H2

BIOLOGY 9648/01

Paper 1 Multiple Choice

23 September 2016
Friday

1 hour 15 mins

Additional Materials: Multiple Choice Answer Paper

READ THESE INSTRUCTIONS FIRST

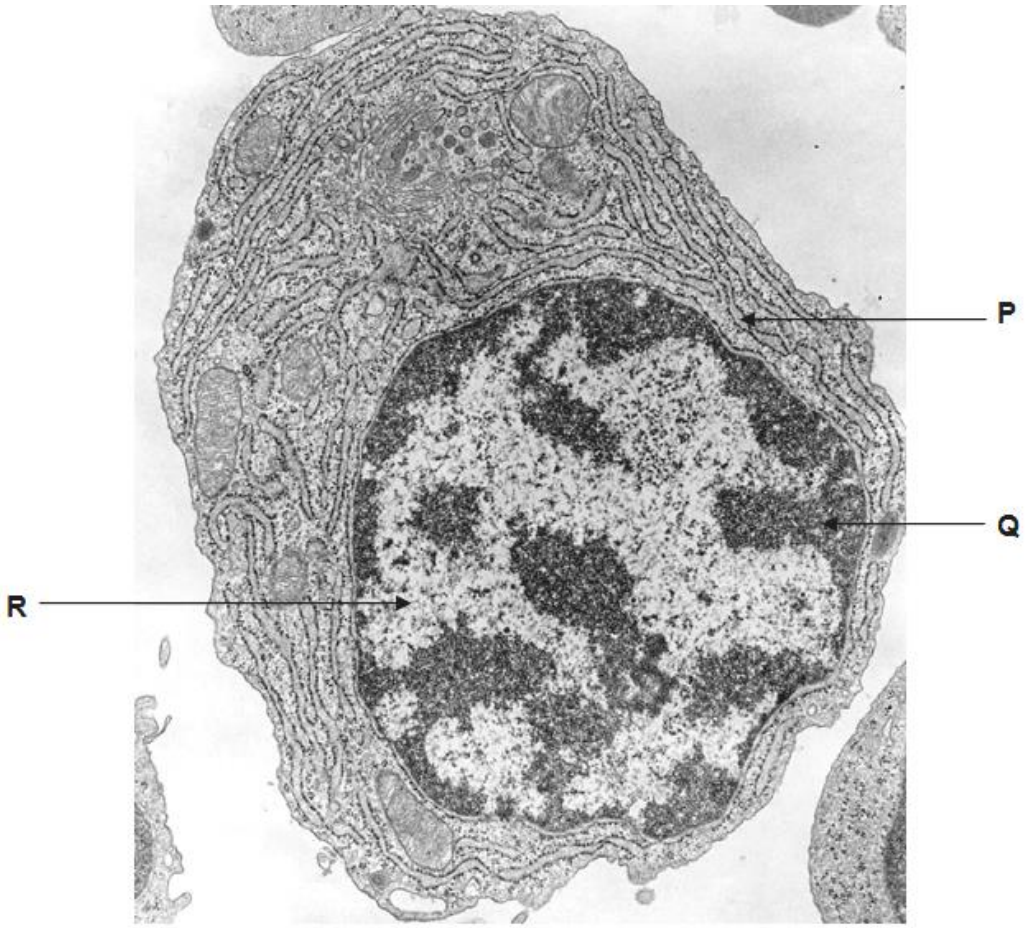
Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, PDG and identification number on the Answer Sheet.

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.

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.

Calculators may be used.

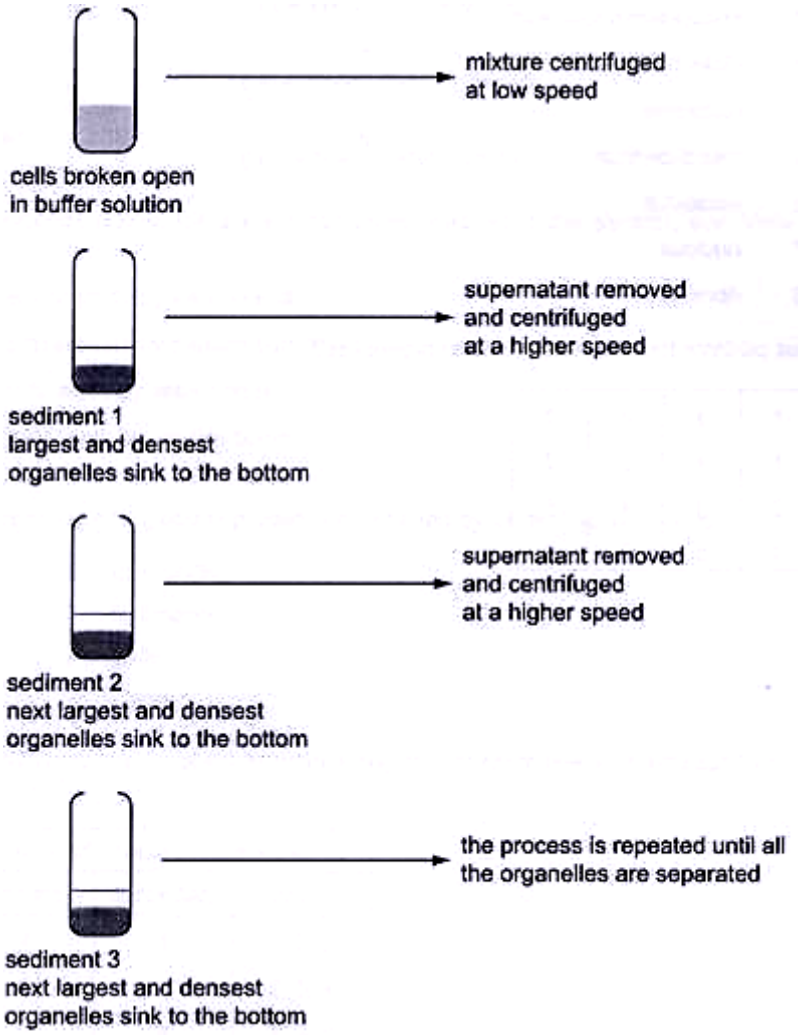
1 The figure below shows an electron micrograph of a cell.



Which of the following about structures **P**, **Q** and **R** are correct?

	P	Q	R
A	provides large surface area for attachment of ribosomes	contains demethylated DNA	contains acetylated histones
B	transport of proteins to Golgi apparatus	histones are deacetylated	active condensation of chromatin
C	synthesis and processing of membrane proteins	contains methylated DNA	active transcription of genes
D	synthesis of phospholipids and steroid hormones	transcription of genes silenced	synthesis of proteins on free ribosomes

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?

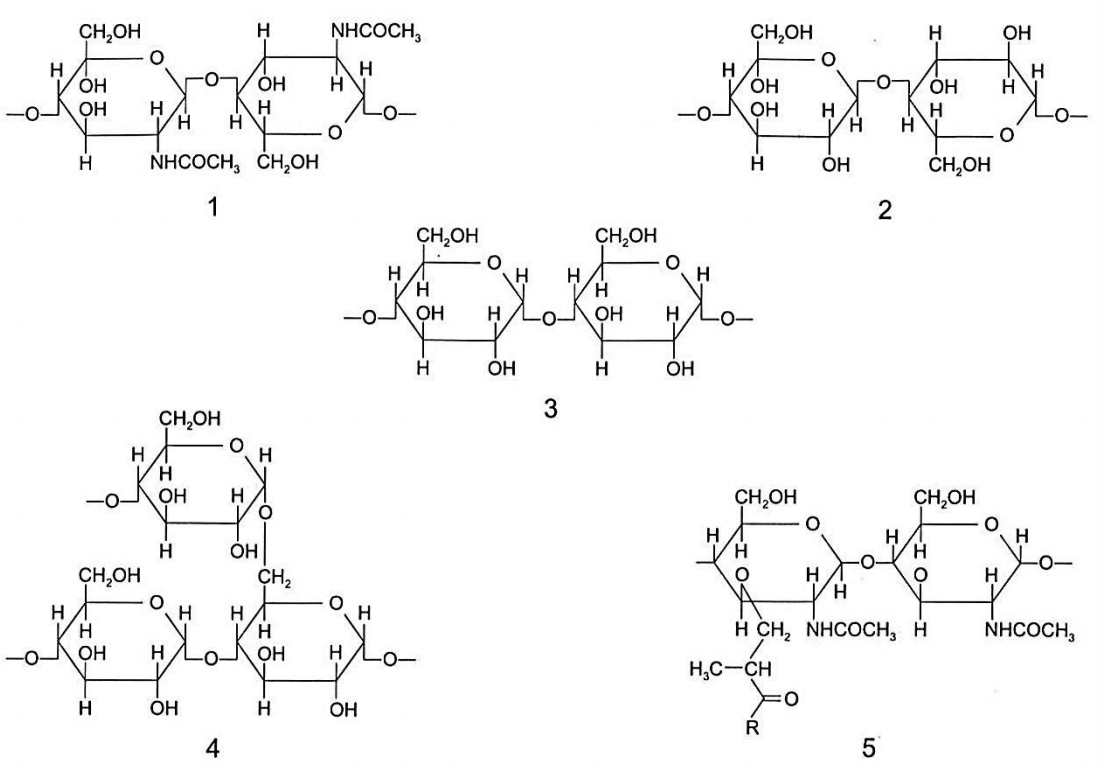
A Chloroplast

B Mitochondria

C Nuclei

D Ribosomes

3 The diagrams show short sections of some common polysaccharides and modified polysaccharides.



The polysaccharides can be described as below.

- polysaccharide **F** is composed of β-glucose monomers with 1,4 glycosidic bonds
- polysaccharide **G** is composed of α-glucose monomers with 1,4 and 1,6 glycosidic bonds
- polysaccharide **H** is composed of N-acetylglucosamine and N-acetylmuramic acid monomers with β-1,4 glycosidic bonds
- polysaccharide **J** is composed of α-glucose monomers with 1,4 glycosidic bonds
- polysaccharide **K** is composed of N-acetylglucosamine monomers with β-1,4 glycosidic bonds

Which shows the correct pairings of polysaccharide descriptions and diagrams?

	polysaccharide **F**	polysaccharide **G**	polysaccharide **H**	polysaccharide **J**	polysaccharide **K**
A	2	4	5	3	1
B	2	5	4	1	3
C	3	4	5	2	1
D	3	5	4	1	2

4 Which description concerning collagen is correct?

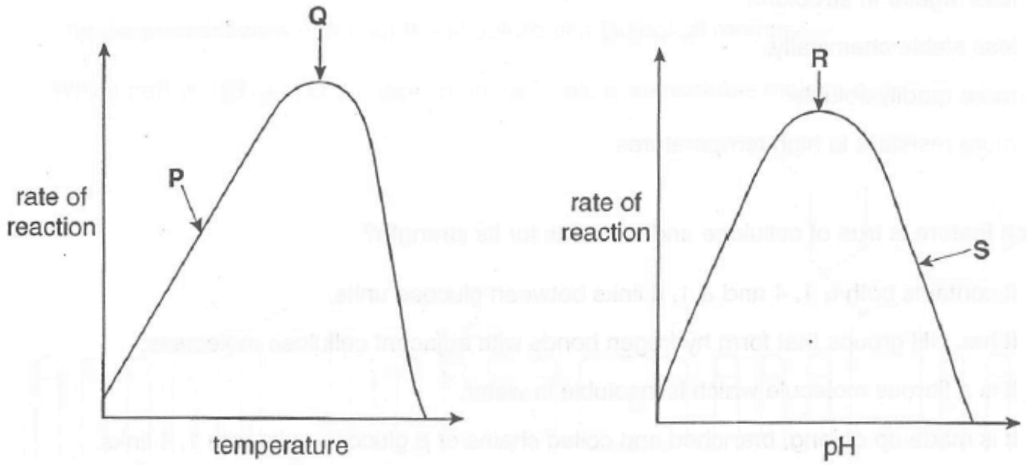
A Collagen has polypeptides arranged parallel to each other and the amino acid sequence contains a large variety of amino acids with different sized R-groups.

B Collagen has polypeptides that are arranged very closely together and the amino acid sequence has every third amino acid as glycine.

C Collagen has three polypeptides that are bounded to one another by covalent cross links and the amino acid sequence contains amino acids with hydrophobic R-groups.

D Collagen is an insoluble molecule and the amino acid sequence contains successive amino acids which are rotated to allow formation of bonds.

5 The graphs show the effects of temperature and pH on enzyme activity.



Which statement is a correct explanation of the rate of reaction at the point shown?

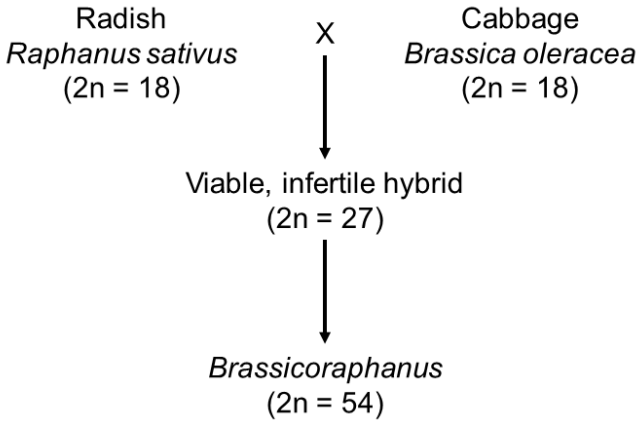
A At **P**, hydrogen bonds in the enzyme are broken.

B At **Q**, the kinetic energy of enzyme and substrate is highest.

C At **R**, covalent bonds are formed between enzyme and substrate.

D At **S**, ionic bonds in the enzyme are broken.

6 A cross between radish (*Raphanus sativus*) and cabbage (*Brassica oleracea*) produced the following results.



Which of the following statements are possible explanations for the results of the cross shown above?

1 Non-disjunction of all sister chromatids during anaphase II resulted in the production of diploid gametes in radish, which fused with a haploid gamete of cabbage to give rise to the infertile hybrid progeny.

2 The hybrid is infertile because it has a diploid number which is odd.

3 The hybrid is infertile as there are nine unpaired chromosomes during prophase I, which prevented the formation of gametes.

4 Addition of colchicine prevents the formation of spindle fibres, which enabled the infertile hybrid to form gametes. Fusion of two of these gametes gives rise to *Brassicoraphanus.*

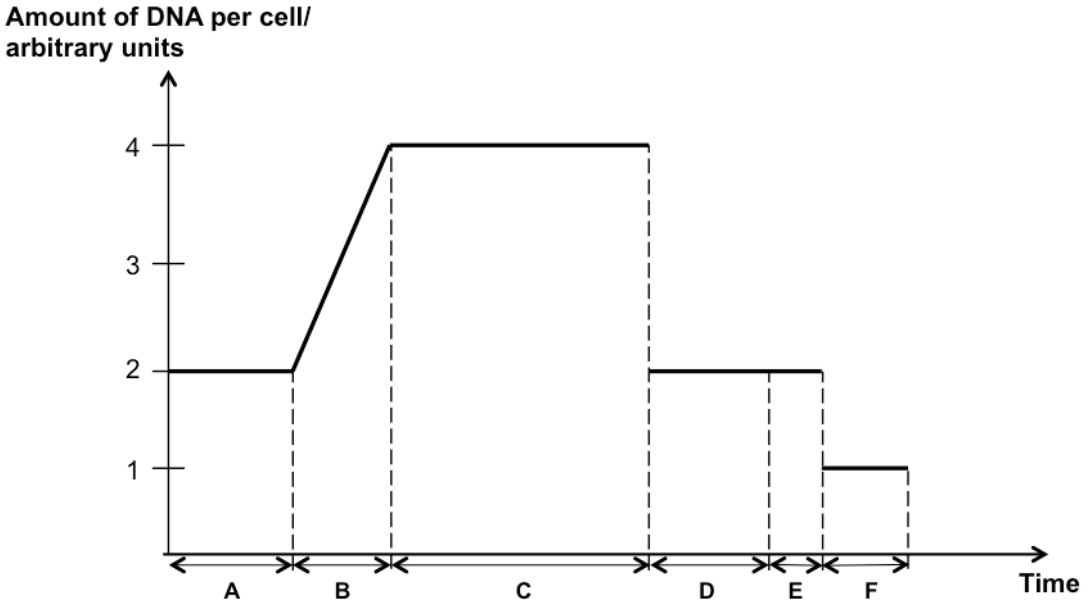
A 1 and 4

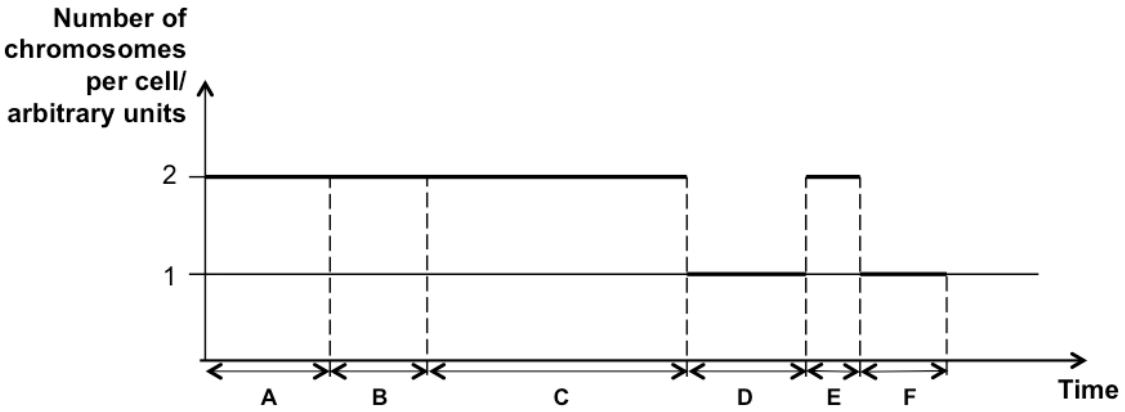
B 2 and 3

C 1, 2 and 4

D 1, 3 and 4

7 The figures below show how the amount of DNA and number of chromosomes vary in a cell of *Chrysanthemum makinoi* during meiosis.





Which of the following statement is **false**?

A Phase A and B correspond to G1 and S phase of interphase respectively.

B In phase C, the cell is undergoing prophase, metaphase, anaphase and telophase of meiosis I only.

C In phase E, the cell is undergoing telophase II only.

D In both phase D and F, the cell has completed cytokinesis.

8 The table below shows a list of characteristics displayed by mutant strains of *E. coli* during DNA replication and the possible reasons.

No.	Characteristics	Enzymes or functions affected by mutation
1	Okazaki fragments accumulate and DNA synthesis is never completed	DNA ligase activity is missing
2	Supercoils are found to remain at the regions that flank the replication bubbles	DNA helicase is hyperactive
3	Synthesis is very slow.	DNA polymerase keeps dissociating from the DNA and has to re-associate
4	No initiation of replication occurs.	The TATA box region at origin of replication is deleted

Which of the reasons correctly explain the characteristics displayed by the mutant *E. coli* strains?

A 1 and 3

B 2 and 3

C 1, 2 and 4

D 1, 3 and 4

9 Tay-Sachs disease is a fatal neurodegenerative disease which is caused by a mutation in the hexosaminidase A (Hex A) gene located on chromosome 15.

Part of the sequence of the non-template (coding) DNA strand of the normal Hex A allele and the mutated Tay-Sachs allele are shown below. The sequences are the same as the mRNA sequence of both alleles.

DNA sequences of normal Hex A allele:

Amino acid position		424	425	426	427	428	429	430	431	
Non-template DNA	5'…	CGT	ATA	TCC	TAT	GGC	CCT	GAC	TGT	…3'

DNA sequences of mutated Tay-Sachs allele:

Amino acid position		424	425	426	427	428	429	430	431	
Non-template DNA	5'…	CGT	ATA	TCT	ATC	CTA	TGG	CCC	TGA	…3'

For both alleles, 9 different amino acids are encoded for by the DNA triplets:

Amino acid	DNA triplet
Arg	CGT
Asp	GAC
Cys	TGG, TGT
Gly	GGC
Ile	ATA, ATC

Amino acid	DNA triplet
Leu	CTA
Pro	CCC, CCT
Ser	TCC, TCT
Tyr	TAT
Stop codon	TAG, TAA, TGA

Which statement is true?

A The disease is caused by the deletion of one DNA nucleotide.

B The Hex A protein encoded for by the Tay-Sachs allele is non-functional due to a frameshift mutation.

C The polypeptide encoded for by the Tay-Sachs allele has the same number of amino acids as that encoded by the normal Hex A allele.

D At amino acid position 431, there is a silent mutation.

10 Scientists were able to excise out the promoter of eukaryotic gene and attach it to the end of a gene as shown below. The gene was reintroduced back to the organism, which is homozygous at the gene loci.

Which of the following outcomes is true?

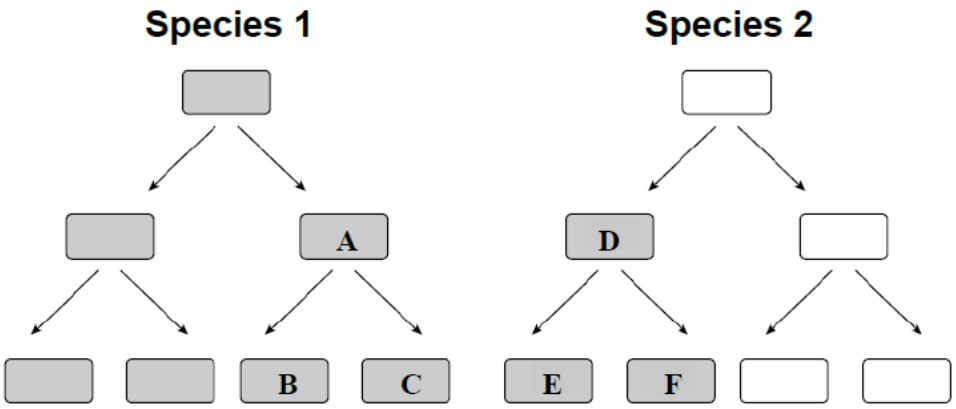
A No transcription of the gene takes place, as the promoter cannot initiate transcription of the non-template strand.

B Transcription initiates but may prematurely terminate due to a premature stop codon.

C Transcription takes place but translation cannot take place because the genetic code is no longer the original code.

D Transcription takes place but less translation occurs to obtain functional protein because the mRNA may form a duplex RNA.

11 The diagram below shows how two species of bacteria reproduce when placed together in a growth medium. The bacteria that are shaded are resistant to the antibiotic penicillin.



Which one of the following statement(s) is likely to be true?

1 Bacteria **B** and **C** are resistant to penicillin as a result of binary fission of Bacterium **A**.

2 Bacteria **C, D** and **F** are resistant to penicillin as a result of random mutation.

3 Bacterium **D** is resistant to penicillin as a result of conjugation from Bacterium **A**.

4 Bacterium **D** is resistant to penicillin through transduction from Bacterium **A** where there is transfer of the complete F plasmid.

A 3 only

B 1 and 3

C 1 and 4

D 2, 3 and 4

12 When a mutant strain of *Escherichia coli* that has lost the regulatory gene of its tryptophan operon is placed in a medium that contains all nutrients the cell need to grow except tryptophan, which of the following will occur?

A The cells will grow even though there is no tryptophan in the medium.

B The cells will grow until excessive tryptophan arrests the expression of the operon.

C The cells will not grow until enough tryptophan has been synthesised to make the repressor active.

D The cells will never grow unless tryptophan is added to the medium.

13 Temperate bacteriophages, such as the lambda phage, undergo the lysogenic cycle in their bacterial host cells.

Which of the following could prevent the temperate bacteriophages from entering the lysogenic life cycle?

1 A loss-of-function mutation in the viral gene which codes for integrase.

2 Deletion of 10 nucleotides at the site of phage integration on the bacterial chromosome.

3 Gain-of-function mutations in the viral genes which code for transcriptional repressor proteins.

4 Loss-of-function mutations in the viral genes which code for nucleases which break down bacterial chromosomal DNA.

A 1 and 2 only

B 1 and 3 only

C 2 and 4 only

D 1, 2 and 3 only

14 Which of the following occurs in the reproductive cycle of the human immunodeficiency virus (HIV) but **not** in that of the influenza virus?

A Newly synthesised viruses are released from host cells by budding from cell surface membrane.

B Host cell ribosomes are used to synthesise viral proteins.

C Viral RNA acts as a template for viral DNA synthesis.

D Viruses enter the host cell by endocytosis.

15 The percentage of the human genome that is transcribed is larger than predicted based on the range of proteins made by the cells.

Which of the following accounts for the difference?

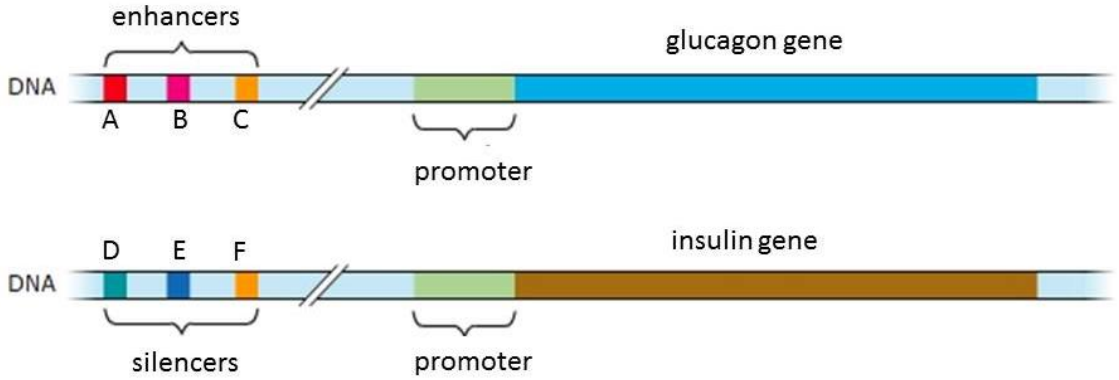
A Alternative splicing can result in more than one kind of protein produced from one gene.

B Some genes are transcribed to give RNA that is not meant to serve as a template for protein synthesis.

C The enhancers present in the human genome are also transcribed to bring about an increase in the transcription of protein-coding genes.

D The telomeric regions are also transcribed to give telomerase, which helps to maintain the telomere length.

16 The diagram below shows the control elements and two genes found in the human genome.



Which of the following statement(s) about the above genes is/are true?

1 The glucagon gene is found only in the α-cells of the Islets of Langerhans while the insulin gene is found only in the β-cells of the Islets of Langerhans.

2 Binding of control elements, specific transcription factors and RNA polymerase at the promoter initiates transcription of glucagon.

3 The glucagon gene will be transcribed at a high level when transcription factors bind to control elements A, B, and C.

4 The expression of insulin can only be suppressed when transcription factors bind to control elements D, E and F.

A 3 only

B 2 and 3 only

C 1, 2 and 4 only

D 2, 3 and 4 only

17 Which statement correctly describes introns and/or exons?

A Different combinations and numbers of exons and introns in the mature mRNA allow more than one type of protein to be coded for by a gene.

B Mutations that occur within introns have no effect on the primary structure of protein as it will not be present in the mature mRNA.

C The exons found in the DNA sequence of a gene are always translated into proteins.

D Mutation at a splice site would result in a truncated protein as the intron, which is not excised, is non-coding and cannot be translated.

18 Which of the following statements correctly describe the changes in cancer cells?

1 Limitless replicative potential often results in the accumulation of chromosomal mutations in many cancer cells.

2 Cancer cells could overproduce signal molecules so that they become self-sufficient in growth signals.

3 Angiogenesis is the result of expression of oncogenes in a cell line that produces blood vessels.

4 Loss-of-function mutations in tumour suppressor genes contribute to tissue invasion and metastasis.

A 1 and 4 only

B 2 and 3 only

C 1, 2 and 4 only

D 2, 3 and 4 only

19 The statements listed below give information on the genetic control of hair curliness in dogs.

1 Chromosome 27 contains the gene responsible for curliness of the dog hair.

2 The nucleotide sequence of the gene produces an enzyme with arginine at residue position 151 but small changes in the nucleotide sequence produces an enzyme with cysteine at this point.

3 A dog may have both nucleotide sequences in its genome.

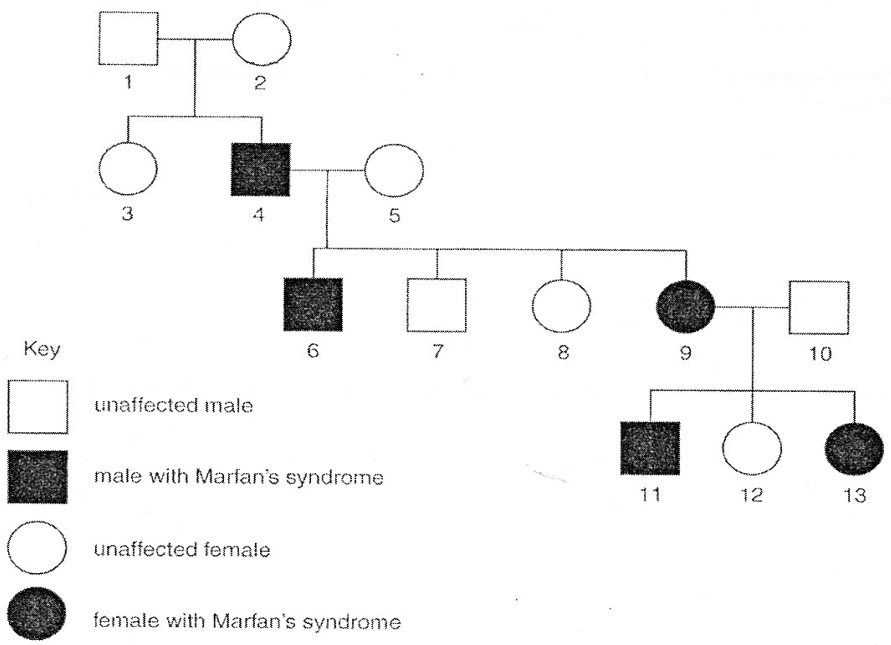
4 A dog producing both enzymes will have 'wavy' coat of hair.

5 At fertilisation, the dog inherits one set of chromosomes from each parent. Each set carries one of each form of the gene.

Which row matches each statement to the genetic term that it most closely describes?

	1	2	3	4	5
A	locus	genotype	allele	heterozygous	phenotype
B	locus	allele	heterozygous	phenotype	genotype
C	genotype	allele	heterozygous	phenotype	locus
D	locus	allele	genotype	phenotype	heterozygous

20 Marfan's syndrome is a rare genetic condition of humans, caused by a dominant allele. This condition is caused by a reduction in the quality or amount of the important protein fibrillin-1. The diagram below shows a family pedigree including some people with the condition.



Which of the following conclusions can be made based from the information provided?

A The fibrillin-1 gene locus is on the X chromosome.

B The mutation that gave rise to a non-functional fibrillin-1 allele occurred in the individual 4 during embryonic development.

C The variation in disease expression will be discontinuous.

D If individual 11 mated with a female who is heterozygous for the gene locus, the probability that they have an unaffected female child is 0.125.

21 In pigeons, the alleles of the gene controlling eye colour are co-dominant.

Two separate crosses were carried out and the results were shown below.

Cross 1

Parental generation	black eye female	X	white eye male
F_1 generation	grey eye females and black eye males		

Cross 2

Parental generation	white eye female	X	black eye male
F_1 generation	grey eye females and white eye males		

What phenotypic ratio would be expected in the F_2 generation in the first cross?

A 1 black-eyed male: 1 white-eyed male: 2 grey-eyed females

B 1 black-eyed male: 1 white-eyed male: 1 grey-eyed female: 1 black-eyed female

C 1 black-eyed male: 1 grey-eyed male: 1 white-eyed female: 1 black-eyed female

D 2 black-eyed males: 1 grey-eyed female: 1 white-eyed female

22 The coat colour of Labrador retrievers is controlled by two genes, **B/b** and **A/a**. Allele **B** (dominant) codes for black coat, while allele **b** (recessive) codes for brown coat. The coat colour of a Labrador retriever with genotype **aa** is yellow.

A cross between a male black Labrador retriever and a female yellow Labrador retriever produced some black puppies and some yellow ones.

What are the genotypes of the parental dogs?

	Black retriever	**Yellow retriever**
A	AaBb	aabb
B	AaBb	aaBb
C	AaBb	aaBB
D	AABb	aaBb

23 A cross was made between 2 pure breeding maize varieties, Tom Thumb and Black Mexican which differed markedly in ear length. The ear length for the parental, F_1 and F_2 generations was measured in centimetres and recorded in the table below with the number of ears in each length category (e.g.13 of the F_1 plants produced ears 12 cm in length).

Generation	Ear length (cm)														
	5	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Black Mexican (parental)									4	11	12	32	27	10	8
Tom Thumb (parental)	4	28	19	3											
F_1					2	12	18	13	17						
F_2			2	3	15	22	33	28	19	13	2	2			

Which of the following statements correctly explains the data shown above?

1 The phenotypic variation is continuous and could be the result of multiple alleles.

2 Variation in environmental factors has a large effect on the phenotype.

3 The increase in phenotypic variation from F_1 to F_2 generation could be due to genetic mutations.

4 The increase in phenotypic variation from F_1 to F_2 generation could be due to sexual reproduction processes like crossing over, independent assortment of homologous chromosomes and random fusion of gametes.

A 1 and 3

B 2 and 4

C 1, 2 and 4

D 2, 3 and 4

24 Unaffected carriers with chromosomal inversions are likely to produce genetically abnormal progeny.

Which of the following explains this?

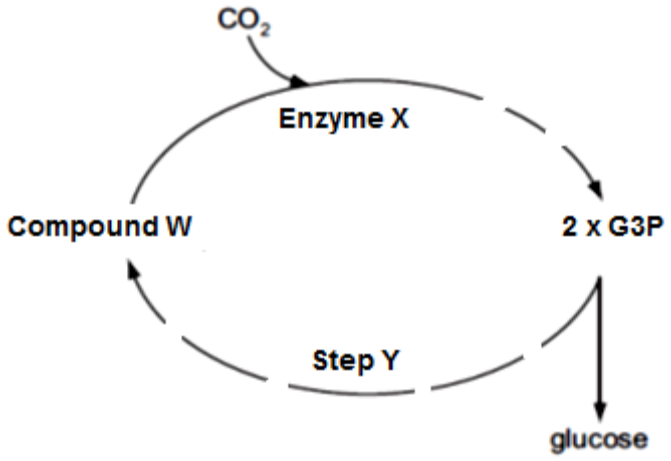
A The mutated chromosome is more likely to be placed in a gamete than the normal chromosome.

B The mutated chromosome is unable to accomplish synapsis with the normal chromosome during meiosis.

C Crossovers cannot occur between normal and mutated chromosomes.

D Crossovers between the normal and mutated chromosomes lead to chromosomes with deletions, deficiencies, or abnormal structure.

25 The figure below summaries some key reactions which occur in the Calvin cycle. The dashed lines indicate that there is more than one reaction present.



Using the figure above and your knowledge of Calvin cycle, determine which one of the following statements below is true.

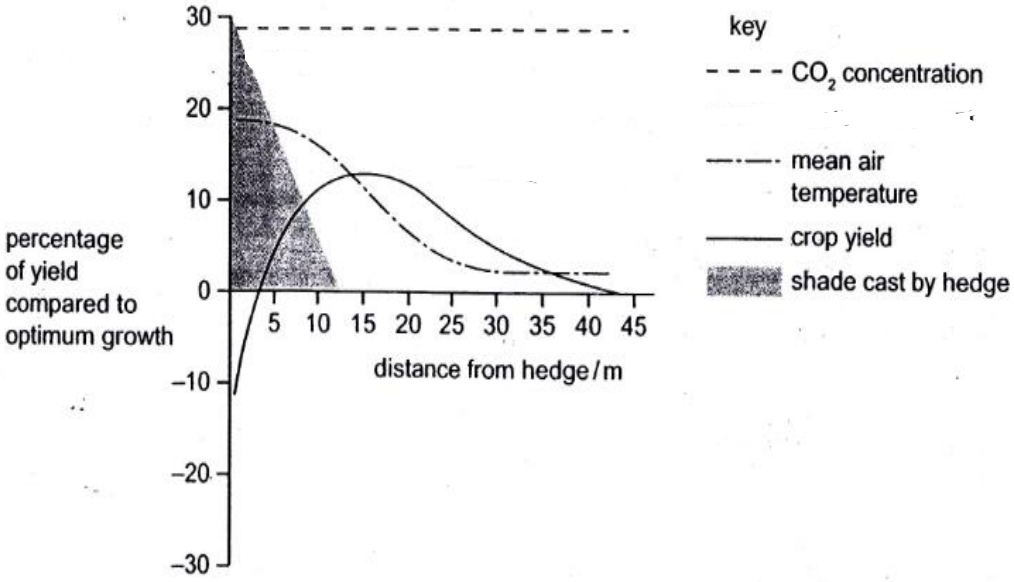
A Compound **W** is expected to accumulate if carbon dioxide concentration increases under low light intensity.

B Products released from Enzyme **X** are expected to accumulate when light intensity is low.

C G3P is expected to accumulate when light intensity is low.

D ATP from substrate level phosphorylation is required for Step **Y** to proceed and Compound **W** to be formed.

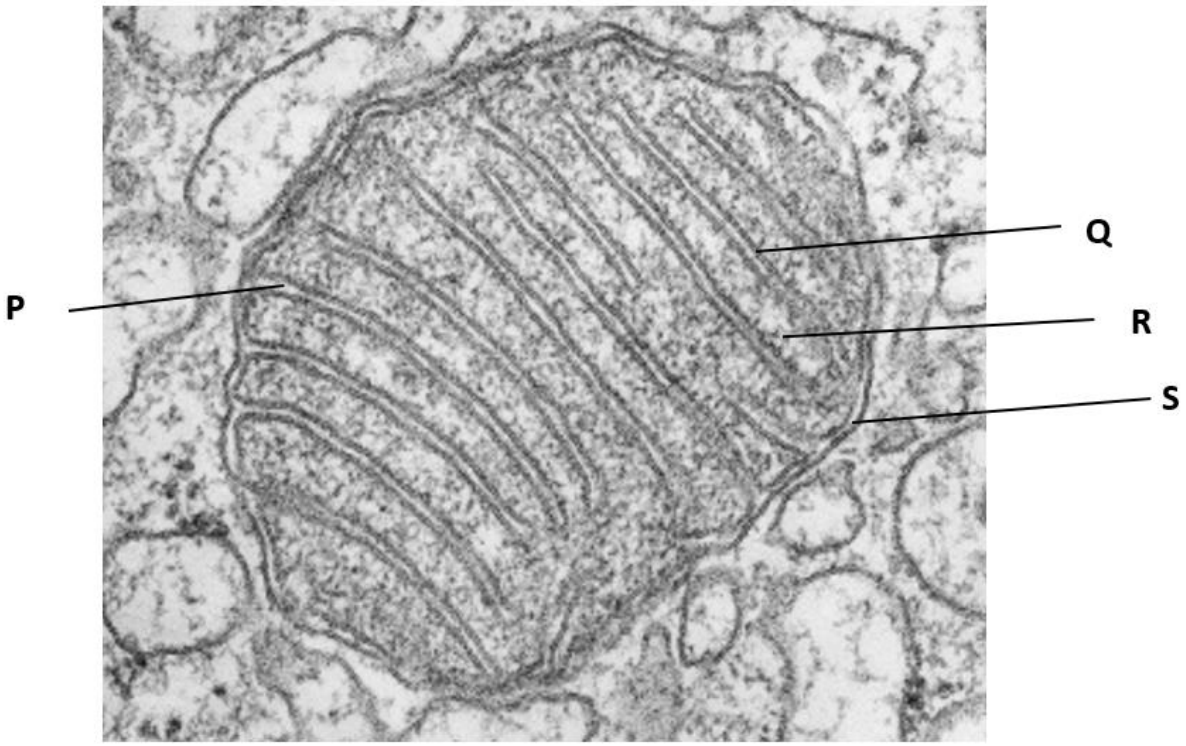
26 In the diagram, researchers superimposed the changes in four environmental factors on a graph of crop yield against distance from a hedge.



Which factor is most likely to have been the limiting factor in crops 8m and 25m from the hedge?

	Limiting Factor	
	8m from hedge	**25m from hedge**
A	CO_2 concentration	Light intensity
B	Light intensity	Mean air temperature
C	Mean air temperature	Mean air temperature
D	Light intensity	CO_2 concentration

27 The figure below shows an electron micrograph of a mitochondrion.



Match the following processes with each of the labelled sites **P** – **S.**

1 Oxidative decarboxylation
2 Lowering of pH
3 Protein synthesis
4 Electron flow
5 Formation of oxidised co-enzymes of dehydrogenase

	P	**Q**	**R**	**S**
A	1, 3, 5	2	4, 5	3
B	2	4, 5	1, 3	2
C	1, 5	3, 4	2	1
D	2	4	1, 3, 5	2

28 Two test tubes containing the following contents are shown below:

Tube 1:
Radioactive glucose solution + yeast cells suspension + oxygen + antimycin

Tube 2:
Radioactive glucose solution + yeast cells suspension + oxygen

Radioactive glucose has all its six carbons made of radioactive ^{14}C. The initial radioactivity measured for the glucose in each test tube is 60 arbitrary units.

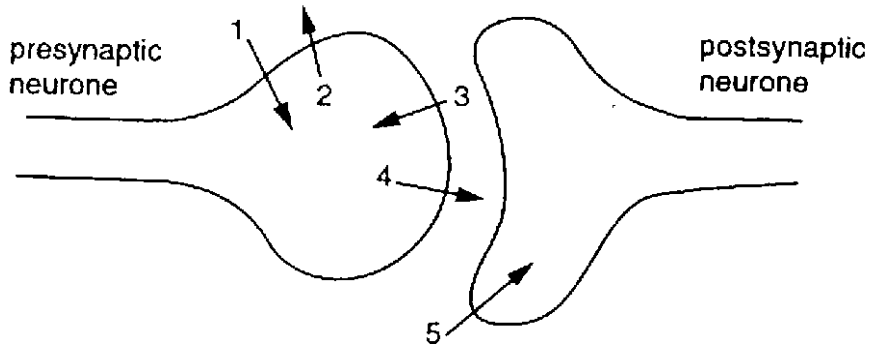
Antimycin is an electron transport chain inhibitor.

If the gaseous product and the aqueous products are tested using a radioactive meter after all the glucose has been metabolised, what would be the final observed readings?

	Tube 1 *(radioactivity measured/ arbitrary units)*		**Tube 2** *(radioactivity measured/ arbitrary units)*	
	aqueous products	**gaseous products**	**aqueous products**	**gaseous products**
A	0	60	40	20
B	20	40	0	60
C	40	20	0	60
D	40	20	60	0

29 The diagram shows the sequence of events occurring as an action potential arrives at a synapse.

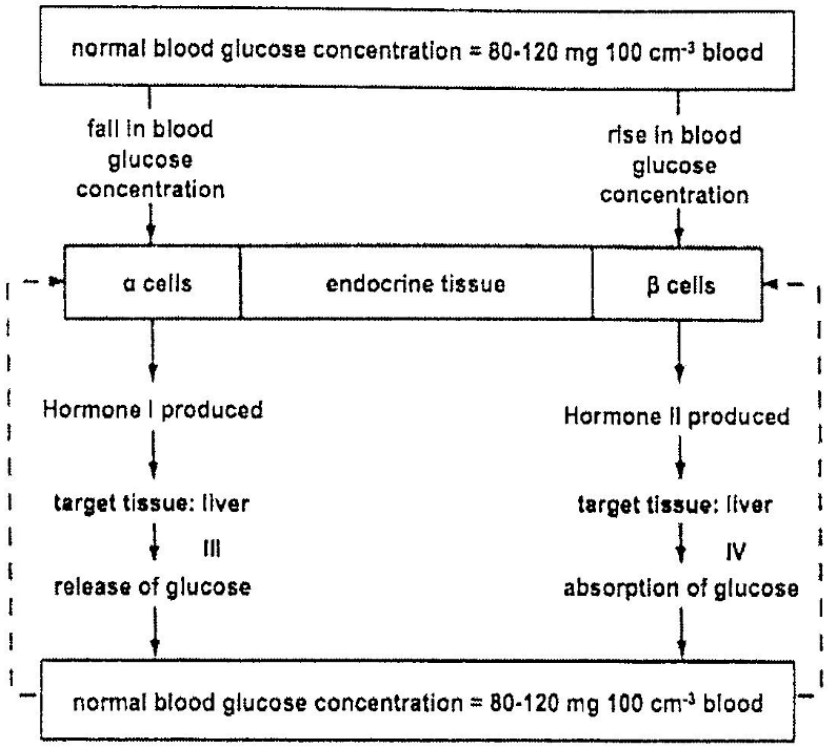
The numbered arrows represent the movement of substance across the membranes.



What are the substances moving across the membranes?

	1	**2**	**3**	**4**	**5**
A	K^+	Na^+	acetylcholine	Ca^{2+}	K^+
B	K^+	Na^+	K^+	Ca^{2+}	acetylcholine
C	Na^+	K^+	Ca^{2+}	acetylcholine	Na^+
D	Na^+	K^+	Na^+	acetylcholine	Ca^{2+}

30 The diagram below shows the role of an endocrine tissue in controlling blood glucose concentration.



Which of the following statements is/are true?

1 Small amounts of hormone I and II inducing a large response in liver tissue demonstrates positive feedback.

2 Hormones I and II inducing different responses from the same target tissue is due to the hormones binding to different receptors on the liver cell surface membrane.

3 The binding of Hormone I to receptors on liver cell surface membrane leads to the activation of second messenger cAMP.

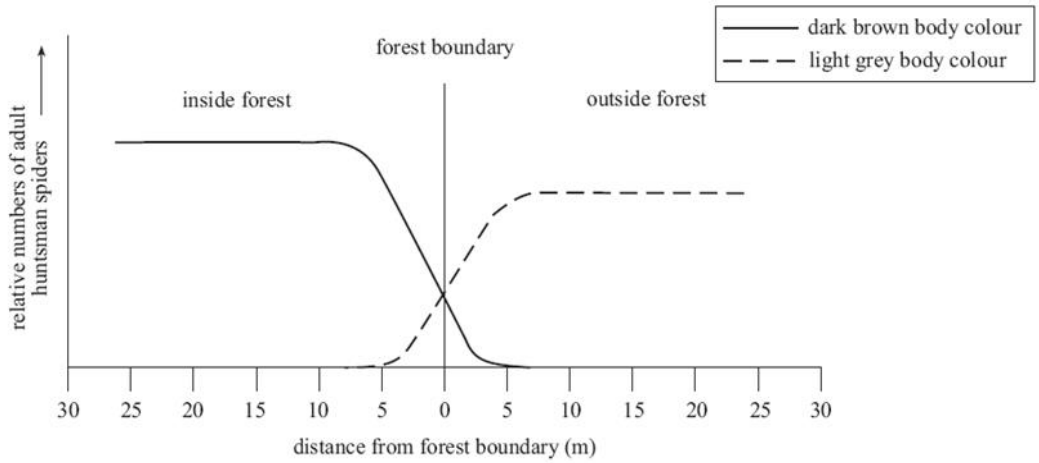
A 1 only

B 2 only

C 1 and 3

D 2 and 3

31 The graph below shows the distribution of huntsman spiders at a forest boundary:



One species of huntsman spider (*Isopeda isopedella*) varies in body colour from dark brown to light grey. In one community at the forest boundary, two populations of this species were found. Some were found living inside the forest and others were found living just outside the forest. The relative numbers of dark brown adult spiders and light grey adult spiders found at certain distances from the forest boundary are shown in the graph above.

Which of the following can be **least** inferred from the graph?

A The type of selective advantage inside the forest is different from the type of selective advantage outside the forest.

B The plateau in the population number as seen inside the forest and outside the forest is due to competition among the adult spiders for limited resources.

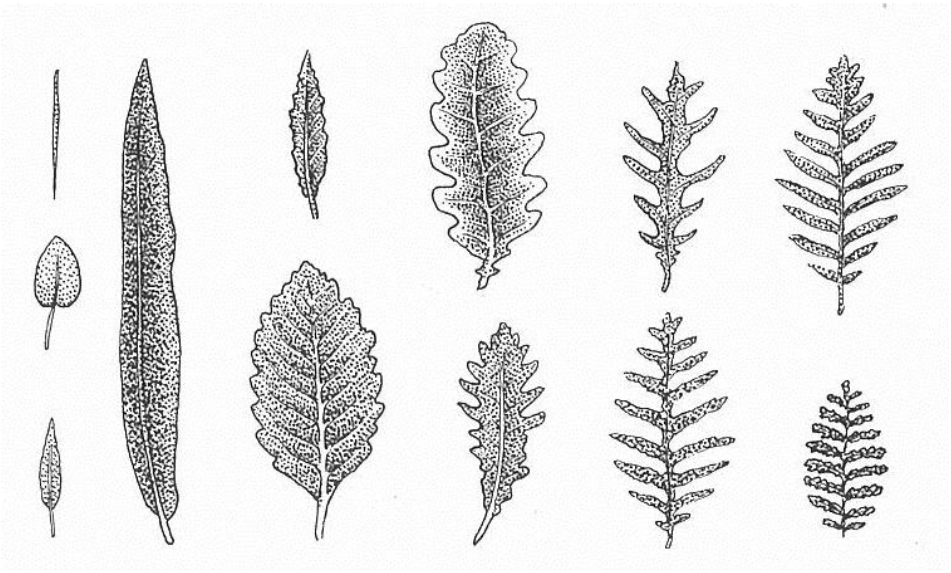
C The lower plateau of spider population outside the forest compared to that of inside the forest is due to the presence of additional selection pressure existing outside the forest.

D Dark brown huntsman spiders are not eaten by birds inside the forest as their colour allows them to camouflage and hence provides a selective advantage.

32 One of the six native genera of *Lobeliaceae, Cyanea,* contains 55 species that constitute 6% of the flora in Hawaii. They are restricted to particular islands or parts of islands. All *Cyanea* descend from a single ancestor, many have undergone striking changes in growth form, leaf size and shape.

Leaf morphology in *Cyanea* is thought to be determined by several gene loci on separate chromosomes.

The leaf morphologies of different *Cyanea* species are shown below.



Which of the following reasons explain the emergence of distinct leaf morphological differences between various species?

1 Mutation in leaf cells

2 Crossing over between non-sister chromatids of homologous chromosomes during gamete formation

3 Different humidity levels on different islands and in different parts of an island

4 The Hawaiian honeycreepers which pollinate the flowers of the plants on one island are unable to fly to other islands

A 1 and 2 only

B 3 and 4 only

C 1, 3 and 4 only

D 2, 3 and 4 only

33 Which of the following statements about the Neutral Theory of Molecular Evolution is **incorrect**?

A The neutral theory involves studying the changes in neutral allele frequencies of a gene pool in the absence of selection.

B The neutral theory involves nucleotide sequence variations that do not affect the reproductive success of organisms.

C The neutral theory contradicts Darwin's theory of natural selection as it postulates that change in allele frequency is driven by genetic drift and not natural selection.

D Rate of change in gene sequence may be greater than the rate of change in amino acid sequence of the polypeptide chain coded for due to degeneracy of the genetic code.

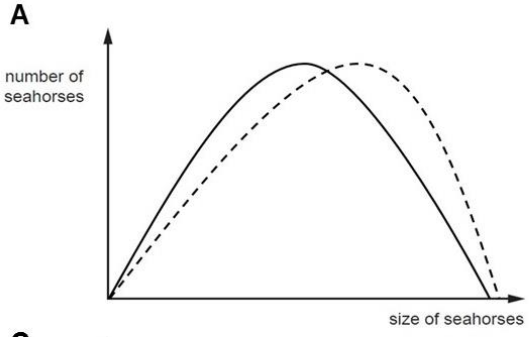
34 The seahorse, *Hippocampus,* is an unusual small fish. It gives birth to live young and it is the male rather than the female that becomes pregnant.

In one species of seahorse, large females within a population mate with large males and small females mate small males. Few medium-sized individuals are produced and they have a low survival rate.

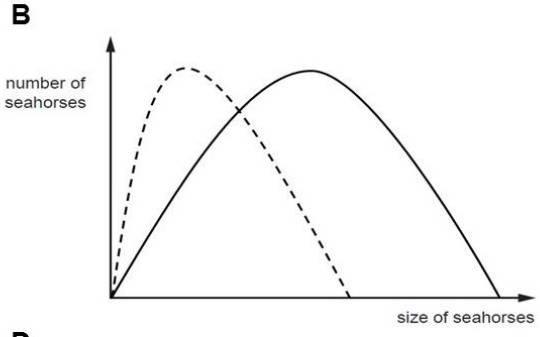
Which graph shows the effect of natural selection on size of seahorses after a fixed period of time?

Legend: ——— Original population – – – Population after selection

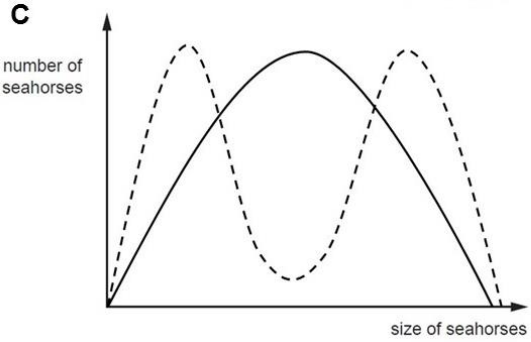
A



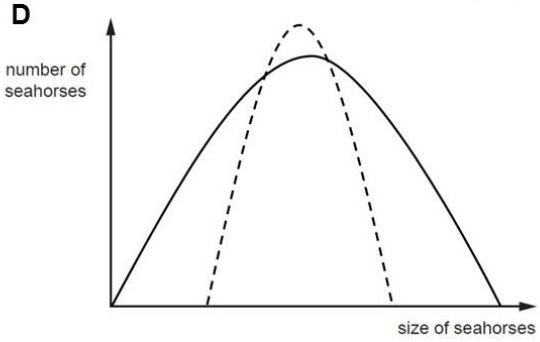
B



C



D



35 Which of the following statements best explains why some restriction sites are suitable to be used in genetic engineering?

A A short nucleotide sequence that can be recognised by many types of endonucleases.

B A short nucleotide sequence that occurs many times in a DNA molecule such that cutting the DNA molecule with an endonuclease will result in many fragments.

C A short nucleotide sequence that can be cut by an endonuclease to produce single-stranded ends that can bind to other single-stranded ends.

D A short nucleotide sequence that allow a fragment of DNA to be introduced into another DNA molecule via homologous recombination.

36 Which of the following factors is **not** critical for the functioning of Polymerase Chain Reaction (PCR)?

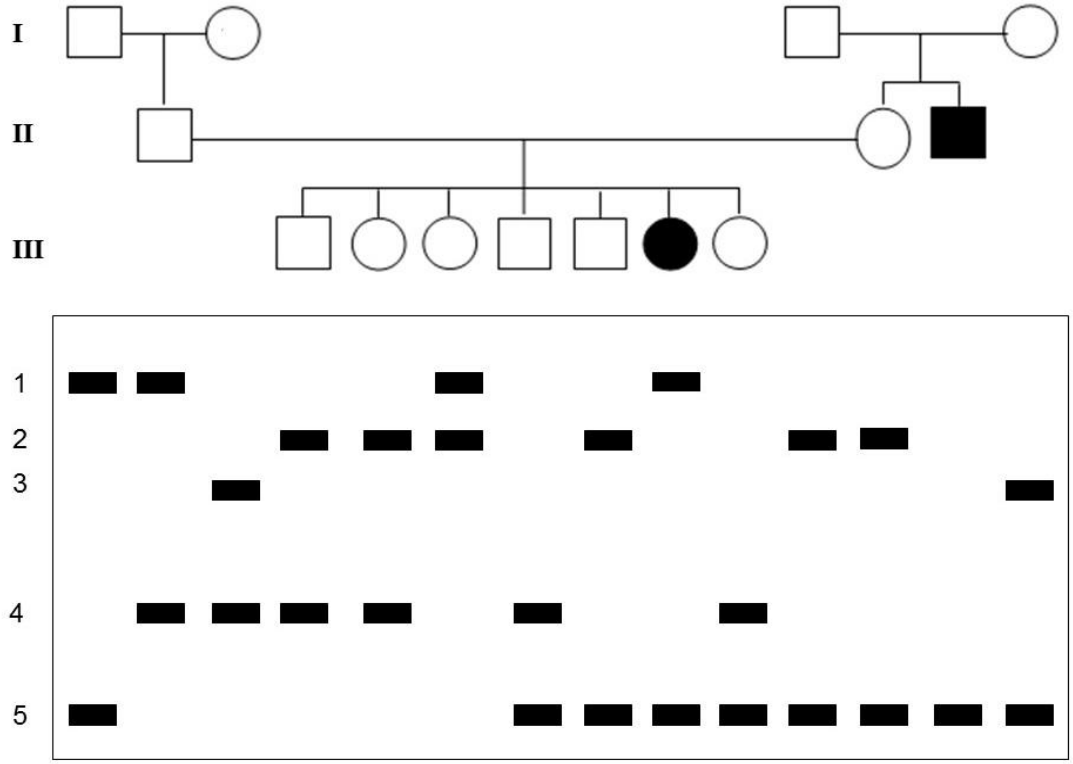
A Presence of DNA sequences other than target DNA.

B Temperatures for Stage 1 and 3 of the PCR cycle are only sustained for a short period of time (1 – 5 minutes).

C Presence of large amount of primers such that it is not the limiting reagent.

D Use of a thermostable polymerase enzyme.

37 A Restriction Fragment Length Polymorphism (RFLP) locus with 5 alleles (1-5), is linked to the gene causing Disease H.



Which of the following conclusions can be made from the information given above?

1 Crossing over occurred at a locus between the gene locus and the RFLP locus in the affected individual from generation III.

2 The disease is an autosomal recessive disease.

3 Among the unaffected individuals, all are heterozygous at the gene locus.

4 The RFLP alleles have different number of tandem repeats between 2 restriction sites.

A 1 and 3

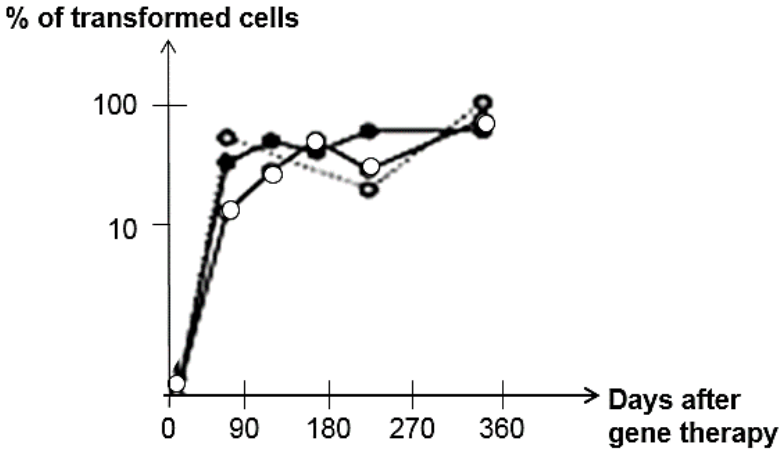
B 2 and 4

C 1, 2 and 4

D 2, 3 and 4

38 Recent research has developed a technique that combines gene therapy with stem cell therapy. This inspired a group of scientists to carry out a clinical trial with such modified stem cells in the hope of treating a neurological disease that is caused by a homozygous recessive genotype at a single gene locus.

Upon introducing stem cells with the functional dominant allele into the brains of three patients, their conditions did not improve although the following results were obtained from analysing the cell count in the target area of their brains.



What would be the most appropriate investigation to carry out in view of the unsuccessful clinical trial?

A regulation of neurone-specific genes in implanted stem cells

B in-vitro efficiency of gene delivery vector

C modification of stem cells to reduce immune reaction to implanted stem cell

D plasticity of neural stem cells to form other types of specialised cells

39 Plant physiologists attempted to produce papaya plants using tissue culture. They investigated the effects of different concentrations of plant growth factors on small pieces of the stem tip from a papaya plant. Their results are shown in the table below.

Concentration of auxin / µmol dm^{-3}	Concentration of cytokinin / µmol dm^{-3}		
	5	25	50
0	No effect	No effect	Leaves produced
1	No effect	Leaves produced	Leaves produced
5	No effect	Leaves produced	Leaves and some plantlets produced
10	Callus produced	Leaves and some plantlets produced	Plantlets produced
15	Callus produced	Callus and some leaves produced	Callus and some leaves produced

What evidence from the table supports that cells from the stem tip are totipotent?

A Under certain concentrations of cytokinin to auxin, there is production of both leaves and calluses or leaves and plantlets showing that more than one type of cells can be produced at any one time.

B Stem tip cells are able to produce calluses when the concentration of cytokinin to auxin is in the ratio of 1:2 or 1:3.

C Stem tip cells are able to produce leaves although they are supposed to differentiate into stems.

D Stem tip cells are able to give rise to plantlets.

40 What is an example of genetically modified organisms?

A Cows that grow to adult size quickly due to injection of growth hormone into the cows.

B Pigs that grow to large size via inbreeding.

C High yielding rice that are flood resistant due to intensive self-pollination over many generations.

D Durians that ripen slowly due to anti-sense RNA technology.

Paper 1 Answer Scheme

Qns	Ans
1	C
2	B
3	A
4	B
5	D
6	D
7	C
8	A
9	B
10	D
11	B
12	A
13	A
14	C
15	B
16	A
17	B
18	C
19	B
20	D

Qns	Ans
21	B
22	C
23	B
24	D
25	B
26	B
27	B
28	C
29	C
30	D
31	D
32	B
33	C
34	C
35	C
36	A
37	B
38	A
39	D
40	D

HIGHER 2

CANDIDATE NAME

PDG

PDG INDEX NUMBER

BIOLOGY
9648/02

Paper 2 Core Paper

13 September 2016
Tuesday

2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your name and PD group on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graph or rough working.
Do not use paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

All working for numerical answers must be shown.
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.

Calculators may be used

For Examiner's Use	
Section A	**80**
1	
2	
3	
4	
5	
6	
7	
8	
Section B	**20**
9 / 10	
Total	**100**

This document consists of **19** printed pages.

Section A

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

1 The enzyme human immunodeficiency virus (HIV) protease is essential for the life cycle of HIV.

Fig. 1.1 shows the structure of the HIV protease. It exists as a homodimer made up of two identical polypeptide chains, each forming a subunit. The active site lies between the subunits, with each subunit contributing an aspartic acid that functions as a catalytic residue.

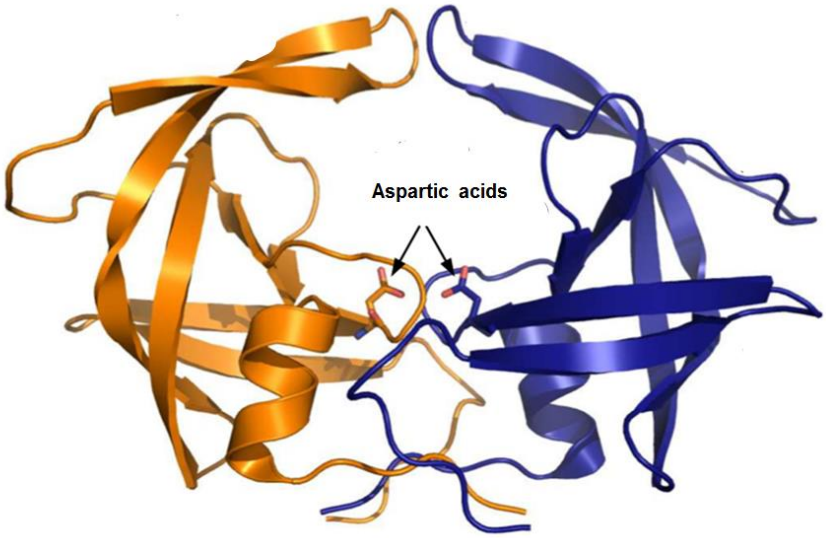


Fig. 1.1

(a) **(i)** Describe the function of aspartic acid in HIV protease.

……. [1]

(ii) With reference to Fig. 1.1, outline how the structure of HIV protease is formed.

……..

……

……

……

……

……. [4]

(iii) Suggest an advantage of protease being a homodimer.

……..

……. [1]

(b) Many HIV proteases inhibitors have been developed to treat people infected with HIV. Most inhibitors act as competitive inhibitors to HIV protease. Fig. 1.2 shows three such inhibitors.

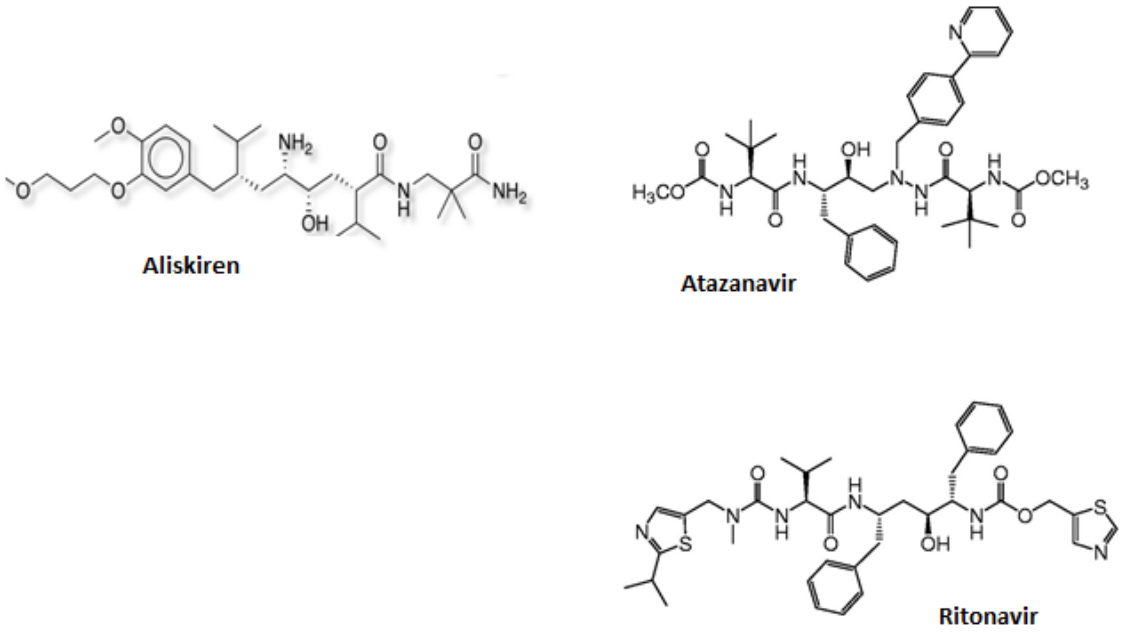


Fig. 1.2

With reference to Fig. 1.2, explain how HIV protease inhibitors work in the treatment of HIV infection.

……

……

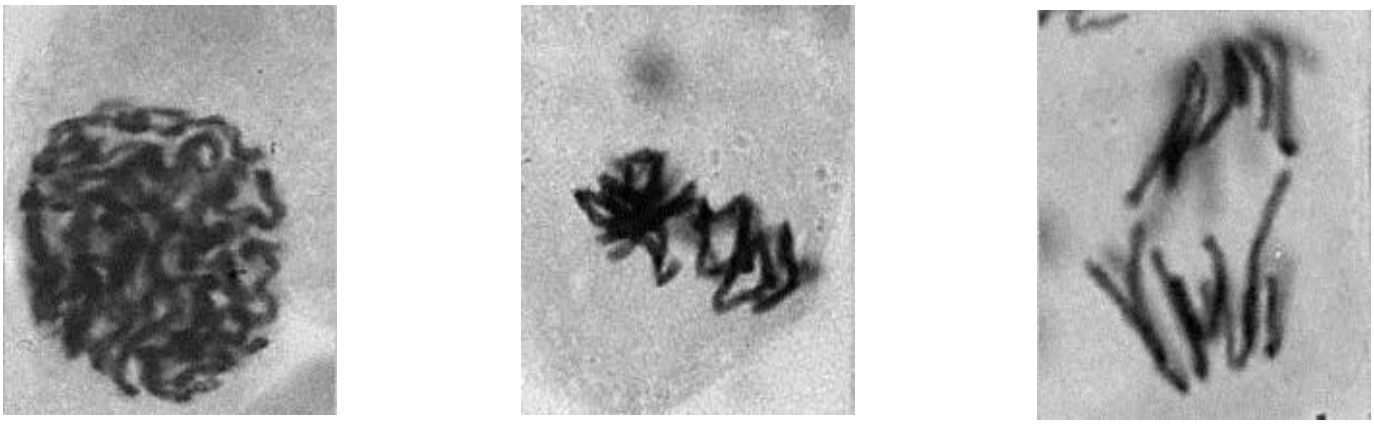
……

……

…… [3]

[Total: 9]

2 Fig. 2.1 shows an electron micrograph of an actively dividing cell from *Bellevalia romana*, a flowering herbaceous plant.



A **B** **C**

Fig. 2.1

(a) **(i)** Identify stages **A** and **B**, and state the visible features that enabled your identification.

……..

……

…… [2]

(ii) Explain the change in distance between centromeres of a chromosome in stage **C**.

……..

……

……

……

…… [3]

(iii) Explain why it is important that replication occurs before mitosis.

……..

……

…… [2]

(iv) Explain how homologous chromosomes in stage **A** are genetically different from those in prophase II of the same plant.

……..

……

……

……

…… [3]

Prokaryotic organisms such as *Escherichia coli* do not divide by mitosis. Apart from ribosomes, prokaryotes have no organelles comparable to those found in eukaryotes and have a circular 'chromosome' with no centromere.

(b) With reference to the information given above and your knowledge of mitosis, suggest why mitosis does not occur in prokaryotes.

……..

……..

……... [2]

[Total: 12]

3 Fig. 3.1 is a diagram showing translation. Table 3.2 shows an mRNA codon table.

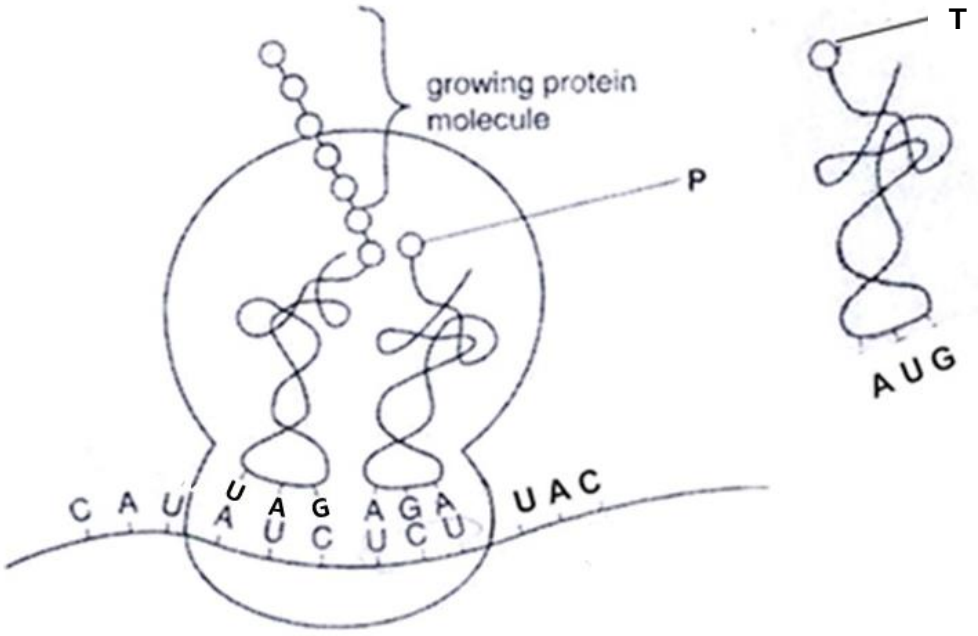


Fig. 3.1

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

Table 3.2

(a) **(i)** State **two** molecules required for translation that are not shown in Fig. 3.1.

……... [1]

(ii) Using Table 3.2 to identify **P** and **T**, briefly describe the process of translation as shown in Fig. 3.1.

……..

……

……

……

……

…… [4]

(b) Suggest why parts of tRNA are double stranded.

……..

……..

…….. [2]

(c) State **two** ways in which DNA replication:

(i) is similar to transcription.

……..

……

…… [2]

(ii) differs from transcription.

……..

……..

…… [2]

[Total: 11]

4

(a) Explain why viruses are obligate parasites.

……..

……..

…… [2]

Fig. 4.1 is an electron micrograph of T4 bacteriophages infecting an *Escherichia coli*.

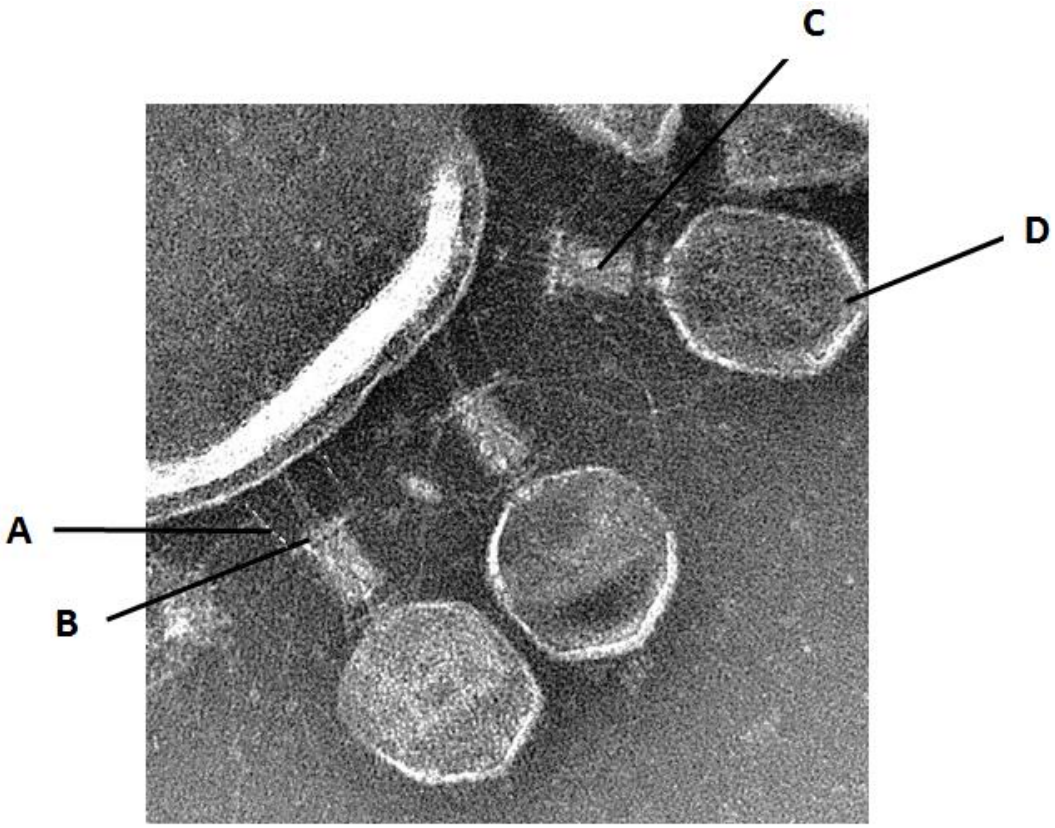


Fig. 4.1

(b) **(i)** Identify the structures labelled **A** - **D**.

A……..

B……

C……

D..…… [2]

(ii) Explain why polymerase enzymes are present in human influenza virus but not in T4 bacteriophage.

……..

……

…… [2]

(c) With reference to the reproductive cycle of bacteriophages, suggest why bacteriophage infection may be beneficial to bacteria population.

……..

……..

……..

……..

…….. [3]

[Total: 9]

5 Voltage-gated sodium ion channels are integral membrane proteins that allow generation of an action potential across the axon membrane.

Fig. 5.1 shows a typical voltage-gated sodium ion channel which has two gates, the activation and inactivation gates. At different membrane potentials, the channel exists in different states depending on which gates are open or close.

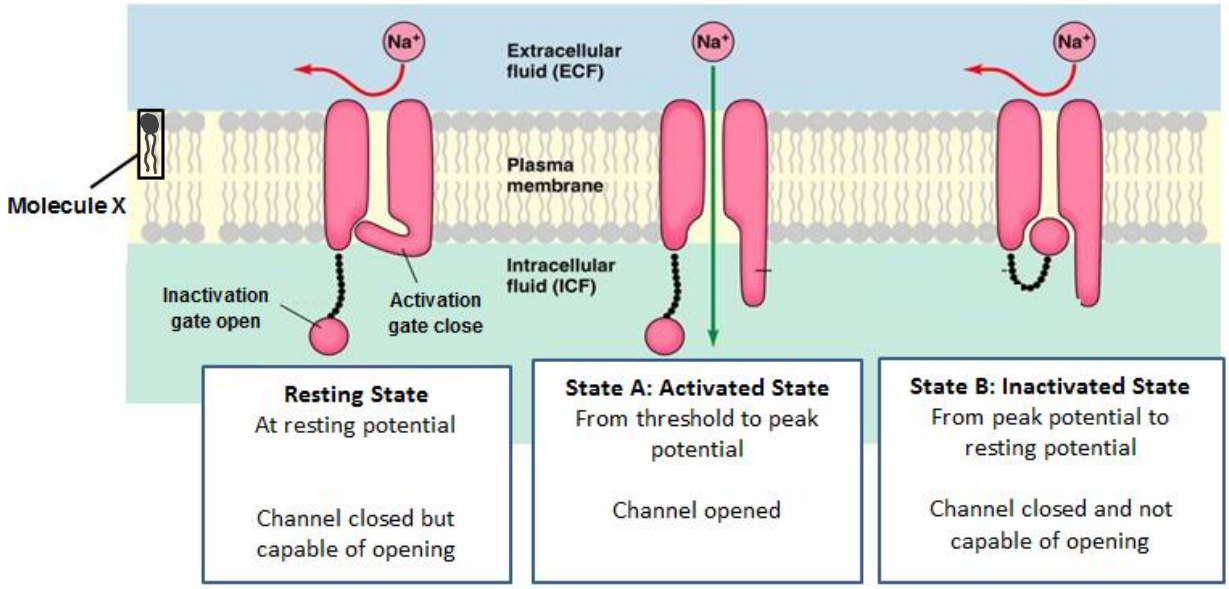


Fig. 5.1

(a) **(i)** Describe how State **A** results in depolarisation**.**

……..

……

…… [2]

(ii) Explain how State **B** ensures unidirectional movement of nerve impulse along the neurone.

……..

……

……

……

…… [3]

(iii) Describe how Molecule **X** differs from a triglyceride in terms of structure.

……..

……..

…….. [2]

(b) Explain why triglycerides are better respiratory substrates than carbohydrates.

……..

……..

…… [2]

[Total: 9]

6 In Drosophila, the characteristics of wing length and body colour are controlled by one gene each. Wild type flies have normal (long) wings and grey body colour while mutant flies have vestigial (undeveloped) wings and black body colour. Pure-breeding wild-type and mutant flies will breed to produce flies with normal wings and grey colour.

A male fly with wild phenotype was crossed with a female fly with mutant phenotype. The resulting offspring were as follows:

normal wings and black body colour	107
vestigial wings and grey body colour	92

Using the following symbols:

N	normal wings	**n**	vestigial wings
E	grey body colour	**e**	black body colour

(a) Draw a genetic diagram in the space below showing the cross described.

[4]

(b) The observed numbers are usually different from the expected numbers in any genetic cross.

(i) Suggest **two** reasons why such a difference may occur in a monohybrid cross, referring only to events after meiosis.

……..

……..

…….. [2]

(ii) A chi-squared test was carried out on the results of the cross. A *p* value of about 0.30 is obtained.

With reference to the cross results, explain the significance of the *p* value.

……..

……..

…….. [2]

(c) The wing length of fruit flies with normal wings varies between 70 to 85 µm.

Suggest a reason for the variation in wing length within fruit flies with normal wings.

……..

…….. [1]

(d) Alleles coding for mutant phenotypes in fruit flies are caused by artificially induced mutations in laboratory bred flies. Suggest why such mutants are unlikely to be found in natural populations.

……..

……..

…… [2]

[Total:11]

7 Giant anteaters, armadillos and Australian numbats (*Myrmecobius fasciatus*) have many similar traits. This led some to believe that they were closely related and that they should be classified into the same taxon of a lower rank under the hierarchical classification system.

Table 7.1 shows the comparison of four characteristics between the three mammals

Mammal	Characteristics			
	Diet	**Body**	**Snout**	**Tongue**
Armadillo	Feed on insects	Covered by bony keratinised plates	Pointy snout	Long tongues
Giant Anteater	Feed on ants and termites	Covered by hair	Elongated narrow snout	Long tongues
Numbats	Feed on termites	Covered by hair	Narrow snout	Long tongues

Table 7.1

DNA sequences of selected genes such as 18s rRNA are subsequently compared between some organisms, including the three mammals, when molecular experimental techniques advanced and the results helped clarified the phylogenetic relationships of the mammals.

Fig. 7.2 shows the simplified phylogenetic tree of the organisms based on nucleotide sequence comparison results.

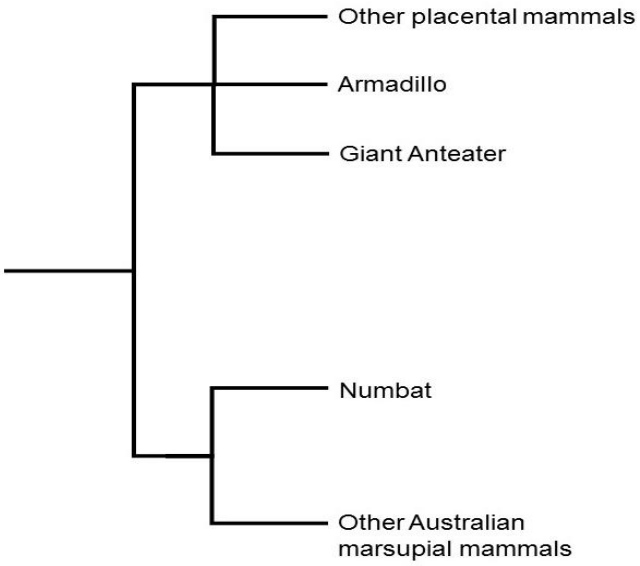


Fig. 7.2

(a) Explain the relationship between classification and phylogeny.

……..

……..

…… [2]

(b) Using the information above, explain why comparison of morphological structures led to the incorrect conclusion about the phylogenetic relationships of the three mammals.

……..

……..

……..

……..

……..

…… [4]

(c) State **one** reason why the 18s rRNA gene was chosen to compare DNA sequences between organisms.

……..

…….. [1]

Fig. 7.3 shows the geographical distribution of the various mammals.

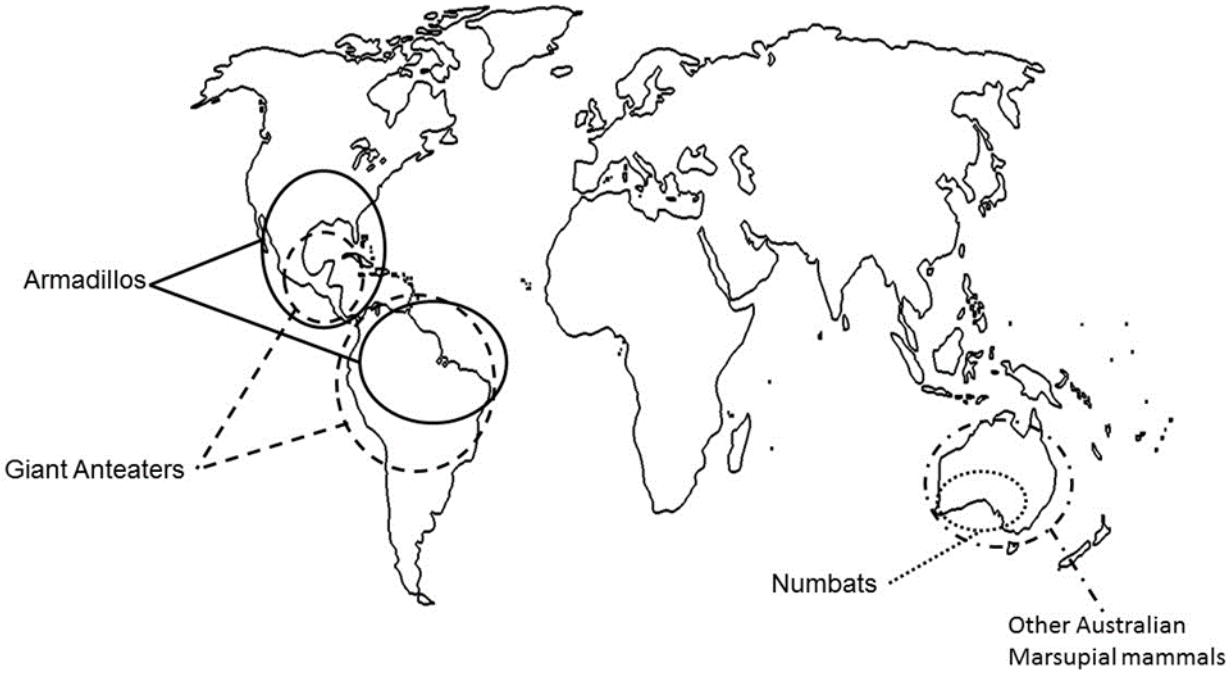


Fig. 7.3

(d) Using the information above, explain how biogeography supports the phylogenetic relationships constructed from DNA sequence comparison.

……

……

…… [2]

[Total: 9]

8 Epidermal growth factor receptors (EGFR), which belong to the ErbB family of receptor tyrosine kinases, have been found to be overexpressed in many cancers, such as glioblastoma, colorectal and breast cancers.

Fig. 8.1 shows the EGFR signalling pathway.

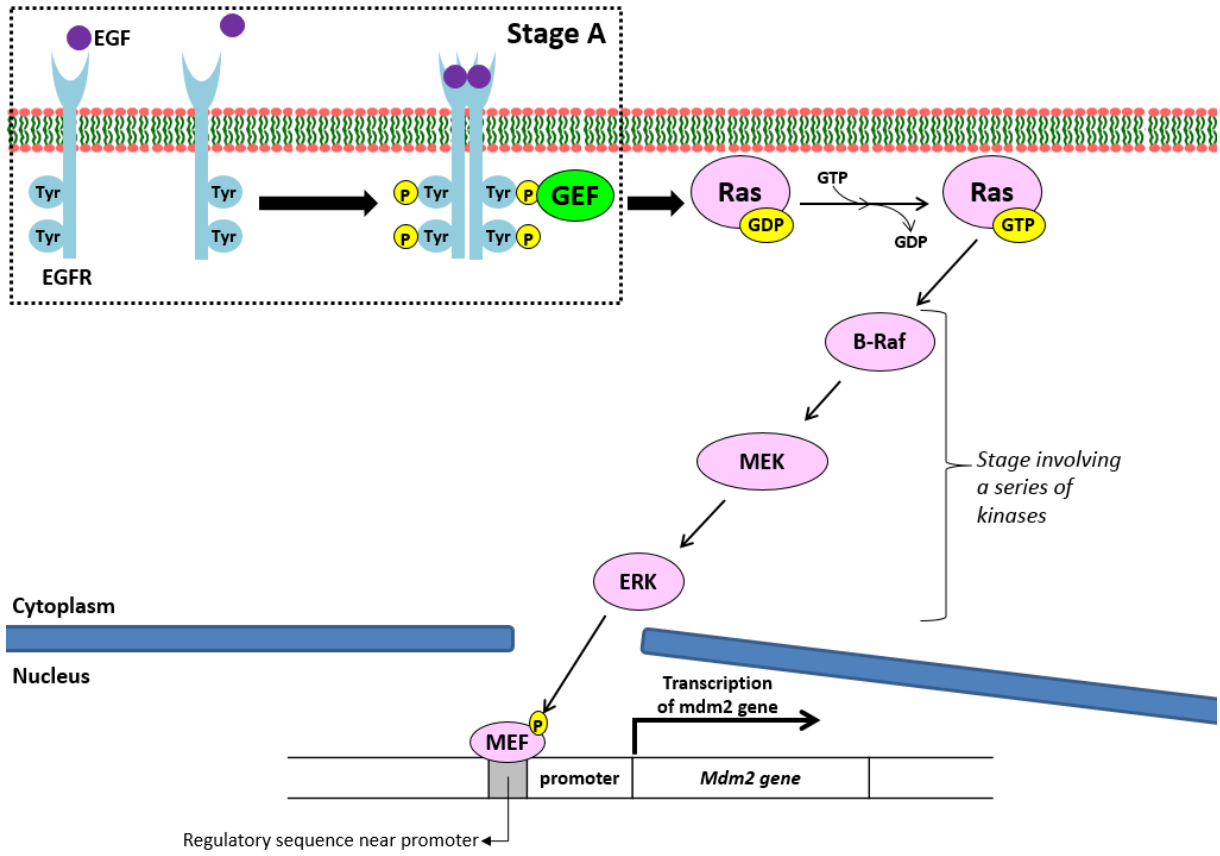


Fig. 8.1

Legend:

EGF	Epidermal growth factor
Ⓟ	Phosphate group
GEF	Guanine nucleotide exchange factor that binds to and activates Ras
B-Raf, MEK, ERK	Kinases
MEF	A specific transcription factor that binds near the promoter

With reference to Fig. 8.1,

(a) Describe the events occurring at stage A.

……

……

……

……

……

…… [4]

(b) **(i)** Suggest how a mutation in Ras GTPase that causes GTP to be permanently bound results in the overexpression of mdm2.

……

……

……

……

…… [3]

(ii) Mdm2 is an enzyme which catalyses the addition of ubiquitin to p53. Explain how high levels of mdm2 enzyme may lead to increased chances of cancerous growth.

……

……

……

……

…… [3]

[Total: 10]

Section B

Answer **EITHER 9 or 10.**

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

9 **(a)** Explain how fluidity of biological membranes can be maintained and the importance of fluidity to membrane function. [8]

(b) Plant cells have a cellulose cell wall outside the cell surface membrane. Explain how the structure of cellulose is related to its function. [7]

(c) Describe how photophosphorylation differs from oxidative phosphorylation. [5]

[Total: 20]

Or

10 **(a)** Distinguish between gene mutation and chromosome structural mutation. [4]

(b) Describe how the most common CFTR gene mutation affects function of the protein and explain why other mutations vary in the extent to which they affect protein function. [8]

(c) With reference to mutation of named genes, outline the development of cancer. [8]

[Total:20]

HIGHER 2

CANDIDATE NAME

PDG

PDG INDEX NUMBER

BIOLOGY
9648/02

Paper 2 Core Paper

13 September 2016
Tuesday

2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your name and PD group on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graph or rough working.
Do not use paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

All working for numerical answers must be shown.
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.

Calculators may be used

For Examiner's Use	
Section A	**80**
1	
2	
3	
4	
5	
6	
7	
8	
Section B	**20**
8 / 9	
Total	**100**

This document consists of **20** printed pages.

Section A

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

1 The enzyme human immunodeficiency virus (HIV) protease is essential for the life cycle of HIV.

Fig. 1.1 shows the structure of the HIV protease. It exists as a homodimer made up of two identical polypeptide chains, each forming a subunit. The active site lies between the subunits, with each subunit contributing an aspartic acid that functions as a catalytic residue.

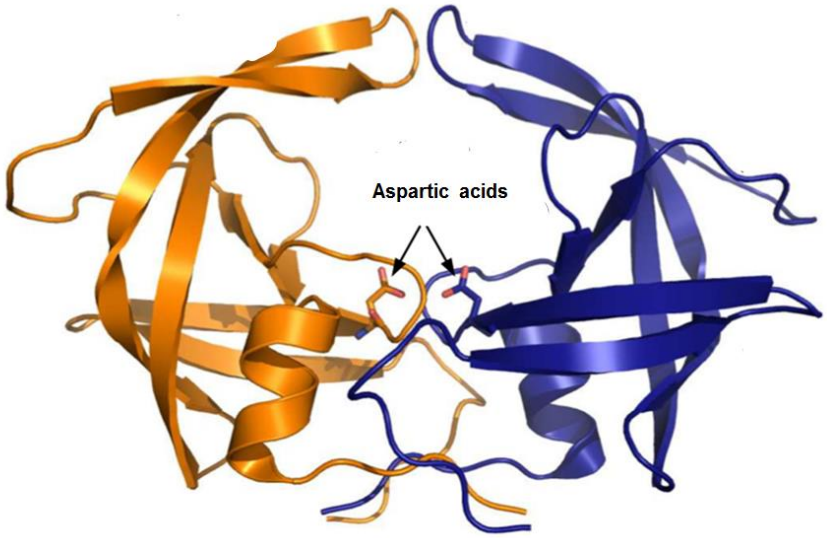


Fig. 1.1

(a) (i) State the function of aspartic acid in HIV protease.

- (R-group) is involved in the **hydrolysis** of **peptide bonds** (between amino acids) [1]

(ii) With reference to Fig. 1.1, outline how the structure of HIV protease is formed.

- **Polypeptide chain** consisting of **amino acids** joined by **peptide bonds**
- Within each subunit, a polypeptide chain is **folded** into (secondary structure) **alpha helices** and **beta-pleated sheets**
  Many cannot identify beta-pleated sheets shown in the diagram, hence only mentioned alpha helices.
- stabilised by **hydrogen bonds** formed between the **O atom of the CO** of one amino acid and **H atom of the NH group** of another amino acid in the **polypeptide backbone**
- Further folding of the polypeptide chain into a **globular shape / 3D shape/tertiary structure**
  structure
- maintained by **disulfide bonds, hydrogen bonds**, **ionic bonds** and **hydrophobic interactions** (name at least 2) formed between the **R groups** of the amino acids of the polypeptide chain

[4]

- The two subunit assemble together via **R-group interactions /** named bonds to form **active site**, exposing the **aspartic acids** (forming the quaternary structure)

Any 4

(iii) Suggest an advantage of protease being a homodimer.

- Shorter/smaller genome/ RNA for virus to package within its capsid
- Lesser types of tRNA / amino acids required from the host cell for synthesis of HIV protease [1]

(b) Many HIV proteases inhibitors have been developed to treat people infected with HIV. Most inhibitors act as competitive inhibitors to HIV protease. Fig. 1.2 shows three such inhibitors.

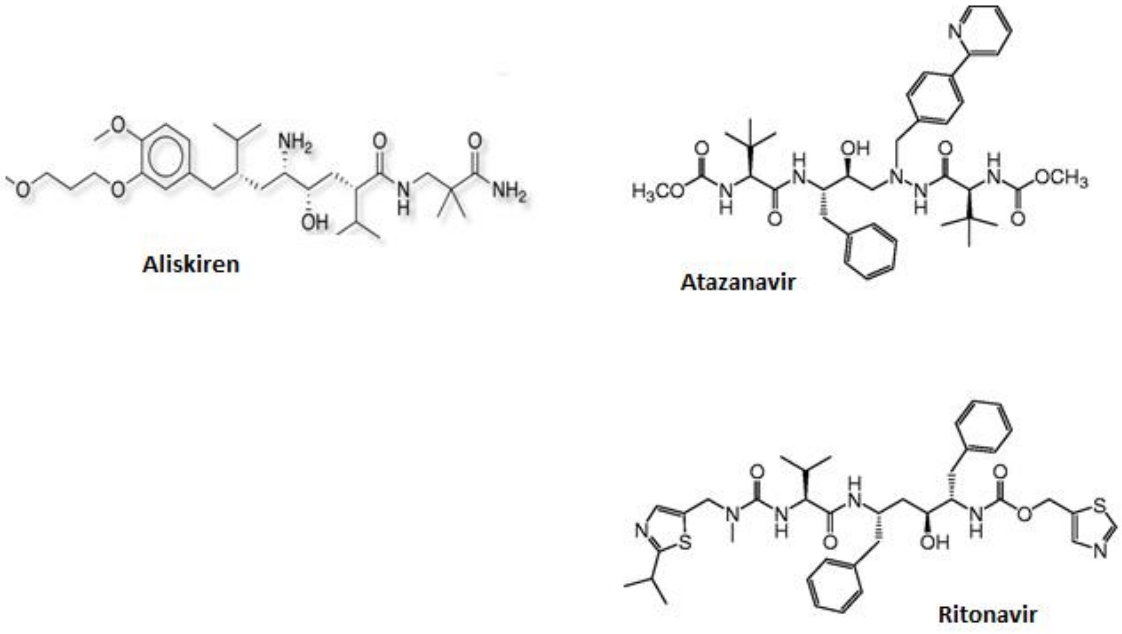


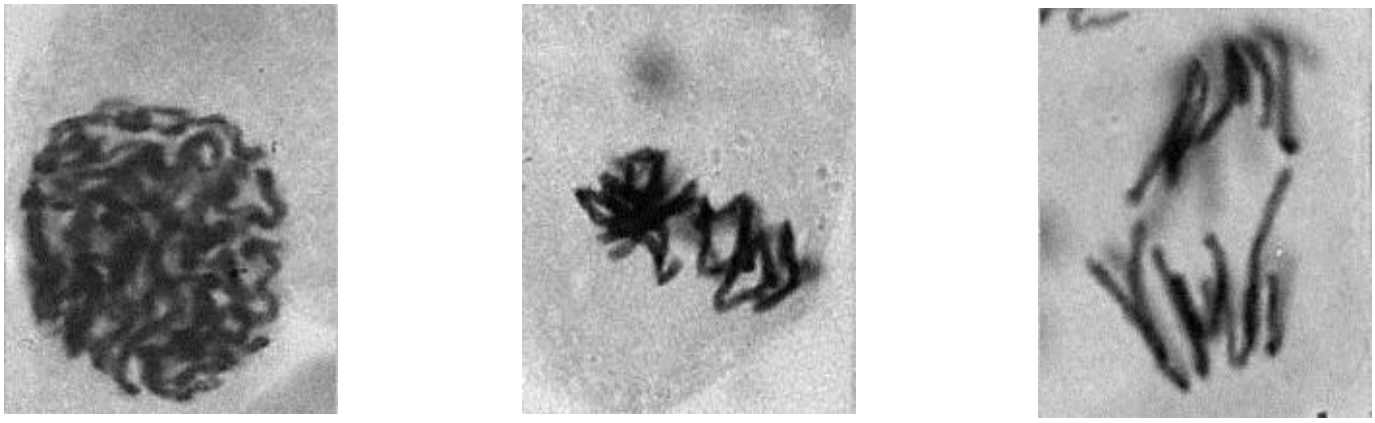
Fig. 1.2

With reference to Fig. 1.2, explain how HIV protease inhibitors work in the treatment of HIV infection.

- HIV protease inhibitors have similar structure/ shape to **polyprotein/proteins/polypeptide chain** as seen in the presence of **peptide bonds / polypeptide backbone**
- Compete with polyprotein for **binding** to **active site** of HIV protease
- Viral **polyprotein** not cleaved
  → functional viral(structural/ enzymatic) proteins not formed / newly formed virus **not** infective/ mature/ **functional** hence unable to infect other cells. [3]

[Total: 9]

2 Fig. 2.1 shows an electron micrograph of an actively dividing cell from *Bellevalia romana*, a flowering herbaceous plant.



A **B** **C**

Fig. 2.1

(a) **(i)** Identify stages **A** and **B**, and state the visible features that enabled your identification.

- Stage A → chromatin fibres (coil and) **condense** to become (discrete) **chromosomes** → thus (early) **prophase;**
- Stage B → chromosomes (starting to) **align singly** at **metaphase plate** → thus (early) **metaphase**; [2]

(ii) Explain the change in distance between centromeres of a chromosome in stage **C**.

- Distance between centromeres of sister chromatids **increase** in stage C;
- Because during stage C, which is anaphase, **centromere divide**;
- **Chromosomes** pulled to opposite **poles** by shortening of kinetochore microtubules/spindle fibres (with centromeres leading); [3]

(iii) Explain why it is important that replication occurs before mitosis.

- So that each **chromosome** consists of **2 genetically identical** sister chromatids (joined at centromere during prophase and metaphase);
- Each (of the two) **daughter cells** receive a copy of exact/same DNA molecule/same number and type of chromosomes → **genetically identical**; [2]

(iv) Explain how homologous chromosomes in stage **A** are genetically different from those in prophase II of the same plant.

- **Sister chromatids** of homologous chromosomes in prophase II have different alleles of the same gene as compared to those in **stage A, prophase**;

OR

- **Sister chromatids** of homologous chromosomes in prophase II are **not genetically identical** while the sister chromatids of homologous chromosomes in prophase are **genetically identical**;

- This is because in **prophase I**, (chiasmata formation and) **crossing over between non-sister chromatids of homologous chromosomes occurred**;
- Exchange of DNA segments with different alleles of the same gene/formation of new linkage [3]

groups/formation of new combinations of alleles;

Prokaryotic organisms such as *Escherichia coli* do not divide by mitosis. Apart from ribosomes, prokaryotes have no organelles comparable to those found in eukaryotes and have a circular 'chromosome' with no centromere.

(b) With reference to the information given above and your knowledge of mitosis, suggest why mitosis does not occur in prokaryotes.

- Prokaryotes do not have centrioles to form/ organise spindle fibres/ form mitotic spindles;
- Prokaryotes do not have centromeres for attachment of spindle fibres/ kinetochore microtubules (via kinetochore proteins) to separate sister chromatids; [2]

[Total: 12]

3 Fig. 3.1 is a diagram showing translation. Table 3.2 shows an mRNA codon table.

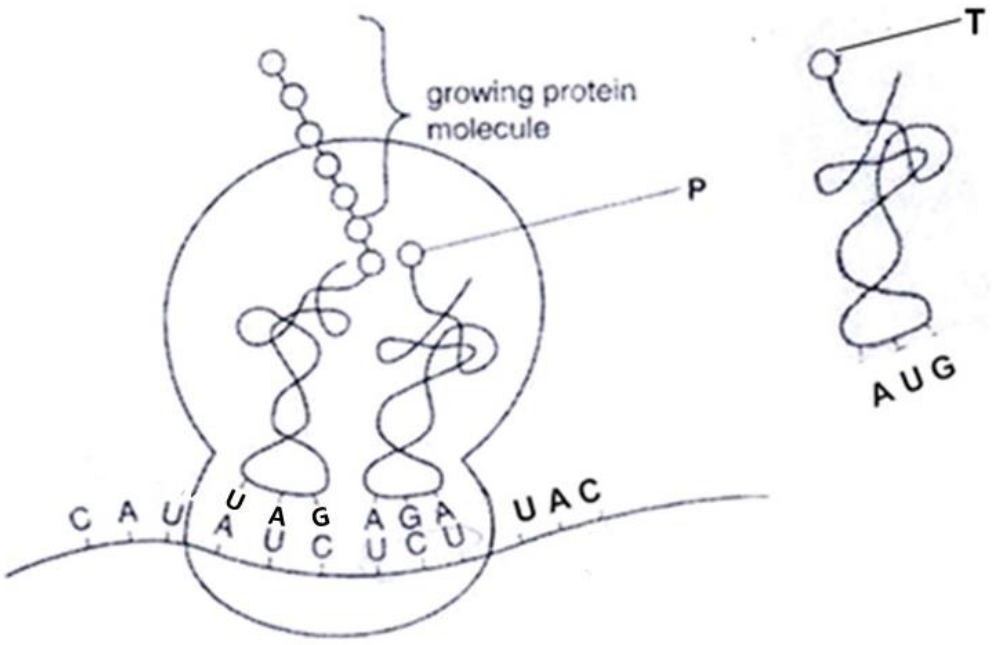


Fig. 3.1

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

Table 3.2

(a) **(i)** State **two** molecules required for translation that are not shown in Fig. 3.1.

- Translation **initiation** factors
- Translation **elongation** factors
- Release factors
- GTP
- ATP
- Initiator tRNA (carrying methionine)
- Aminoacyl-tRNA **synthetase**
- Peptidyltransferase

[Any 2, 0.5 marks each] [1]

(ii) Using Table 3.2 to identify **P** and **T**, briefly describe the process of translation as shown in Fig. 3.1.

- **Peptide bond formation** occurs between growing protein molecule/ last amino acid of the growing protein molecule/ isoleucine and **serine** (identify amino acid P).
- **catalysed** by **peptidyl transferase**
- ribosome translocates **1 codon/3 bases** down mRNA in **5' to 3' direction**
- tRNA carrying **tyrosine**(identify amino acid T) enters A site of ribosome
- anticodon **AUG** binds with codon **UAC**
- via (hydrogen bonds) between **complementary** base pairs/complementary base pairing.

[0.5 m each] [4]

(b) Suggest why parts of tRNA are double stranded.

rRNA is doube-stranded due to

- **Complementary base pairing** between different parts of a signle stranded tRNA.
- This contributes to the **stability** of the tRNA molecule
- allow tRNA to have a **shape** that fits into /is complementary into the E,P,A sites of ribosome/active sites of aminoacyl-tRNA sythetase. [2]

(c) State **two** ways in which DNA replication:

(i) is similar to transcription.

- Both occur in the **nucleus**;
- Both require DNA as template strand;
- Formation of **phosphodiester bonds** between **nucleotides** in DNA replication and transcription;
- **Reading** of DNA template strand is 3' to 5' direction for both DNA replication and transcription **OR Elongation** of the newly synthesis occur from 5' to 3' direction

[max 2m] [2]

(ii) differs from transcription.

- Synthesis of **a RNA strand** in transcription but synthesis of **DNA molecule** in DNA replication;
- Transcription uses **one DNA strand** as a **template** to synthesise mRNA while DNA replication uses **two DNA strands** as **template** to synthesise DNA;
- **RNA nucleotides** used as **monomers** to form polynucleotide chain in transcription while **DNA nucleotides** are used in DNA replication
- Phosphodiester bond formation/addition of monomers catalysed by DNA polymerase in DNA replication while it is catalysed by **RNA polymerase** in transcription;
- DNA replication requires a pre-existing strand known as a primer to provide a 3'OH group for polymerase to add nucleotides to while transcription can be initiated without the pre-existing strand.
- In DNA Replication, the whole DNA molecule is replicated in a single process, but in transcription only certain region/gene is being transcribed in a single process. (the phrase "in a single process" is crucial as it provides a basis of comparison)

[max 2m]

[2]

[Total: 11]

4

(a) Explain why viruses are obligate parasites.

- Related organelles/ enzymes to function: e.g lacks ribosomes for protein synthesis/ lack mitochondria for ATP generation / DNA polymerase for DNA replication

- Contains only 1 type of nucleic acid either DNA or RNA as genome but not both

any 1

AND

- hence need to takes over/ takes control/hijacks host cell metabolic machinery for the production/replication of progeny viruses [2]

Fig. 4.1 is an electron micrograph of T4 bacteriophages infecting an *Escherichia coli*.

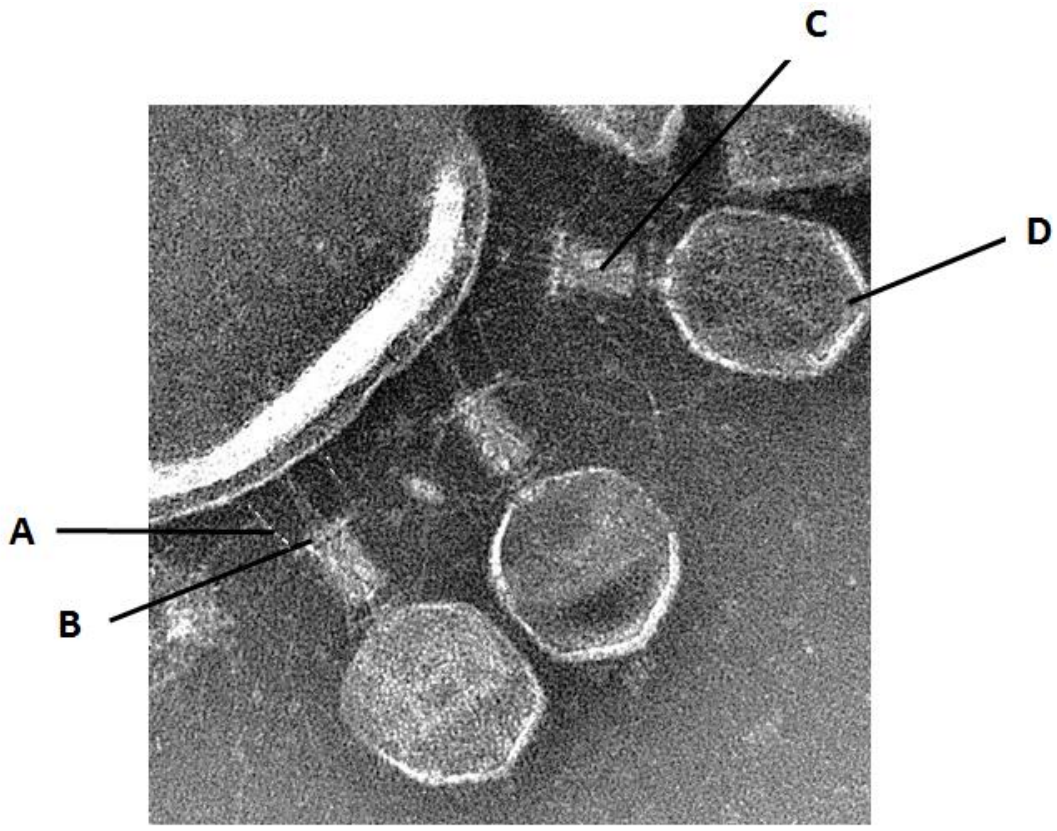


Fig. 4.1

(b) **(i)** Identify the structures labelled **A** - **D**.

A Tail fibre
B Base plate
C Tail/tail sheath
D Capsid head / capsid / nucleocapsid [2]

(ii) Explain why polymerase enzymes are present in human influenza virus but not in T4 bacteriophage.

- T4 phage genome is **DNA** while influenza virus genome is **RNA**
- T4 uses **host cell DNA polymerase** to replicate its genome / host cell **RNA polymerase** for transcription
  while influenza virus uses **RNA-dependent RNA polymerase** for transcription / replication which is <u>not present</u> in the host cell [2]

(c) With reference to the reproductive cycle of bacteriophages, suggest why bacteriophage infection may be beneficial to bacteria population.

- A **small piece** of a **bacteria DNA** can be incorporated into the **phage capsid** due to mistakes during viral assembly / a small region of bacterial DNA may be **excised** together with the prophage (and packaged)

- The resulting transducing phages **infect other / recipient bacteria** and newly infected cell **acquires** [3]

the original bacterial DNA

- Idea of allows **genetic recombination**/ increase **genetic variation** → increase adaptability of the bacteria to changes in environment

[Total: 9]

5 Voltage-gated sodium ion channels are integral membrane proteins that allow generation of an action potential across the axon membrane.

Fig. 5.1 shows a typical voltage-gated sodium ion channel which has two gates, the activation and inactivation gates. At different membrane potentials, the channel exists in different states depending on which gates are open or close.

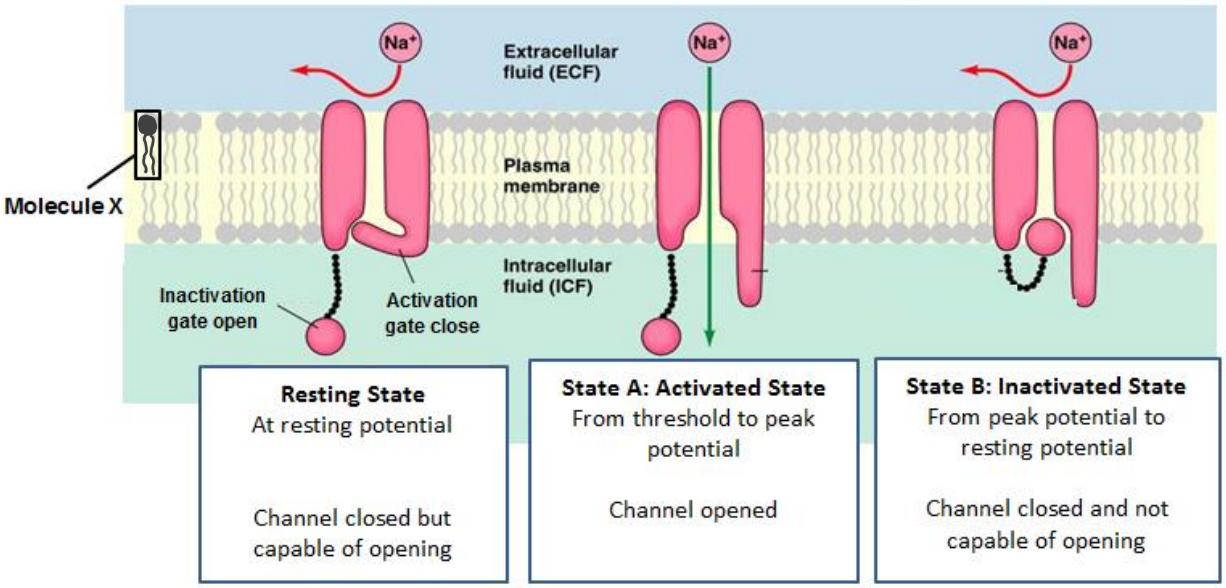


Fig. 5.1

(a) (i) Describe how State **A** results in depolarisation**.**

- In the activated state, (inactivation and) **activation gates open**
- **Na+ influx/** diffuse into the axon **through the opened ion channel** , increasing **membrane potential**

[2]

(ii) Explain how State **B** ensures unidirectional movement of nerve impulse along the neurone.

- In the inactivated state, (activation gate is open) but **inactivation gate is closed**
- this results in absolute **refractory period**
- No stimulus, can initiate another action potential / No depolarisation occurs at this part of the membrane (,resulting in the unidirectional movement of the impulse)

[3]

(iii) Describe how Molecule **X** differs from a triglyceride in terms of structure.

Molecule A (phospholipid)	Triglyceride
2 fatty acid/ hydrocarbon tails / chains	3 fatty acid/ hydrocarbon tails / chains
A phosphate group present	No phosphate group
2 ester bonds and 1 phosphoester bond	3 ester bonds

[2]

(b) Explain why triglycerides are better respiratory substrates than carbohydrates.

- release **twice as much/more** energy on oxidation/ during respiration per unit mass compared carbohydrate / compared with an **same mass** of carbohydrate

- due to two times **more hydrogen atoms** per gram/ **greater ratio of hydrogen to oxygen** atoms/ **more C-H bonds** (compared to the same mass of carbohydrate)

- Only award one mark if both answers are given but didn't mention that basis of comparison "per unit mass" at all.

[2]

[Total: 9]

6 In Drosophila, the characteristics of wing length and body colour are controlled by one gene each. Wild type flies have normal (long) wings and grey body colour while mutant flies have vestigial (undeveloped) wings and black body colour. Pure-breeding wild-type and mutant flies will breed to produce flies with normal wings and grey colour.

A male fly with wild phenotype was crossed with a female fly with mutant phenotype. The resulting offspring were as follows:

normal wings and black body colour	107
vestigial wings and grey body colour	92

Using the following symbols:

N	normal wings	**n**	vestigial wings
E	grey body colour	**e**	black body colour

(a) Draw a genetic diagram in the space below showing the cross described.

- Correct parental genotypes linked to phenotypes;
- Correct gametes;
- Correct F1 genotypes;
- Correct F1 phenotypes linked to genotypes; [4]

(b) The observed numbers are usually different from the expected numbers in any genetic cross.

(i) Suggest **two** reasons why such a difference may occur in a monohybrid cross, referring only to events after meiosis.

- sample size too small;
- chance variation / variation statistically insignificant;
- difference in survival rate of sperm / ova with particular genotypes;
- difference in survival rates of zygotes with particular genotypes; [2]

(ii) A chi-squared test was carried out on the results of the cross. A *p* value of about 0.30 is obtained.

With reference to the cross results, explain the significance of the *p* value.

- *p* value is the probability that the difference between observed and expected ratio is due to chance alone;
- since *p* is more than 0.05 / probability is more than 5%, there is no significant difference between the observed and expected ratio of 1:1;

[2]

(c) The wing length of fruit flies with normal wings varies between 70 to 85 µm.

Suggest a reason for the variation in wing length within fruit flies with normal wings.

- environmental factors such as nutrition affected the expression of allele coding for normal wings / environmental factors such as nutrition has a small effect on wing length; [1]

(d) Alleles coding for mutant phenotypes in fruit flies are caused by artificially induced mutations in laboratory bred flies. Suggest why such mutants are unlikely to be found in natural populations.

- Mutation rate is low;
- Mutant alleles may **confer selective disadvantage**, resulting in alleles being removed by **natural selection** / ref. to **decrease in frequency** of mutant alleles / unable to survive, **reproduce to pass on the alleles**;
- Mutant alleles are **recessive** and their effect on the phenotype can be **masked** by the normal dominant allele;

[max 2m] [2]

[Total:11]

7 Giant anteaters, armadillos and Australian numbats (*Myrmecobius fasciatus*) have many similar traits. This led some to believe that they were closely related and that they should be classified into the same taxon of a lower rank under the hierarchical classification system.

Table 7.1 shows the comparison of four characteristics between the three mammals

Mammal	**Characteristics**			
	Diet	**Body**	**Snout**	**Tongue**
Armadillo	Feed on insects	Covered by bony keratinised plates	Pointy snout	Long tongues
Giant Anteater	Feed on ants and termites	Covered by hair	Elongated narrow snout	Long tongues
Numbats	Feed on termites	Covered by hair	Narrow snout	Long tongues

Table 7.1

DNA sequences of selected genes such as 18s rRNA are subsequently compared between some organisms, including the three mammals, when molecular experimental techniques advanced and the results helped clarified the phylogenetic relationships of the mammals.

Fig. 7.2 shows the simplified phylogenetic tree of the organisms based on nucleotide sequence comparison results.

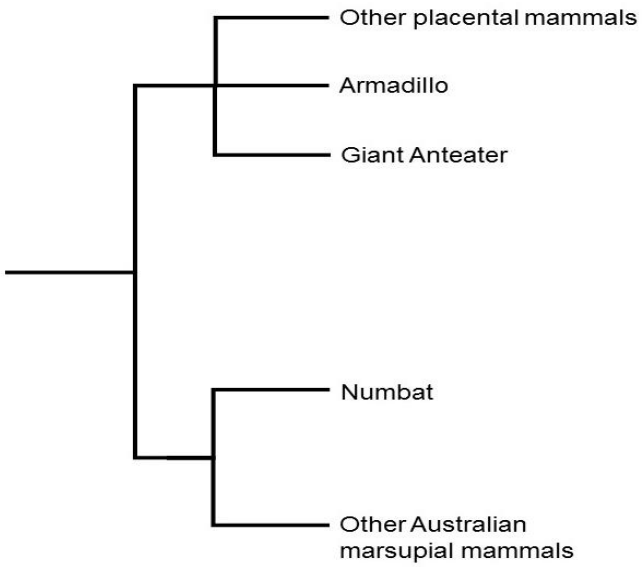


Fig. 7.2

(a) Explain the relationship between classification and phylogeny.

- Classification is organisation of species according to particular characteristics, may not take into consideration evolutionary relationship between the species;
- Phylogeny is organisation of species according to particular characteristics which takes into consideration evolutionary relationship between the species;

[2]

(b) Using the information above, explain why comparison of morphological structures led to the incorrect conclusion about the phylogenetic relationships of the three mammals.

- Structures were **analogous structures** arising from **convergent evolution**;
- All are subjected to **similar selection pressures**, e.g. same type of food (insects);
- Similar **structures** were **inherited** from **different ancestors** but selected for;
- E.g. of selective advantage: strong digging limbs to dig for insects / long tongue probe into insect nest;

[4]

(c) State **one** reason why the 18s rRNA gene was chosen to compare DNA sequences between organisms.

- 18s rRNA gene is **ubiquitous** / will be present in all organisms which serves as a good basis of comparison between organisms;
- **Essential gene** which changes very **slowly,** useful for estimating time of divergence that occurred [1]

long time ago;
- accumulates mutations at a constant rate and therefore can be used to calibrate a molecular clock for the estimation of time of divergence between species;

[max 1m]

Fig. 7.3 shows the geographical distribution of the various mammals.

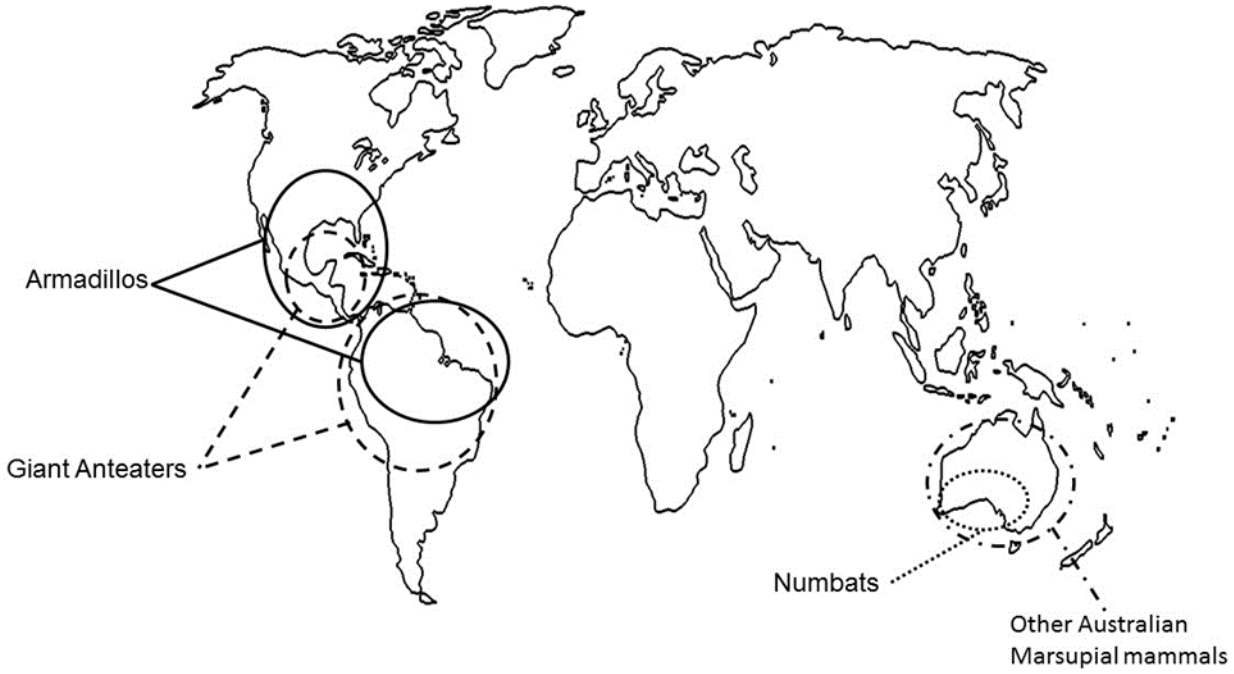


Fig. 7.3

(d) Using the information above, explain how biogeography supports the phylogenetic relationships constructed from DNA sequence comparison.

- Numbats are **more closely located** to other Australian marsupial mammals than to giant anteaters and armadillos / giant anteaters and armadillos are **more closely located**;
- Supports the phylogenetic relationship that numbats are **more closely related** to other Australian marsupial mammals than to giant anteaters and armadillos / giant anteaters and armadillos are **more closely related** / diverge from a **more recent** common ancestor;

[2]

[Total: 9]

8 Epidermal growth factor receptors (EGFR), which belong to the ErbB family of receptor tyrosine kinases, have been found to be overexpressed in many cancers, such as glioblastoma, colorectal and breast cancers.

Fig. 8.1 shows the EGFR signalling pathway.

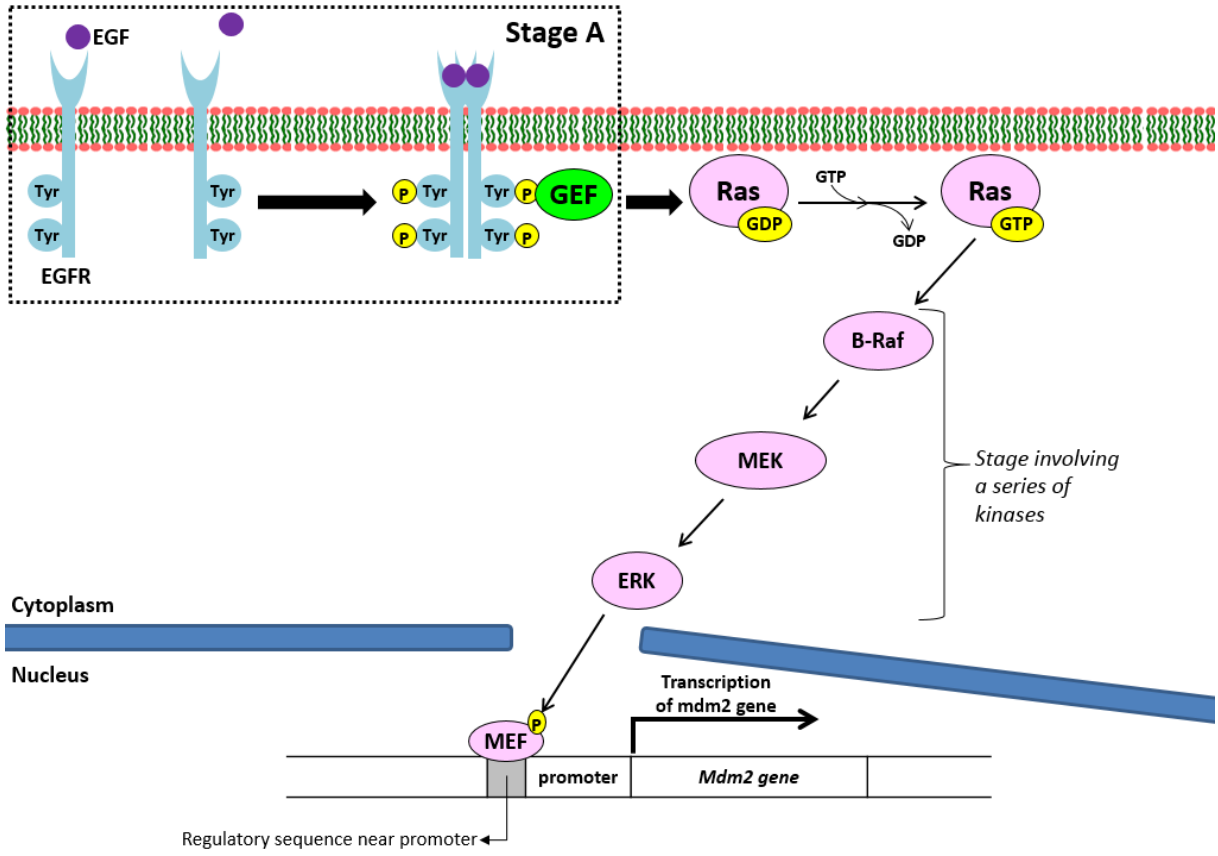


Fig. 8.1

Legend:

EGF	Epidermal growth factor
P	Phosphate group
GEF	Guanine nucleotide exchange factor that binds to and activates Ras
B-Raf, MEK, ERK	Kinases
MEF	A specific transcription factor that binds near the promoter

With reference to Fig. 8.1,

(a) Describe the events occurring at stage A.

- Epidermal growth factor (EGF) binds to **extracellular ligand-binding site** of epidermal growth factor receptor (EGFR) via complementary shape;
- leads to **dimerisation** of EGFR subunits occur/EGFR subunits aggregate to **form dimer**, causing the tyrosine kinase region on each EGFR subunit to be (exposed and) **activated**;
- **Autophosphorylation** occurs, each activated tyrosine kinase region **cross-phosphorylates** the other receptor at the tyrosine residues on their cytoplasmic/intracellular domain;
- (GEF binds to phosphorylated tyrosine kinase residues of fully-activated EGFR and) GEF is **activated** by phosphorylation;

[4]

(b) **(i)** Suggest how a mutation in Ras GTPase that causes GTP to be permanently bound results in the overexpression of mdm2.

- Mutation of (intrinsic) GTPase of Ras → GTP bound to Ras cannot be hydrolysed to GDP (→ Ras remains/always active/hyperactive);
- Kinase B-Raf is **always activated** by Ras, and kinases MEK and ERK are always phosphorylated and active/resulting in **continuous** trigger of **phosphorylation cascade**;
- (Specific) transcription factor MEF is always phosphorylated and thus is able to bind to the proximal control element (via complementary shape)
- accelerating and stabilising formation of transcription initiation complex and hence a high rate of transcription of mdm2;

[Any 3] [3]

(ii) Mdm2 is an enzyme which catalyses the addition of ubiquitin to p53. Explain how high levels of mdm2 enzyme may lead to increased chances of cancerous growth.

- Ubiquitinated p53 degraded/hydrolysed/broken down (by proteasome into short peptides);
- Absence of p53 (transcription factor binding to DNA/control elements) to **trigger transcription of genes** that code for proteins involved in cell cycle arrest/DNA repair/apoptosis;
- (Fail to inhibit the cell cycle /no DNA repair mechanism / allow evasion of mutated cells from apoptosis → accumulation of mutations in other proto-oncogene/ tumour suppressor genes to occur) → uncontrolled cell division.

[3]

[Total: 10]

Section B

Answer **EITHER 9 or 10.**

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

9 (a) Explain how fluidity of biological membranes can be maintained and the importance of fluidity to membrane function. [8]

How fluidity is maintained (max 4)

- Definition of fluidity: phospholipids and proteins free to move laterally within membrane/ transversely (phospholipids only)
- Unsaturated hydrocarbon/ fatty acid tails / C=C in hydrocarbon tails have **kinks** which keep the phospholipid molecules in the membrane from **packing close together** (enhancing membrane fluidity) (Accept reverse argument)
- **Cholesterol** found in between phospholipids/ embedded in membrane prevents / disrupts close/ regular packing of phospholipids in the membrane at low temperature
- **Hydrophobic interactions** between cholesterol and phospholipid tails restrict phospholipid movement at high temperature
- Hence cholesterol preventing membrane from freezing at lower temperatures and membrane prevented from being overly fluid / integrity of the membrane is maintained at high temperature
- Membranes freeze at a lower temperature/ has more fluidity if it has a higher proportion of phospholipids with unsaturated hydrocarbon tails and cholesterol (accept converse) reject unsaturated phospholipids
- Accept longer length of saturated fatty acid chains ensures more hydrophobic interactions between them → membrane less fluid

Importance of fluidity to membrane function (max 4) :

- ref. to need for **invagination / pinching in** of the cell surface membrane during cytokinesis
- ref. to need for **invagination / pinching in** of the cell surface membrane during endocytosis/ pinocytosis
- ref to need forformation of **pseudopodia** in cell surface membrane to engulf substances phagocytosis
- ref. to **budding/ pinching off vesicles** for the
  - transport / trafficking of proteins from rough ER to Golgi apparatus
  - from *trans* face of the Golgi apparatus during protein sorting to outside of the cell / / other membrane-bound organelles

- ref. to **fusion of vesicles membrane**
  - from endoplasmic reticulum / containing proteins to (cis-face)Golgi apparatus for protein modification;
  - with cell surface membrane to release secretory molecules from the cell / exocytosis;
  - fusion of endocytotic vesicles with lysosomes for digestion

- ref. to membrane fluidity allowing **movement of protein molecules embedded** on the cell surface membrane for dimerisation of receptors;

- ref. diffusion of small or non-polar molecules through the **gaps/transient pores** (between the phospholipids) in membrane, e.g. water / oxygen / carbon dioxide

- ref. to fluidity important for transmembrane transport **proteins changing conformation,** such as sodium-potassium pump / ligand-gated sodium ion channel / voltage-gated sodium ion channel (at least one named example);

- accept fluidity required for **embedment of protein molecules** such as ETC in thylakoid membrane / channel proteins on cell surface membrane for transport.

(b) Plant cells have a cellulose cell wall outside the cell surface membrane. Explain how the structure of cellulose is related to its function. [7]

- Each cellulose **chain/molecule** is made up of **large number** of **β-glucose** monomers
- giving a **long/ large** molecule which is **insoluble** in water
- **Alternate/ successive/neighboring** glucose monomers are being **inverted/rotated 180°** relative to one another to allow the formation of **β(1, 4) glycosidic bonds**,
- resulting in a **straight / linear** cellulose chain.
- **Straight parallel chains with OH-groups projecting in all directions** from each chain, allowing large number of **hydrogen bonds** to **cross -links** neighboring chains.
- allowing **bundling of cellulose chains** into microfibrils, macrofibrils and fibres
- resulting in **high tensile strength**
- in plant cell wall, this prevents plant cells from bursting when placed in solutions of high water potential.
- Maintain the **shape** of the cell/protect cells from physical and mechanical injury
- Cellulose has **large intermolecular spaces between macrofibrils**
- allows the passage of water and solute molecules through the plant cell walls (fully permeable)

(c) Describe how photophosphorylation differs from oxidative phosphorylation. [5]

Features	Oxidative phosphorylation	Photophosphorylation
Location	inner mitochondrial membrane	thylakoid membrane of chloroplast
Functions in the presence of	oxygen	light
Source of energy	(from oxidation of) glucose	light

No. of electron transport chain	one	two
Electron flow	linear - one-way	linear or cyclic
Final electron acceptor	oxygen	NADP (non-cyclic) P700 (cyclic)
Involvement of water	water produced	photolysis of water
Establishment of proton gradient	protons pumped outwards from matrix across inner mitochondrial membrane into intermembrane space	protons pumped inwards from stroma across thylakoid membrane into thylakoid space
Products	ATP, water	ATP (cyclic) ATP, NADPH and oxygen (non-cyclic)

[Total: 20]

Or

10 **(a)** Distinguish between gene mutation and chromosome structural mutation. [4]

Gene mutation	Chromosomal mutation
Change in structure of DNA or nucleotide / DNA sequence of a gene / a single locus on a chromosome	Change in chromosome structure / DNA / nucleotide sequence of gene (mostly) unchanged
Caused by deletion, insertion, substitution or inversion of one / several bases / nucleotides	Deletion, inversion, translocation or duplication of chromosomal fragments / several gene loci
Give rise to new alleles	Rearrangement of loci of genes / alleles / reshuffling / recombination / new combination of alleles
More frequent than chromosomal mutations because genes outnumber chromosomes by several thousand to one	Less frequent
Play more important role in evolution than chromosomal mutations because new alleles increases gene pool for natural selection to operate	Play a less important role in evolution than gene mutations because chromosomal mutations involve only reshuffling of alleles that already exist in gene pool.

(b) Describe how the most common CFTR gene mutation affects function of the protein and explain why other mutations vary in the extent to which they affect protein function. [8]

How the most common CFTR gene mutation affects function of protein

- **Deletion** of 3 bases **GAA** from CFTR gene on **chromosome 7**
- Net effect: results in **loss** of amino acid **phenylalanine** (position 508) in the polypeptide chain;
- Altering / affecting **R-group interactions** of protein→ **tertiary structure** of CFTR changed
- Mutant CFTR cannot allow chloride ions to diffuse out of the cells / degraded therefore cannot (serve as channel protein to) allow diffusion of chloride ions out of the cell;

Why other mutations vary in the extent to which they affect protein function (max 5)

Non-function proteins

- **Base addition / deletion** (not in multiple of threes) results in **frameshift mutation**
- All nucleotides downstream of mutation will be improperly wronged into codons
  Accept frameshift mutation leading to nonsense mutation
- Drastic change in tertiary structure→ non-functional proteins

- **Base substitution/ addition / deletion** resulting in **nonsense mutation**
- resulting in codon coding for amino acid changing to **stop codon** → translation terminated
- resulting in **truncated protein** → non-functional proteins

Little effect / some change in function

- **Base substitution/ addition / deletion** results in **missense mutation**

Either

- Codon encode for a **different amino acid** of **different R-group property** as original amino acid or amino acid change occur at essential region
- **change** in **tertiary structure** of CFTR protein→ less functional CFTR

OR

- Codon encode for a **different amino acid** of **similar R-group property** as original amino acid or Amino acid changed at a **non-essential region** of the protein
- **Little/small change** in **tertiary structure** of CFTR protein → little change/ small effect in function

No change in function

- **Base substitution** on the **wobble base** of a codon results in **silent** mutation
- will lead to altered codon coding for the **same amino acid**
- **Tertiary structure** of CFTR protein not changed, function not changed

OR

- Mutation that occurs in CFTR gene occurs in **non-coding introns**
- Does not change the DNA sequence that is eventually expressed / mRNA sequence that is eventually translated
- No change in tertiary structure → function not changed

(c) With reference to mutation of named genes, outline the development of cancer. [8]

Max 6 for outlining the development of cancer.

- Cancer involves **uncontrolled cell division**;
- Mutation first occurs to **single cell**, leading to **abnormal proliferation of single cell** into (clonally derived / **genetically identical tumour cells;)**
- Normal cells are converted to cancer cells by **accumulation of several mutations**;
- **Daughter cells** of a cell bearing such mutations will **become dominant within tumour cell population;**
- **Gain of function mutations** of **proto-oncogenes**, converted to **oncogenes**;
- Proteins encoded in oncogenes **produced in excessive amounts / high expression of oncogenes** producing high levels of proteins or **Hyperactive proteins** may be produced (which are constitutively active or resistant to degradation)
- **Loss of function mutations** of **tumour suppressor genes**;
- **No functional/inactive tumour suppressor proteins**
- **Deactivation** of genes involved in **cell-to-cell adhesion**, resulting in loss of anchorage dependence / tissue invasion and **metastasis**;
- **Activation** of genes involved in **angiogenesis,** resulting in formation of blood vessels that provide cancer cells with nutrients and oxygen;

Max 2 for named genes.

- E.g. of proto-oncogene: mutataion of Ras gene, involved in **signalling pathway / signal transduction** that results in **stimulation of cell cycle → cell division.**
- E.g. of proto-oncogene: mutation of c-myc, **transcription factor** that regulates expression of genes involved in cell division;
- E.g. of tumour suppressor gene: mutation of p53 gene, which encodes for a **transcription factor** which stimulation transcription of genes involved in **cell cycle arrest**, **DNA repair** and **initiation of apoptosis** when there is **DNA damage**.
- Activation of **telomerase gene**, allowing telomerase to **maintain length of telomeres** → Preventing the cell from entering **replicative senescence/ divide unlimited number of times**;

[Total:20]

HIGHER 2

CANDIDATE NAME

PDG

PDG INDEX NUMBER

BIOLOGY 9648/03

Applications Paper and Planning Question Paper 3

20 September 2016 Tuesday

2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your name and PD group on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graph or rough working.
Do not use paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

All working for numerical answers must be shown.
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.

Calculators may be used

For Examiner's Use	
1	
2	
3	
4	
5	
Total	72

This document consists of **14** printed pages.

Answer **all** the questions.

1

(a) State **three** differences between a genomic DNA library and a cDNA library.

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…… [3]

Many countries are trying to increase their production of bioethanol in order to fuel a range of vehicles. Most bioethanol is produced from the cellulose cell walls of plants. The cellulose synthase gene have been identified and sequenced.

In initial experiments to increase cellulose production, DNA containing the cellulose synthase gene were inserted into plasmid vectors and subsequently introduced into bacteria cells through transformation. Fig. 1.1 is a diagram of the pUC 19 plasmid map used in the experiments.

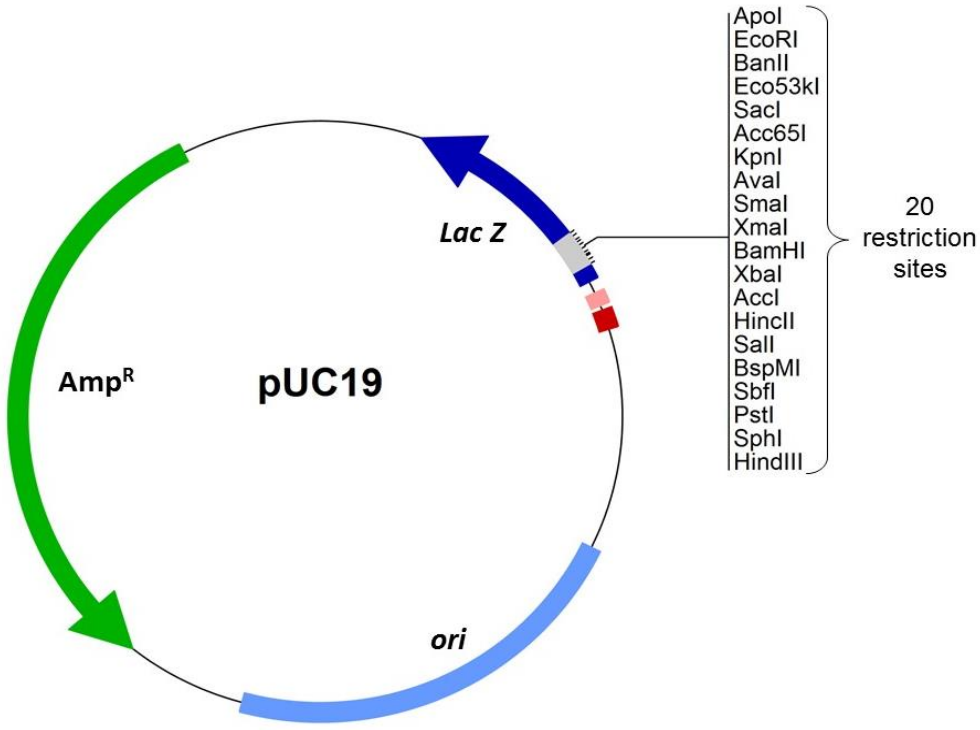

Fig. 1.1

(b) **(i)** State and explain **two** visible properties of the pUC 19 plasmid that allow it to be used as a DNA cloning vector.

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…… [4]

(ii) Explain how successfully transformed bacterial cells containing recombinant plasmids can be selected for.

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(c) The cellulose synthase gene obtained from a plant species has approximately 5000 base pairs (bp). However the length of the gene sequence inserted into bacterial cells was shortened to only approximately 3300bp.

Explain why the length of the gene inserted into bacterial cells was shortened.

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…… [2]

(d) Using bacteriophages to introduce the cellulose synthase gene into bacterial cells was thought to improve transformation efficiency. However, a lower than expected proportion of bacterial cells was found to contain the gene after bacterial transduction using bacteriophages.

Explain why using bacteriophages to introduce DNA into bacterial cells was not successful.

……

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…… [2]

[Total: 14]

2 Antithrombin (AT) is a protein required for the prevention of blood clots in the blood plasma. Patients with hereditary AT deficiency requires AT injection before they undergo any surgery to prevent the formation of blood clot in the veins.

ATryn, a recombinant AT (rAT) is the first medicine produced using genetically engineered animals. rAT is made from the mammary glands of goats that have been genetically modified (GM). The DNA construct introduced into goats comprises of the cDNA of human AT and regulatory elements of the goat beta casein gene, an essential milk protein produced in goat mammary glands. Microinjection was used to insert the DNA construct into a goat zygote which is then transplanted into the uterus of a female goat. GM progeny goat will produce large amounts of AT into its milk which are then isolated and purified.

(a) Explain why the DNA construct used is a recombinant DNA.

……

…… [1]

(b) Suggest why the DNA construct used must include regulatory elements of the goat beta casein gene.

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…… [2]

The effectiveness of rAT can be measured in terms of percentage activity compared with normal human blood plasma AT (hpAT). rAT was injected into four patients with AT deficiency (AT activity ≤ 60%) and their AT activities were measured every two days after the injection. Fig. 2.1 shows the results of the study.

Table 2.1 shows a comparison between the structure of rAT and hpAT.

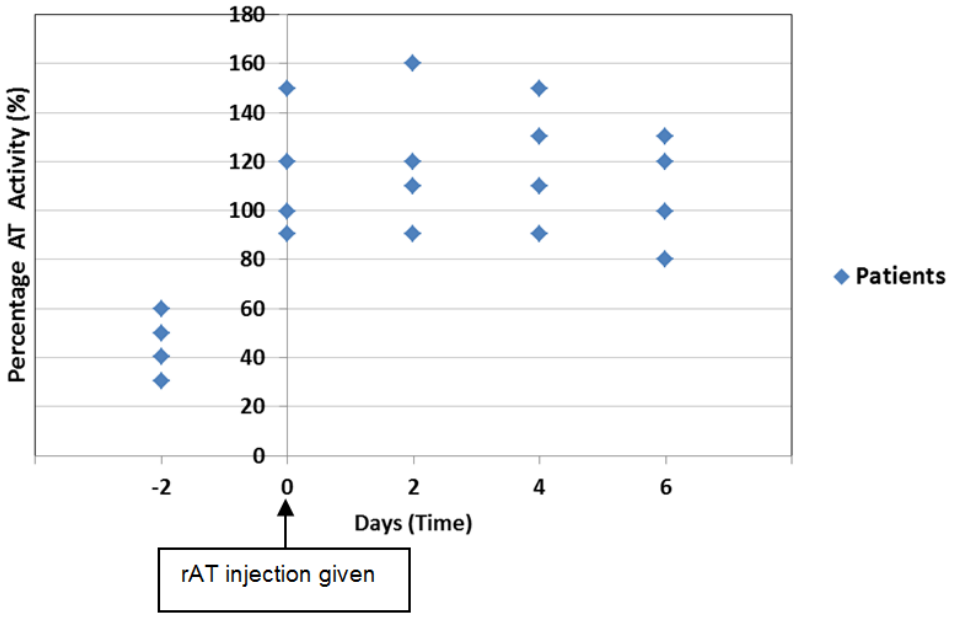

Fig. 2.1

	rAT	hpAT
Primary structure	Single chain of 432 amino acids	Single chain of 432 amino acids
Glycosylation	Glycosylation at 3 asparagine amino acid residues (Asn 96, 155, 192)	Glycosylation at 4 asparagine amino acid residues (Asn 96, 135, 155, 192)
Analysis of carbohydrate chains on the protein	Mainly N-acetyl neuraminic acid	Mainly N-glycolyl neuraminic acid

Table 2.1

(c) Using the information above,

(i) describe the effect of injecting rAT on the patients .

……

…….. [1]

(ii) describe a difference between the structures of rAT and hpAT and the effect of the difference on the patients.

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……... [2]

(iii) suggest what resulted in the differences in the structures of rAT and hpAT.

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…….. [1]

Polymerase chain reaction (PCR) and gel electrophoresis can be used to distinguish between a DNA construct containing both cDNA of human AT and regulatory elements and one which contains only the regulatory elements.

Fig. 2.2 shows the DNA construct used in forming rAT.

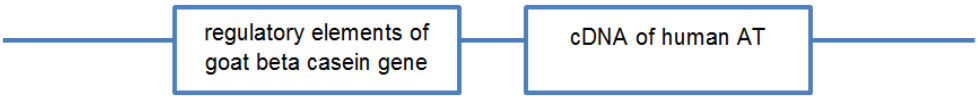

Fig. 2.2

(d) **(i)** On Fig. 2.2, indicate with ***5'*** ⟶ ***3'*** where the primers will bind in the PCR reaction.

5' and ***3'*** represents the 5' and 3' ends of the primers respectively. [1]

(ii) Explain how gel electrophoresis can be used to distinguish between a DNA construct with both cDNA of human AT and regulatory elements and one which contains only regulatory elements.

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…… [2]

(e) A new project, GenomeAsia 100K, aims to sequence the genomes of 100,000 Asians across Asia to tailor-made drugs for Asians, an approach known as precision medicine.

(i) State **one** benefit of precision medicine.

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…… [1]

(ii) While there are many benefits of precision medicine, some people are apprehensive that the project will unravel genetic differences in ethnicity "making some people a lesser man and others a better man"

Explain why the project may result in the ethical issue of "making some people a lesser man and others a better man".

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…… [2]

[Total: 13]

3 In 2006, scientists Takahashi and Yamanaka stimulated mouse tail-tip cells, which are fully differentiated cells, to change back into stem cells in tissue culture. Such stem cells obtained from the de-differentiation of somatic cells are known as induced pluripotent stem cells (iPS cells). In the last decade, iPS cells have been generated from humans cells isolated from different tissues by introduction of various growth factors that affects the expression of many genes, such as the gene coding for human telomerase reverse transcriptase (hTERT).

(a) Explain how the expression of hTERT may help the cells regain stem cell properties.

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…… [3]

(b) 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.

Explain why X-linked SCID can be treated by gene therapy.

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…… [2]

The ability to generate iPS cells that have characteristics that are similar to embryonic stem cells has provided a promising alternative to the use of haematopoietic stem cells for gene therapy to treat X-linked SCID. Fig 3.1 shows a possible process of using iPS cells for gene therapy.

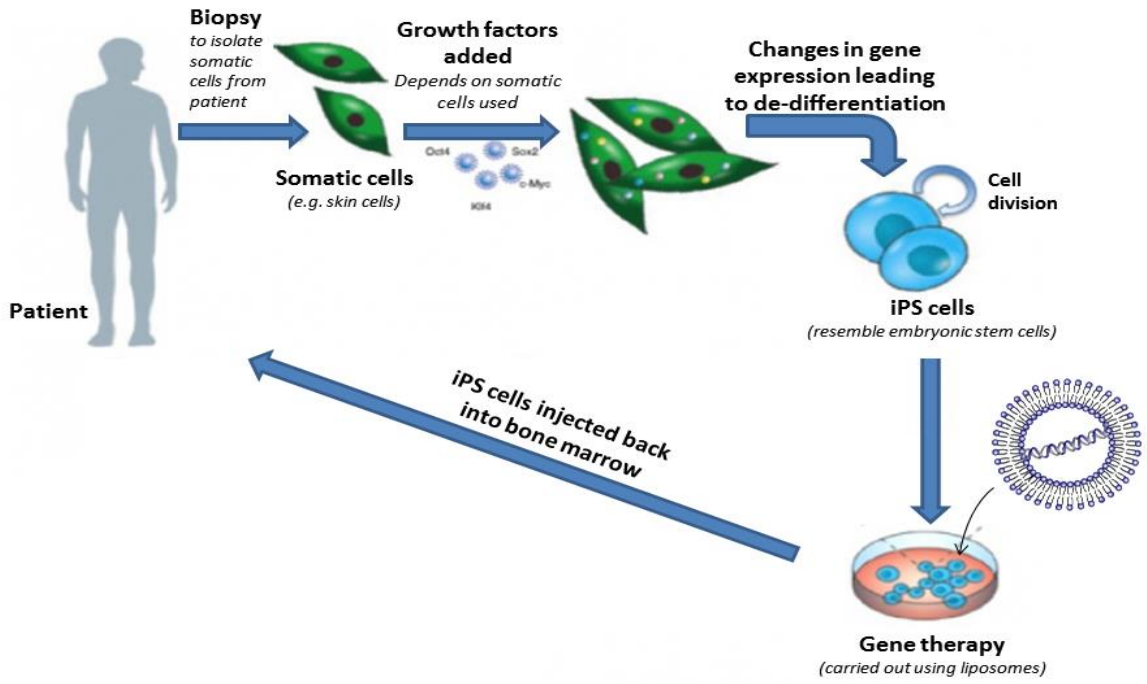

Fig. 3.1

(c) Describe and explain **two** factors that prevent this method of gene therapy for X-linked SCID from becoming an effective treatment.

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…… [4]

(d) Although the use of retroviral vectors for gene therapy has been highly successful in treating SCID, many patients who received treatment also developed immune responses against the virus and leukaemia.

Suggest another challenge of using viral vectors in the process shown in Fig. 3.1.

……

…… [1]

(e) **(i)** Discuss the arguments for and against the use of human embryonic stem cells for therapy.

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…… [2]

(ii) Explain whether you agree or disagree that use of iPS cells resolve the issues discussed above.

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…… [1]

[Total: 13]

4 Planning question

Diffusion of molecules can be observed using the Visking tubing.

The Visking (dialysis) tubing is a selectively permeable membrane that allows small molecules to diffuse through. The tubing can be tightly knotted at one end and a solution can be contained within the tubing. The filled tubing can then be placed in distilled water for the diffusion of the solute molecules out of the tubing into the distilled water. Fig. 4.1 shows the Visking tubing set-up as described.

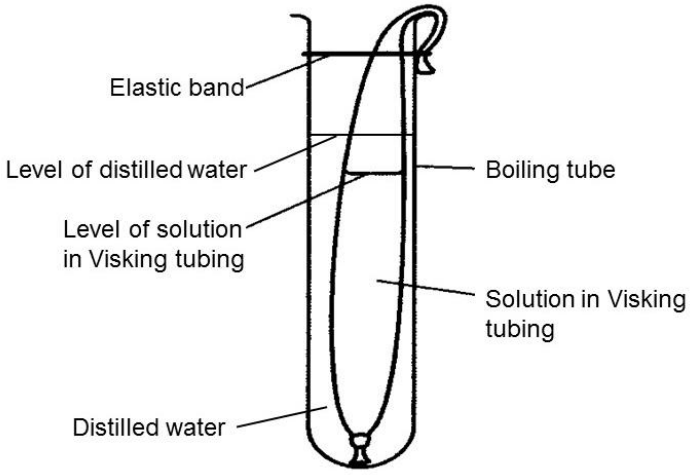

Fig. 4.1

The presence of solutes in distilled water surrounding the tubing can then be tested using quantitative / qualitative analysis.

Presence of glucose in solution can be tested using Benedict's test. The concentration of glucose in a solution can be estimated using a colour standard made with solutions with known glucose concentrations.

Using this information and your own knowledge, design an experiment to investigate the effect of temperature on the diffusion of glucose.

You must use:

- 100 cm^3 of 10g / 100 cm^3 glucose solution,
- 10 cm^3 of 5g / 100 cm^3 glucose solution for colour standard,
- Distilled water,
- Thermostatically-controlled water bath and thermometer,
- Benedict's solution,
- Boiling tubes,
- Stopwatch.

You may select from the following apparatus and chemicals:

- Normal laboratory glassware, e.g. test-tubes, beakers, measuring cylinders, graduated pipettes, glass rods etc.,
- Syringes.

Your plan should:

- Have a clear and helpful structure such that the method you use is able to be repeated by anyone reading it,
- identify the independent and dependent variables,
- describe the method with the scientific reasoning used to decide the method so that the results are as accurate and reliable as possible,
- show how you will record your results and the proposed layout of results tables and graphs,
- use the correct technical and scientific terms,
- include reference to safety measures to minimise any risks 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)** Outline nucleic acid hybridisation and explain how it can be used in the detection of DNA sequences. [9]

(b) Explain the advantages and disadvantages of tissue culture over more traditional methods of cloning plants, such as taking cuttings or grafting. [5]

(c) Describe the goals of the Human Genome Project, and with a named example, explain how the findings of the HGP may benefit the genetic modification of crops. [6]

[Total:20]

H2 ANDERSON JUNIOR COLLEGE
HIGHER 2

CANDIDATE NAME

PDG

PDG INDEX NUMBER

BIOLOGY 9648/03

Applications Paper and Planning Question
Paper 3

20 September 2016
Tuesday

2 hours

Additional Materials: Answer Paper

READ THESE INSTRUCTIONS FIRST

Write your name and PD group on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graph or rough working.
Do not use paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

All working for numerical answers must be shown.
At the end of the examination, fasten all your work securely together.
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Calculators may be used

For Examiner's Use	
1	
2	
3	
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Total	72

This document consists of **13** printed pages and **1** blank page.

Answer **all** the questions.

1

(a) State **three** differences between a genomic DNA library and a cDNA library.

Genomic Library	cDNA Library
A collection of clones containing fragments of genomic DNA representing the entire genome of a species;	A collection of clones containing cDNA copies of all the mRNAs (expressed genes) in a cell type at a particular time;
Library size is larger;	Library size is smaller and more compact;
A Genomic library is derived from the DNA of the entire genome of an organism;	A cDNA library is derived from the mRNA isolated from a cell of the organism;
DNA sequences contained include exons, introns and regulatory sequences;	cDNA sequences contain only exons / lack intron and regulatory sequences;
Gene sequences are not intact because they are cut by restriction enzymes at restriction sites;	Gene sequences are intact because cDNA are reverse-transcribed from mRNA;
More difficult to find desired gene sequence;	Easier to find desired gene sequence;
Vectors include bacteriophage lambda, cosmid, bacteriophage P1, bacterial artificial chromosome and yeast artificial chromosome;	Vectors used include plasmid or bacteriophage lambda;

[3]

Many countries are trying to increase their production of bioethanol in order to fuel a range of vehicles. Most bioethanol is produced from the cellulose cell walls of plants. The cellulose synthase gene have been identified and sequenced.

In initial experiments to increase cellulose production, DNA containing the cellulose synthase gene were inserted into plasmid vectors and subsequently introduced into bacteria cells through transformation. Fig. 1.1 is a diagram of the pUC 19 plasmid map used in the experiments.

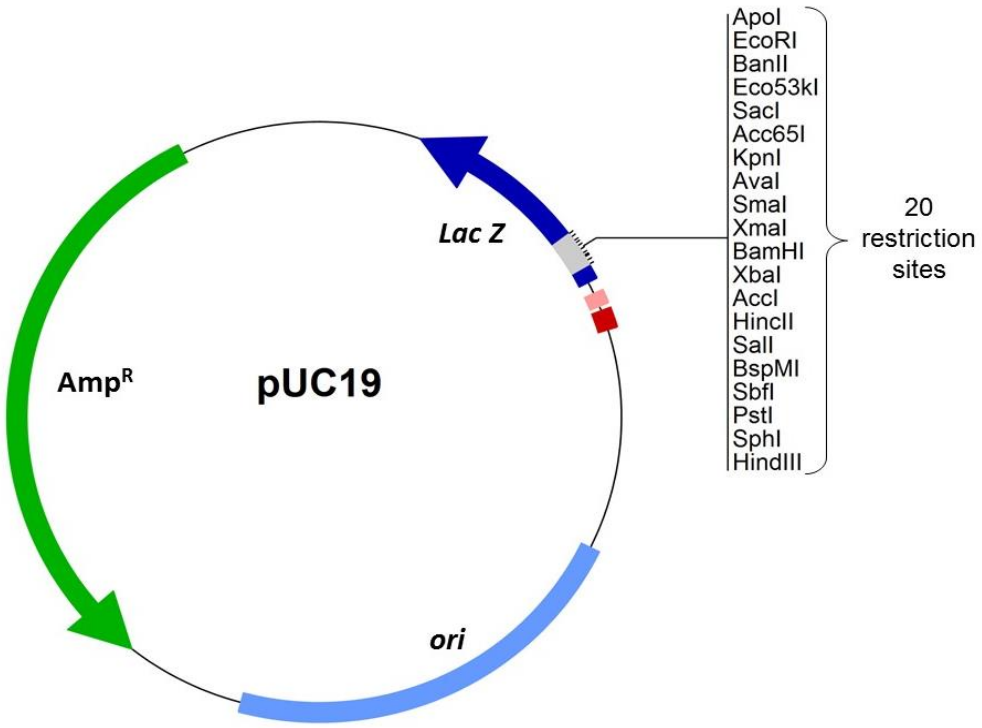

Fig. 1.1

(b) **(i)** State and explain **two** visible properties of the pUC 19 plasmid that allow it to be used as a DNA cloning vector.

- Contain **two selectable marker genes** (need to cite amp and LacZ);
- Expression of genes confer well-defined phenotype on the host cell, allowing for selection of transformed cells which have taken up vector or recombinant DNA molecules;

- contains **multiple cloning site / polylinker**;
- allow **20 different restriction enzymes** to cleave the plasmid DNA to insert some / many genes;

- have **origin of replication**;
- plasmid can be **replicated independently** of bacteria chromosome, to give **multiple copies** of the plasmid and gene of interest within **one bacterium**, ensures gene of interest can be passed onto daughter cells;

[max 4m] [4]

(ii) Explain how successfully transformed bacterial cells containing recombinant plasmids can be selected for.

- Bacterial cells grown on **medium** containing **ampicillin** and **X-gal**;
- Bacterial cells that **survive** and **form white colonies** are successfully transformed cells containing recombinant plasmids;
- Bacterial cells that survive **contain ampicillin gene** which is **transcribed and translated** to produce **ampicillin resistance proteins**;
- Cells that contain recombinant plasmids will have where there is **insertional inactivation of lacZ gene**, **no functional β-galactosidase enzymes** produced through transcription and translation and **X-gal not hydrolysed** to form blue products;

[max 3m] [3]

(c) The cellulose synthase gene obtained from a plant species has approximately 5000 base pairs (bp). However the length of the gene sequence inserted into bacterial cells was shortened to only approximately 3300bp.

Explain why the length of the gene inserted into bacterial cells was shortened.

- **Introns** from the gene sequence removed / gene **only** contain **exons**;
- **Lack of splicing mechanism** in bacterial cells;
- Translation of mRNA would produce a polypeptide chain with correct amino acid sequence;

[max 2m] [2]

(d) Using bacteriophages to introduce the cellulose synthase gene into bacterial cells was thought to improve transformation efficiency. However, a lower than expected proportion of bacterial cells was found to contain the gene after bacterial transduction using bacteriophages.

Explain why using bacteriophages to introduce DNA into bacterial cells was not successful.

- Bacterial cells have **restriction enzymes / endonucleases**;
- **Cleave / hydrolyse the DNA** containing the gene of interest to **protect bacterial cells from viral / bacteriophage infections**; [2]

[Total: 14]

2 Antithrombin (AT) is a protein required for the prevention of blood clots in the blood plasma. Patients with hereditary AT deficiency requires AT injection before they undergo any surgery to prevent the formation of blood clot in the veins.

ATryn, a recombinant AT (rAT) is the first medicine produced using genetically engineered animals. rAT is made from the mammary glands of goats that have been genetically modified (GM). The DNA construct introduced into goats comprises of the cDNA of human AT and regulatory elements of the goat beta casein gene, an essential milk protein produced in goat mammary glands. Microinjection was used to insert the DNA construct into a goat zygote which is then transplanted into the uterus of a female goat. GM progeny goat will produce large amounts of AT into its milk which are then isolated and purified.

(a) Explain why the DNA construct used is a recombinant DNA.

- Comprises of DNA from **2 different species / sources:** human and goat [1]

(b) Suggest why the DNA construct used must include regulatory elements of the goat beta casein gene.

[2]

- Regulatory elements of the goat casein gene can be bounded by transcription factors present in (cells of) mammary gland
- To allow expression/ transcription and translation of the human AT gene only in the goat mammary gland

The effectiveness of rAT can be measured in terms of percentage activity compared with normal human blood plasma AT (hpAT). rAT was injected into four patients with AT deficiency (AT activity ≤ 60%) and their AT activities were measured every two days after the injection. Fig. 2.1 shows the results of the study.

Table 2.1 shows a comparison between the structure of rAT and hpAT.

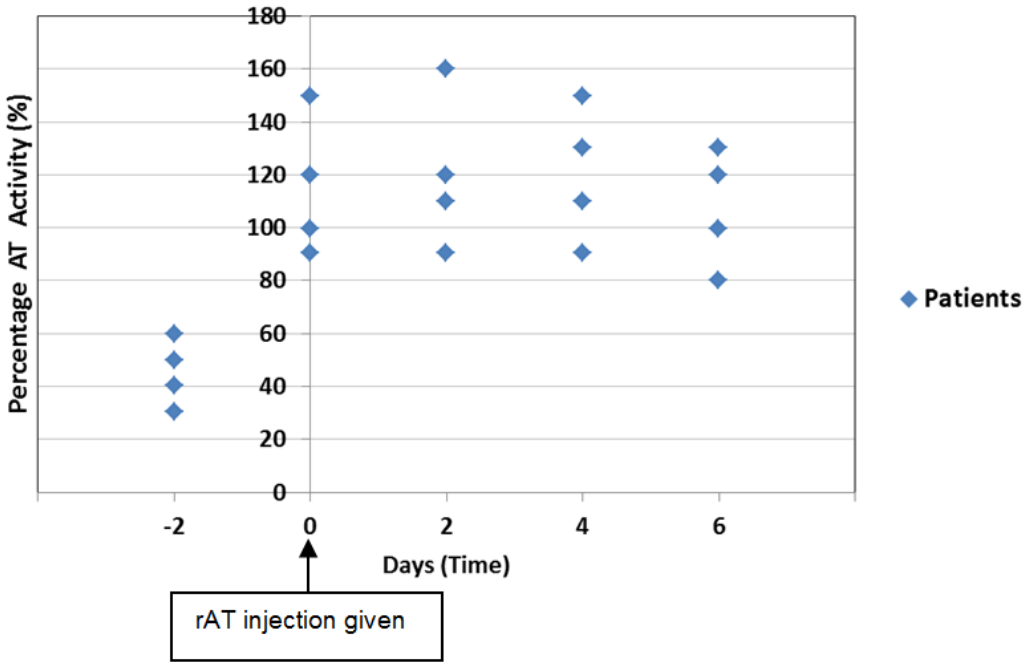

Fig. 2.1

	rAT	hpAT
Primary structure	Single chain of 432 amino acids	Single chain of 432 amino acids
Glycosylation	Glycosylation at 3 asparagine amino acid residues (Asn 96, 155, 192)	Glycosylation at 4 asparagine amino acid residues (Asn 96, 135, 155, 192)
Analysis of carbohydrate chains on the protein	Mainly N-acetyl neuraminic acid	Mainly N-glycolyl neuraminic acid

Table 2.1

(c) Using the information above,

(i) describe the effect of injecting rAT on the patients .

- AT activity in all patients increased from a range of 30-60% AT activity before treatment to 80-160% AT after treatment

[1]

(ii) describe a difference between the structures of rAT and hpAT and the effect of the difference on the patients.

Describe the difference (any 1)

- Glycosylation at 4 asparagine amino acid residues while rAT had glycosylation at 3 asparagine amino acid residues/ Asn 135 in rAT is not glycosylated

- rAT has mainly N-acetyl neuraminic acid attached while hpAT has mainly N-glycolyl-neuraminic acid

Effects on patients

rAT has different tertiary structure from hpAT → Patients have AT activity (up to 160% which is 60%) more than normal human AT [2]

(iii) suggest what resulted in the differences in the structures of rAT and hpAT.

- different enzymes carrying out glycosylation in goat and human
- N-glycolyl neuraminic acid not synthesised / found in goat cells and vice versa
- AVP

[1]

Polymerase chain reaction (PCR) and gel electrophoresis can be used to distinguish between a DNA construct containing both cDNA of human AT and regulatory elements and one which contains only the regulatory elements.

Fig. 2.2 shows the DNA construct used in forming rAT.

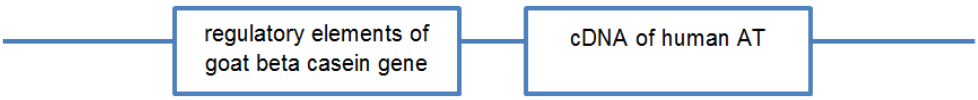

Fig. 2.2

(d) **(i)** On Fig. 2.2, indicate with ***5'*** ⟶ ***3'*** where the primers will bind in the PCR reaction.

5' and ***3'*** represents the 5' and 3' ends of the primers respectively. [1]

- 2 arrows either flanking the region containing both regulatory elements and cDNA or flanking/ on the cDNA of human AT

(ii) Explain how gel electrophoresis can be used to distinguish between a DNA construct with both cDNA of human AT and regulatory elements and one which contains only regulatory elements.

- gel electrophoresis to separate the PCR products by **size** under a **direct current**

- DNA containing AT and regulatory elements are bigger/larger, hence travel slower across the gel / DNA band appear nearer to the cathode *accept converse* [2]

OR
- A (1296 bp) band will be observed for DNA containing AT and promoter while no bands observed for DNA containing only regulatory elements

(e) A new project, GenomeAsia 100K, aims to sequence the genomes of 100,000 Asians across Asia to tailor-made drugs for Asians, an approach known as precision medicine.

(i) State **one** benefit of precision medicine.
- greater drug efficacy
- prevents dangerous side effects
- AVP [1]

(ii) While there are many benefits of precision medicine, some people are apprehensive that the project will unravel genetic differences in ethnicity "making some people a lesser man and others a better man"

Explain why the project may result in the ethical issue of "making some people a lesser man and others a better man".

- Discrimination/labelling/stereotyping of certain ethnic group based on **genetic profile/ genome**
- Idea of genetic influence on behaviour, character traits, susceptibility to diseases e.g. People will be tempted to draw connections between genes and propensity to violence, intelligence, creativity etc [2]

[Total: 13]

3 In 2006, scientists Takahashi and Yamanaka stimulated mouse tail-tip cells, which are fully differentiated cells, to change back into stem cells in tissue culture. Such stem cells obtained from the de-differentiation of somatic cells are known as induced pluripotent stem cells (iPS cells). In the last decade, iPS cells have been generated from humans cells isolated from different tissues by introduction of various growth factors that affects the expression of many genes, such as the gene coding for human telomerase reverse transcriptase (hTERT).

(a) Explain how the expression of hTERT may help the cells regain stem cell properties.

- hTERT catalyses the formation of phosphodiester bonds between DNA nucleotides which are added to the 3' end of parental DNA strands (via complementary base pairing with telomerase RNA) during DNA replication;
- Increases length of telomeres/prevents telomeres from shortening → prevents telomeres from reaching critical length after few rounds of DNA replication;
- iPS cells are able to self-renew and divide by mitosis continuously/repeatedly (must have idea of many rounds of cell division);

[3]

(b) 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.

Explain why X-linked SCID can be treated by gene therapy.

- X-linked-SCID is a single gene disorder/idea of only one gene mutated OR sequence of the IL2RG gene is well characterised
- Introduction/ insertion of only one normal interleukin 2 receptor gamma (IL2RG) allele into target cells is sufficient to mask the phenotypic effect of recessive mutation;

OR

- Normal IL2RG dominant allele introduced into the targeted blood stem cell codes for sufficient common gamma chain of (several) cytokine receptors (via transcription and translation of the normal IL2RG allele); [2]

The ability to generate iPS cells that have characteristics that are similar to embryonic stem cells has provided a promising alternative to the use of haematopoietic stem cells for gene therapy to treat X-linked SCID. Fig 3.1 shows a possible process of using iPS cells for gene therapy.

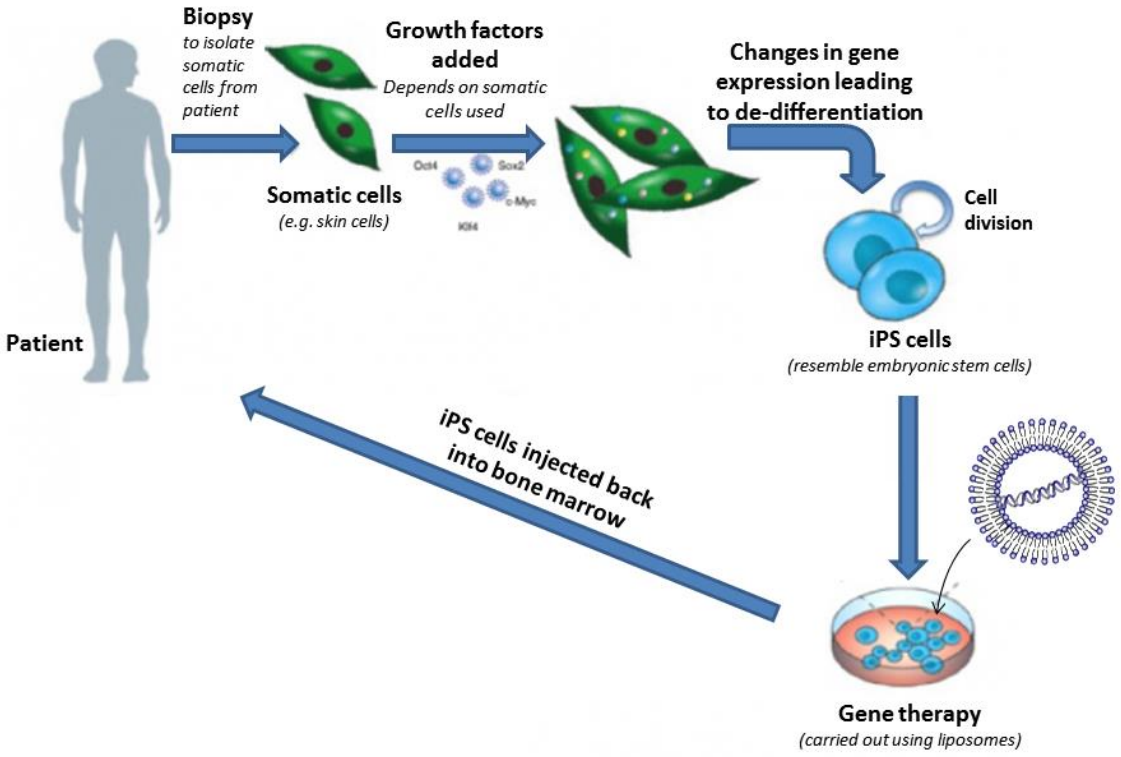

Fig. 3.1

(c) Describe and explain **two** factors that prevent this method of gene therapy for X-linked SCID from becoming an effective treatment.

Difficulties in de-differentiating somatic cells to iPS cells

- Difficult to ensure that specialised/completely differentiated somatic cells become pluripotent (completely) as it is difficult to determine the growth factors to be used;
- Treatment may not be effective as the iPS cells obtained are unable to differentiate into blood stem cells in the bone marrow;

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; [4]

- this leads to transient expression of normal functional proteins and multiple treatments are required;
  N2011 Examiner's report: Candidates should take care not to suggest that genes die or do not live for very long. Also note that retroviral vectors may not be suitable for treatment of all genetic diseases as they may not be able to infect certain target cells

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;

(d) Although the use of retroviral vectors for gene therapy has been highly successful in treating SCID, many patients who received treatment also developed immune responses against the virus and leukaemia.

Suggest another challenge of using viral vectors in the process shown in Fig. 3.1.

- Difficult to find viral vectors which have surface glycoproteins that are complementary in shape/can bind to the cell surface receptors of the target iPS cells; [1]

(e) **(i)** Discuss the arguments for and against the use of human embryonic stem cells for therapy.

- 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.
- For use of ES cells
  - unclear whether ES cells are considered human life → (it does not have any interests to be protected) and thus should be used to benefit/treat/save patients with life-threatening diseases;
  - ES cells are pluripotent → able to differentiate into any other cell types of the 3 germ layer → potential to treat diseases where harvesting of adult stem cells are difficult; [2]

(ii) Explain whether you agree or disagree that use of iPS cells resolve the issues discussed above.

- 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;

OR

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

(Student must state a clear stand to gain mark) [1]

[Total: 13]

4 Planning question

Diffusion of molecules can be observed using the Visking tubing.

The Visking (dialysis) tubing is a selectively permeable membrane that allows small molecules to diffuse through. The tubing can be tightly knotted at one end and a solution can be contained within the tubing. The filled tubing can then be placed in distilled water for the diffusion of the solute molecules out of the tubing into the distilled water. Fig. 4.1 shows the Visking tubing set-up as described.

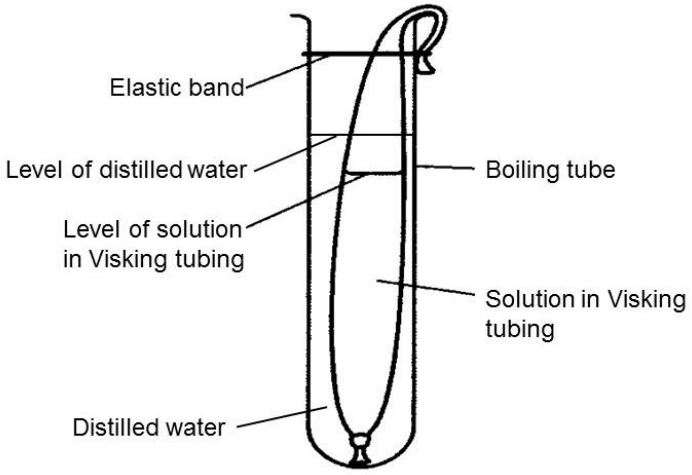

Fig. 4.1

The presence of solutes in distilled water surrounding the tubing can then be tested using quantitative / qualitative analysis.

Presence of glucose in solution can be tested using Benedict's test. The concentration of glucose in a solution can be estimated using a colour standard made with solutions with known glucose concentrations.

Using this information and your own knowledge, design an experiment to investigate the effect of temperature on the diffusion of glucose.

You must use:

- 100 cm^3 of 10g / 100 cm^3 glucose solution,
- 10 cm^3 of 5g / 100 cm^3 glucose solution for colour standard,
- Distilled water,
- Thermostatically-controlled water bath and thermometer,
- Benedict's solution,
- Boiling tubes,
- Stopwatch.

You may select from the following apparatus and chemicals:

- Normal laboratory glassware, e.g. test-tubes, beakers, measuring cylinders, graduated pipettes, glass rods etc.,
- Syringes.

Your plan should:

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- use the correct technical and scientific terms,
- include reference to safety measures to minimise any risks associated with the proposed experiment.

[Total: 12]

Theory of Explanation [0.5m each, 1m]

Effect of Temperature on diffusion of Glucose
- The higher the temperature, the higher the **kinetic energy** of glucose molecules;

Benedict's Test
- Producing brick red precipitate from reduction of copper (II) ions;

Hypothesis [0.5m each, 1m]
- The **higher the temperature**, the **faster the diffusion of glucose / more glucose diffuse** into the surrounding distilled water / out of the Visking tubing;
- The greater the concentration of glucose in distilled water, the **greater the amount of brick-red precipitate** produced in the reducing sugar test;

Step-by-step experimental procedure [0.5m each, max 5m]

Making of glucose standard solutions [0.5m each, max 1m]
- Using serial dilution / simple dilution, concentration stated 0.1 g – 5 g per 100 cm^3 (any reasonable range);
- Description of dilution process / drawing of dilution table;

Diffusion of glucose at different temperatures [0.5m each, max 2.5m]
- Tie one end of the Visking tubing;
- Use syringe to add 10 cm^3 of 10 g per 100 cm^3 glucose solution into Visking tubing (accept any reasonable volume of solution);
- Use syringe to add 20cm^3 of distilled water into a boiling tube (accept any reasonable volume of solution);
- Place the boiling tube into the **thermostatically controlled water bath** set at 30^oC;
- Time 1 minute using a stopwatch for **equilibration**;
- Measure the temperature of the water bath water using a **thermometer**;

- Place Visking tubing into the boiling tube and time for **2 minutes** using **stopwatch** (accept any fixed period of time);
- After 2 minutes, remove the boiling tube from the water bath and remove the Visking tubing from the boiling tube;
- Repeat the experiment at different temperatures, (Accept any temperature range from 30^{o}C to 100^{o}C, five stated temperatures required, reject any temperatures below 25^{o}C);
- Dependent variable: Rate of glucose diffusion;
- Independent variable: Temperature;

Reducing sugar test [0.5m each, max 1.5m]
- Add 2cm^3 of solution from one boiling tube and 1cm^3 of Benedict's solution into a test tube using 5cm^3 syringe;
- Place test tubes into a thermostatic water bath set at 90^{o}C / boiling water bath for 2 minutes (accept reasonable time);
- Repeat with the solutions from four boiling tubes and the glucose solutions of known concentration;
- **Compare** the **colour of the precipitates** from the solutions of the boiling tubes with the colour of the precipitates from the glucose solutions of known glucose concentration to **determine the glucose concentration of solutions from the boiling tubes**;

Reliability and Reproducibility [0.5m each, max 1m]
- Carry out 3 replicates at each diffusion temperature to obtain an average rate of glucose diffusion to ensure reliability of the experiment;
- Repeat the entire experiment twice to ensure the reproducibility of the results;

Control [0.5m each, max 1m]
- Repeat the entire experiment, replacing the solution in the Visking tubing with an **equal volume of distilled water**;
- No brick red precipitate produced from the solution;
- Presence of glucose in the distilled water in the boiling tube is due to the presence of glucose solution in the Visking tubing;

Results [0.5m each, max 2m]
- **Tabulation** of data with **headings and units** (temperature / ^{o}C, average glucose concentration in boiling tube solution in 2 minutes / g 100 cm^3);
- Processing of data, includes average rate of glucose diffusion (g 100cm^{-3}s^{-1});
- Graph showing trend of average glucose diffusion vs. temperature;
- Correct labeling of x and y-axis with units;

Risk assessment [0.5m each, max 1m]
- Risk: Benedict's solution is an irritant to skin and the eyes;
- Precaution: Wear gloves and goggles to avoid contact with skin and eyes respectively;

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)** Outline nucleic acid hybridisation and explain how it can be used in the detection of DNA sequences. [9]

- The formation of a double-stranded nucleic acid molecule by binding of one single stranded nucleic acid to another;
- Via **complementary base-pairing** / formation of hydrogen bonds between complementary bases;
- Possible hybrid nucleic acid molecules, two strands of DNA, two strands of RNA or DNA-RNA hybrid molecules;

[max 2m]

- **Southern blotting** is a method that uses nucleic acid hybridisation to detect specific DNA sequences;
- DNA fragments of different sizes separated by **gel electrophoresis**
- Double-stranded DNA are **denatured** into single strands by adding alkali to the gel;
- The denatured DNA is transferred to a piece of nitrocellulose membrane by **capillary action**;

[max 2m]

- **Colony hybridisation** is a method that uses nucleic acid hybridisation to identify which bacteria colonies on an agar plant contains a specific DNA sequence of interest / target DNA sequence;
- Colonies on an agar plate is pressed against a nitrocellulose membrane
- Treated with alkali to lyse cells and denature DNA;

[max 2m]

- membrane then **incubated with a labelled single-stranded** DNA or RNA **probe**;
- Probe has **complementary sequence** to the target DNA sequence / sequence of interest;
- If target DNA sequence is present, probe will hybridise with the target DNA and indicate its presence;
- Hybridised probe is detected via autoradiography, colour development or development of fluorescence on membrane;
- Nitrocellulose membrane will show a visual band where the probe hybridised with the complementary target DNA;

[max 3m]

(b) Explain the advantages and disadvantages of tissue culture over more traditional methods of cloning plants, such as taking cuttings or grafting. [5]

Advantages:

- **Less space** is required to grow the plants in the lab, as compared to the field.
- Plant cultures (stored in culture flasks) are **easier and cheaper to transport** (via air freight) compared to adult plants

- **Disease-free** plants can be produced
- **Genetic modification** of plant cells is possible during tissue culture.
- Production is **not affected by weather / environmental conditions**.
- Plants that are difficult to germinate from seeds (e.g. orchids) can be easily produced via tissue culture.

[max 2m/3m]

Disadvantages:

- **Expensive** because of labour intensive/equipment/ requirement to maintain a sterile environment via e.g. use of laminar flow hoods which are expensive.
- An infected stock plant (with fungi) can produce many infected progeny/some plants are very difficult to disinfect of fungal organisms.
- Not all plants can be successfully tissue-cultured, often because the growth medium (for that plant species) is not known.
- Monocultures / (genetically identical plants) are susceptible to new diseases or pests.

[max 2m/3m]

Accept converse if student talked about advantages/disadvantages of traditional methods of plant cloning.

(c) Describe the goals of the Human Genome Project, and with a named example, explain how the findings of the HGP may benefit the genetic modification of crops. [6]

Goal of HGP **[max 4m]**	Possible benefit to plant cloning **[max 2m]**
• Knowledge of plant genomics: To **determine the sequence** of the coded information contained in the DNA of the various genomes studied; OR • **Completing the sequences of several other organisms** (such as bacteria, yeast, *Drosophila melanogaster* and the mouse) to be used as models for research → Knowledge gained by the study of genomes of other organisms would assist in the analysis of the human genome;	• Give example: determine sequence of ○ *psy* gene (from daffodil) *crtI* gene (from soil bacterium); OR ○ *Bt* gene (from soil bacterium/ *Bacillus thuringiensis*) • (In the process of sequencing and mapping of human genome), **genetic engineering/ techniques of cloning** were developed (which could be applied to create genetically modified crops);
• Functional genomics: **studying genes' normal functions**;	• Idea of allowing the isolation of gene(s) of interest from other organisms which code for traits which are desirable to have in GM crop; • Give example: ○ Golden rice: *psy* gene and *crtI* gene code for enzymes (phytoene synthase and carotene desaturase) that convert phytoene to β-carotene (in rice endosperm) (→ improve nutritious value/increase quality of rice); OR ○ Bt corn: *Bt* gene codes for toxin which causes the death of corn borer (→ increase crop yield without use of chemical insecticides/pesticides)

	• to improve the yield and quality of crop plants to solve world demand for food (don't double award if benefits are explained with the examples);
• Storing all sequence information in databases that are accessible by all;	• Idea of: easy access of shared data enables different groups of researchers to search for information about e.g. gene sequences and functions without having to do extensive/time-consuming research on their own to create new GM crops with novel traits;
• Studying and addressing the ethical, legal and social implications (ELSI) of genome research;	
• Improving tools for analysis such as sequencing technology development, developing technology for functional genomics, developing technology in bioinformatics;	

[Total:20]