conversion of glycogen to glucose (glycogenolysis and gluconeogenesis) is inhibited;

...[4]

Diabetes mellitus is a disease in which high blood glucose cannot be regulated back to normal set point within the body. The hormone insulin is commonly used in the treatment of diabetes. There are two forms of diabetes mellitus: Type 1 and Type 2. Type 2 diabetes mellitus is characterized by insulin resistance whereby the body tissues do not respond effectively to insulin.

(d) Suggest why the body tissue is insensitive to insulin in Type 2 diabetes mellitus.

- The three dimensional configuration/shape of the receptor for insulin may be changed/defective/mutated, hence insulin cannot bind/non-complementary to receptor.
- Receptor-mediated endocytosis of insulin receptors / reduce number of insulin receptors on target cells;

.....

...[1]

Glucagonoma is a rare tumour of the α-cells of the islet of Langerhans which results in an overproduction and secretion of glucagon.

(e) Suggest how glucose metabolism is affected when an individual has a glucagonoma.

- Increase breakdown of glycogen to glucose / glycogenolysis → (high blood glucose levels);
- Increase conversion of amino acids and pyruvate to glucose / gluconeogenesis;
- Increase lipolysis;

[1]

Cancer development occurs in stages. The advanced stage of cancer is characterized by the spread of cancer development to other parts of the body via the circulatory system to form secondary tumours by a process known as metastasis.

(f) Explain the properties of cancer cells required for metastasis.

- Ability to evade white blood cells and prevent them from being degraded;
- No anchorage dependence allows cancer cells to migrate to other parts of the body.
- Angiogenesis/stimulate growth of blood vessels towards itself allows cancer cells to gain access to circulatory system.
- Invasion of surrounding tissue cells allow cancer cells to form secondary tumours in other parts of the body.
- Cancerous cells can adhere to walls of capillary blood vessel;

[2]

[Total: 13]

7. In New Zealand, there are two species and three sub-species of native bush robins. It is believed that the robins evolved from a common ancestral stock, members of which flew from Australia across the Tasman Sea and became established in New Zealand over a million years ago. This ancestral form is considered to be similar to the present day Australian flame robin, *Petroica multicolor*, a bird with a brightly coloured red breast. The New Zealand birds do not have this red colour. Some characteristics of the birds and their distributions are shown in Fig. 7.1.

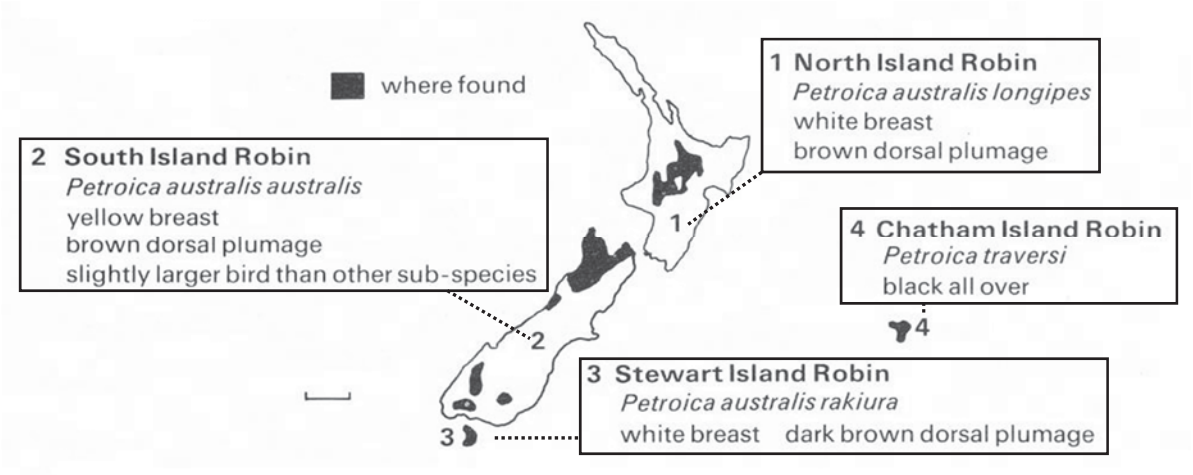


Fig. 7.1

(a) State the scientific name of the two species of native bush robins in New Zealand.

Petroica australis; *Petroica traversi* .....

[1]

(b) Explain why the robins in locations **1**, **2** and **3** are similar but different from those in location **4**.

- Birds in locations 1, 2 and 3 are capable of interbreeding (because of the) short distances between the islands;
- (similar environment and so) subjected to similar selection pressure / gene flow is not interrupted / shared a common gene pool for a long time;
- Birds on location 4 could not interbreed with the other birds;
- Allopatric speciation / geographically isolated;
- mutation such as the genes for black plumage would tend to be confined within the isolated inbreeding population;

.....

.....**[3]**

Based on earlier research, the native bush robin species and subspecies were distinguished based on a number of phenotypic differences such as plumage and breast colour. However, with modern technology, researchers have been using molecular methods such as direct DNA and amino acid comparison to further determine the phylogeny between the native bush robin species.

(c) Explain why molecular homology is better than anatomical homology in determining evolutionary relationship between species of native bush robins.

- Similarity in anatomical features could be due to convergent evolution;
- Study of anatomical homology is not possible between morphologically different species;
- Using molecular method, organisms can be compared even if they are morphologically very different + all organisms have certain molecular traits in common, e.g. rRNA sequences or certain fundamental proteins;
- Using morphological features as a benchmark is subjective and non-quantifiable;
- Molecular data is quantifiable and objective. Nucleic acid and amino acid sequence data are precise and easy to quantify, hence allows an objective assessment of evolutionary relationships;
- Fossils obtained from ancestral species may be incomplete thus comparative study of anatomy is not possible;
- Compare molecular divergence of ancestral species with incomplete/no fossil record with that found in other lineages with more complete fossil records;

; for 1 mark, max is 2 marks

.....

.....

.....

.....

...[2]

Differences in the *cytochrome b* DNA sequence of several native bush robins from different regions of New Zealand were measured and plotted against time since divergence from the primitive ancestor as seen in Fig. 7.2.

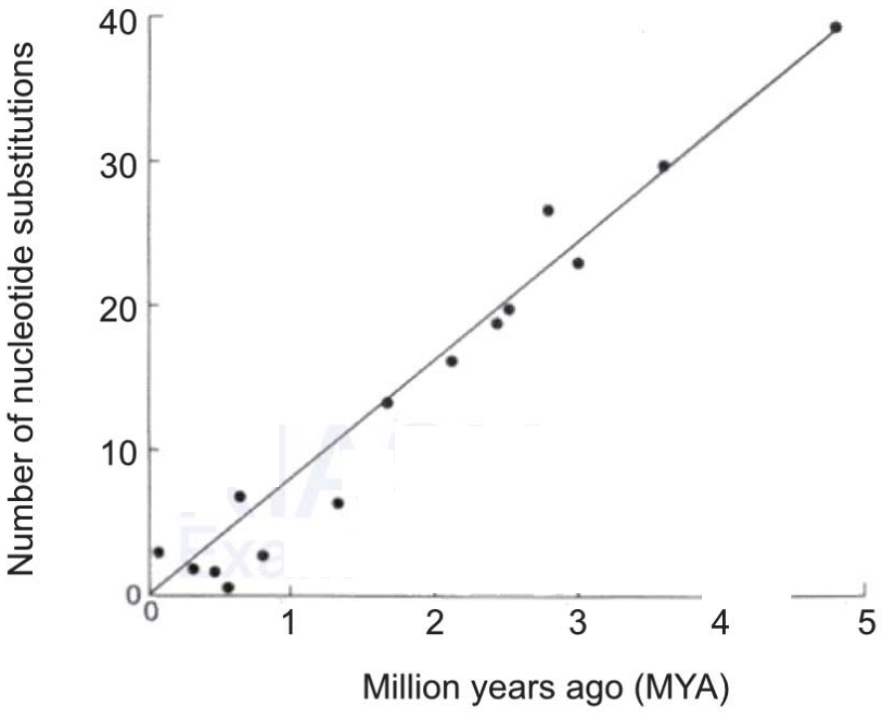


Fig. 7.2

(d) Describe how the differences in the number of nucleotide substitutions support the neutral theory of molecular evolution.

- The plot of the line is straight, indicating that the rate of mutation is constant;
- Changes in the nucleotide sequence arise through neutral mutation;
- for e.g. silent mutation or missense mutation where the change in amino acid does not occur in a critical region of the enzyme;
- There is no effect on the phenotype and fitness of organism and thus allowed to accumulate;
- Small number of changes over millions of years indicating that rate of mutation is slow as
- Cytochrome b gene is a crucial gene in living organisms for cellular respiration;

; for 1 mark, max is 3 marks

…
…
…
..[2]

(e) Suggest why New Zealand robins do not have the red breast trait even though it is present in its Australian robin ancestors.

- Australian robins might have gained the red breast by a mutation (which occurred in the Australian population);
- after the colonization of New Zealand by forms which did not possess it / ref to Founder effect;
- Red-breasted forms might have reached New Zealand where the characteristic was at a selective disadvantage / vice versa;
- Frequency of red breast allele decreased and eventually disappeared from the gene pool;
- Ref. to genetic drift such that red breast individuals accidently die;

……
……..[1]

[Total: 9]

Section B

Answer **one** question.

Write your answers on the separate answer paper provided.
Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.
Your answers must be in continuous prose, where appropriate.
Your answers must be set out in sections **(a), (b)** etc., as indicated in the question.

8.

(a) Compare between DNA replication and transcription. **[6]**

Similarities
1. Both involve unwinding of the double helix DNA;
2. Both involve breaking of the weak hydrogen bonds between complementary bases;
3. Both involve formation of phosphodiester bonds between neighbouring nucleotides;
4. Both involve aligning free nucleoside triphosphates through complementary base pairing;
5. Both products elongate in 5' to 3' direction;
6. Both occur in the nucleus;

Features	**DNA replication**	**Transcription**
(Main) Enzyme involved in polymerisation ***DO NOT LIST DOWN ALL ENZYMES as it is not a fair comparison. You are afterall comparing processes with different functions! Will you ever ask a child to wrestle with a full grown adult? Common sense must prevail during exams too.***	DNA polymerase - binds to the parental DNA molecule @ the origin of replication	RNA polymerase - binds to the promoter. a region near the beginning of the gene to be transcribed
Enzyme used for unwinding the double helix	Helicase	RNA polymerase
Binding site for start of process	Origin of Replication	Promoter sequence
Raw Material	Deoxyribonucleotides	Ribonucleotides
Template	Both strands of DNA molecule act as a template Whole DNA molecule is being replicated	One strand of DNA molecule acts the template The anti-sense / non-coding / template strand of DNA molecule is being transcribed; the other strand is not transcribed
Base Pairing	Adenine with thymine and vice verse Cytosine with guanine and vice versa	Adenine with uracil and vice verse Cytosine with guanine and vice versa
Presence of proofreading property on enzyme involved	DNA polymerase proofreads the newly synthesized daughter strand, ensuring precise complementary base pairing	NIL

Products	2 DNA molecules. Each DNA molecule comprises of 1 parental strand and 1 complementary daughter strand Products remain in the nucleus	1 RNA molecule Products leave the nucleus
When the process occur	Prior to nuclear division (mitosis and meiosis)	Prior to translation
Purpose	Double the amount of DNA so that: after mitosis - the 2 daughter cells will have the same amt of DNA (2n) as parental cell after meiosis - the 4 daughter cells each will have half (n) the amt of DNA	Protein synthesis

(b) Describe how differences in the structure and organization of prokaryotic and eukaryotic genomes affect their control of gene expression. **[7]**

		Prokaryotic Genome	**Eukaryotic Genome**
Structure	Level of condensation	• DNA not highly condensed / Not bound to histones • Because genome size is smaller	• Many levels of condensation of DNA / DNA bound to histones • Because genome size is larger
	Significance	• No need to decondense chromosome / uncoil DNA from histones before transcription can occur	• Chromatin must be decondensed / have a looser conformation for transcription to occur so that RNA polymerase & transcription factors can bind to DNA
		• Changes in chromosome structure not used as method to regulate transcription	• Rate of transcription can be regulated by histone acetylation • resulting in conversion between euchromatin and heterochromatin, • affecting the ease of transcription
Structure / Organisation	Chromosomes / Genomes bound by membrane	• Not bound by membrane / genome in nucleoid	• Bound by the nuclear membrane / genome in nucleus
	Significance	• Transcription and translation occur simultaneously	• Transcription occurs before translation / transcription occurs within the nucleus and translation outside the nucleus / transcription and translation occur in different locations in the cell
		• Post-transcriptional control of gene expression not possible • Thus mRNA is more easily degraded / less stable	• Post transcriptional control of gene expression is possible • Eg. Alternative splicing / mRNA modifications before translation – 5' cap or poly-A tail • Thus mRNA is less easily degraded / more stable
Structure / Organisation	Presence / Absence of introns	• No introns	• Presence of introns
	Need for mRNA splicing & allows for alternative splicing	• No splicing of mRNA is needed	• Splicing of pre-mRNA is needed / exons / coding regions must be spliced together
		• No alternative splicing possible • Only one mRNA / protein product per gene	• Allows for alternative splicing • giving rise to varying mature mRNA molecules and hence multiple possible protein variants from the same gene
Organisation	Presence / absence of operon	• Genes coding for enzymes with related function grouped in an operon	• Dispersed genes coding for enzymes with related function each controlled by an individual / separate promoter
	Need for coordinate control, eukary genes having	• Produces polycistronic mRNA	• Produces monocistronic mRNA

	shared control elements	• Allows coordinated control of metabolic enzymes involved in the same pathway	• Coordinated control occurs via binding of transcription factors to control elements shared by genes with related functions (when genes are on diff chrom) • Coordinated control also occurs by DNA methylation / histone acetlyation that causes all the genes in the same region to be made available or unavailable for transcription (when genes w related fns are close together on the same chrom)
		• All gene products of an operon are produced in the same amount	• Each gene product can be produced in different amounts or not at all
Organisation	Presence / Absence of (distal) control elements	• No distal control elements or its regulatory sequences are close to promoter	• Presence of distal control elements
	Allows for more fine-tuned control of transcription	• Simple control possible, either transcription switched on or off • Level of expression cannot be finely tuned / regulated as specifically	• Allows for fine tuned control of gene expression / allows for different levels of expression of a particular gene • depending on the activators and repressors present in the cell at a specific time

(c) Outline the viral reproduction cycle of HIV. **[7]**

Stage	Description
Attachment / Adsorption	• gp120 glycoproteins on the surface of the HIV binds to CD4 receptors on T helper cells and macrophage. o CD4 (cluster of differentiation 4) is a glycoprotein expressed on the surface of T helper cells, regulatory T cells, monocytes, macrophages, and dendritic cells. • Binding of gp120 to CD4 is mediated by conformational changes in the gp120 protein but such conformational change is not sufficient for fusion. • The co-receptor CCR5 produces a conformational change in gp41 on HIV virion which allows fusion of HIV to host cell membrane.
Penetration	• The viral envelope of HIV fuses with the host cell membrane, releasing the nucleocapsid into the host cell, leaving the viral envelope outside the host cell
Uncoating	• The capsid is degraded, releasing the viral enzymes (integrase, protease and reverse transcriptase) as well as the viral RNA genome into the host cell cytoplasm.
Synthesis / Replication	• HIV's reverse transcriptase uses viral RNA as a template to form a complementary strand of DNA. This forms an RNA-DNA hybrid. • Next, the RNA strand is degraded and reverse transcriptase proceeds to use the remaining DNA strand as a template to form another complementary DNA strand. This forms a dsDNA molecule. • The dsDNA enters the nucleus and is integrated into the host genome using the enzyme integrase and the integrated viral DNA is known as a provirus; • When the provirus is activated, the host RNA polymerase transcribes the viral DNA into viral RNA molecule. • The new RNA genomes serve as nucleic acid for new HIV. • Proviral DNA is also transcribed into viral mRNA, which is then translated by the host cell machinery to produce a single long chain of HIV protein (polyprotein). • Capsid proteins and the various viral enzymes are synthesized by free ribosomes in the cytosol. • Viral glycoproteins (gp 120 and gp 41) are synthesized by fixed ribosomes of the RER and are transported to the GA for chemical modification before incorporation into the host cell membrane. Max 2 marks
Assembly	• Vesicles embedded with viral glycoproteins migrate towards and fuse with the cell surface membrane. • Assembly of two single-stranded RNA molecules associated with reverse transcriptase, integrase and protease occurs within an assembled capsid.
Maturation & Release	• Viral maturation occurs when the polyprotein is cleaved into smaller functional proteins by viral protease. • The virus leaves the host cell via budding, with the host cell membrane forming the new viral envelope.

[Total: 20]

9.

(a) Contrast the structures of viral, prokaryotic and eukaryotic genome. **[5]**

	Viral genome	Prokaryotic genome	Eukaryotic genome
Genetic material	Either DNA or RNA;	DNA;	DNA;
	Either double-stranded; or single-stranded;	Double-stranded;	Double-stranded;
	Either linear; or circular ;	Circular;	Linear;
	Either segmented; or single;	Singular chromosome	segmented / many different chromosomes;
Presence of telomeres	May or may not be present;	None;	Present
Presence of origin of replication	May or may not be present;	One present	Yes / many present
DNA enclosed in …	capsid;	Nucleoid body	nucleus;
DNA associated with histones	No;	No;	Yes;
Amount of noncoding DNA	Little ;	Little;	Large amounts;
Introns	Absent;	Absent;	Present;
Amount of repetitive DNA / centromeres	Absent	Absent	Large amounts/ Present
spacer DNA between genes	Little	Little	Large amounts
Presence of introns in genes	No (in most cases);	No	Yes;
Size	Smallest;	Smaller	Larger;

1 mark per row. Max 6 marks.

(b) Relate the structure of ribosome to its role in protein synthesis. **[7]**

- Made out of ribosomal RNA and proteins.
- Consists of a small subunit and a large subunit
- Prokaryotes have 70S ribosomes, each consisting of a small (30S) and a large (50S) subunit.

  OR
- Eukaryotes have 80S ribosomes, each consisting of a small (40S) and large (60S) subunit.
- small sub-unit allows attachment of mRNA to form initiation complex
- large sub-unit contain 'P' site: peptidyl-tRNA site, 'A' site: aminoacyl-tRNA site, 'E' site: exit site
- large subunit of the ribosome contains peptidyl transferase, for formation of peptide bond/elongation of polypeptide chain
- A site for receiving the aminoacyl-tRNA complex
- P site holds the 1^{s} aa-tRNA complex/elongating polypeptide chain
- the 'E' site is where the tRNA released into the cytoplasm
- freely floating Ribosomes in the cytosol – produce proteins that function within the cytosol
- Ribosomes attached to the endoplasmic reticulum - synthesise proteins that are meant for insertion into the membrane, for packaging within certain organelles e.g. lysosomes or for secretion out of the cell

(c) Outline the processes involved in oxidative phosphorylation. **[8]**

- Oxidative phosphorylation is the process where ATP is generated using the energy released during transfer of electrons from NADH or $FADH_2$ to oxygen via a series of electron carriers;
- NADH and 2 $FADH_2$ are responsible for donating electrons to the electron transport chain (ETC) during oxidative phosphorylation;
- As electrons move from one carrier to the next, they are moving from a higher energy level to a lower energy level, therefore they lose potential energy;
- At the end of the ETC, electrons combine with the final electron acceptor oxygen and H^+ in the mitochondrial matrix → oxygen is reduced to water;
- This energy is used by ETC carriers to pump H^+ from the matrix into the intermembrane space;
- The pumping of H^+ across the inner mitochondrial membrane against its concentration gradient generates a proton gradient;
- The potential energy contained in this electrochemical gradient is known as the proton-motive force;
- Chemiosmosis is an energy-coupling mechanism that uses the proton-motive force to drive generation of ATP from ADP and P_i;
- Due to the proton-motive force, H^+ tends to diffuse down its gradient and leak back from the intermembrane space into the matrix;
- H^+ can pass through a channel in ATP synthase and the energy released from the movement of H^+ down its gradient is used to form ATP;
- ATP synthase can use the exergonic flow of H^+ to drive the phosphorylation of ATP from ADP and P_i.;
- 34 ATP molecules formed from 1 glucose molecule after oxidative phosphorylation;

End of Paper

Class Adm No

Candidate Name: _____

H

millennia institute

2017 Preliminary Examination 2
Pre-University 3

H2 Biology **9648/03**

Applications Paper and Planning Question **19 September 2017**

2 hours

Additional Materials: Writing paper

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your Admission number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

The use of an approved scientific calculator is expected, where appropriate.
You will lose marks if you do not show your working or if you do not use appropriate units.
At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

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1	
2	
3	
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5	
Total	

This question paper consists of 20 printed pages

[Turn over

Answer **all** questions.

1. The ability to model human diseases using cultured pluripotent stem cells (PSCs) has revolutionized the ways in which we study monogenic, complex and epigenetic disorders, as well as early- and late-onset diseases. Several strategies are used to generate such disease models using either embryonic stem cells (ES cells) or patient-specific induced PSCs (iPSCs), creating new possibilities for the establishment of models and their use in drug screening. Fig. 1.1 shows strategies for generating human pluripotent stem cells (hPSCs) carrying a genetic disorder for research purposes. Disease-specific ES cells can be identified during the in-vitro fertilization (IVF) process by pre-implantation genetic diagnosis (PGD) or pre-implantation genetic screening (PGS).

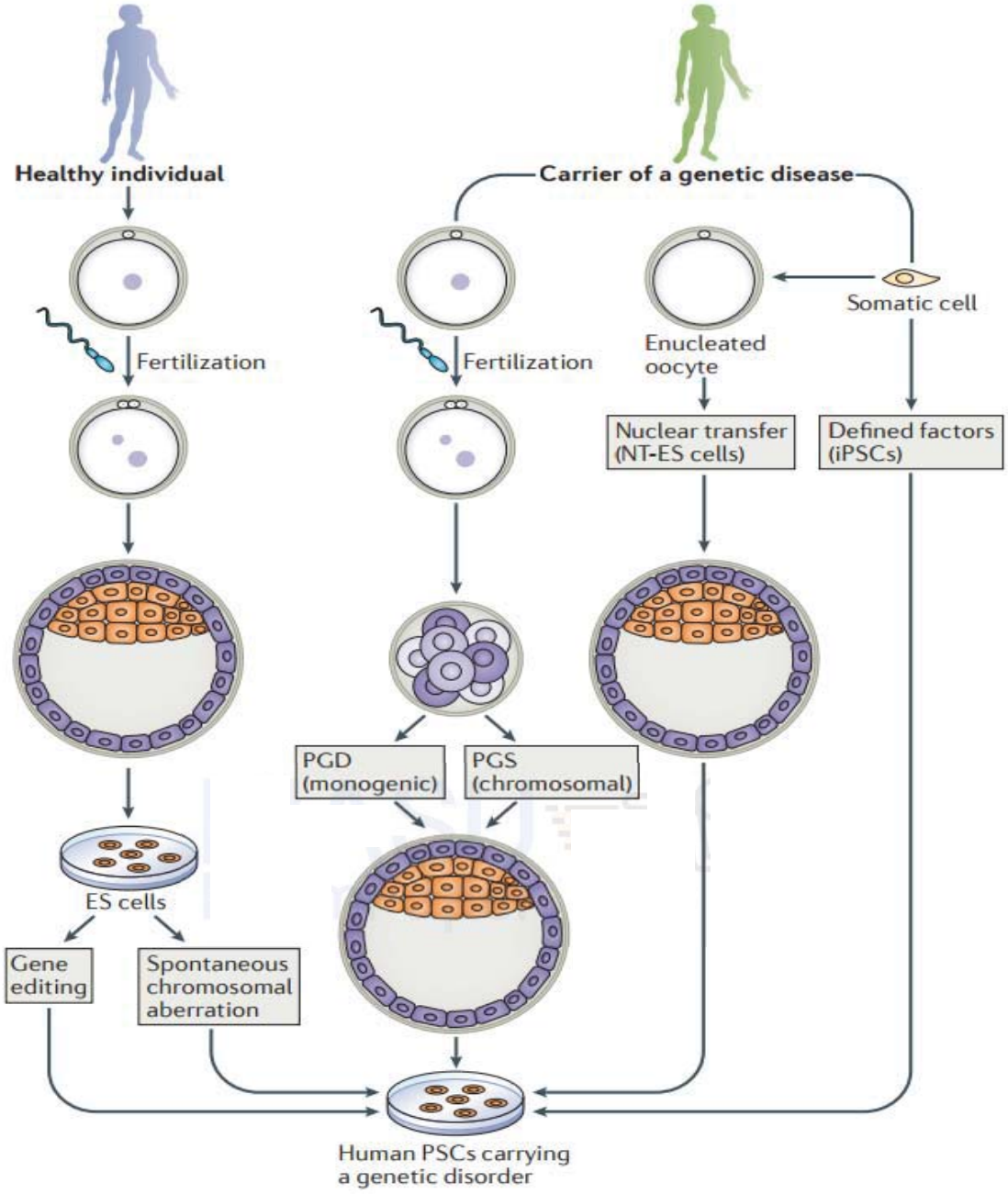

Fig. 1.1

(a) Describe one similarity and one difference between a blastocyst and embryo.

- Both blastocysts and embryos are a cluster of undifferentiated cells;
- Both are pluripotent;
- Both have high telomerase activity;
- Both have self-renewal property that can undergo indefinite rounds of replication;

- Blastocysts are earlier stage of embryo;
- Blastocysts consist of inner cell mass but an embryo does not have an inner cell mass;
- Blastocysts consist of cells that will form the placenta but embryo does not have those cells;

[2]

(b) Describe one advantage and one limitation of using somatic cell nuclear transfer (SCNT) to generate human PSCs carrying a genetic disorder.

- Easier to isolate nucleus with defective allele from somatic cells;
- Easier to harvest eggs and somatic cells;
- Pluripotent stem cell is genetically identical to the patient;
- Able to harvest pluripotent stem cells without the need to kill embryos;

- Low success rate;
- Cells obtained from SCNT may have additional abnormalities and chromosome aberrations due to incorrect reprogramming;

[2]

In order to optimise the conditions and increase the chances of creating iPSCs from somatic cells, extensive research has been conducted on 4 main genes, *Oct4*, *Sox2*, *Nanog* and *Lin28* using M4 cell cultures. Fig. 1.2 shows the effect of different combinations of genes in the reprogramming mixture on the number of induced-pluripotent stem cell colonies formed.

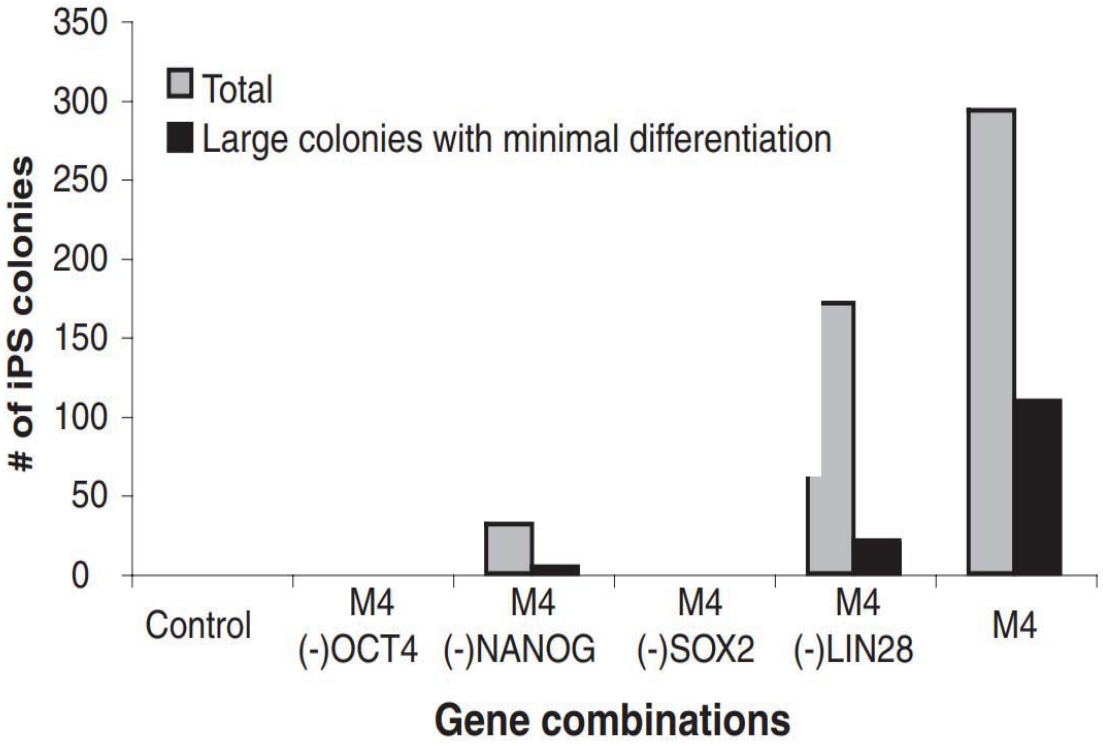

Fig. 1.2

(c) With reference to Fig. 1.2,

(i) explain the purpose of the control.

The control group in this experiment are somatic cells that are not treated with any reprogramming genes to investigate the extent of each of the 4 genes that can reprogram somatic cells to form iPSCs;

[1]

(ii) describe the results produced from varying gene combinations in the reprogramming mixture.

- Oct4 and Sox2 are the more important genes with significant effect in reprogramming somatic cells to iPSCs as M4 without Oct4 and M4 without Sox2 shows zero colony of iPSCs.;
- Lin28 is the least significant gene in reprogramming somatic cells to iPSCs as 25 undifferentiated iPSC colonies / 180 total colonies can still be obtained even though M4 does not have Lin28;

[2]

(d) Describe one possible regulatory process at the chromosomal level that could increase the expression of *Oct4*, *Sox2*, *Nanog* and *Lin28* genes.

- Demethylation of DNA where methyl groups of certain DNA sequences are removed.
- Histone methyltransferase causes methylation of histone tails;
- allowing the DNA segment containing the 4 genes to be more accessible for RNA polymerase to bind to for transcription;

- Acetylation of histone tails lead to weaker binding between DNA and histones by Histone Acetylase (HAT);
- allowing the DNA segment containing the 4 genes to be more accessible for RNA polymerase to bind to for transcription;

- Demethylation of histone tails lead to weaker binding between DNA and histones by histone demethylase;
- allowing the DNA segment containing genes to be more accessible for RNA polymerase to bind to for transcription;

(e) Suggest one reason why the number of cell colonies with minimal differentiation differs from the total number of cell colonies produced.

- There are other genes involved in reprogramming somatic cells into undifferentiated iPSCs that are not included in the mixture;
- Reprogramming of the nucleus is not always successful for all the somatic cells;

[1]

X-linked Severe Combined Immunodeficiency (SCID) is a rare congenital disorder characterised by improper development of immune cells which has been treated by gene therapy. The ability to generate iPS cells that have similar characteristics with embryonic stem cells has provided a promising alternative to the use of haematopoietic stem cells for gene therapy to treat X-linked SCID.

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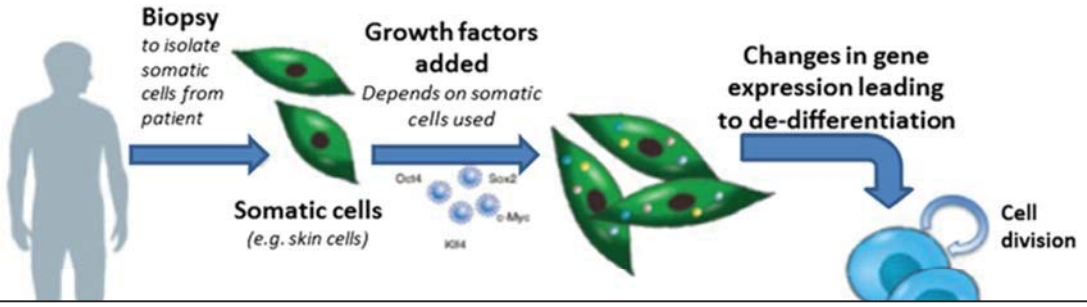
Fig 1.3 shows a possible process of using iPS cells for gene therapy.



Use of liposome as vector

- Lower probability of liposomes binding to cell surface membrane of iPS cells and membrane fusion occurring to release DNA into target cells;
- therefore not all target cells receive normal IL2RG allele, some still express non-functional IL2RG protein;

OR

- Normal IL2RG allele not integrated into the iPS cell's DNA, unless retroviral vector is used;
- this leads to transient expression of normal functional proteins and multiple treatments are required;

OR

Gene therapy does not offer complete cure

- Difficult to control the expression of the normal IL2RG alleles
- Expression of proteins may be unstable – there may be too much or too little proteins being expressed → immune cells may have insufficient cytokine receptors/are abnormal, cannot carry functions;

(carried out using liposomes)

Fig. 1.3

(f) Besides difficulties with de-differentiating somatic cells to iPS cells, explain one other factor that could prevent this method of gene therapy for X-linked SCID from becoming an effective treatment.

.....

.....

Against use of ES cells

- involves removal of inner cell mass from blastocyst → destruction of embryo which has the potential/ability to develop into a foetus/a human being → akin to murder/killing of a life for own benefit/to treat own disease;
- ES cells are able to divide continuously via mitosis → potential of developing tumours, causing more harm to the patient;
- ES cells could potentially develop into individuals and they did not give their consent for experimental use;

AND

- Disagree → iPS cells have characteristics of ES cells and hence have the potential of developing into a develop into a foetus/a human being;

OR

- Agree → iPS cells were not harvested from embryos but were obtained from de-differentiation of somatic cells → no destruction of human life so it is acceptable;
- Agree -> Donors of IPS cells would be able to give their consent for experimental use;

.....**[2]**

[Total: 14]

2. Conventional DNA ladders are traditional molecular weight standards used for sizing and approximate quantification of linear double-stranded DNA fragments in agarose and non-denaturing polyacrylamide gels for research purposes. The markers are composed of lambda phage DNA digested to completion with the appropriate restriction enzyme(s), purified and dissolved in storage buffer. The DNA fragments contain blunt or sticky ends depending on the restriction enzyme used for the marker's preparation. Fig. 2.1 shows the genome of Lambda DNA with the restriction sites corresponding to six different restriction enzymes.

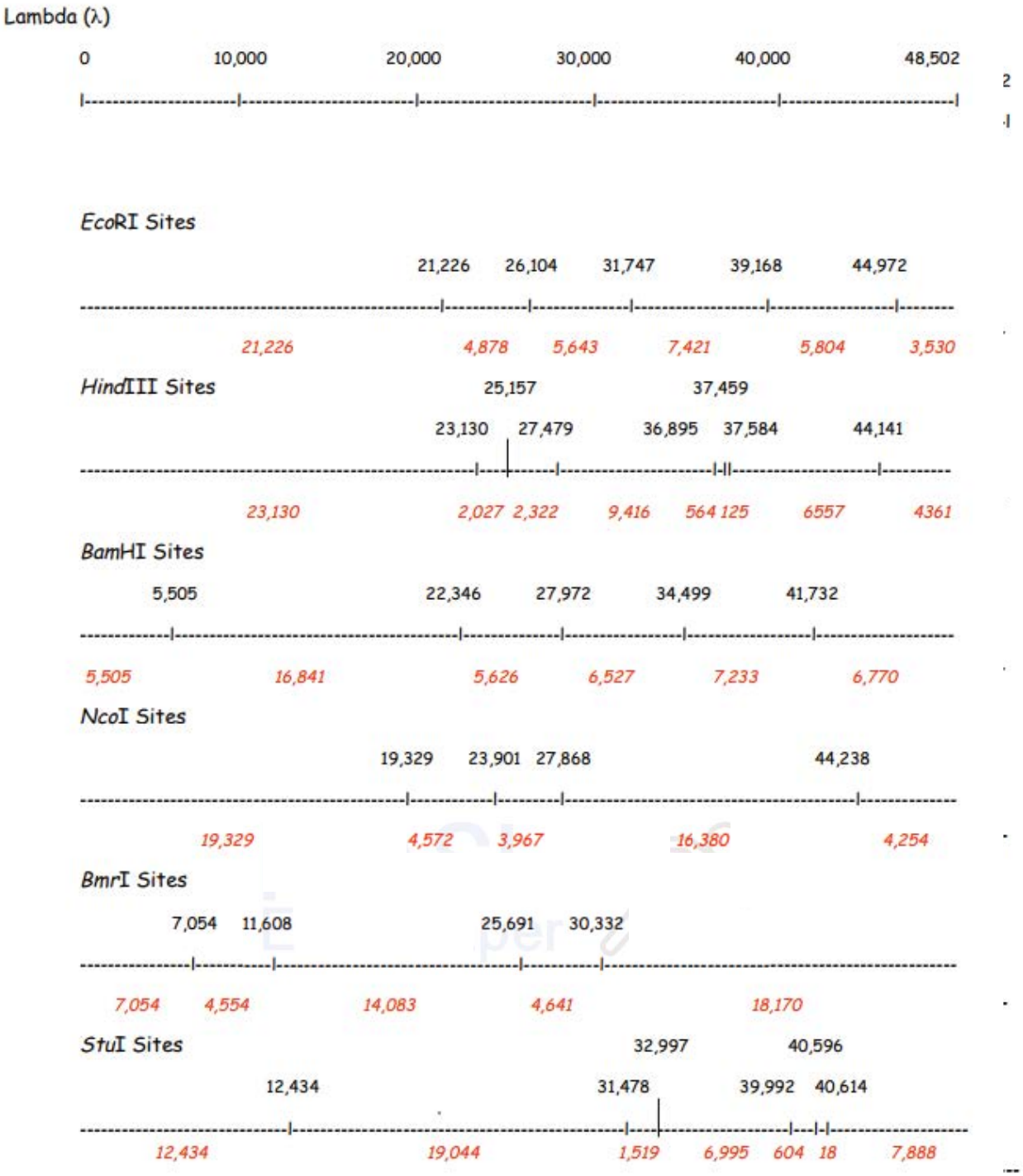


Fig. 2.1

Table 2.1

EcoRI	HindIII	BamHI	NcoI	BmrI	StuI
21226	23130	16841	19329	18170	19044
7421	9416	7233	16370	14083	12434
5804	6557	6770	4572	7054	7888
5643	4361	6527	4264	4641	6995
4878	2322	5626	3967	4554	1519
3530	2027	5505			604
	564				18
	125				

(a) With reference to Fig. 2.1, fill in the columns of Table 2.1 with the respective DNA fragments generated from their corresponding restriction enzymes. List each fragment from the largest to the smallest. **[2]**

(b) Explain two factors that would influence a researcher's decision in choosing a restriction enzyme for the restriction digest step of the gene cloning experiment.

- The position of the restriction site of the restriction enzyme as the researcher would not choose a restriction enzyme that can target a sequence within the gene of interest as a restriction site;
- Proximity of restriction site to the gene of interest as the researcher would choose a restriction enzyme that can excise the gene at restriction sites that a flanking right next to the gene;
- Restriction enzyme must be able to target restriction sites on both the vector and gene of interest;
- Restriction enzyme would be preferred if it generates sticky ends because if it generates blunt ends, it requires additional steps of adding linker DNA;
- Restriction enzyme chosen should make a single and unique cut to the vector as the researcher would not want to fragment the vector / gene of interest is not incorporated into multiple sites;
- Availability of the restriction enzyme;
- Cost of the restriction enzyme;
- AVP;

..

2]

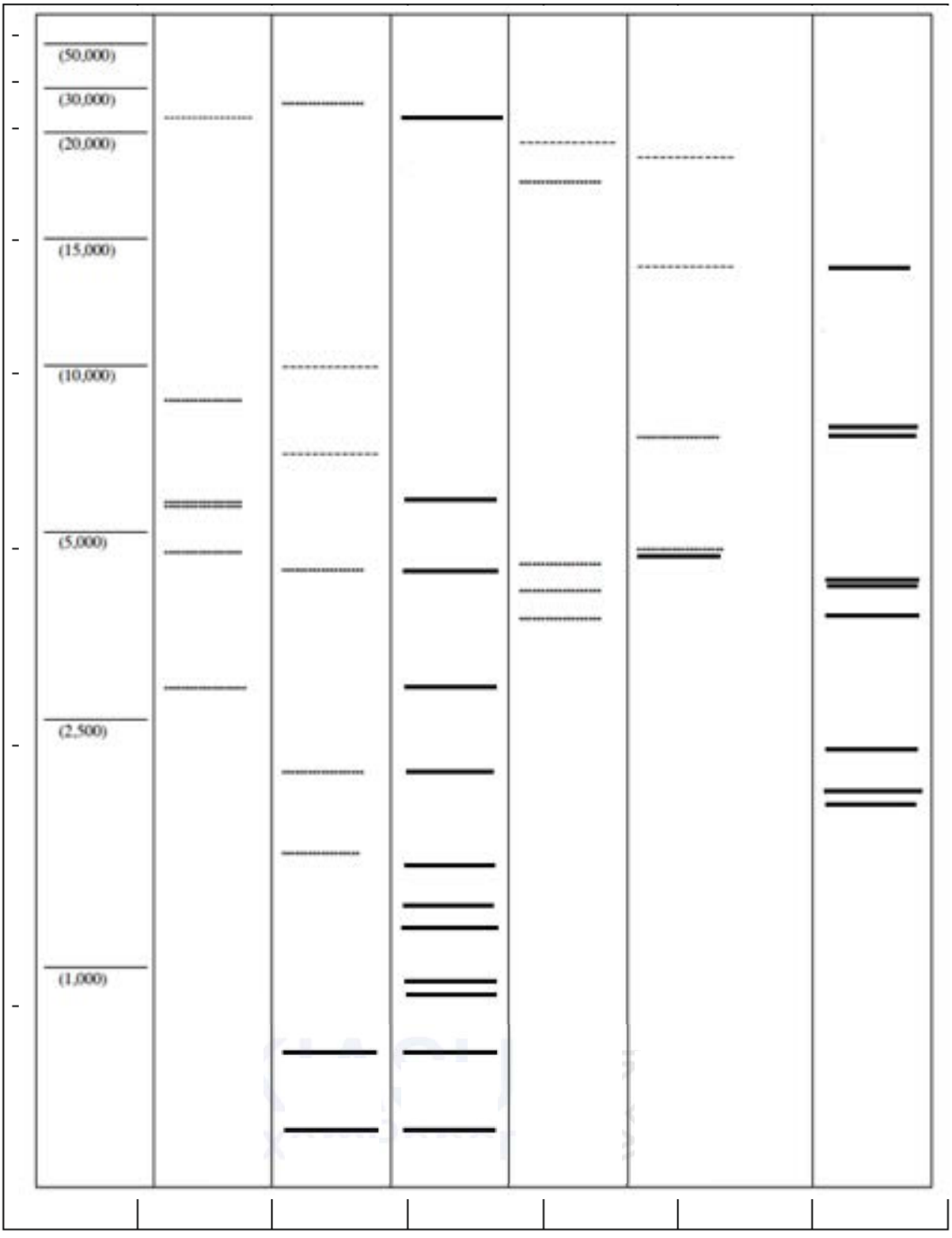


Fig. 2.2

(c) Complete Fig. 2.2 below by drawing the DNA band patterns after gel electrophoresis. **[2]**

(d) Explain how DNA bands can be visualized after gel electrophoresis.

- Ethidium bromide / Bromophenol blue / xylene cyanol is added to the gel in order to facilitate visualization of DNA after electrophoresis;
- Ethidium bromide / Bromophenol blue / xylene cyanol binds to only DNA;
- DNA bands are viewed under UV light;

…….[2]

(e) Suggest a method to improve the separation of DNA bands during gel electrophoresis.

- Decrease voltage during gel electrophoresis;
- Increase the concentration of agarose used to cast the gel;
- Add glycerol to the DNA samples in the loading well;
- Cast an agarose gel that is longer in length;
- AVP;

- R! Increase duration of electrophoresis

……[1]

Besides being used for DNA fragment separation, gel electrophoresis can also be conducted to separate protein fragments for agricultural research purposes in order to study relationships between protein band patterns and phenotypic traits.

Barley (*Hordeum vulgare)* is an important crop in southern Brazil where its production is used in the brewing industry. Hence, the malting quality of different barley plant cultivars must be continuously researched and improved upon. Cultivars are new plant species obtained via artificial selecting breeding processes.

Malt is germinated cereal grains that have been dried via malting. Malting grains develop the enzymes required for modifying the starch in the grains into various types of sugars such as maltose and glucose. Characteristics of importance for malting quality, which can differ considerably among barley cultivars, include grain size, grain protein concentration and nitrogen content in the seeds.

Recently, researchers are researching on how the quality of a particular storage protein named hordein could affect the malting quality of barley plants. Barley is highly polymorphic regarding the hordein polypeptide composition. Electrophoresis is particularly attractive as a screening test to differentiate barley plant cultivars and to determine malting quality of each variety. By comparing the total hordein pattern from barley cultivars of different malting quality, researchers can investigate the relationship between malting quality and band patterns and to explore the feasibility of using hordein protein electrophoresis to assist in the selection of barley plant cultivars for malting.

Fig. 2.3 shows the hordein polypeptide band patterns of 14 different barley plant species. On the right of the gel, a polypeptide fragment ladder showing the band positions of 26 different hordein polypeptide sizes serves as a reference point for comparison.

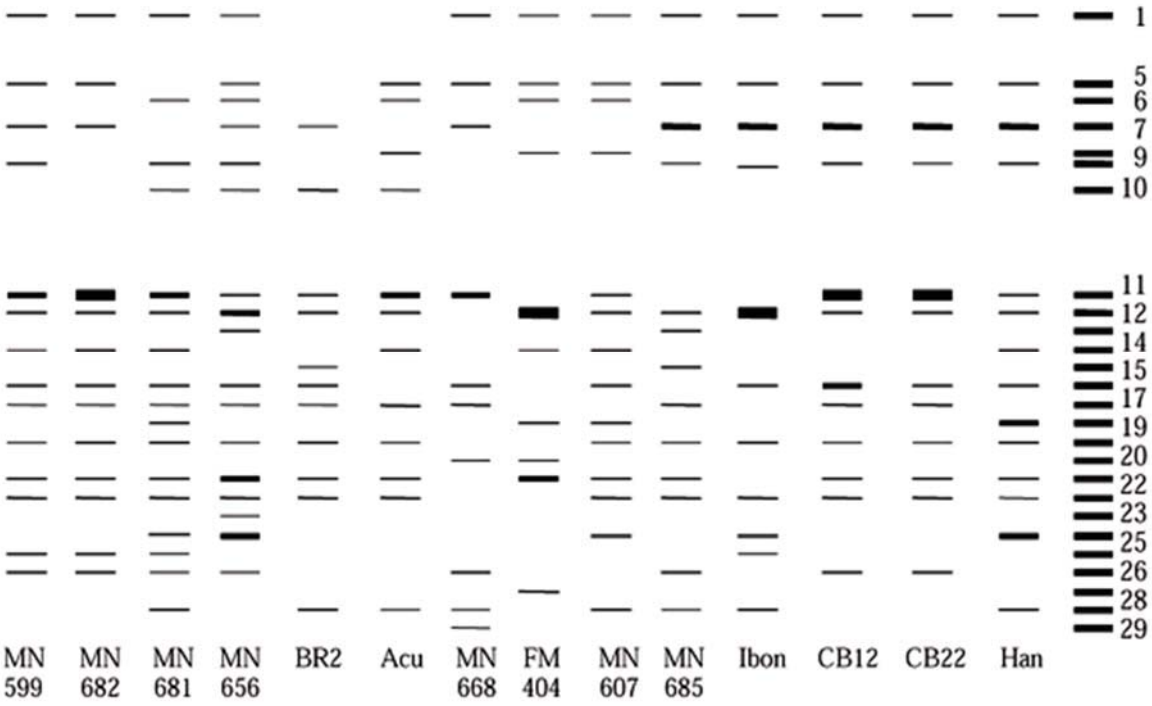


Fig. 2.3

(f) With reference to Fig. 2.3, complete the phylogenetic tree shown in Fig. 2.4.

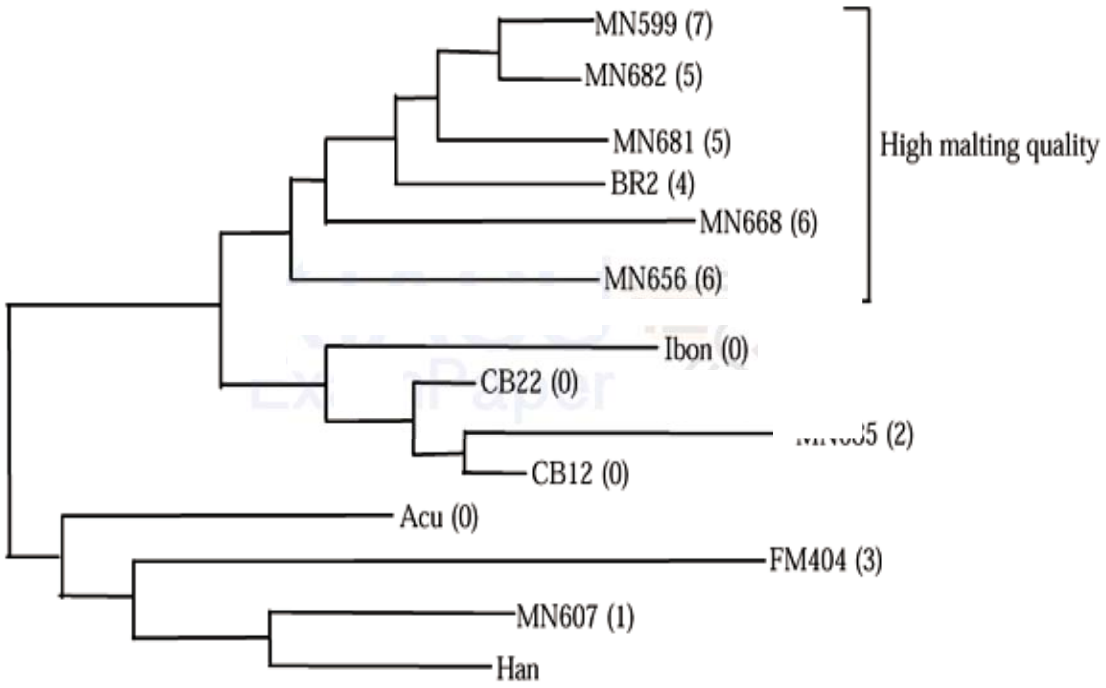


Fig. 2.4 **[2]**

Table 2.2 shows the correlation of each polypeptide band with the malting quality of barley varieties studied. The number of + / - in Table 2.2 indicates the strength of correlation between the polypeptide band and malting quality.

Table 2.2

Band	Correlation	Band	Correlation
1	-	17	-
5	- -	18	-
6	+	19	- - -
7	-	20	+
8	-	21	-
9	-	22	-
10	+	23	+
11	+	24	-
12	- -	25	+
13	+	26	+
14	-	27	+
15	+	28	-
16	+	29	+

Table 2.3 shows the frequency of the hordein polypeptide bands (in percentage) in each barley variety studied.

Table 2.3

Hordein band	Varieties[1]													
	MN 599	MN 682	MN 668	MN 681	MN 656	BR2	Acu	Han	FM 404	MN 607	MN 685	Ibon	CB12	CB22
1	20	20	27	27	38	0	0	78	100	70	100	90	100	100
5	20	10	18	0	8	0	91	71	100	70	100	90	100	90
6	0	0	0	9	8	0	75	0	100	70	0	0	0	0
7	20	20	27	0	31	13	0	78	0	0	100	90	100	100
8	0	0	0	0	0	0	75	0	100	50	0	0	0	0
9	20	0	0	27	8	0	0	64	0	0	100	70	100	90
10	0	0	0	9	8	33	8	0	0	0	0	0	0	0
11	100	100	00	100	54	100	100	100	0	100	0	0	100	100
12	100	70	0	64	92	40	100	100	100	100	100	100	100	100
13	0	0	0	0	46	0	0	0	0	0	100	0	0	0
14	30	30	0	27	0	0	100	100	100	100	0	0	0	0
15	0	0	0	0	0	60	0	0	0	0	100	0	0	0
16	100	100	100	100	54	00	0	100	0	30	0	100	100	100
17	50	60	100	73	23	60	91	0	0	0	100	0	100	100
18	0	0	0	18	0	0	0	100	100	100	0	0	0	0
19	20	20	0	36	54	66	100	100	0	90	100	100	100	100
20	0	0	9	0	0	0	0	0	100	0	0	0	0	0
21	100	100	0	100	46	100	42	100	100	100	100	0	100	100
22	100	100	0	100	46	100	91	36	0	100	100	100	100	100
23	0	0	0	0	23	0	0	0	0	0	0	0	0	0
24	0	0	0	27	54	0	0	100	0	100	0	90	0	0
25	50	30	0	45	0	0	0	0	0	0	0	20	0	0
26	40	40	100	9	23	0	0	0	0	0	100	0	100	100
27	0	0	0	0	0	0	0	0	100	0	0	0	0	0
28	0	0	64	9	0	6	8	93	0	100	50	100	0	0
29	0	0	27	0	0	0	0	0	0	0	0	0	0	0

[Turn over

For Examiner's Use

(g) With reference to Fig. 2.4, Table 2.2 and Table 2.3, identify and explain which barley variant would have the best malting quality.

- MN668;
- The presence of the hordein bands 5, 12 and 19 can be useful as molecular indicator of a low malting quality / Bands 5 and 12 and 19 strongly correlated negatively with malting quality scores;
- According to the phylogenetic tree diagram, MN688 also belongs to the family of barley plant variants of high malting quality;
- Lowest frequency of polypeptides band 12 and 19 at 0% and relatively low frequency of polypeptide band 5 at 18%;
- Presence of hordein band 29 is positively correlated to malting quality and MN668 has the highest frequency of polypeptides band 29 at 27% compared to the other variants;
- Bands 11, 16 and 19 correlate positively with malting quality scores and MN668 has 100% frequency of those 3 bands;

.....

.....

.....**[4]**

[Total: 15]

3. Rice is the staple diet in many parts of the world. It lacks a number of important nutrients, including β carotene, from which vitamin A is synthesised. Adequate concentrations of vitamin A give protection from night blindness. Higher concentrations act as an antioxidant that may give some protection from cancer and heart disease. Golden rice, which contains β carotene, was developed in Switzerland by genetically modifying rice using genes from a daffodil (a flowering plant) and a bacterium.

Fig. 3.1 shows an artificial DNA sequence used.

Key:

pro – promoter sequence for polymerase enzymes

ter – termination signal for polymerase enzymes

Hyg resist – Hygromycin B antibiotic resistance gene from a bacterium

Fig. 3.1

Fig. 3.2 shows the main events involved in obtaining a transgenic rice plant.

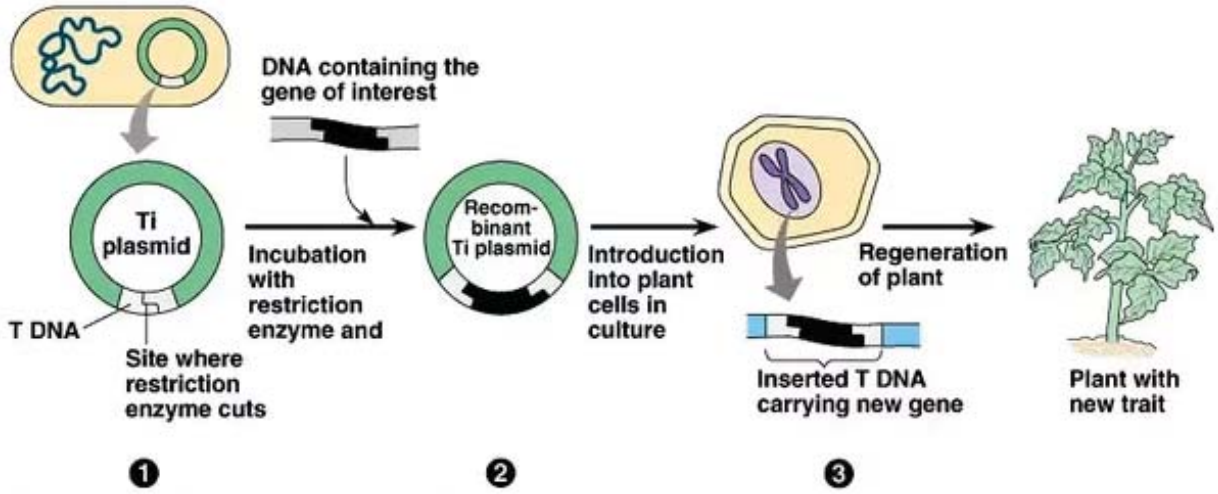


Fig. 3.2

(a) Define the term 'transgenic'.

Relating to or denoting an organism that contains genetic material into which DNA from an unrelated organism has been artificially introduced.

.....[1]

For Examiner's Use

(b) Describe two unique and distinct regions found within the Ti plasmid.

- Genes in the virulence region code for the enzymes responsible for mediating conjugative transfer of T-DNA to plant cells.
- T-DNA region consists of genes such as auxin, cytokinin and opine that code for plant growth regulators that alter the development and metabolism of the host plant cell;
- Ori which represents origin of replication where helicase would bind to to unwind DNA for DNA replication;
- Ti plasmids contain selectable marker allows for identification of transformed cells;
- Ti plasmids have multiple restriction sites, to allow introduction of genes;

.....**[2]**

(c) With reference to Fig. 3.1 and Fig. 3.2,

(iii) outline the processes involved from stage **2** to stage **3**.

.....

- Bacterial transformation via calcium chloride treatment + heat shock / electroporation to facilitate uptake of recombinant Ti plasmid into agrobacterium;
- Hyg resistance gene is also inserted into the recombinant Ti plasmid to enable selection of the transgenic cells such that only the bacterial cells with the new DNA can grow in the presence of Hygromycin B;
- The modified agrobacterium is placed in a liquid suspension to the leaves of susceptible plants, infecting them;
- The T-DNA is excised from Ti plasmid, transferred into nucleus and integrated into the plant genome;

.....

.....

.....**[4]**

(iv) outline the processes involved from stage **3** to generate a full-grown transgenic plant.

- The explant is then aseptically transferred to culture vessels containing aseptic culture medium that contains nutrients and plant growth regulators;
- Auxin and cytokinin in equal ratio is added to the nutrient agar to stimulate the cells of the explant to divide by mitosis to form a callus;
- As callus increases in size, it can be subcultured into many calli by placing them in separate culture vessels containing culture medium with plant growth regulators;
- The cells of a callus can be induced to either proliferate or differentiate into particular tissues
- Low level of cytokinin and high level of auxin triggers formation of roots growth / High level of cytokinin and low level of auxin triggers shoot growth / Auxin and gibberellin stimulates cell differentiation; (any one e.g.)
- With differentiation of cells of callus into particular tissues, a plantlet can form;
- Plantlets are then allowed to acclimatized before transfer to soil to grow into a whole plant;

.....

.....

.....**[4]**

[Total: 11]

4. A pineapple plantation owner wants to find out the amount of ascorbic acid (vitamin C) in the pineapples cultivated in the plantation. He believes that his pineapples produce the most vitamin C compared to the standard pineapple breeds which typically contain 40.0 – 48.5 %.

The amount of ascorbic acid present in a sample can be determined using the dye dichlorophenol indophenol (DCPIP). At pH 7 and above, ascorbic acid reduces solutions of the dye dichlorophenol indophenol (DCPIP) from blue to colourless. The pH of the samples must be adjusted to pH 9 for this experiment to work. Ascorbic acid does not chemically change when neutralised by sodium hydroxide or when boiled.

Using this information and your own knowledge, design an experiment to determine the validity of the plantation owner's claim that the pineapples from his plantation contain higher concentrations of ascorbic acid.

Your planning must be based on the assumption that you have been provided with the following equipment and materials which you must use:

- 100 cm^3 of 5.0 % stock solution of ascorbic acid, adjusted to pH 7
- 100 cm^3 distilled water
- 100 cm^3 molten agar containing DCPIP
- Sterile petri dishes
- 1ml syringes
- Plastic straw to create wells in the agar plate
- Labels
- Stopwatch
- Forceps
- Normal laboratory glassware e.g. test tubes, beakers, graduated pipettes, droppers, glass rods etc
- 10 cm^3 pineapple juice, supplied by the plantation owner
- Sodium hydroxide
- pH meter

Your plan should:

- have a clear and helpful structure such that the method you use is able to be repeated by anyone reading it,
- be illustrated by relevant diagrams, if necessary,
- identify the independent and dependent variable,
- describe the method with the scientific reasoning used to decide the method so that results are as accurate and reliable as possible,
- show how you will record your results and the proposed layout of tables and graphs,
- use correct technical and scientific terms,
- include references to safety measures to minimize any risk associated with the proposed experiment.

[Total: 12]

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Introduction

- Ascorbic acid reduces blue DCPIP to colourless. .
- Increase in concentration of ascorbic acid will increase the rate of decolourisation of DCPIP
- Different concentrations of ascorbic acid can be created from the stock solution. A standard curve of the amount of decolourisation of DCPIP by the different concentrations of ascorbic acid can be created. The amount of ascorbic acid in pineapple can be determined by reading off the standard curve

Explain how to determine concentration of ascorbic acid in pineapples using the standard curve [1m]

Procedure

1. Obtain 10cm^3 of different concentrations of ascorbic acid solution by dilution.

Concentration of ascorbic acid solution / mmolL-1	Volume of 5.0 mmolL-1 ascorbic acid solution / cm^3	Volume of distilled water / cm^3
5	10	0
4	8	2
3	6	4
2	4	6
1	2	8
0	0	10

Describe how to obtain different concentrations of ascorbic acid [1m]

1. Pour the molten agar containing DCPIP into the petri dishes and allow the agar to cool.
2. Once the agar is cooled, use the plastic straw to make eight equal sized wells in the agar gel plate. Ensure that the wells are well-spaced.

Describe the settling up of the DCPIP agar plates and wells in the plates[1m]

3. Prepare a control experiment using boiled and cooled pineapple juice, following the same experimental procedures and conditions, to show that the decolourisation of DCPIP is due to the action of ascorbic acid and not due to the action of any enzymes in the juice.

Describe control to prove reaction is due to ascorbic acid in the pineapple juice and is not enzyme catalysed [1m]

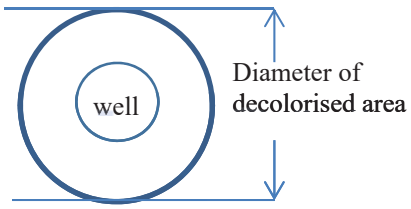
4. Add 10% sodium hydroxide solution to the boiled and cooled pineapple juice, drop by drop with a dropper, until the pH is between 7 to 9. Check the pH by removing a drop of solution with a clean glass rod and placing it on indicator paper.
5. Neutralise the fresh pineapple juice in the same manner as described in step 4.

Describe neutralisation of fresh pineapple juice.[1m]

6. Using the 1 ml syringe, place 0.2 ml of each of the ascorbic acid solutions prepared according to the dilution table, 0.2 ml of pineapple juice and 0.2 ml of boiled and neutralised pineapple juice into one well each. Label the wells.

State appropriate volumes scorbic acid [1m]

7. Replace the lid of the petri dish and leave the plates on the table for one hour.
8. After one hour, place the dish on the graph paper and measure the diameter of each of the rings where the blue DCPIP has been decolourised
9. Repeat step 1 to 7 three times.



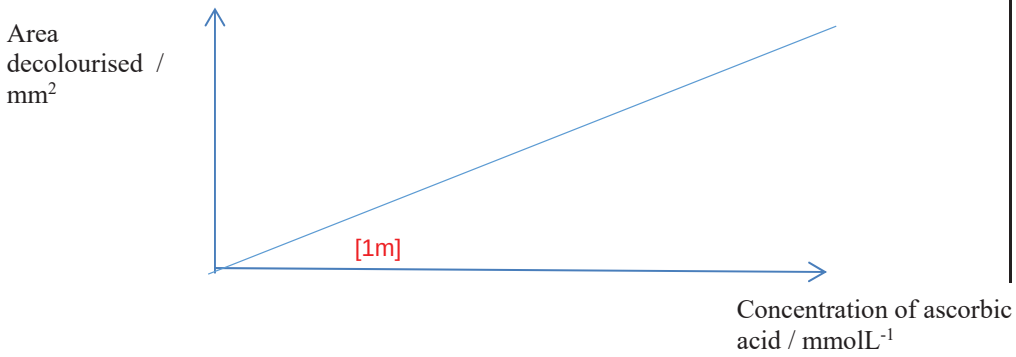
Describe the measurement of ring of decolourisation [1m]
Describe repeats [1m]

Draw a labelled diagram [1m]

10. Record the results in the table below and calculate the area of decolorisation

Concentration of ascorbic acid	Diameter of ring of decolourisation / mm				Area decolourised/ mm^2
	Experiment 1	Experiment 2	Experiment 3	Average	
5					
4					
3					
2					
1					
0					
Sample of neutralised pineapple juice					
Sample of boiled and cooled pineapple juice which has been neutralised					

[1m]



From the standard curve drawn, calculate the concentration of ascorbic acid found in the sample of pineapple juice from the area of decolorisation obtained from the experiment with the sample of pineapple juice. If the concentration is higher than 0.8 to 1.6 $mmolL^{-1}$, the plantation owner's claim of his breed producing a higher concentration of Vitamin C than standard pineapple breeds is valid. [1m]

Safety

Sodium hydroxide and ascorbic acid may cause irritation when in contact with skin. Wear gloves when handling these reagents. [1m]

Free-response question

Write your answers to this question on the separate answer paper provided.

Your answer:

- should be illustrated by large, clearly labelled diagrams, where appropriate;
- must be in continuous prose, where appropriate;
- must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

5.

(a) Describe the use of restriction fragment length polymorphism analysis in creating a linkage map. **[6]**

- *Using RFLP with known physical location on a chromosome;*
- *Construct map using recombination frequency to determine order/sequence of genes and relative distance between different genes and genetic markers along a chromosome;*

; for 1 mark, max is 1 mark

- *A linkage map shows the relative location or the order of genes along a chromosome;*
- *constructed based on the assumption that the probability of a crossover between two genetic loci/RFLP markers is proportional to the distance separating the loci;*
- *Linkage maps are usually constructed with several thousand known genetic markers spaced evenly throughout the genome;*
- *The RFLP markers can be any genes or any other identifiable DNA sequences, such as variation number tandem repeats (VNTR) and short tandem repeats (STR);*

; for 1 mark, max is 2 marks

How to carry out linkage mapping using RFLP:

- *Linkage map must be done based on experimental crosses;*
- *After mating/fertilization, RFLP from parental and offspring organisms are obtained and analysed;*
- *Using gel E & Southern blot/nucleic acid hybridisation;*
- *RFLP pattern obtained are used to calculate the total percentage of recombinant offspring;*
- *Give an indication of the distance between the RFLP markers/sequences based on the recombination frequencies obtained;*
- *the farther apart the two RFLP markers/sequences are, the higher the probability that a crossover that generates genetic variation will occur between them and therefore the higher the recombination frequency;*
- *For example, if 70% of the progeny produced are parental and 30% were recombinant, the two RFLP loci are 30 centi-Morgans (cM) apart from each other;*

; for 1 mark, max is 3 marks.

(b) Describe the processes involved in PCR.

[6]

Stage 1: Denaturation

a) DNA denaturation by heating to 90^0C; [accept 90 – 100^0C] in a thermocycler;
b) DNA is separated into single strands by breaking of hydrogen bonds;

Stage 2: Annealing of primers

c) Annealing of primers to gene of interest by cooling to 54^0C; [accept 30 – 65^0C]
d) primers/ oligonucleotides bind to single (DNA) strands / 3' ends;
e) by annealing/hybridise to their complementary sequences on either side of the target sequence;

Stage 3: Extension

f) DNA synthesis by heating to 72^0C; [accept 60 – 75^0C]
g) optimum temperature (for Taq polymerase);
h) new strands (of DNA) are synthesised by Taq/ DNA polymerase;
i) starts at position of DNA primers;
j) addition of free deoxyribonucleotide to the free 3'OH end;
k) through the formation of phosphodiester bond between the nucleotides;
l) using the single strand DNA (target sequence) as a template;

(c) Discuss the goals and benefits of the Human Genome Project.
[8]

Goals

1. Construct a detailed genetic map (i.e. map formed using recombination frequencies and measured in terms of cM) of the entire human genome.;
2. Determine the nucleotide sequences of all 24 human chromosomes (i.e. the physical map of the genome as measured in base pairs) by the year 2005.;
3. Identify all the approximately 20,000-25,000 genes in human DNA.;
4. Improve technology for DNA sequencing and studying the function of DNA on a genomic scale.;
5. Sequence genomes of model organisms (*E. coli*, budding yeast, *C. elegans*, *Drosophila*, and mouse) in order to compare genomes.;
6. Develop bioinformatics support – to (a) create and operate databases for easy access to data and (b) develop and improve tools for data analysis eg. Comparing and interpreting genome information.;
7. Address the ethical, legal and social issues that may arise from the project.;

Max 4 marks

Benefits

A. Molecular medicine (no marks for heading; max 2 mks, @ 1 mk)
1 Earlier diagnosis/detection of genetic diseases;
2 Gene therapy;
3 Rational drug design/control systems for drugs/rational drug design/pharmacogenomics & custom drugs;

B. Energy and Environmental Applications (max 1 mk, @ 1 mk)
4 Use microbial genomics research to create new energy sources (biofuels);
5 Use microbial genomics research to develop environmental monitoring techniques to detect pollutants ;
6 Use microbial genomics research for safe, efficient environmental remediation;

C. DNA Forensics (max 3 mk, @ 1 mk)
7 Identify potential suspects whose DNA may match evidence left at crime scenes;
8 Exonerate persons wrongly accused of crimes;
9 Identify crime and catastrophe victims;
10 Establish paternity and other family relationships;
11 Identify endangered and protected species as an aid to wildlife officials (could be used for prosecuting poachers);
12 Detect bacteria and other organisms that may pollute air, water, soil, and food;
13 Match organ donors with recipients in transplant programs;
14 Determine pedigree for seed or livestock breeds;
15 Authenticate consumables such as caviar and wine;

D. Agriculture, Livestock Breeding, and Bioprocessing (max 1 mk, @ 1 mk)
16 Healthier, more productive, disease-resistant crops/ farm animals / higher yield;
17 More nutritious produce ;
18 Edible vaccines incorporated into food products;
19 New environmental cleanup uses for plants like tobacco;

E. Bioarchaeology, anthropology, evolution and human migration (max 1 mk, @ 1 mk)
20 Study human evolution (through germline mutations in lineages);
21 Study of migration of diff pop groups based on female genetic inheritance/lineage and migration of males via Y chromosomes;
22 Compare breakpoints in the evolution of mutations with ages of populations and historical events;

F. Risk assessment (@ 1 mk)
23 Assess health damage and risks caused by radiation exposure/mutagenic chemicals/ cancer-causing toxins;

Max 4 marks

[Total: 20]