BIOLOGY **9648/01**

HIGHER 2 **31 August 2016**

Paper 1 Multiple Choice **1 hour 15 mins**

Additional Material: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

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

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

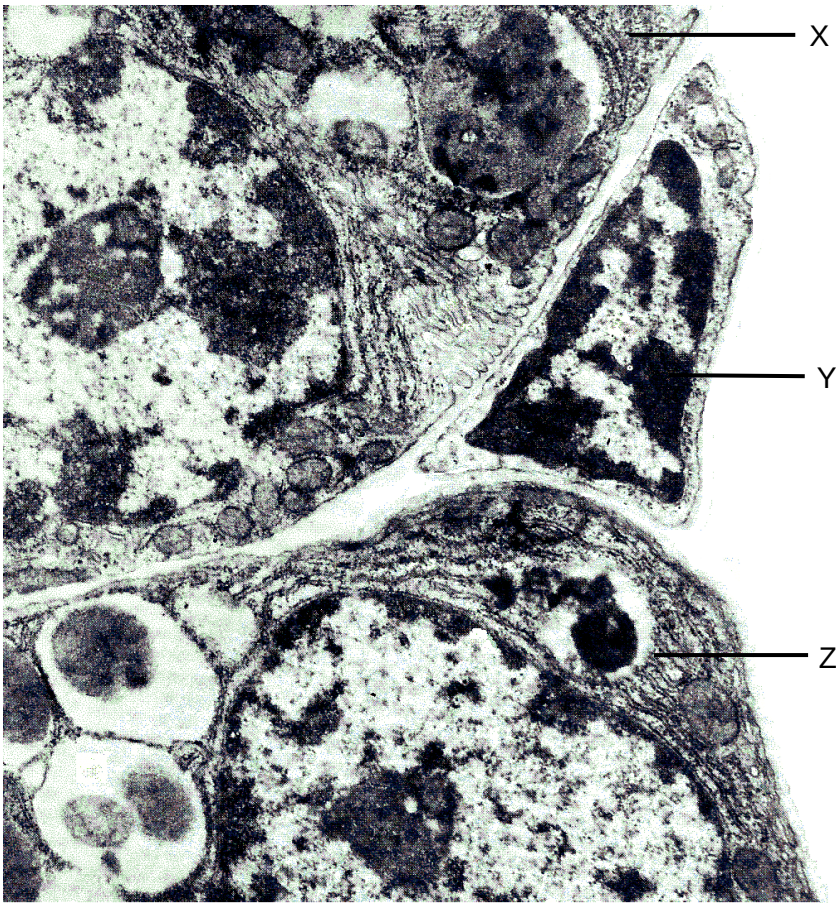
Read the instructions on the Answer Sheet very carefully.

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

Calculators may be used.

This question paper consists of **27** printed pages.

1 The following electron micrograph shows three adjacent cells, X, Y and Z.



Which of the following descriptions about these cells is **not** true?

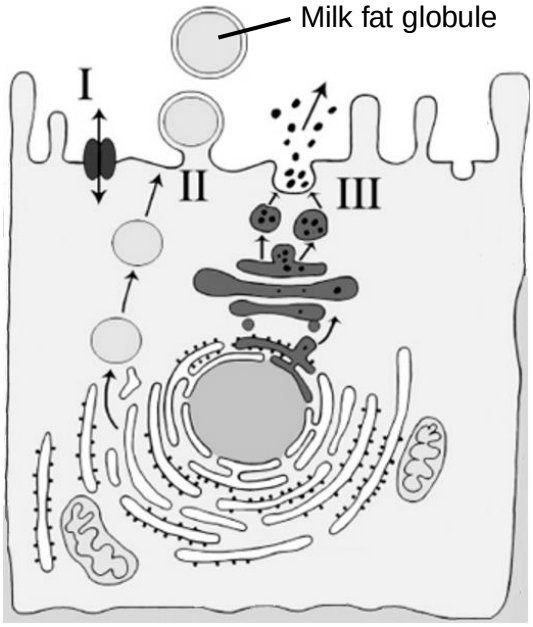
A Cell X contains both linear and circular molecules as its genetic material.

B Cell Y has a rigid cellulose cell wall which resists osmotic lysis.

C Cell Z contains 40S and 60S ribosomal subunits in its cytoplasm.

D Both cell X and cell Z possess intracellular membranes.

2 The diagram shows an epithelial cell in the mammary glands of a mammal. Such cells are responsible for the secretion of milk, an emulsion made up of lactose, lipids, proteins, ions and water. The various substances in milk are secreted through three different transport processes I, II and III.



Which of the following correctly describes the secretion of substances in milk?

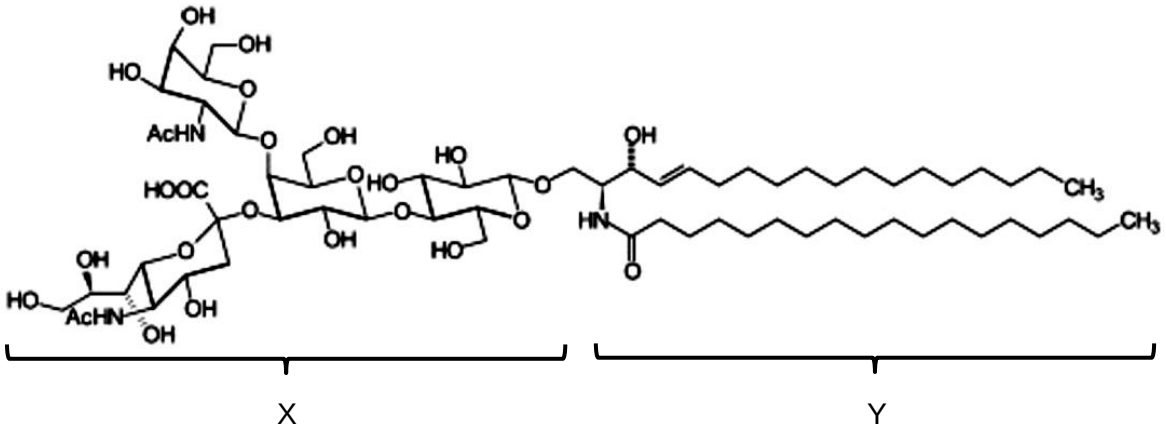
A The secretion of large fat globules occurs by exocytosis, with the expenditure of ATP.

B Lactose and ions have to be secreted through process I due to their hydrophobicity.

C Water can be transported in vesicles budding from the rough endoplasmic reticulum and secreted through process II.

D Milk proteins are transported out of the cell through process III, due to their large molecular size.

3 A ganglioside is a molecule commonly found in cell membranes, and its structure comprises two main components, X and Y.



Which of the following statements regarding a ganglioside is true?

A It comprises two fatty acid chains joined to a glycerol molecule by ester bonds.

B Component X helps to regulate the permeability of the cell membrane.

C Component X is responsible for cell-to-cell recognition and acts as a receptor for other molecules.

D Component X is embedded in the cell membrane while component Y faces the extracellular fluid.

4 The winged bean is a tropical crop that has high protein content. Winged beans have been reported to have a low level of protein digestibility. Protease inhibitors in the bean have been suggested to be responsible for the low digestibility.

In an experiment to study the effect of heat treatment on protein digestibility in winged beans, one of two winged beans was subjected to heat treatment. Trypsin was subsequently added to each reaction mixture and incubated for 30 minutes. The protein concentration of each reaction mixture at the beginning and at the end of the incubation period is shown in the table below.

Incubation period / min	Protein concentration of the reaction mixture / %	
	Trypsin + heat-treated winged bean	Trypsin + untreated winged bean
0	100	100
30	40	70

Which of the following statements is a likely explanation for the data shown?

A Heat treatment of winged bean caused the activation of trypsin inhibitors.

B Heat treatment of winged bean denatured trypsin by changing the 3-dimensional configuration of the enzyme.

C Heat treatment of winged bean disrupted cellular structure and improved accessibility of trypsin to protein.

D Heat treatment of winged bean lowered the activation energy of trypsin and increased the rate of enzyme-catalysed reaction.

5 In *Caenorhabditis elegans*, studies on the synapsis of homologous chromosomes revealed that one end of each chromosome becomes attached to protein patches on the nuclear envelope. The protein patches form a bridge between the chromosomes and the cytoskeleton outside the nucleus. The microtubules in the cytoskeleton facilitate movement of the patches and associated chromosomes, enabling encounters between chromosomes. A protein, dynein, is involved in the separation of mispaired chromosomes. It is also required in the formation of a protein complex between the correctly paired homologous chromosomes.

Which of the following statements are valid conclusions from these findings?

1 The formation of the protein complex between paired homologous chromosomes occurs spontaneously.
2 Mutations in genes coding for protein patches on the nuclear envelope that link the chromosomes to the cytoskeleton inhibit synapsis.
3 Successful formation of the protein complex between paired homologous chromosomes is required for the cell to proceed into metaphase of mitosis.
4 Dynein is necessary to ensure proper synapsis of homologous chromosomes.

A 2, 3 and 4 only

B 1, 2 and 4 only

C 1 and 3 only

D 2 and 4 only

6 The amount of DNA present in a diploid germ cell of 12 chromosomes is 6 picograms (pg). During meiosis I, non-disjunction of a pair of homologous chromosomes occurred.

Which row correctly identifies the amount of DNA and number of chromosomes at different stages of nuclear division?

	Telophase I		Telophase II	
	Amount of DNA (pg) per cell	Number of chromosomes per nucleus	Amount of DNA (pg) per cell	Number of chromosomes per nucleus
A	12	5 or 7	5 or 7	5 or 7
B	12	12	5 or 7	4 or 14
C	6	5 or 7	2.5 or 3.5	5 or 7
D	6	12	2.5 or 3.5	4 or 14

7 Which of the following statement(s) is/are **not** true of the translation process in all eukaryotes?

1 Polypeptides are only synthesised in the cytosol.
2 Amino acids are linked by the formation of peptide bonds catalysed by a ribozyme.
3 Ribosomes contain an amino-acyl tRNA site that is occupied by the initiator tRNA attached to methionine.
4 Amino-acyl tRNA synthetase attaches an amino acid to the 5' end of a tRNA molecule.

A 1, 3 and 4 only

B 2, 3 and 4 only

C 2 and 4 only

D 1 only

8 RNA is involved in the process of protein synthesis. Which of the following descriptions is true about RNA in eukaryotes?

A rRNA, which is coded for by genes found in nucleolus, associates with ribosomal proteins in the cytoplasm to form ribosomal subunits.

B Functional mRNA is formed as a result of post-transcriptional modifications of primary RNA transcript in the nucleus.

C The ribonucleotide sequence of tRNA molecules allows extensive folding and inter-strand complementarity to generate a three-dimensional structure.

D All RNAs must undergo alternative splicing.

9 The template DNA strand for a segment of polypeptide is shown below:

3' ------ GTA ACC GCA TCT CAG AGG ------ 5'

Which of the following will most likely occur if nitrous acid (a mutagenic agent) introduces mutations to this DNA strand by replacing cytosine bases with uracil bases?

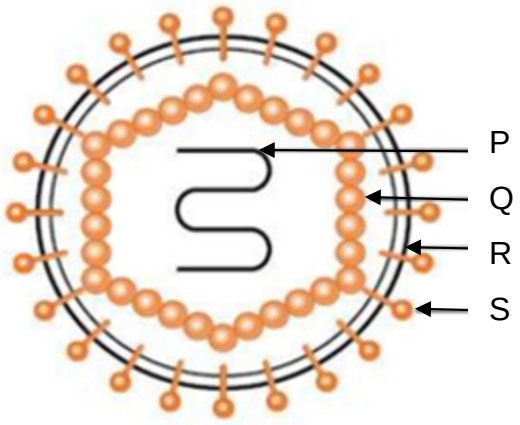
A No polypeptide will be synthesised.

B A truncated polypeptide will be synthesised.

C Four new amino acids with different chemical properties will be found in the polypeptide.

D A polypeptide of original length but with a few new amino acids of different side chains will be synthesised.

10 The diagram shows the structure of a virus.



Which of the following statements are true?

1 P determines the structure of Q and S.
2 Q assists viral entry into the host cell.
3 R and S are required for the entry of the virus into the host cell.
4 Q and R are made of the same components.

A 1 and 2 only

B 1 and 3 only

C 2 and 3 only

D 2 and 4 only

11 How many of these statements about the Human Immunodeficiency Virus (HIV) are correct?

1 The genome is made up of deoxyribonucleotides.
2 The viral enzyme reverse transcriptase is coded for by *pol* gene.
3 Haemagglutinin on viral surface binds to CD4 receptor of helper T cell.
4 HIV enters the host cell via fusion.

A 1

B 2

C 3

D 4

12 The following statements describe the process of conjugation between two bacterial cells.

1 F plasmid replicates semi-conservatively in the donor cell.
2 Replication of F plasmid occurs to form double-stranded DNA in recipient cell.
3 Conjugation tube breaks and retracts.
4 Conjugation tube forms between two bacterial cells.
5 Single-stranded copy of F plasmid is transferred into recipient cell.

Which of the following order describes conjugation correctly?

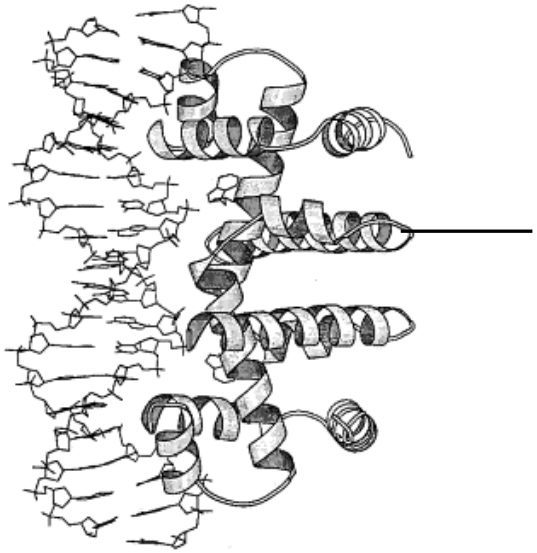
A 1 → 4 → 5 → 2 → 3

B 1 → 5 → 4 → 3 → 2

C 4 → 1 → 5 → 2 → 3

D 4 → 5 → 3 → 1 → 2

13 The diagram shows the binding of an active *trp* repressor protein to DNA.



Which of the options shows the most possible effect of a mutation of the *trp* repressor?

	Part of *trp* repressor affected by mutation	Type of mutation	State of *trp* operon in the presence of tryptophan
A	DNA binding site	Gain-of-function	Transcribed
B	DNA binding site	Loss-of-function	Not transcribed
C	Tryptophan binding site	Loss-of-function	Transcribed
D	Tryptophan binding site	Loss-of-function	Not transcribed

14 The table shows a comparison of some aspects of the genomes and protein-coding genes of eukaryotic and prokaryotic organisms.

Organism	Genome size / base pairs	Chromosome number	Estimated gene number
Human (*Homo sapiens*)	3 billion	46	About 25,000
Mouse (*Mus musculus*)	2.9 billion	40	About 25,000
Fruit fly (*Drosophila melanogaster*)	165 million	8	13,000
Plant (*Arabidopsis thaliana*)	157 million	10	25,000
Roundworm (*Caenorhabditis elegans*)	97 million	12	19,000
Yeast (*Saccharomyces cerevisiae*)	12 million	32	6,000
Bacteria (*Escherichia coli*)	4.6 million	1	3,200

Which of the following statement(s) account(s) for the differences seen in the table?

1 The greater the number of chromosomes an organism has, the larger its genome.
2 The presence of introns in the eukaryotes results in larger genomes and more chromosomes.
3 A larger number of genes would result in a significantly larger genome.
4 *Homo sapiens* and *Mus musculus* are the most closely related, hence they have similar genome size, number of chromosomes and gene number.

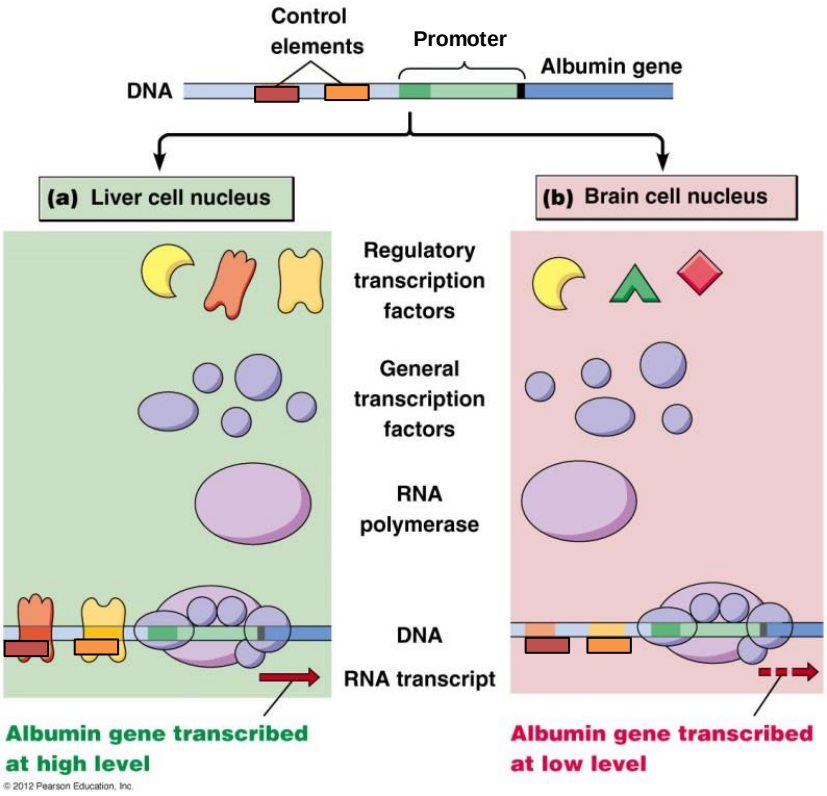
A 2, 3 and 4 only

B 1 only

C 4 only

D None of the above

15 Gene expression of albumin gene is regulated by two control elements and its promoter. These control elements are recognised by regulatory transcription factors which bind to allow for high rate of transcription of the albumin gene.



Which of the following is a result of differential albumin gene expression in liver cells and brain cells?

A Liver and brain cells are differentiated from different pluripotent stem cells, hence they contain different control elements which result in differential gene expression.

B Brain cells contain different RNA polymerases and general transcription factors resulting in low transcription of the albumin gene.

C Brain cells do not contain the regulatory transcription factors that are required to bind to the control elements of the albumin gene to promote the assembly of the transcription complex.

D Liver and brain cells contain the same regulatory control elements, RNA polymerase and transcription factors but a mutation has occurred in the regulatory control elements of the brain cells hence making them dysfunctional.

16 Which of the following is an example of translational control of gene expression?

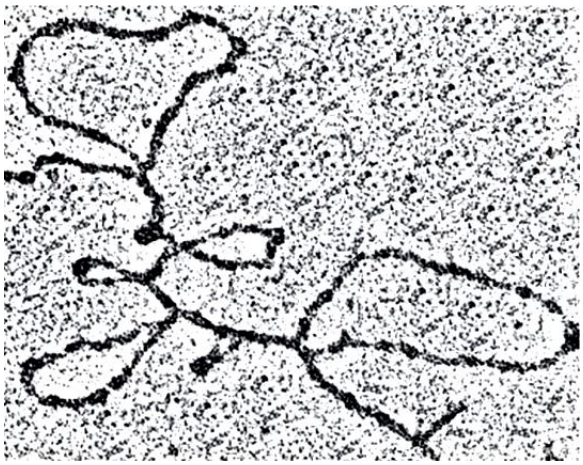
A The binding of protein factors to mRNA to prevent the binding of the small ribosomal subunit

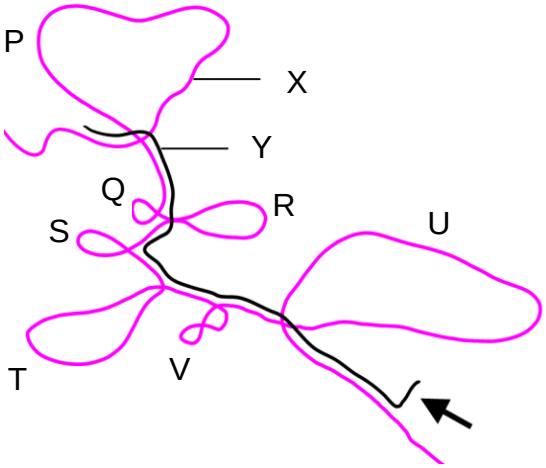
B The activation of proteins by association with other proteins

C The addition of chemical groups such as phosphates to free amino acids

D The degradation of a protein by proteasome

17 The ovalbumin gene from chicken was isolated and made single-stranded and then subsequently mixed together with its mature mRNA. The results were observed under an electron microscope. The electron micrograph and its corresponding diagrammatic representation show the binding of the mRNA to certain regions of the DNA.





Which of the following statement(s) can be concluded?

1 X is the template strand of DNA and Y is the mRNA strand transcribed from X.
2 P, Q, R, S, T, U and V correspond to the introns on the DNA that have been excised from the mRNA.
3 The arrow indicates the 3' end of the mRNA where the poly(A) tail was added during post-transcriptional modification.
4 The 3' end of the mRNA is free because there is no corresponding stretch on the template DNA where complementary base pairing can take place.

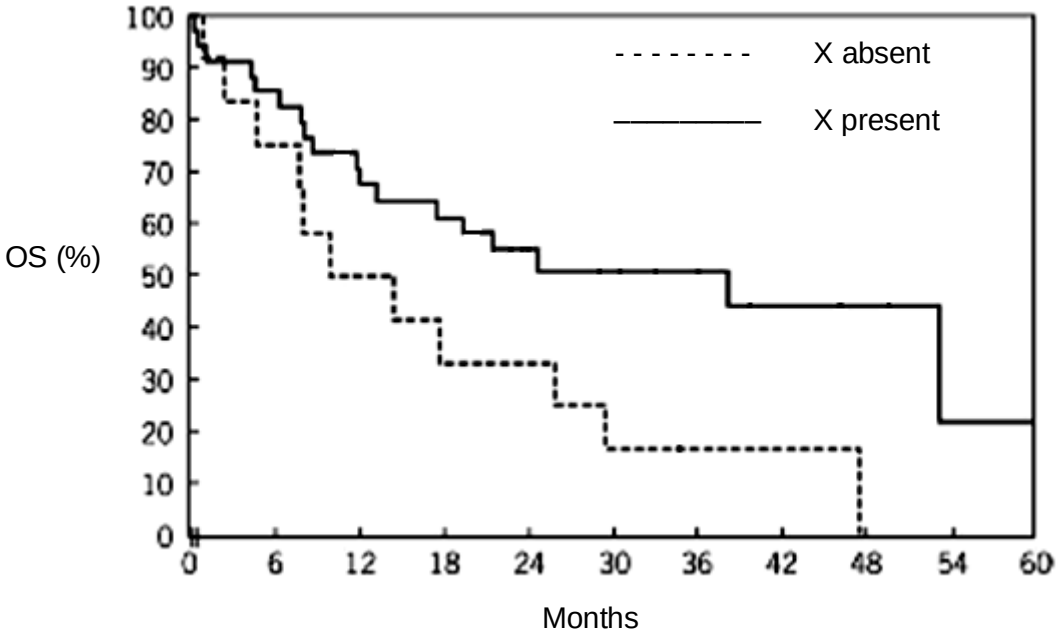
A 1, 2, 3 and 4

B 2, 3 and 4 only

C 1 and 2 only

D 1 only

18 A group of scientists discovered a novel protein and named it X. X is implicated in chromatin structure rearrangement in mammalian cells. The figure shows the overall survival (OS) percentage of cancer patients in the absence and presence of X.



Which of the following statement can best account for the increased survival rates of the cancer patients?

A X is involved in histone acetylation which results in the chromatin having a less compact structure leading to increased expression of tumour suppressor genes, hence allowing cell division to be regulated.

B X is involved in histone acetylation which results in the chromatin having a less compact structure leading leading to expression of oncogenes, hence allowing cell division to be regulated.

C X is involved in histone deacetylation which results in the chromatin having a less compact structure leading to expression of the telomerase gene, hence allowing cell division to be regulated.

D X is involved in histone deacetylation which results in chromatin having a more compact structure leading to a lack of expression of genes involved in angiogenesis, hence allowing cell division to be regulated.

19 In Shorthorn cattle, the allele for the absence of horns is dominant to the allele for the presence of horns. Coat colour can be red (genotype: $\mathbf{C^RC^R}$), roan (genotype: $\mathbf{C^RC^W}$) or white (genotype: $\mathbf{C^WC^W}$).

A roan bull, heterozygous for the hornless trait, is crossed with a cow of the same genotype. Which of the following statement(s) regarding the F_1 offspring is/are true?

1 The probability that a calf from this cross would have the same phenotype as its parents is 3/8.
2 The ratio of horned to hornless calves is 3:1.
3 The number of red and white calves is more than that of roan calves.

A 1 and 2 only

B 2 and 3 only

C 1 only

D 3 only

20 Wing size in *Drosophila* is controlled by a gene with three alleles. The normal wings are long while the other two traits arise as a result of mutation in the same gene locus. The order of dominance for these alleles is as follows.

Long (L) > Vestigial (L^{vg}) = Antlered (L^{a})

How many different genotypes for wing size are possible?

A 3

B 4

C 6

D 8

21 The coat colour of Norwegian cattle is mainly determined by the distribution of two pigments: red and black. Both pigments are produced by the action of the enzyme tyrosinase in cells called melanocytes. A low level of activity of the enzyme leads to the production of red pigment, whilst a high activity allows only black pigment production. The activity of the enzyme is increased by the melanocyte stimulating hormone (MSH), which binds to a MSH receptor. The receptor is coded for by the **E** gene locus, which has two alleles, **E** and **e**. No receptor is produced by the recessive allele **e**.

The dominant allele of a second gene, the **A** locus, codes for a protein which binds to and blocks the MSH receptors, thus preventing stimulation of tyrosinase activity in a melanocyte.

Which of the following statements about the two genes and their effects in the colouration of Norwegian cattle is true?

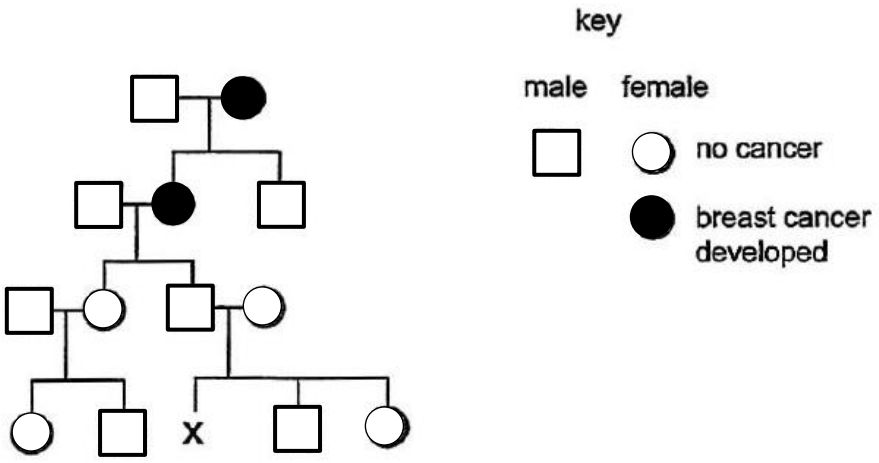
A Allele A is completely epistatic to allele a and allele E is completely epistatic to allele e.

B Cattle with the genotype AAEE have red coats.

C Cattle with black coats must have the genotype aaEe only.

D Cattle with the genotypes aaEE, aaEe and Aaee will have high tyrosinase activity.

22 The diagram below shows the inheritance of a form of breast cancer associated with the presence of just one mutant allele of an autosomal gene *BRCA1*.



What is the probability that woman X inherits the *BRCA1* mutant allele associated with breast cancer?

A 0.00

B 0.25

C 0.50

D 1.00

23 The table below shows the results of an early investigation into the genetic control of phenotypic variation. The dry masses of 5493 bean seeds collected from many plants were classified into nine categories.

Mass of bean/mg	51-150	151-250	251-350	351-450	451-550	551-650	651-750	751-850	851-950
Number of beans	5	38	370	1676	2255	928	187	32	2

Which statement correctly describes these data and could account for the variation shown?

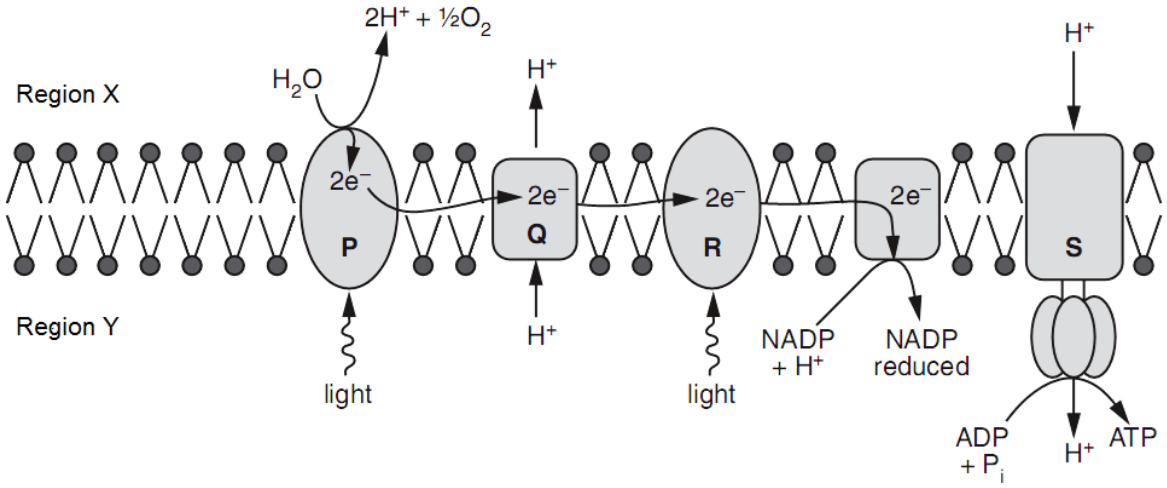
A The phenotypic variation is continuous and could be the result of two non-linked genes acting on their own.

B The phenotypic variation is continuous and could be the result of several non-linked genes acting on their own.

C The phenotypic variation is discontinuous and could be the result of two linked genes acting on their own.

D The phenotypic variation is discontinuous and could be the result of several linked genes acting on their own.

24 The diagram below represents a cross section of a thylakoid, showing some components which are involved in the light-dependent stage of photosynthesis.



Which of the following statements about the following components in the light-dependent stage is true?

A An inhibitor which blocks electron flow through R would inhibit the production of oxygen at P.

B In structures P and R, electrons are passed from one pigment molecule to another until it reaches chlorophyll *a*.

C Region X is expected to have a higher pH than Region Y.

D There is a non-cyclical flow of electrons through structures P, Q, R and S.

25 In respiration, the enzyme hexokinase uses ATP to transfer a phosphate group to glucose to form glucose-6-phosphate.

If a cell only has glucose available for energy and the activity of hexokinase is suddenly inhibited in this cell, which of the following will occur?

1 The cell will not be able to produce pyruvate through glycolysis.
2 Respiratory processes in the mitochondria would not proceed.
3 The use of oxygen by the cell will decrease.

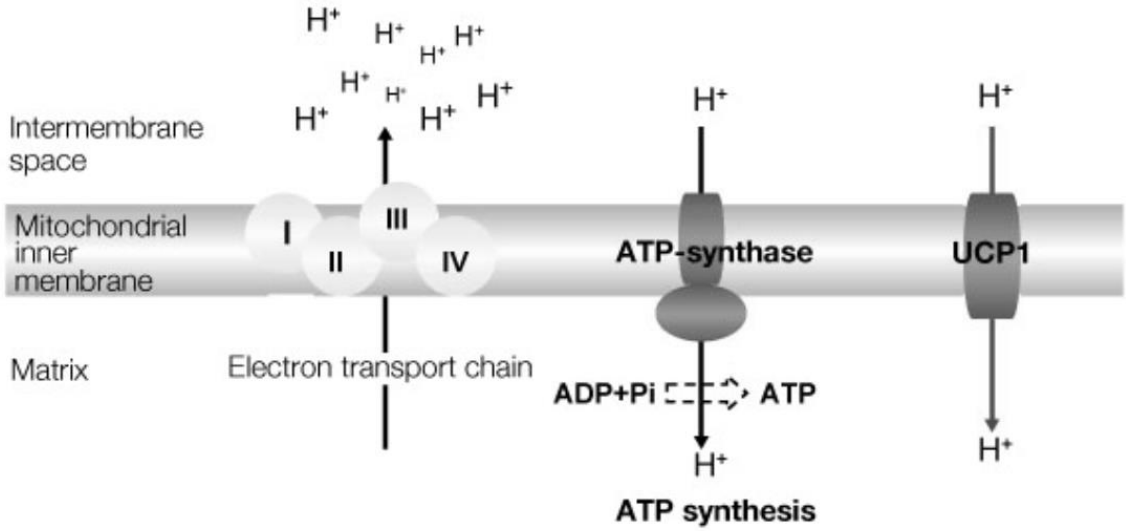
A 1, 2 and 3

B 1 and 2 only

C 1 and 3 only

D 2 and 3 only

26 Thermogenesis is a process that helps certain animals to maintain a constant body temperature. Such animals are found to contain a lot of mitochondria which have proton channels known as UCP1 embedded in the inner membrane as shown below.



Based on the above information, which of the following statements is a likely explanation for the role of UCP1 in thermogenesis?

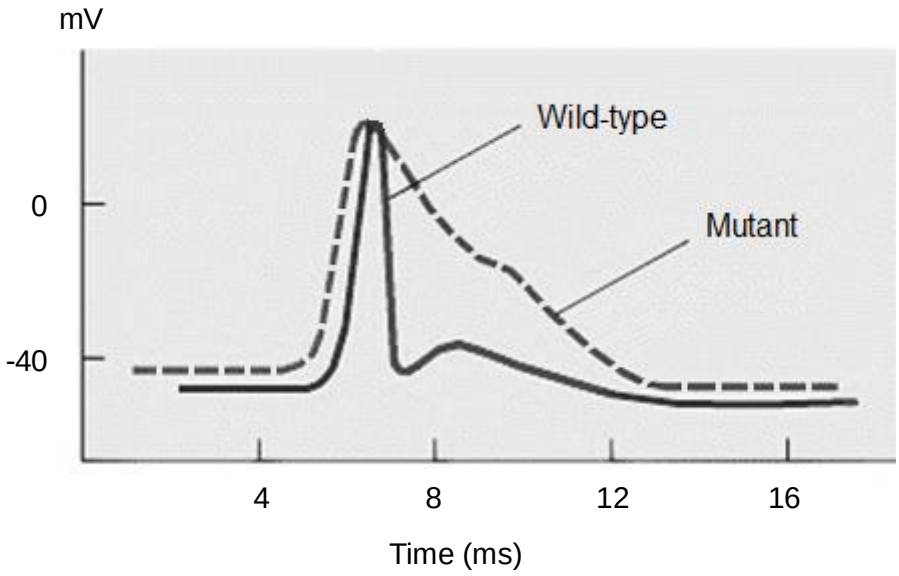
A UCP1 disrupts the flow of electrons along the electron transport chain, channelling protons through it instead of ATP synthase, thus producing heat in the process.

B A proton gradient cannot be established as UCP1 allows protons to pass through the inner membrane passively, hence the energy released from electron transfer is used for heat production.

C The proton motive force is dissipated as heat due to protons flowing through UCP1 instead of passing through ATP synthase.

D The presence of UCP1 allows more protons to diffuse into the intermembrane space so that more protons can eventually diffuse through ATP synthase for ATP production to generate heat.

27 An experiment was carried out to investigate the effect of a particular gene mutation. The action potentials of wild-type flies and mutant flies are shown below.



Which of the following can explain the shape of the action potential in the mutant flies?

A Voltage-gated sodium ion channels were unable to close

B Defective voltage-gated potassium ion channels

C Hyperactive sodium-potassium pumps

D Slow-opening ligand-gated potassium ion channels

28 Some receptors for growth factors activate a protein kinase cascade, usually with the participation of multiple enzymes which cause changes in gene expression. Which of the following statements regarding cell signalling are true?

1 Multiple steps allow the amplification of a signal.
2 External signals can lead to changes in gene expression.
3 The same signal can lead to different responses in cells due to the presence of different target proteins.
4 All cascade systems modify gene expression by activating kinases that enter the cell nucleus by phosphorylating specific transcription factors.

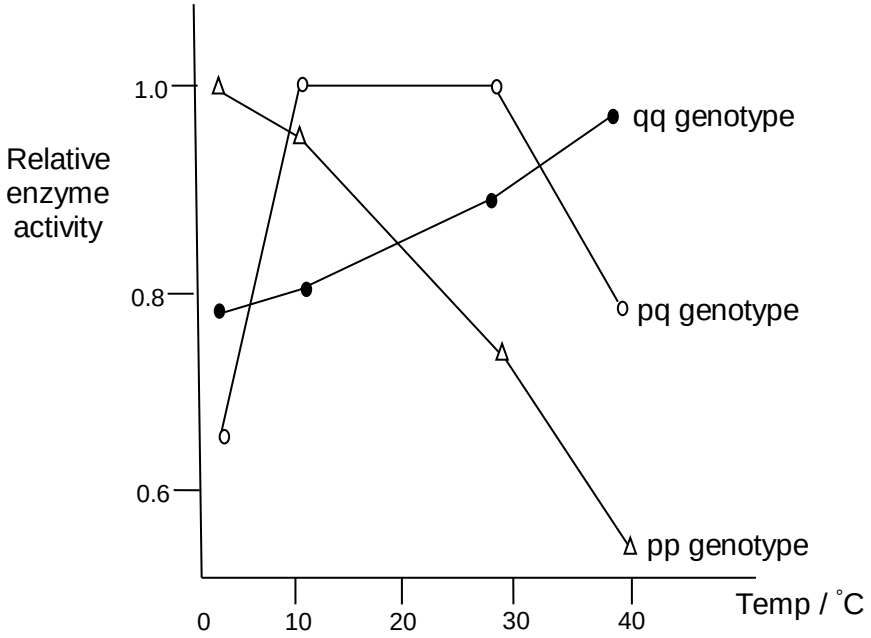
A 1, 2, 3 and 4

B 1, 2 and 3 only

C 1 and 2 only

D 3 and 4 only

29 In the North American catfish *Catostomus elarki*, two alleles represented by p and q, control the synthesis of a vital enzyme. The three possible genotypes (pp, pq, qq) lead to the synthesis of variations of the same enzyme with different temperature optima as shown in the graph below.



When the mean annual temperature is 5°C, which of the following statements are correct?

1 Allele q will be positively selected for.
2 The proportion of allele p in the gene pool will increase over time.
3 The heterozygotes will have a selective advantage over the homozygotes.
4 The catfish will develop a new enzyme variant that has a temperature optimum at 5°C.
5 Catfish with genotype pp will have a selective advantage over the others.

A 1 and 3 only

B 2 and 4 only

C 2 and 5 only

D 3 and 4 only

30 A large population of a certain species of freshwater fish lives in a South America lake. Assuming that there are no mutations, all immigration into the population is prevented and there is no change in selection pressure, which one of the following statements best expresses the probable future of the population?

A All evolution will promptly cease because without mutation, there will be no raw material for evolution.

B The population will begin to decrease in size after three to four generations because of excessive inbreeding that will result from the absence of immigration.

C The population will continue to evolve as selection acts on the different allelic combinations formed during meiosis.

D The population will cease to evolve and may survive for a long time as long as there is no selection.

31 When organochlorine insecticides such as DDT were in widespread use, mosquitoes in malarial regions developed resistance more rapidly than did houseflies in Britain. What could account for the difference in the rates of the development of resistance?

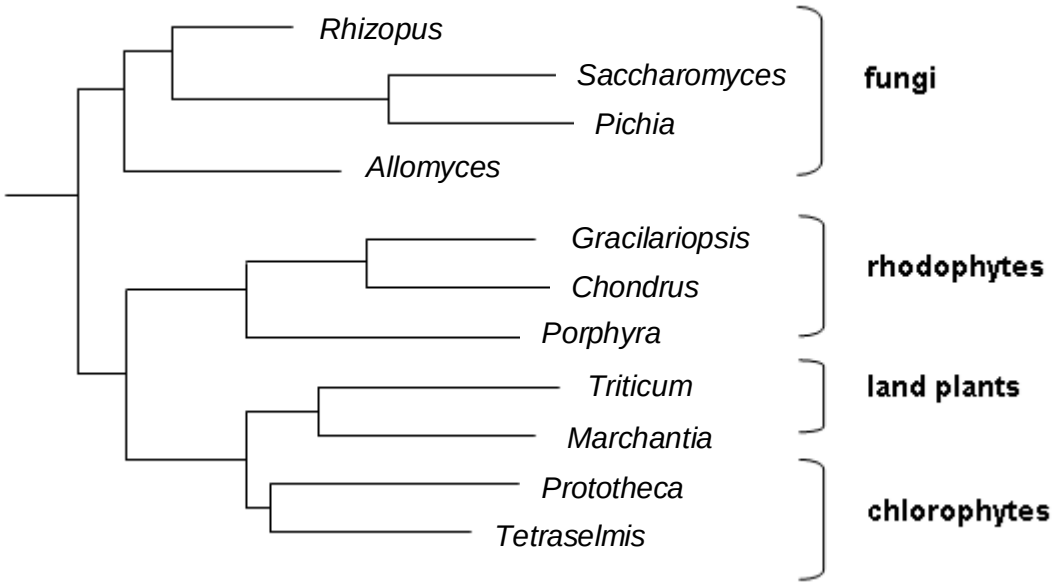
A Mosquitoes produce fewer generations a year.

B More insecticide was used in Britain.

C More insecticide was used in malarial regions.

D Mosquitoes show fewer random mutations per generation.

32 The phylogenetic tree below is derived from comparisons made with mitochondrial DNA from animals, fungi, rhodophytes (red algae) and plants.



What may be concluded from the above phylogenetic tree?

1 *Triticum* and *Marchantia* form a clade while *Allomyces* does not belong to any clade.
2 *Gracilariopsis*, *Chondrus* and *Porphyra* have evolved from the same most recent ancestor.
3 Chlorophytes and land plants are more closely related compared to chlorophytes and rhodophytes.
4 The rhodophytes share a common ancestry with chlorophytes and land plants.

A 1, 2 and 3 only

B 2, 3 and 4 only

C 2 and 4 only

D 3 and 4 only

33 In genetic engineering, which of the following are possible reasons for the limit on the size of the gene to be inserted into a plasmid vector?

1 cDNA is usually used instead of genomic DNA.
2 Probability of number of errors during replication increases as size of gene increases.
3 Number of ligases needed increases with an increase in the size of gene.
4 Efficiency of transformation of competent bacteria decreases with an increase in size of gene.

A 1, 2 and 4 only

B 2, 3 and 4 only

C 1 and 3 only

D 2 and 4 only

34 Which of the following statements regarding Restriction Fragment Length Polymorphisms (RFLP) and their analyses are correct?

1 RFLPs tightly linked to a gene coding for a disease can be used for disease detection.
2 All RFLPs exist as dominant and recessive alleles.
3 RFLPs can identify all single base pair changes in a chromosome.
4 All changes in restriction enzyme sites can be used as genetic markers.

A 1, 2, 3 and 4

B 1, 2 and 3 only

C 2, 3 and 4 only

D 1 and 4 only

35 Which of the following is an ethical concern of the Human Genome Project?

A Difficult to develop treatment for diseases involving multiple genes

B Costly procedures limit genetic testing to those who can afford them

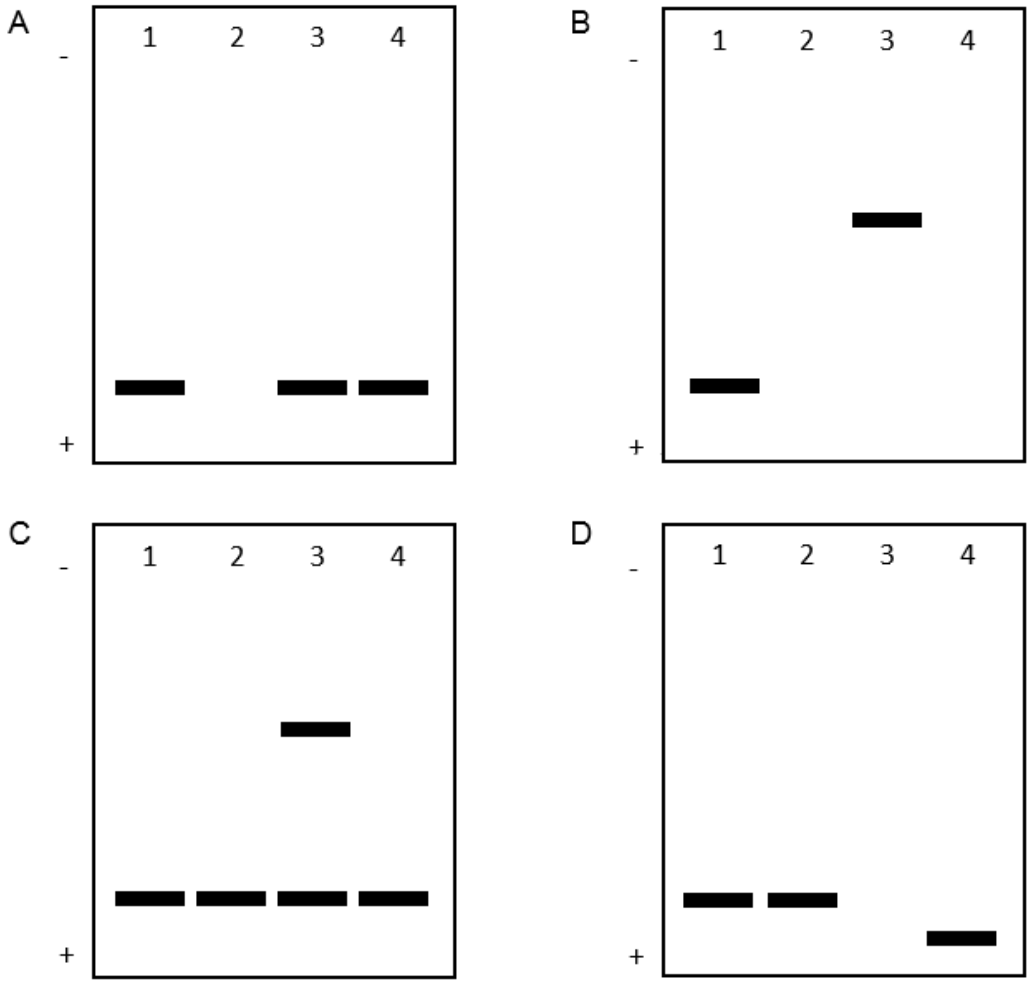
C Genetic testing may not provide reliable and accurate information

D Unborn foetuses detected with diseases may be aborted

36 Polymerase chain reactions (PCRs) were carried out on fruit fly genomic DNA. The DNA was added to four test-tubes and the treatments for the test-tubes are shown in the table below. The primers were designed to amplify a DNA section which is about 2 kb long.

Test-tube	Reagents	Temperature
1	Forward and reverse primers, deoxyribonucleotides, *Taq* polymerase	94°C (for 30 s) → 55°C (for 45 s) → 72°C (for 120 s)
2	Forward and reverse primers, deoxyribonucleotides, *Taq* polymerase	55°C (for 75 s) → 72°C (for 120 s)
3	Forward primers only, deoxyribonucleotides, *Taq* polymerase	94°C (for 30 s) → 55°C (for 45 s) → 72°C (for 120s)
4	Forward and reverse primers, deoxyribonucleotides, *Taq* polymerase	94°C (for 30 s) → 55°C (for 45 s) → 37°C (for 120 s)

After the above treatments were completed, gel electrophoresis was carried out on the contents of each test-tube. Which of the following electrophoregrams shows the correct results for each of the tubes?



37 Which of the following best illustrates totipotency?

A A somatic cell isolated from a root tip develops into a normal adult plant.

B Stem cells are able to divide indefinitely.

C Mesenchymal stem cells can differentiate into an extensive range of cell types, including bone cells, cartilage cells, muscle cells and fat cells.

D The replacement of the nucleus of an unfertilised egg with that of a pancreatic cell converts the egg into a pancreatic cell.

38 Which of the following are social implications for the use of gene therapy in treating genetic diseases?

1 Gene therapy might provide alternative treatments for patients where conventional treatments have failed.
2 Genetic enhancements can be costly and accessible only to the wealthy.
3 There is difficulty in determining which conditions are normal and which are considered disorders.

A 1, 2 and 3

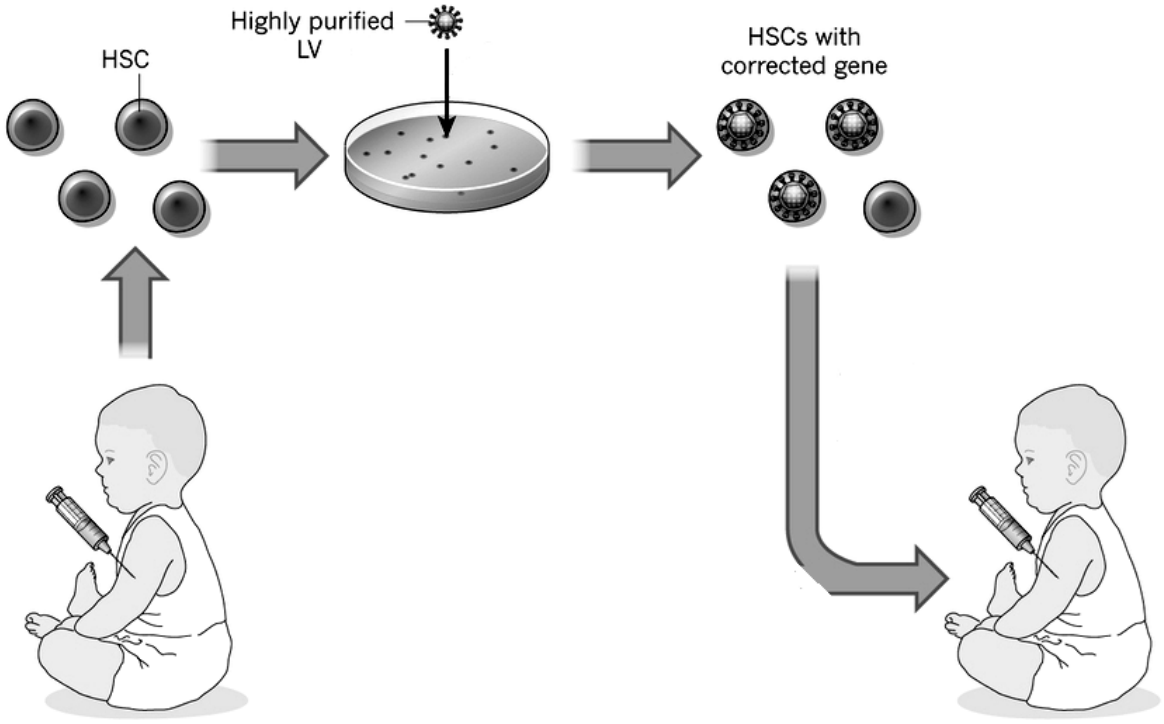
B 1 and 2 only

C 1 and 3 only

D 2 and 3 only

39 Metachromatic leukodystrophy (MLD) is an inherited disorder caused by a deficiency in arylsulphatase A (ARSA) enzyme activity in leukocytes. Patients with MLD accumulate a toxic metabolite and die within a few years.

In a clinical trial, a team of scientists collected haematopoietic stem cells (HSCs) from the bone marrow of children with MLD and exposed them to lentiviral vectors (LV) carrying normal ARSA genes. These genes were then integrated into HSC genomic DNA. HSCs with the corrected gene were then re-introduced into the children's bone marrow.



Which of the following statement(s) regarding the treatment of MLD is/are true?

1 This method of treatment is beneficial as it reduces the risk of incompatibility of HSC transplants.
2 This method of treatment is less effective than introducing lentiviruses containing the normal ARSA genes into the patient directly.
3 Other than HSCs, it is also possible to use leukocytes as target cells for gene therapy.

A 1, 2 and 3
B 1 and 2 only
C 1 and 3 only
D 3 only

40 Transgenic crops expressing insecticidal toxins could provide an effective means of pest control. However, the widespread cultivation of such transgenic crops is expected to promote the development of toxin-resistant pests, hence eventually compromising the usefulness of the pest management strategy. Two planting strategies have thus been recommended to prevent the development of toxin-resistant pests:

Strategy 1: Separate fields of transgenic plants and non-transgenic plants are planted

Strategy 2: 'Seed mixtures' of such transgenic plants and non-transgenic plants in the same field are planted

Which of the following considerations would most likely encourage farmers to favour Strategy 1 over Strategy 2?

A Low mortality of susceptible insects on toxin-free plants

B Movement of randomly mating insects from plant to plant within a field

C Concern that 'superweeds' might emerge in fields with 'seed mixtures'

D When toxin resistance is recessive and frequency of recessive alleles is low

BIOLOGY **9648/01**

HIGHER 2 **31 August 2016**

Paper 1 Multiple Choice **1 hour 15 mins**

Additional Material: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

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

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

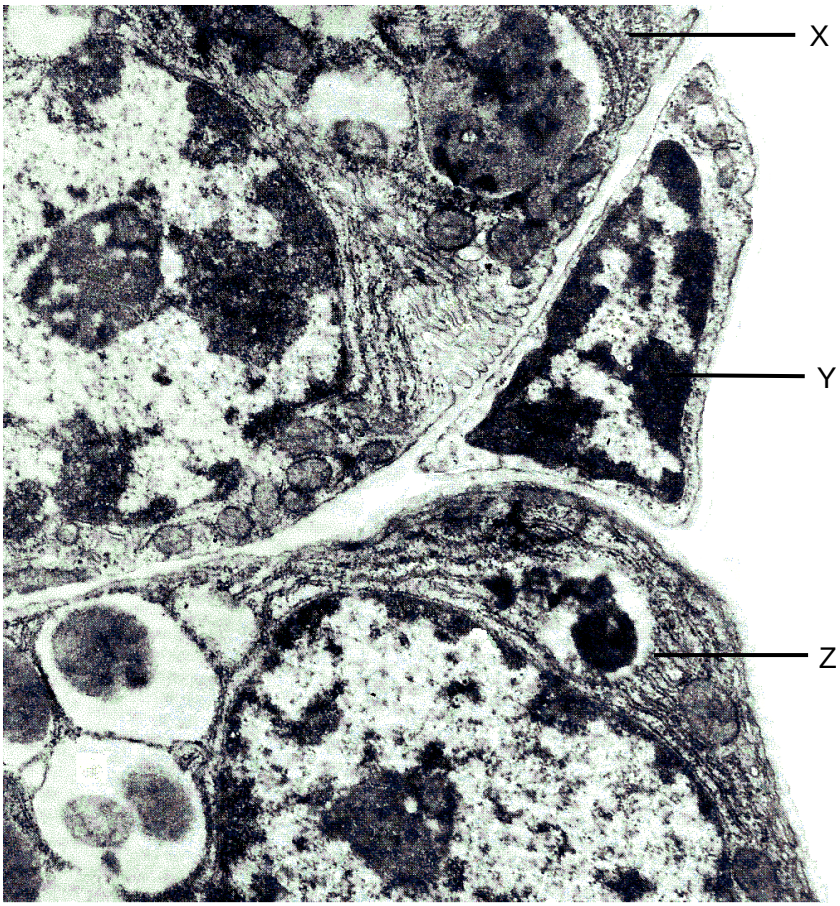
Read the instructions on the Answer Sheet very carefully.

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

Calculators may be used.

This question paper consists of **27** printed pages.

1 The following electron micrograph shows three adjacent cells, X, Y and Z.



Which of the following descriptions about these cells is **not** true?

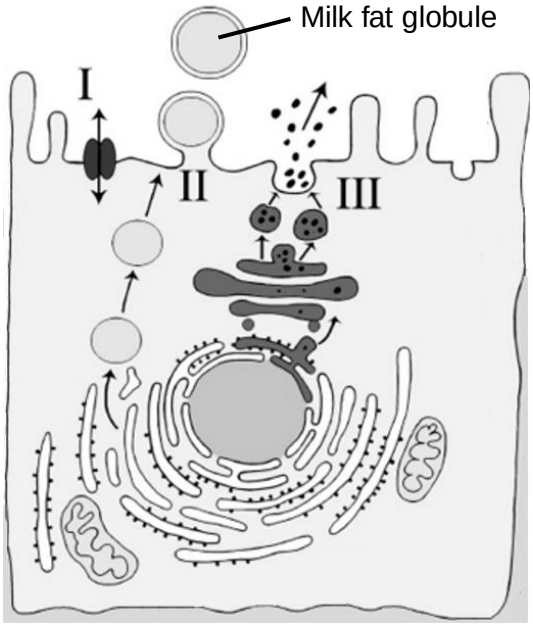
A Cell X contains both linear and circular molecules as its genetic material.

B Cell Y has a rigid cellulose cell wall which resists osmotic lysis.

C Cell Z contains 40S and 60S ribosomal subunits in its cytoplasm.

D Both cell X and cell Z possess intracellular membranes.

2 The diagram shows an epithelial cell in the mammary glands of a mammal. Such cells are responsible for the secretion of milk, an emulsion made up of lactose, lipids, proteins, ions and water. The various substances in milk are secreted through three different transport processes I, II and III.



Which of the following correctly describes the secretion of substances in milk?

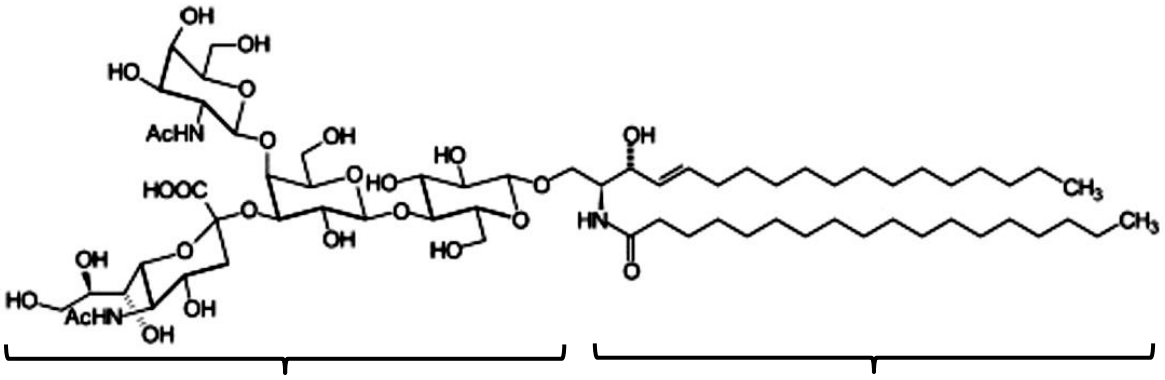
A The secretion of large fat globules occurs by exocytosis, with the expenditure of ATP.

B Lactose and ions have to be secreted through process I due to their hydrophobicity.

C Water can be transported in vesicles budding from the rough endoplasmic reticulum and secreted through process II.

D Milk proteins are transported out of the cell through process III, due to their large molecular size.

3 A ganglioside is a molecule commonly found in cell membranes, and its structure comprises two main components, X and Y.



Which of the following statements regarding a ganglioside is true?

A It comprises two fatty acid chains joined to a glycerol molecule by ester bonds.

B Component X helps to regulate the permeability of the cell membrane.

C Component X is responsible for cell-to-cell recognition and acts as a receptor for other molecules.

D Component X is embedded in the cell membrane while component Y faces the extracellular fluid.

4 The winged bean is a tropical crop that has high protein content. Winged beans have been reported to have a low level of protein digestibility. Protease inhibitors in the bean have been suggested to be responsible for the low digestibility.

In an experiment to study the effect of heat treatment on protein digestibility in winged beans, one of two winged beans was subjected to heat treatment. Trypsin was subsequently added to each reaction mixture and incubated for 30 minutes. The protein concentration of each reaction mixture at the beginning and at the end of the incubation period is shown in the table below.

Incubation period / min	Protein concentration of the reaction mixture / %	
	Trypsin + heat-treated winged bean	Trypsin + untreated winged bean
0	100	100
30	40	70

Which of the following statements is a likely explanation for the data shown?

A Heat treatment of winged bean caused the activation of trypsin inhibitors.

B Heat treatment of winged bean denatured trypsin by changing the 3-dimensional configuration of the enzyme.

C Heat treatment of winged bean disrupted cellular structure and improved accessibility of trypsin to protein.

D Heat treatment of winged bean lowered the activation energy of trypsin and increased the rate of enzyme-catalysed reaction.

5 In *Caenorhabditis elegans*, studies on the synapsis of homologous chromosomes revealed that one end of each chromosome becomes attached to protein patches on the nuclear envelope. The protein patches form a bridge between the chromosomes and the cytoskeleton outside the nucleus. The microtubules in the cytoskeleton facilitate movement of the patches and associated chromosomes, enabling encounters between chromosomes. A protein, dynein, is involved in the separation of mispaired chromosomes. It is also required in the formation of a protein complex between the correctly paired homologous chromosomes.

Which of the following statements are valid conclusions from these findings?

1 The formation of the protein complex between paired homologous chromosomes occurs spontaneously.
2 Mutations in genes coding for protein patches on the nuclear envelope that link the chromosomes to the cytoskeleton inhibit synapsis.
3 Successful formation of the protein complex between paired homologous chromosomes is required for the cell to proceed into metaphase of mitosis.
4 Dynein is necessary to ensure proper synapsis of homologous chromosomes.

A 2, 3 and 4 only

B 1, 2 and 4 only

C 1 and 3 only

D 2 and 4 only

6 The amount of DNA present in a diploid germ cell of 12 chromosomes is 6 picograms (pg). During meiosis I, non-disjunction of a pair of homologous chromosomes occurred.

Which row correctly identifies the amount of DNA and number of chromosomes at different stages of nuclear division?

	Telophase I		Telophase II	
	Amount of DNA (pg) per cell	Number of chromosomes per nucleus	Amount of DNA (pg) per cell	Number of chromosomes per nucleus
A	12	5 or 7	5 or 7	5 or 7
B	12	12	5 or 7	4 or 14
C	6	5 or 7	2.5 or 3.5	5 or 7
D	6	12	2.5 or 3.5	4 or 14

7 Which of the following statement(s) is/are **not** true of the translation process in all eukaryotes?

1 Polypeptides are only synthesised in the cytosol.
2 Amino acids are linked by the formation of peptide bonds catalysed by a ribozyme.
3 Ribosomes contain an amino-acyl tRNA site that is occupied by the initiator tRNA attached to methionine.
4 Amino-acyl tRNA synthetase attaches an amino acid to the 5' end of a tRNA molecule.

A 1, 3 and 4 only

B 2, 3 and 4 only

C 2 and 4 only

D 1 only

8 RNA is involved in the process of protein synthesis. Which of the following descriptions is true about RNA in eukaryotes?

A rRNA, which is coded for by genes found in nucleolus, associates with ribosomal proteins in the cytoplasm to form ribosomal subunits.

B Functional mRNA is formed as a result of post-transcriptional modifications of primary RNA transcript in the nucleus.

C The ribonucleotide sequence of tRNA molecules allows extensive folding and inter-strand complementarity to generate a three-dimensional structure.

D All RNAs must undergo alternative splicing.

9 The template DNA strand for a segment of polypeptide is shown below:

3' ------ GTA ACC GCA TCT CAG AGG ------ 5'

Which of the following will most likely occur if nitrous acid (a mutagenic agent) introduces mutations to this DNA strand by replacing cytosine bases with uracil bases?

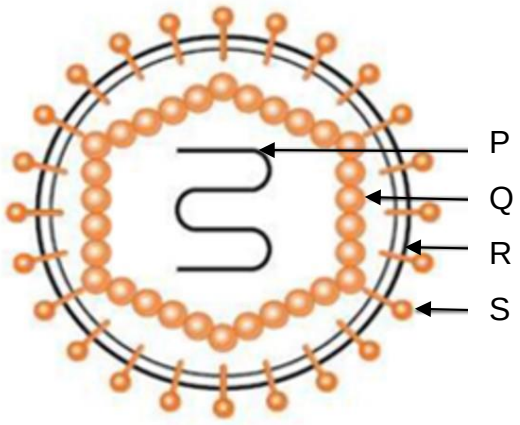
A No polypeptide will be synthesised.

B A truncated polypeptide will be synthesised.

C Four new amino acids with different chemical properties will be found in the polypeptide.

D A polypeptide of original length but with a few new amino acids of different side chains will be synthesised.

10 The diagram shows the structure of a virus.



Which of the following statements are true?

1 P determines the structure of Q and S.
2 Q assists viral entry into the host cell.
3 R and S are required for the entry of the virus into the host cell.
4 Q and R are made of the same components.

A 1 and 2 only

B 1 and 3 only

C 2 and 3 only

D 2 and 4 only

11 How many of these statements about the Human Immunodeficiency Virus (HIV) are correct?

1 The genome is made up of deoxyribonucleotides.
2 The viral enzyme reverse transcriptase is coded for by *pol* gene.
3 Haemagglutinin on viral surface binds to CD4 receptor of helper T cell.
4 HIV enters the host cell via fusion.

A 1

B 2

C 3

D 4

12 The following statements describe the process of conjugation between two bacterial cells.

1 F plasmid replicates semi-conservatively in the donor cell.
2 Replication of F plasmid occurs to form double-stranded DNA in recipient cell.
3 Conjugation tube breaks and retracts.
4 Conjugation tube forms between two bacterial cells.
5 Single-stranded copy of F plasmid is transferred into recipient cell.

Which of the following order describes conjugation correctly?

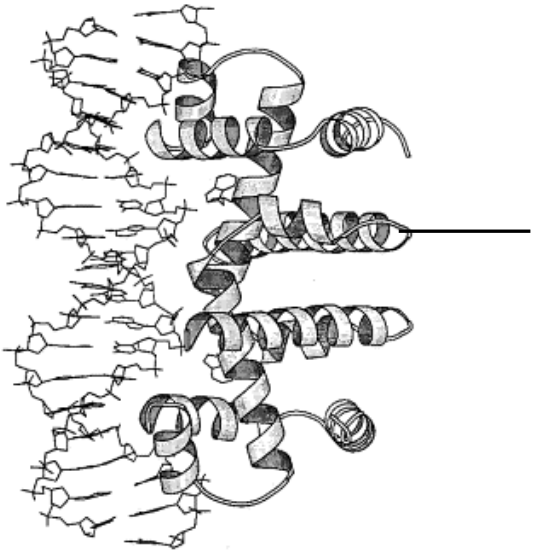
A 1 → 4 → 5 → 2 → 3

B 1 → 5 → 4 → 3 → 2

C 4 → 1 → 5 → 2 → 3

D 4 → 5 → 3 → 1 → 2

13 The diagram shows the binding of an active *trp* repressor protein to DNA.



Which of the options shows the most possible effect of a mutation of the *trp* repressor?

	Part of *trp* repressor affected by mutation	Type of mutation	State of *trp* operon in the presence of tryptophan
A	DNA binding site	Gain-of-function	Transcribed
B	DNA binding site	Loss-of-function	Not transcribed
C	Tryptophan binding site	Loss-of-function	Transcribed
D	Tryptophan binding site	Loss-of-function	Not transcribed

14 The table shows a comparison of some aspects of the genomes and protein-coding genes of eukaryotic and prokaryotic organisms.

Organism	Genome size / base pairs	Chromosome number	Estimated gene number
Human (*Homo sapiens*)	3 billion	46	About 25,000
Mouse (*Mus musculus*)	2.9 billion	40	About 25,000
Fruit fly (*Drosophila melanogaster*)	165 million	8	13,000
Plant (*Arabidopsis thaliana*)	157 million	10	25,000
Roundworm (*Caenorhabditis elegans*)	97 million	12	19,000
Yeast (*Saccharomyces cerevisiae*)	12 million	32	6,000
Bacteria (*Escherichia coli*)	4.6 million	1	3,200

Which of the following statement(s) account(s) for the differences seen in the table?

1 The greater the number of chromosomes an organism has, the larger its genome.
2 The presence of introns in the eukaryotes results in larger genomes and more chromosomes.
3 A larger number of genes would result in a significantly larger genome.
4 *Homo sapiens* and *Mus musculus* are the most closely related, hence they have similar genome size, number of chromosomes and gene number.

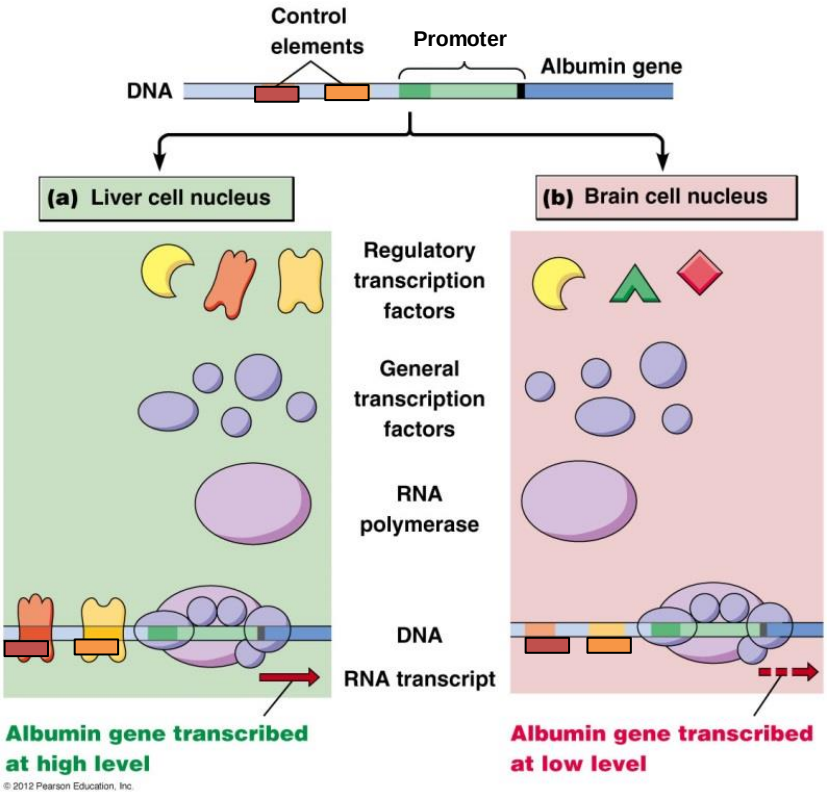
A 2, 3 and 4 only

B 1 only

C 4 only

D None of the above

15 Gene expression of albumin gene is regulated by two control elements and its promoter. These control elements are recognised by regulatory transcription factors which bind to allow for high rate of transcription of the albumin gene.



Which of the following is a result of differential albumin gene expression in liver cells and brain cells?

A Liver and brain cells are differentiated from different pluripotent stem cells, hence they contain different control elements which result in differential gene expression.

B Brain cells contain different RNA polymerases and general transcription factors resulting in low transcription of the albumin gene.

C Brain cells do not contain the regulatory transcription factors that are required to bind to the control elements of the albumin gene to promote the assembly of the transcription complex.

D Liver and brain cells contain the same regulatory control elements, RNA polymerase and transcription factors but a mutation has occurred in the regulatory control elements of the brain cells hence making them dysfunctional.

16 Which of the following is an example of translational control of gene expression?

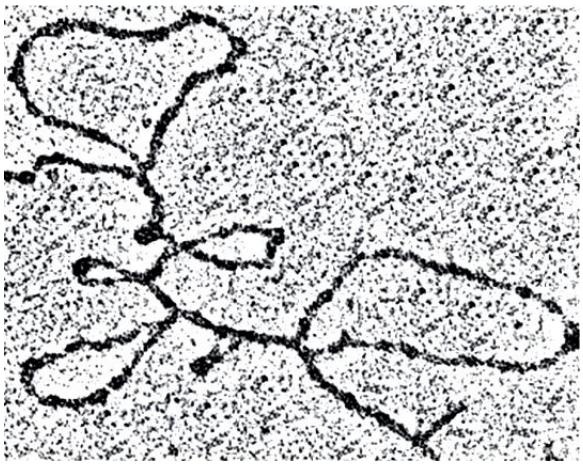
A The binding of protein factors to mRNA to prevent the binding of the small ribosomal subunit

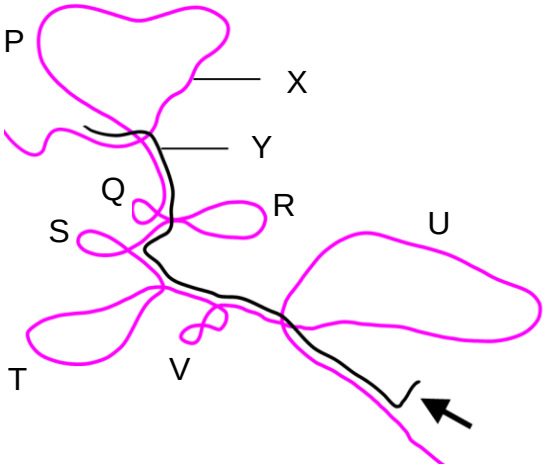
B The activation of proteins by association with other proteins

C The addition of chemical groups such as phosphates to free amino acids

D The degradation of a protein by proteasome

17 The ovalbumin gene from chicken was isolated and made single-stranded and then subsequently mixed together with its mature mRNA. The results were observed under an electron microscope. The electron micrograph and its corresponding diagrammatic representation show the binding of the mRNA to certain regions of the DNA.





Which of the following statement(s) can be concluded?

1 X is the template strand of DNA and Y is the mRNA strand transcribed from X.
2 P, Q, R, S, T, U and V correspond to the introns on the DNA that have been excised from the mRNA.
3 The arrow indicates the 3' end of the mRNA where the poly(A) tail was added during post-transcriptional modification.
4 The 3' end of the mRNA is free because there is no corresponding stretch on the template DNA where complementary base pairing can take place.

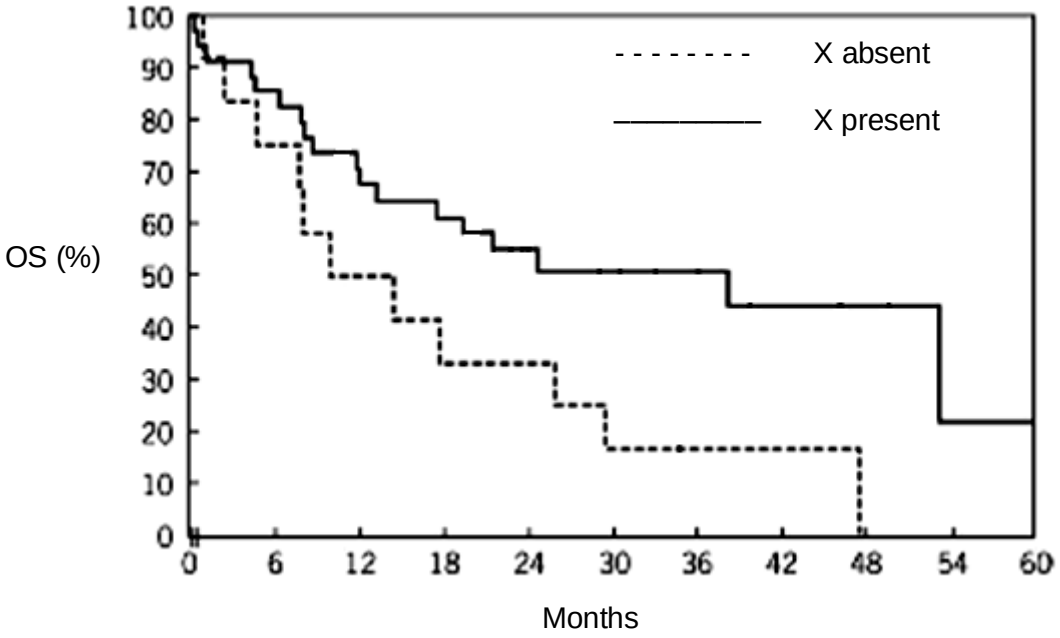
A 1, 2, 3 and 4

B 2, 3 and 4 only

C 1 and 2 only

D 1 only

18 A group of scientists discovered a novel protein and named it X. X is implicated in chromatin structure rearrangement in mammalian cells. The figure shows the overall survival (OS) percentage of cancer patients in the absence and presence of X.



Which of the following statement can best account for the increased survival rates of the cancer patients?

A X is involved in histone acetylation which results in the chromatin having a less compact structure leading to increased expression of tumour suppressor genes, hence allowing cell division to be regulated.

B X is involved in histone acetylation which results in the chromatin having a less compact structure leading leading to expression of oncogenes, hence allowing cell division to be regulated.

C X is involved in histone deacetylation which results in the chromatin having a less compact structure leading to expression of the telomerase gene, hence allowing cell division to be regulated.

D X is involved in histone deacetylation which results in chromatin having a more compact structure leading to a lack of expression of genes involved in angiogenesis, hence allowing cell division to be regulated.

19 In Shorthorn cattle, the allele for the absence of horns is dominant to the allele for the presence of horns. Coat colour can be red (genotype: $\mathbf{C^RC^R}$), roan (genotype: $\mathbf{C^RC^W}$) or white (genotype: $\mathbf{C^WC^W}$).

A roan bull, heterozygous for the hornless trait, is crossed with a cow of the same genotype. Which of the following statement(s) regarding the F_1 offspring is/are true?

1 The probability that a calf from this cross would have the same phenotype as its parents is 3/8.
2 The ratio of horned to hornless calves is 3:1.
3 The number of red and white calves is more than that of roan calves.

A 1 and 2 only

B 2 and 3 only

C 1 only

D 3 only

20 Wing size in *Drosophila* is controlled by a gene with three alleles. The normal wings are long while the other two traits arise as a result of mutation in the same gene locus. The order of dominance for these alleles is as follows.

Long (L) > Vestigial (L^{vg}) = Antlered (L^{a})

How many different genotypes for wing size are possible?

A 3

B 4

C 6

D 8

21 The coat colour of Norwegian cattle is mainly determined by the distribution of two pigments: red and black. Both pigments are produced by the action of the enzyme tyrosinase in cells called melanocytes. A low level of activity of the enzyme leads to the production of red pigment, whilst a high activity allows only black pigment production. The activity of the enzyme is increased by the melanocyte stimulating hormone (MSH), which binds to a MSH receptor. The receptor is coded for by the **E** gene locus, which has two alleles, **E** and **e**. No receptor is produced by the recessive allele **e**.

The dominant allele of a second gene, the **A** locus, codes for a protein which binds to and blocks the MSH receptors, thus preventing stimulation of tyrosinase activity in a melanocyte.

Which of the following statements about the two genes and their effects in the colouration of Norwegian cattle is true?

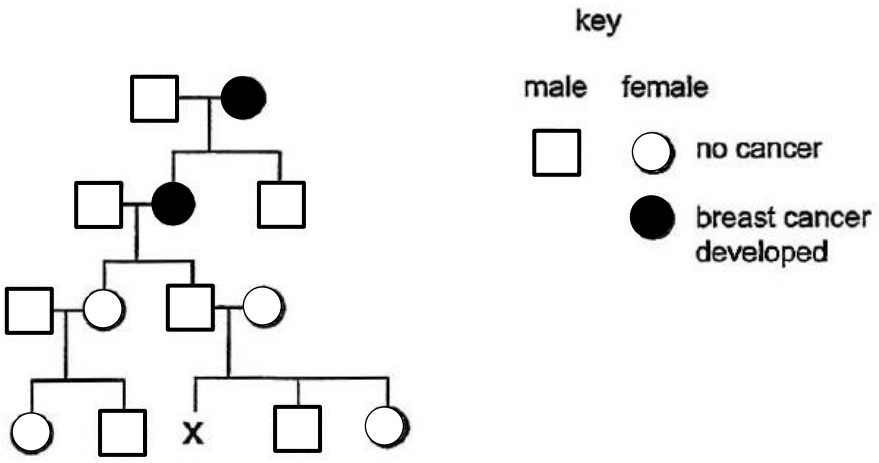
A Allele A is completely epistatic to allele a and allele E is completely epistatic to allele e.

B Cattle with the genotype AAEE have red coats.

C Cattle with black coats must have the genotype aaEe only.

D Cattle with the genotypes aaEE, aaEe and Aaee will have high tyrosinase activity.

22 The diagram below shows the inheritance of a form of breast cancer associated with the presence of just one mutant allele of an autosomal gene *BRCA1*.



What is the probability that woman X inherits the *BRCA1* mutant allele associated with breast cancer?

A 0.00

B 0.25

C 0.50

D 1.00

23 The table below shows the results of an early investigation into the genetic control of phenotypic variation. The dry masses of 5493 bean seeds collected from many plants were classified into nine categories.

Mass of bean/mg	51-150	151-250	251-350	351-450	451-550	551-650	651-750	751-850	851-950
Number of beans	5	38	370	1676	2255	928	187	32	2

Which statement correctly describes these data and could account for the variation shown?

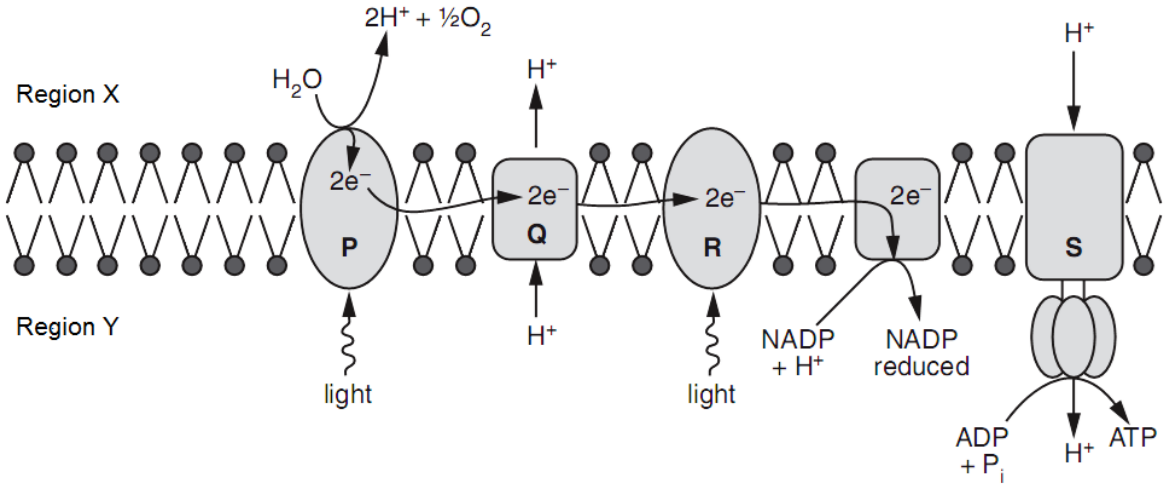
A The phenotypic variation is continuous and could be the result of two non-linked genes acting on their own.

B The phenotypic variation is continuous and could be the result of several non-linked genes acting on their own.

C The phenotypic variation is discontinuous and could be the result of two linked genes acting on their own.

D The phenotypic variation is discontinuous and could be the result of several linked genes acting on their own.

24 The diagram below represents a cross section of a thylakoid, showing some components which are involved in the light-dependent stage of photosynthesis.



Which of the following statements about the following components in the light-dependent stage is true?

A An inhibitor which blocks electron flow through R would inhibit the production of oxygen at P.

B In structures P and R, electrons are passed from one pigment molecule to another until it reaches chlorophyll *a*.

C Region X is expected to have a higher pH than Region Y.

D There is a non-cyclical flow of electrons through structures P, Q, R and S.

25 In respiration, the enzyme hexokinase uses ATP to transfer a phosphate group to glucose to form glucose-6-phosphate.

If a cell only has glucose available for energy and the activity of hexokinase is suddenly inhibited in this cell, which of the following will occur?

1 The cell will not be able to produce pyruvate through glycolysis.
2 Respiratory processes in the mitochondria would not proceed.
3 The use of oxygen by the cell will decrease.

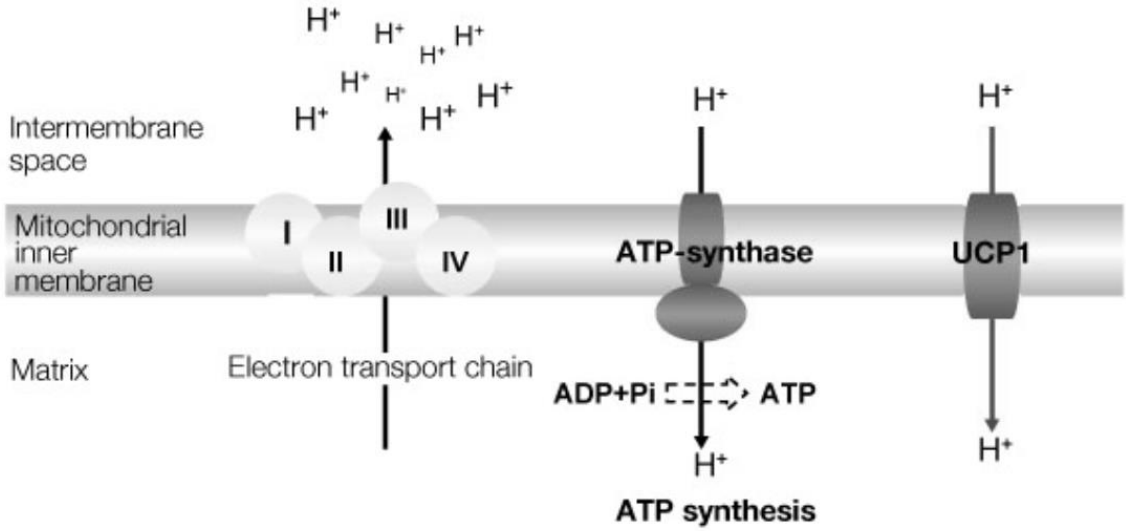
A 1, 2 and 3

B 1 and 2 only

C 1 and 3 only

D 2 and 3 only

26 Thermogenesis is a process that helps certain animals to maintain a constant body temperature. Such animals are found to contain a lot of mitochondria which have proton channels known as UCP1 embedded in the inner membrane as shown below.



Based on the above information, which of the following statements is a likely explanation for the role of UCP1 in thermogenesis?

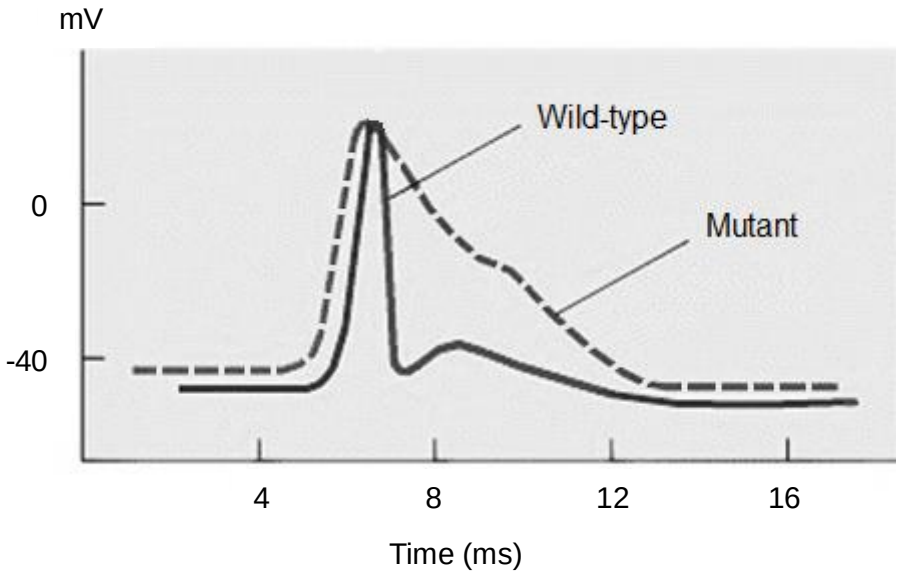
A UCP1 disrupts the flow of electrons along the electron transport chain, channelling protons through it instead of ATP synthase, thus producing heat in the process.

B A proton gradient cannot be established as UCP1 allows protons to pass through the inner membrane passively, hence the energy released from electron transfer is used for heat production.

C The proton motive force is dissipated as heat due to protons flowing through UCP1 instead of passing through ATP synthase.

D The presence of UCP1 allows more protons to diffuse into the intermembrane space so that more protons can eventually diffuse through ATP synthase for ATP production to generate heat.

27 An experiment was carried out to investigate the effect of a particular gene mutation. The action potentials of wild-type flies and mutant flies are shown below.



Which of the following can explain the shape of the action potential in the mutant flies?

A Voltage-gated sodium ion channels were unable to close

B Defective voltage-gated potassium ion channels

C Hyperactive sodium-potassium pumps

D Slow-opening ligand-gated potassium ion channels

28 Some receptors for growth factors activate a protein kinase cascade, usually with the participation of multiple enzymes which cause changes in gene expression. Which of the following statements regarding cell signalling are true?

1 Multiple steps allow the amplification of a signal.
2 External signals can lead to changes in gene expression.
3 The same signal can lead to different responses in cells due to the presence of different target proteins.
4 All cascade systems modify gene expression by activating kinases that enter the cell nucleus by phosphorylating specific transcription factors.

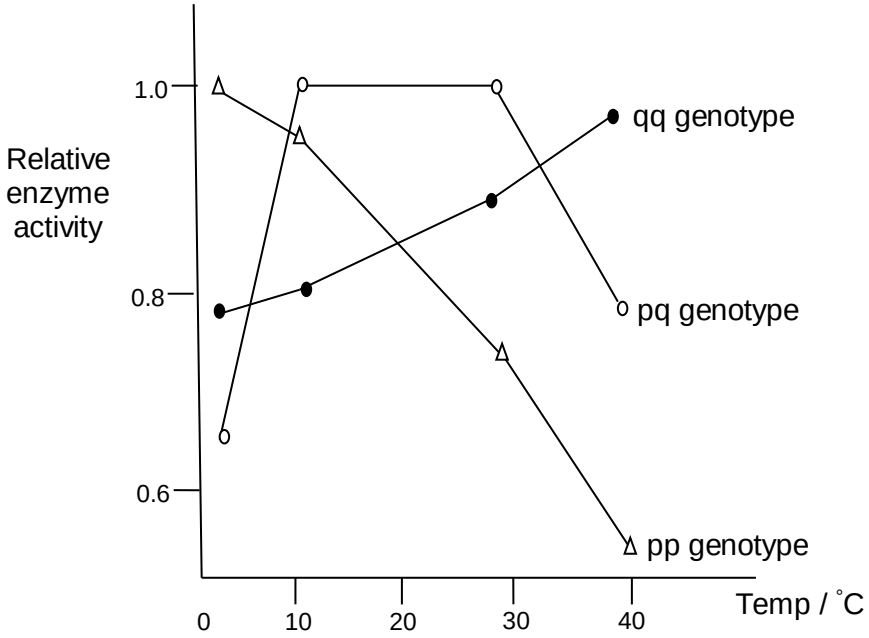
A 1, 2, 3 and 4

B 1, 2 and 3 only

C 1 and 2 only

D 3 and 4 only

29 In the North American catfish *Catostomus elarki*, two alleles represented by p and q, control the synthesis of a vital enzyme. The three possible genotypes (pp, pq, qq) lead to the synthesis of variations of the same enzyme with different temperature optima as shown in the graph below.



When the mean annual temperature is 5°C, which of the following statements are correct?

1 Allele q will be positively selected for.
2 The proportion of allele p in the gene pool will increase over time.
3 The heterozygotes will have a selective advantage over the homozygotes.
4 The catfish will develop a new enzyme variant that has a temperature optimum at 5°C.
5 Catfish with genotype pp will have a selective advantage over the others.

A 1 and 3 only
B 2 and 4 only
C 2 and 5 only
D 3 and 4 only

30 A large population of a certain species of freshwater fish lives in a South America lake. Assuming that there are no mutations, all immigration into the population is prevented and there is no change in selection pressure, which one of the following statements best expresses the probable future of the population?

A All evolution will promptly cease because without mutation, there will be no raw material for evolution.

B The population will begin to decrease in size after three to four generations because of excessive inbreeding that will result from the absence of immigration.

C The population will continue to evolve as selection acts on the different allelic combinations formed during meiosis.

D The population will cease to evolve and may survive for a long time as long as there is no selection.

31 When organochlorine insecticides such as DDT were in widespread use, mosquitoes in malarial regions developed resistance more rapidly than did houseflies in Britain. What could account for the difference in the rates of the development of resistance?

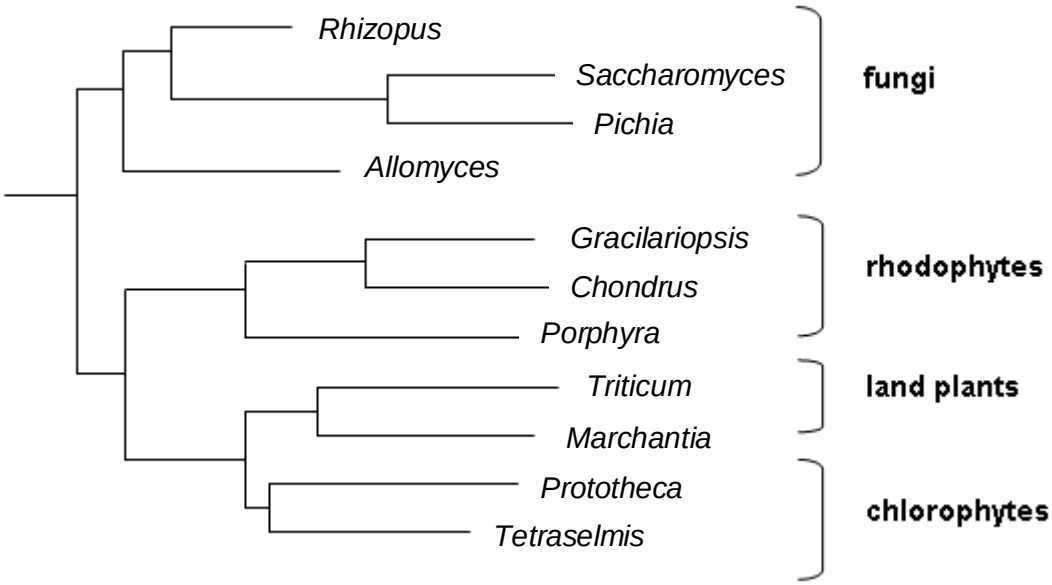
A Mosquitoes produce fewer generations a year.

B More insecticide was used in Britain.

C More insecticide was used in malarial regions.

D Mosquitoes show fewer random mutations per generation.

32 The phylogenetic tree below is derived from comparisons made with mitochondrial DNA from animals, fungi, rhodophytes (red algae) and plants.



What may be concluded from the above phylogenetic tree?

1 *Triticum* and *Marchantia* form a clade while *Allomyces* does not belong to any clade.
2 *Gracilariopsis*, *Chondrus* and *Porphyra* have evolved from the same most recent ancestor.
3 Chlorophytes and land plants are more closely related compared to chlorophytes and rhodophytes.
4 The rhodophytes share a common ancestry with chlorophytes and land plants.

A 1, 2 and 3 only

B 2, 3 and 4 only

C 2 and 4 only

D 3 and 4 only

33 In genetic engineering, which of the following are possible reasons for the limit on the size of the gene to be inserted into a plasmid vector?

1 cDNA is usually used instead of genomic DNA.
2 Probability of number of errors during replication increases as size of gene increases.
3 Number of ligases needed increases with an increase in the size of gene.
4 Efficiency of transformation of competent bacteria decreases with an increase in size of gene.

A 1, 2 and 4 only

B 2, 3 and 4 only

C 1 and 3 only

D 2 and 4 only

34 Which of the following statements regarding Restriction Fragment Length Polymorphisms (RFLP) and their analyses are correct?

1 RFLPs tightly linked to a gene coding for a disease can be used for disease detection.
2 All RFLPs exist as dominant and recessive alleles.
3 RFLPs can identify all single base pair changes in a chromosome.
4 All changes in restriction enzyme sites can be used as genetic markers.

A 1, 2, 3 and 4

B 1, 2 and 3 only

C 2, 3 and 4 only

D 1 and 4 only

35 Which of the following is an ethical concern of the Human Genome Project?

A Difficult to develop treatment for diseases involving multiple genes

B Costly procedures limit genetic testing to those who can afford them

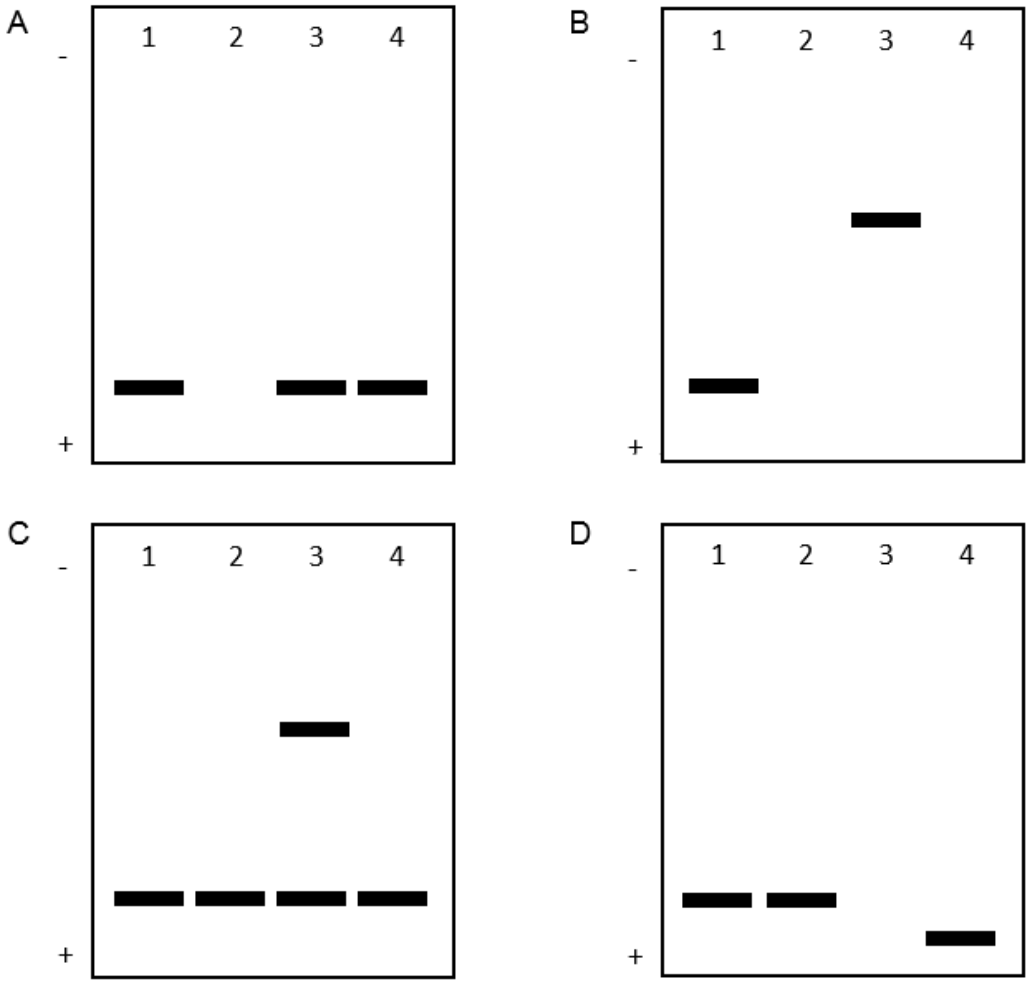
C Genetic testing may not provide reliable and accurate information

D Unborn foetuses detected with diseases may be aborted

36 Polymerase chain reactions (PCRs) were carried out on fruit fly genomic DNA. The DNA was added to four test-tubes and the treatments for the test-tubes are shown in the table below. The primers were designed to amplify a DNA section which is about 2 kb long.

Test-tube	Reagents	Temperature
1	Forward and reverse primers, deoxyribonucleotides, *Taq* polymerase	94°C (for 30 s) → 55°C (for 45 s) → 72°C (for 120 s)
2	Forward and reverse primers, deoxyribonucleotides, *Taq* polymerase	55°C (for 75 s) → 72°C (for 120 s)
3	Forward primers only, deoxyribonucleotides, *Taq* polymerase	94°C (for 30 s) → 55°C (for 45 s) → 72°C (for 120s)
4	Forward and reverse primers, deoxyribonucleotides, *Taq* polymerase	94°C (for 30 s) → 55°C (for 45 s) → 37°C (for 120 s)

After the above treatments were completed, gel electrophoresis was carried out on the contents of each test-tube. Which of the following electrophoregrams shows the correct results for each of the tubes? Ans B



37 Which of the following best illustrates totipotency?

A A somatic cell isolated from a root tip develops into a normal adult plant.

B Stem cells are able to divide indefinitely.

C Mesenchymal stem cells can differentiate into an extensive range of cell types, including bone cells, cartilage cells, muscle cells and fat cells.

D The replacement of the nucleus of an unfertilised egg with that of a pancreatic cell converts the egg into a pancreatic cell.

38 Which of the following are social implications for the use of gene therapy in treating genetic diseases?

1 Gene therapy might provide alternative treatments for patients where conventional treatments have failed.
2 Genetic enhancements can be costly and accessible only to the wealthy.
3 There is difficulty in determining which conditions are normal and which are considered disorders.

A 1, 2 and 3

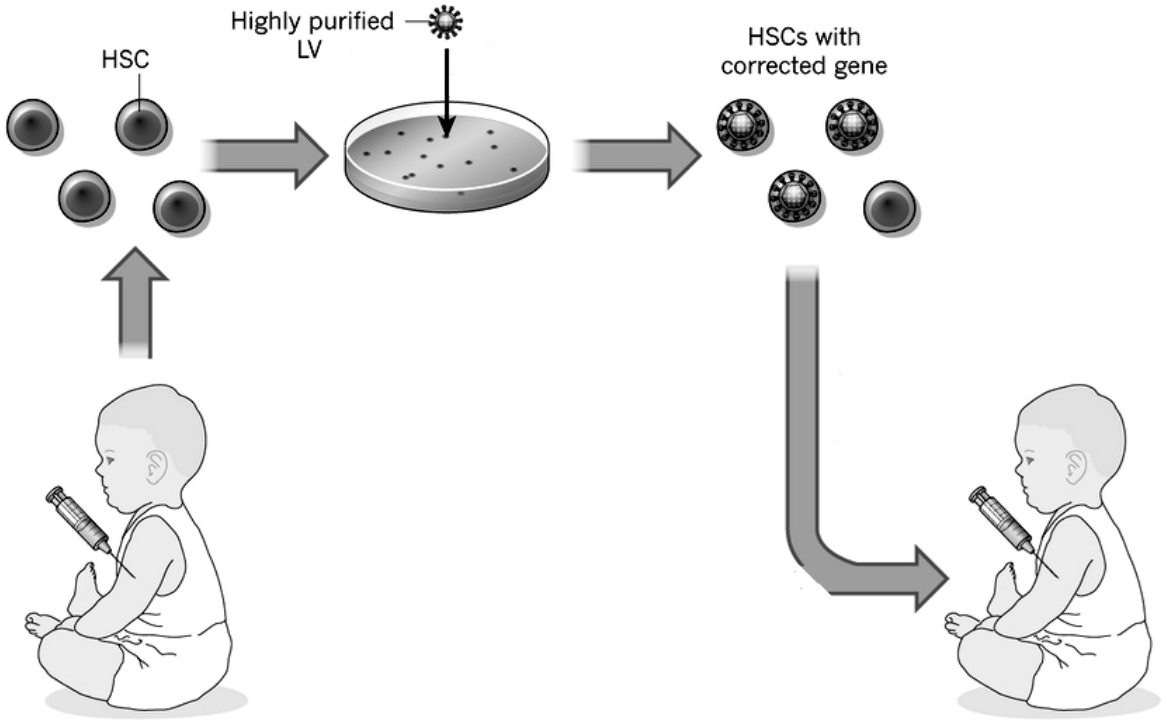
B 1 and 2 only

C 1 and 3 only

D 2 and 3 only

39 Metachromatic leukodystrophy (MLD) is an inherited disorder caused by a deficiency in arylsulphatase A (ARSA) enzyme activity in leukocytes. Patients with MLD accumulate a toxic metabolite and die within a few years.

In a clinical trial, a team of scientists collected haematopoietic stem cells (HSCs) from the bone marrow of children with MLD and exposed them to lentiviral vectors (LV) carrying normal ARSA genes. These genes were then integrated into HSC genomic DNA. HSCs with the corrected gene were then re-introduced into the children's bone marrow.



Which of the following statement(s) regarding the treatment of MLD is/are true?

1 This method of treatment is beneficial as it reduces the risk of incompatibility of HSC transplants.
2 This method of treatment is less effective than introducing lentiviruses containing the normal ARSA genes into the patient directly.
3 Other than HSCs, it is also possible to use leukocytes as target cells for gene therapy.

A 1, 2 and 3
B 1 and 2 only
C 1 and 3 only
D 3 only

40 Transgenic crops expressing insecticidal toxins could provide an effective means of pest control. However, the widespread cultivation of such transgenic crops is expected to promote the development of toxin-resistant pests, hence eventually compromising the usefulness of the pest management strategy. Two planting strategies have thus been recommended to prevent the development of toxin-resistant pests:

Strategy 1: Separate fields of transgenic plants and non-transgenic plants are planted

Strategy 2: 'Seed mixtures' of such transgenic plants and non-transgenic plants in the same field are planted

Which of the following considerations would most likely encourage farmers to favour Strategy 1 over Strategy 2?

A Low mortality of susceptible insects on toxin-free plants

B Movement of randomly mating insects from plant to plant within a field

C Concern that 'superweeds' might emerge in fields with 'seed mixtures'

D When toxin resistance is recessive and frequency of recessive alleles is low

Name	Subject Class	Class	Candidate Number
	2BI		

BIOLOGY **9648/02**
22 AUGUST 2016
HIGHER 2 **2 hours**

Paper 2 Core Paper

Additional Material: Writing Paper

READ THESE INSTRUCTIONS FIRST
Write your name, index number and class on this answer booklet.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

At the end of the examination, circle the number of the Section B question you have answered in the grid opposite.
Fasten all your work securely together.

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

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

This question paper consists of **21** printed pages.

[Turn over

For examiner's use

1 The appearance of cancer cells has been known to be different from normal cells. These differences have been used as a method of diagnosis by doctors. Prostate cells taken from wild-type mice and mice with prostate cancer were analysed.

Fig. 1.1 compares the same organelle found in these cells viewed under the electron microscope, while Fig. 1.2 shows the levels of ribosomal RNA (rRNA) measured in these two types of cells.

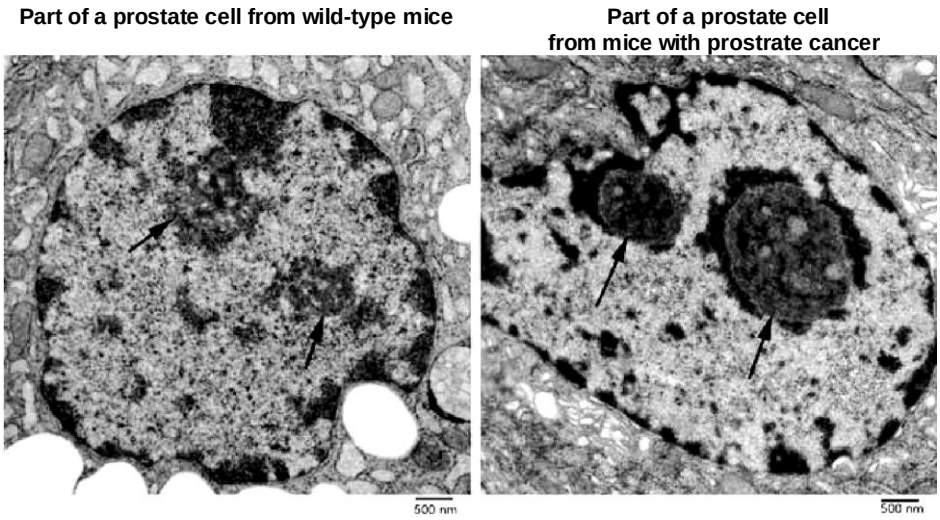


Fig. 1.1

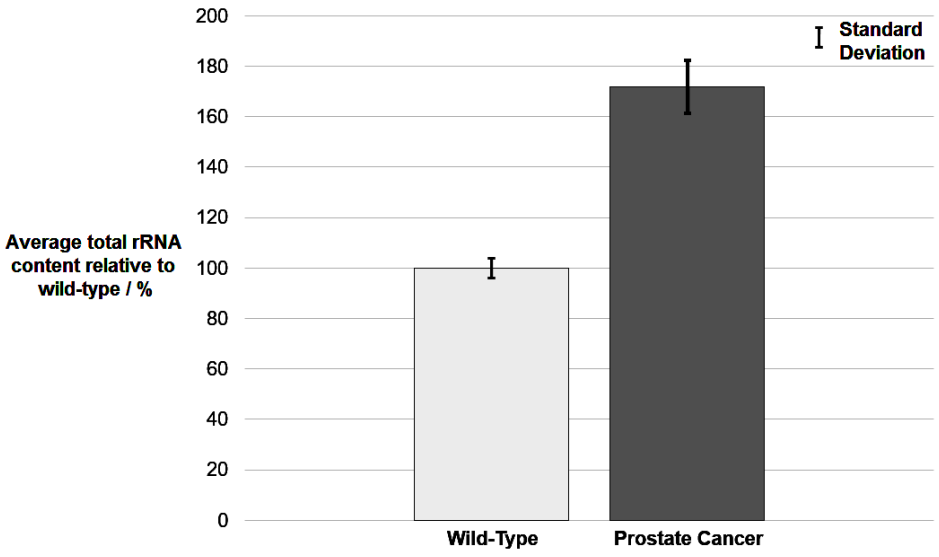


Fig. 1.2

For Examiner's Use

For examiner's use

Formatted Table

(a) (i) Identify the regions indicated by the arrows in Fig. 1.1.

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..... [1]

(ii) With reference to the regions identified in Fig. 1.1 and information given in Fig. 1.2, describe the differences between wild-type prostate cells and prostate cancer cells.

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..... [2]

(iii) Explain the differences described in (a)(ii).

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Studies on ribosomal proteins have shown that these proteins undergo a high degree of post-translational modifications, including methylation, acetylation and phosphorylation.

(b) Suggest reasons why post-translational modification of ribosomal proteins is needed.

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[Total: 8m]

For examiner's use

2 The meiotic cell cycle in the diploid germ cells of an organism can be followed by measuring the number of chromosomes as well as the amount of DNA material per cell over a period of time. Fig. 2.1 shows the results of the analyses, beginning with the start of prophase.

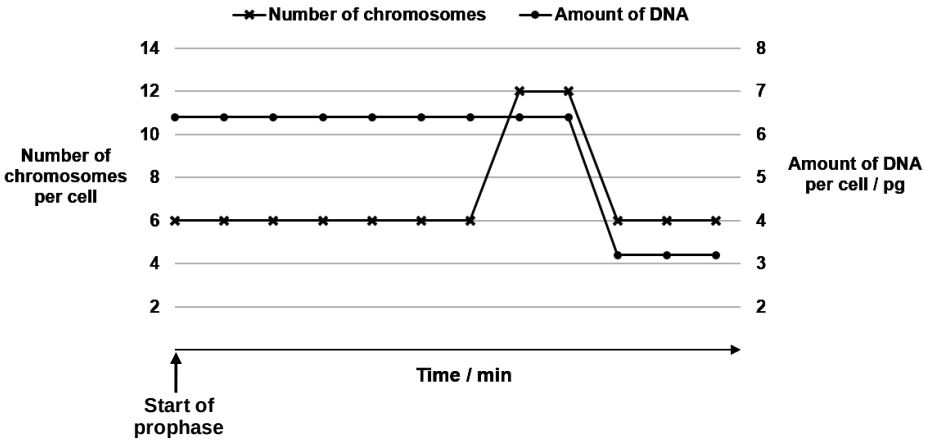

Fig. 2.1

(a) (i) On Fig. 2.1, indicate with an arrow where anaphase begins. . [1]

(ii) Explain whether Fig. 2.1 shows the first or the second meiotic division.

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(iii) The centromere of a chromosome comprises non-coding tandem repeats. Suggest how the structure of the centromere allows it to carry out one of its functions in cell division.

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In normal cells, the ends of chromosomes do not normally fuse with each other. However, in senescent cells where the ends of chromosomes are eroded to a critical length due to the end-replication problem, chromosomes may undergo end-to-end fusions. Fig. 2.2 shows how the ends of two sister chromatids may fuse and subsequently break during cell division at a location other than the point of fusion.

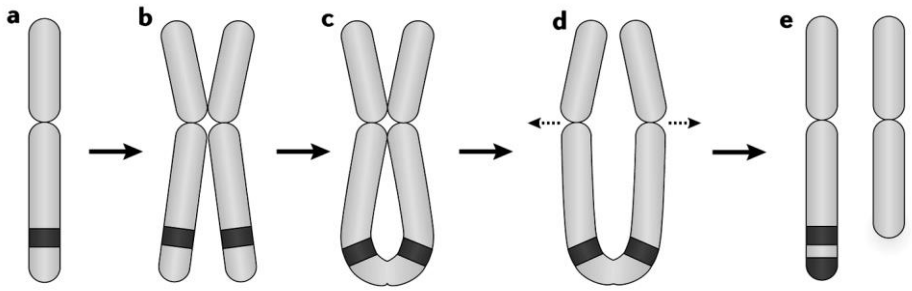

Fig. 2.2

(b) (i) Describe the result of the chromosomal mutation on the chromosomes shown in Fig. 2.2(e).

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..... [1]

(ii) Suggest how the ends of chromosomes are normally protected from end-to-end fusions.

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(iii) Explain how the end-replication problem will lead to the erosion of the ends of chromosomes.

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[Total: 11m]

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3 **(a)** A new type of influenza drug has been shown to be effective against drug-resistant strains of the flu virus, according to a study led by University of British Columbia researchers in 2013. This drug works by inhibiting newly-formed influenza viruses from leaving the cell surface membrane of host cells, thus preventing the infection of other host cells.

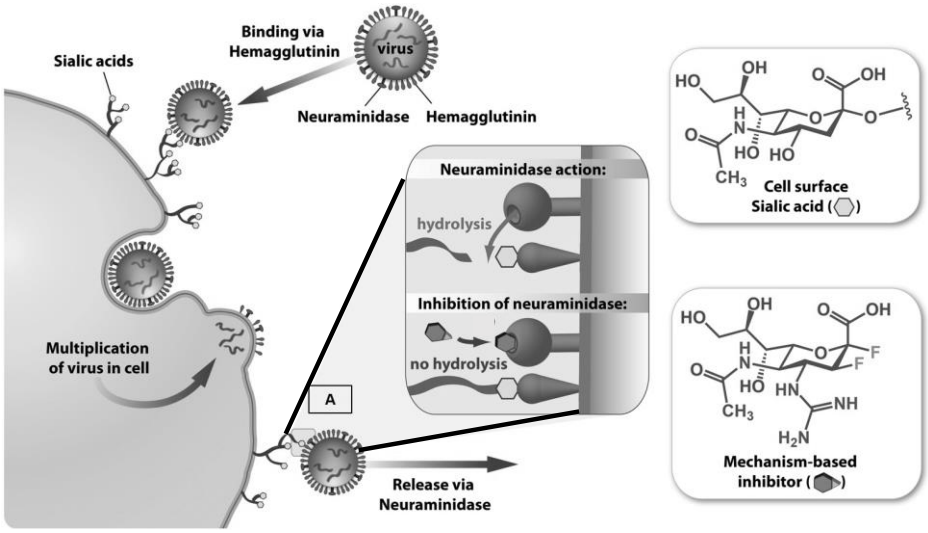

Fig. 3.1

(i) Describe the process by which influenza viruses replicate in host cells.

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For examiner's use

(ii) With reference to Fig. 3.1, describe how the drug prevents the newly formed influenza viruses from infecting other host cells in the process labelled **A**.

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(iii) Suggest a limitation of using this type of influenza drug.

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(b) Describe the differences between the lysogenic life cycle of a lambda phage and the life cycle of an influenza virus.

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[Total: 10m]

For examiner's use

4 The most common type of lung cancer is non-small cell lung cancer (NSCLC) which affects between 75% to 85% of all lung cancer patients. The *c-Met* gene which is located on chromosome 7 has been implicated in NSCLC.

To investigate the role of *c-Met* gene in NSCLC, researchers studied the level of expression of c-Met receptor tyrosine kinase protein in several NSCLC cancer cell lines.

cDNA was generated from mRNA samples from the cancer cell lines and subsequently sequenced. Fig. 4.1a shows the normal cDNA. The corresponding protein regions it codes for are labelled. Fig. 4.1b shows two mutant cDNAs and the corresponding protein regions they code for. The corresponding regions shown in the mutant cDNA may or may not be translated to functional protein structures.

Normal cDNA:

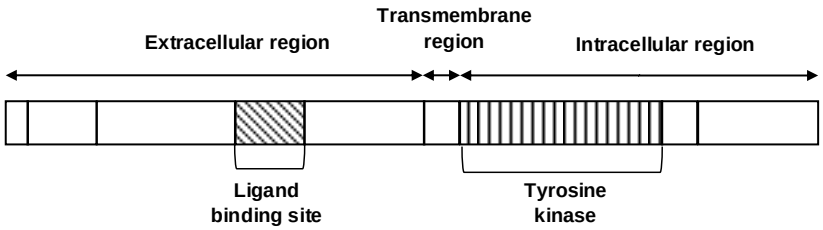
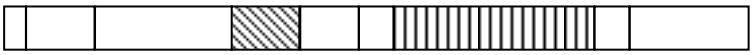


Fig. 4.1a

Mutant 1 cDNA:



Mutant 2 cDNA:

Fig. 4.1b

With reference to Fig. 4.1a and 4.1b,

(a) (i) State and explain the types of mutation in the *c-Met* gene that could have resulted in mutant 1 and mutant 2.

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Fig. 4.2 shows the cell signaling pathway of the c-Met receptor tyrosine kinase protein.

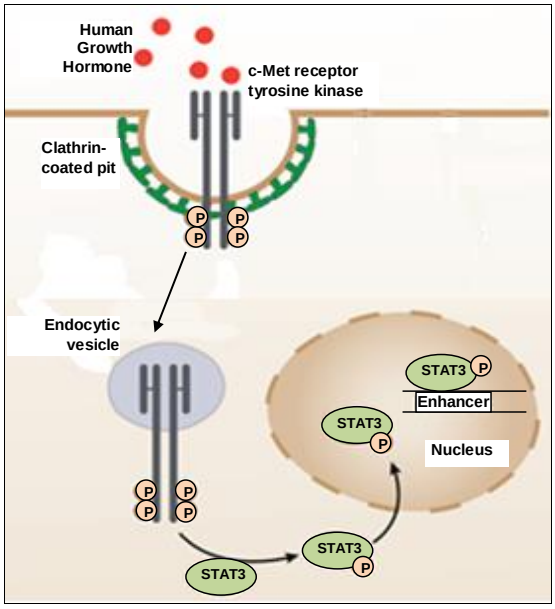

Fig. 4.2

(b) With reference to Fig. 4.2, describe the mechanism by which STAT3 controls the expression of genes involved in cell division.

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For Examiner Use

For examiner's use

(c) Many cells are shown to have a mutation in the *c-Met* gene resulting in a hyperactive c-Met receptor tyrosine kinase. However, not all of these cells develop into cancerous cells. Explain why.

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[Total: 12m]

For Examiner's Use

For examiner's use

5 (a) A geneticist is interested in studying eye and body pigmentation in *Drosophila*. The genes for eye colour and body colour are located 11 cM apart on chromosome 3. Purple eye is produced by a dominant mutation that is lethal in a homozygous state.

Female flies with purple eyes (**E**) and ebony bodies (**b**) were mated with male flies which were true-breeding for red eyes (**e**) and yellow bodies (**B**). All the F_1 offspring of this cross had yellow bodies. F_1 female flies which had purple eyes were chosen and test-crossed with male flies. 200 flies were present in the F_2 generation. There were equal numbers between the two parental phenotypes and equal numbers between the recombinant phenotypes.

(i) Draw a genetic diagram of the F_1 cross to show the observed results, indicating clearly the number of individuals in each different phenotypic class in the F_2 offspring.

[5]

In many other crosses, the proportion of recombinant offspring obtained is lower than the one observed in (a)(i). One possible cause is the occasional occurrence of a double cross-over in female *Drosophila*, as shown in Fig. 5.1 for a doubly heterozygous female.

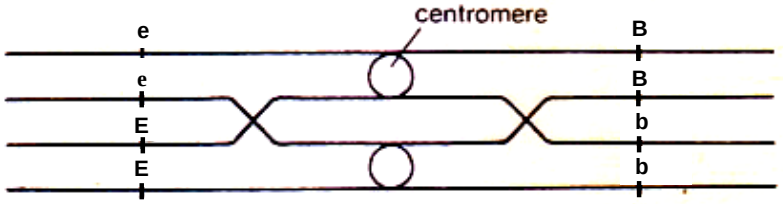

Fig. 5.1

(ii) Assuming that a double cross-over does occur between the two genes, suggest why the recombination frequency between the two loci would be lower than the predicted percentage.

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..... [1]

In a separate experiment, the geneticist decides to investigate the chromosomal positions of genes controlling body pigmentation and wing shape in *Drosophila*. The alleles for these traits are shown below.

B: Allele for grey body **b:** Allele for black body
C: Allele for straight wings **c:** Allele for curved wings

He carried out a cross between a female fly heterozygous for both loci with a homozygous recessive black-bodied, male fly with curved wings and obtained a large number of offspring. Table 5.1 shows the results.

Table 5.1

Phenotype	**Number of offspring**
Grey-bodied, straight wings	35
Black-bodied, straight wings	37
Grey-bodied, curved wings	35
Black-bodied, curved wings	33

A chi-squared test was used to find out if there is any significant difference between the observed and expected ratios.

The table of probabilities is given as follows:

degrees of freedom	probability, p				
	0.10	**0.05**	**0.02**	**0.01**	**0.001**
1	2.71	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.67	13.28	18.47

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(b) The calculated χ^2 value is found to be 0.229. Using the chi-squared (χ^2) test and the information given above, state the conclusion that may be drawn from the result.

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[Total: 10m]

For Examiner's Use

For examiner's use

6 Fig. 6.1 shows an electron micrograph of a plant cell.

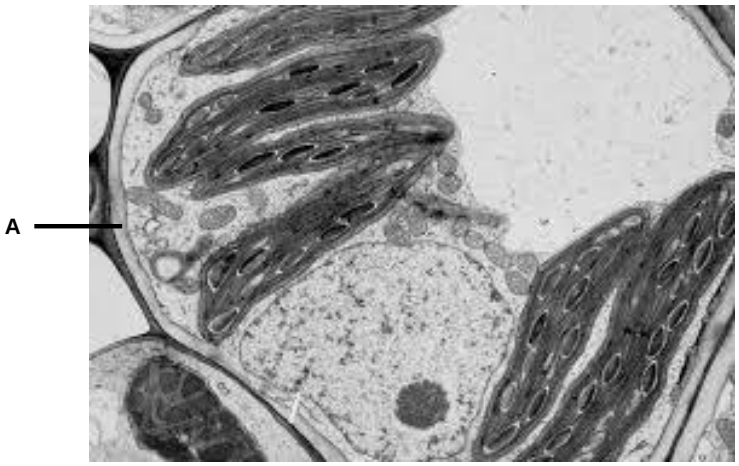

Fig. 6.1

(a) (i) Name the macromolecule which makes up structure **A**.

.....[1]

(ii) Describe how the structure of the named macromolecule in (a)(i) gives rise to its fibrous nature.

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.....[3]

For examiner's use

Fig. 6.2 shows how a seed undergoes germination to form a seedling.

Fig. 6.2

(b) (i) State what is meant by respiratory quotient (RQ).

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.....[1]

(ii) In some pea plants, the RQ has been found to be between three and four at the start of germination. Suggest a reason to explain the high RQ obtained at the early stages of germination.

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.....[2]

(iii) Following root growth, leaves will develop and this is necessary for the seedling to harvest energy from the sun. Light intensity plays a role in determining the rate of photosynthesis. State why the rate of photosynthesis remains constant even at high light intensity.

.....

.....[1]

[Total: 8m]

For examiner's use

7 The Fluid Mosaic Membrane Model of biological membrane structures was proposed as a basic framework model to describe the basic structures of biological membranes.

Synapses are unique cell junctions found between a neurone and another cell that serve to conduct signals in a neural pathway. A chemical synapse is cholinergic if it uses acetylcholine as its neurotransmitter.

(a) Explain the significance of the Fluid Mosaic Model of membrane structures in the transmission of signals across a cholinergic synapse.

[4]

For Examiner's Use

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Transmission at the neuromuscular junctions takes place in the same way as synapses between nerve cells. Fig. 7.1 shows a chemical synapse formed by the contact between a motor neurone and a muscle cell at the neuromuscular junction.

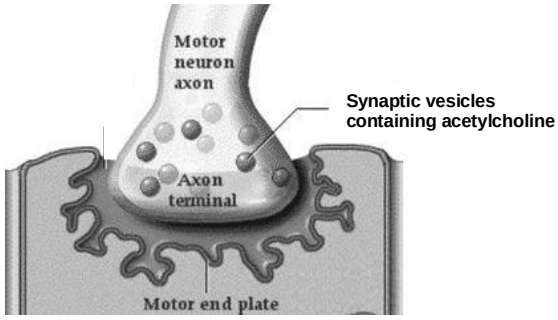

Fig. 7.1

Suxamethonium is a drug that mimics the action of acetylcholine (ACh) at acetylcholine receptors of the motor end plate. Unlike ACh, it cannot be hydrolysed by acetylcholinesterase.

(b) With reference to the above information, explain the effect of suxamethonium on the muscles.

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.....[4]

[Total: 8m]

For examiner's use

8 (a) The camelids are a group of mammals that share a large numbers of homologies. Recognisable camelids have been found fossilized in rock that are 45 million years old. Modern camelids have a discontinuous distribution. Guanacos and vicunas are found in South America together with the domesticated llamas and Alpacas. Bactrian Camels and Dromedaries are found in the Asian and South African deserts.

(i) Explain how homologies in camelids supports Darwin's theory of descent with modification.

[4]

(ii) Without considering the theory of continental drift, explain how discontinuous distribution of modern day camelids poses a problem to Darwin's theory of descent with modification.

[2]

For Examiner Use

For examiner's use

(b) Fig. 8.1 is a graph which shows the relationship between the number of amino acid changes of the protein haemoglobin with respect to the number of years since two organisms diverged from their common ancestor.

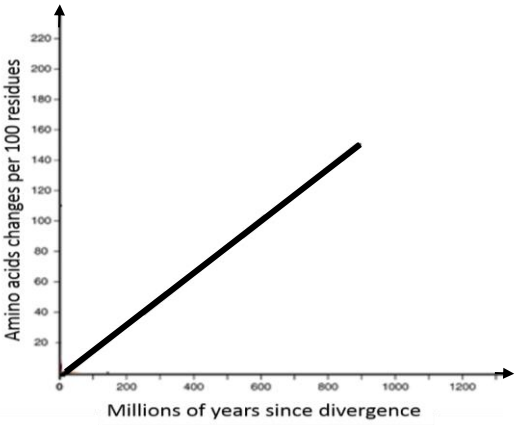

Fig. 8.1

(i) Explain the significance of the shape of the graph shown in Fig. 8.1.

[4]

(ii) Compare neutral mutation and silent mutation.

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[Total: 13m]

For examiner's use

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Section B

Answer **EITHER 9 OR 10**.

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

EITHER

9 **(a)** Using the induced-fit hypothesis, explain the mode of action of enzymes. [6]

(b) With reference to haemoglobin, explain the significance of bonds in maintaining the protein's structure and function. [8]

(c) Compare competitive and non-competitive inhibition of enzyme action. [6]

[Total: 20m]

OR

10 **(a)** Explain the roles of the key components of the homeostatic control system. [6]

(b) With the use of named examples, describe the role of hormones in the regulation of blood glucose concentration in humans. [8]

(c) Explain the significance of cell signalling pathways in homeostasis. [6]

[Total: 20m]

For examiner's use

For Examiner Use

Name	Subject Class	Class	Candidate Number
	2BI		

BIOLOGY **9648/02**
22 AUGUST 2016
HIGHER 2 **2 hours**

Paper 2 Core Paper

Additional Material: Writing Paper

READ THESE INSTRUCTIONS FIRST
Write your name, index number and class on this answer booklet.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

At the end of the examination, circle the number of the Section B question you have answered in the grid opposite.
Fasten all your work securely together.

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

For Examiner's Use	
Section A	
1	
2	
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Section B	
9 or 10	
Total	**100**

This question paper consists of **21** printed pages.

[Turn over

For examiner's use

1 The appearance of cancer cells has been known to be different from normal cells. These differences have been used as a method of diagnosis by doctors. Prostate cells taken from wild-type mice and mice with prostate cancer were analysed.

Fig. 1.1 compares the same organelle found in these cells viewed under the electron microscope, while Fig. 1.2 shows the levels of ribosomal RNA (rRNA) measured in these two types of cells.

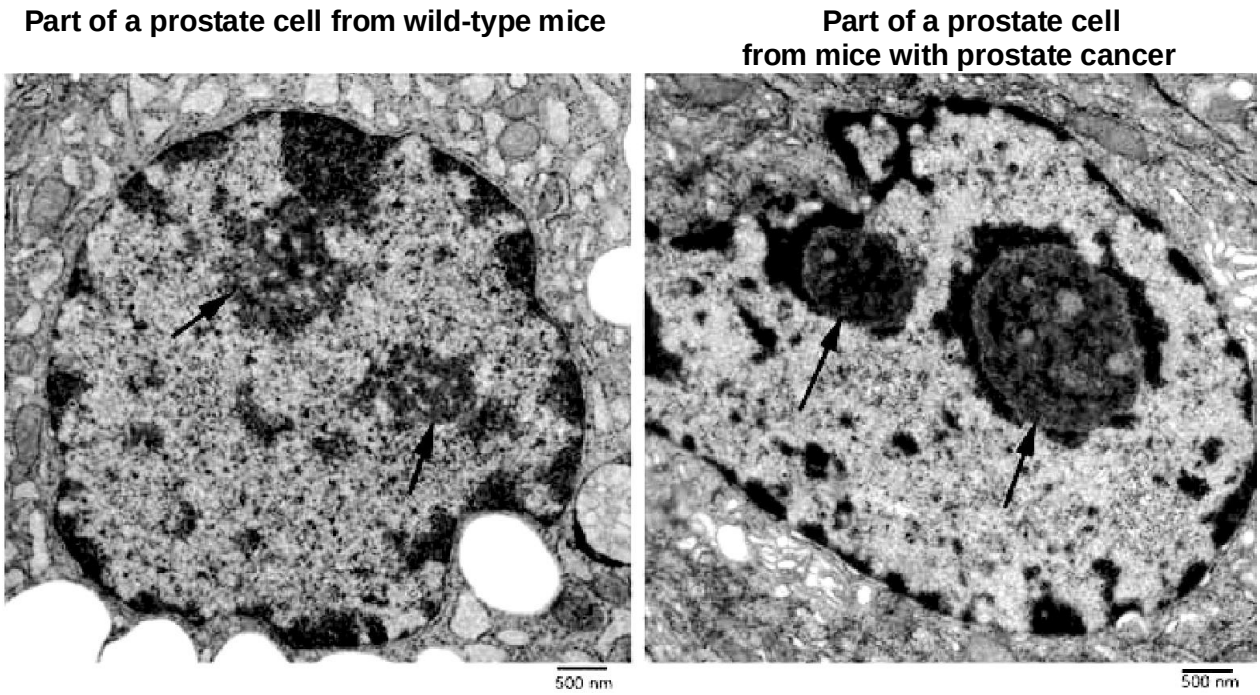


Fig. 1.1

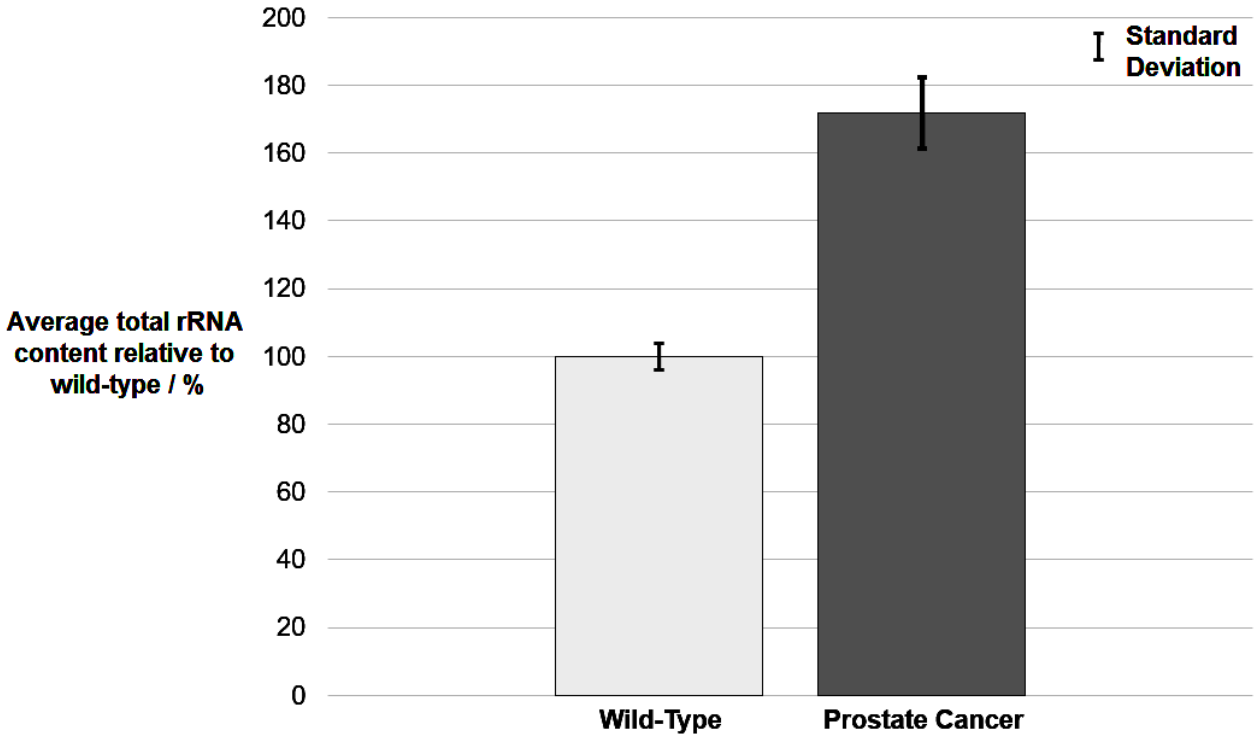


Fig. 1.2

For examiner's use

(a) (i) Identify the regions indicated by the arrows in Fig. 1.1.

Nucleoli;

R! Nucleolus [1]

(ii) With reference to the regions identified in Fig. 1.1 and information given in Fig. 1.2, describe the differences between wild-type prostate cells and prostate cancer cells.

1. **Prostate cancer cells have denser / larger nucleoli;**
2. **Prostate cancer cells contain more rRNA / show greater variation in rRNA content compared to wild-type cells + Ref. to data from Fig. 1.2 (72% higher in average total rRNA content / higher standard deviation of 20% vs 8%);**

@ 1m

[2]

(iii) Explain the differences described in (a)(ii).

1. **Nucleoli are the sites of rRNA synthesis through transcription / sites of assembly of ribosomal subunits, hence appear denser in cancer cells;**
2. **Cancer cells undergo higher rates of protein synthesis in preparation for faster rate of cell division;**
3. **Higher rates of translation is facilitated by a greater number of ribosomes, hence the higher rRNA content in cancer cells;**
4. **(Different cancer cells have different mutations resulting in) dysregulation of gene expression in cancer cells lead to different cells having different rates of protein synthesis and greater variation in rRNA content;**

@ 1m, max 3

[3]

Studies on ribosomal proteins have shown that these proteins undergo a high degree of post-translational modifications, including methylation, acetylation and phosphorylation.

(b) Suggest reasons why post-translational modification of ribosomal proteins is needed.

1. **Plays a role in the regulation of rate of translation / rate of protein synthesis / translation accuracy;**
2. **Affects the folding / 3D configuration of ribosomal proteins, which affects their binding with rRNA / assembly of ribosomal subunits;**
3. **Contributes to the stability of ribosomal proteins, making them more resistant to degradation by proteases;**
4. **Provides for diversity in protein structure beyond that allowed by the 20 encoded amino acids;**
5. **Ref. to inactive proteins becoming active, or making proteins functional;**

@ 1m, max 2

[2]

[Total: 8m]

2 The meiotic cell cycle in the diploid germ cells of an organism can be followed by measuring the number of chromosomes as well as the amount of DNA material per cell over a period of time. Fig. 2.1 shows the results of the analyses, beginning with the start of prophase.

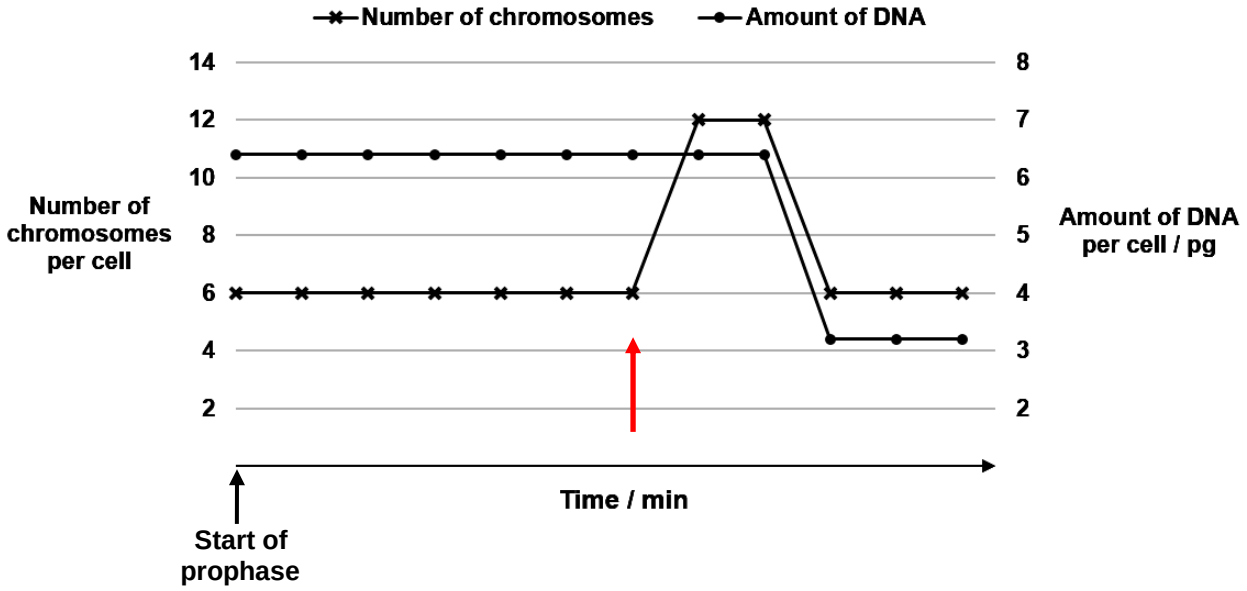


Fig. 2.1

(a) (i) On Fig. 2.1, indicate with an arrow where anaphase begins. [1]

Indicated as red arrow above;

(ii) Explain whether Fig. 2.1 shows the first or the second meiotic division.

1. **Second meiotic division / Meiosis II;**
2. **The number of chromosomes at the end of the division remained the same as that during prophase, of 6 chromosomes per cell / Cells were haploid at the start of the division and remained haploid;**
3. **During anaphase II, chromatids were separated to opposite poles and each chromatid is considered as an individual chromosome (hence no. of chromosomes / ploidy level remain unchanged); OR**
   The number of chromosomes at the end of meiosis I would have been half that of the parent cell / cells would be diploid at the start of the division but daughter cells would be haploid;

@ 1m

[3]

(iii) The centromere of a chromosome comprises non-coding tandem repeats. Suggest how the structure of the centromere allows it to carry out one of its functions in cell division.

1. **Nucleotide sequence of the centromere results in a specific 3D conformation which is complementary to (DNA-)binding site of proteins;**
2. **which facilitate adhesion of sister chromatids / which make up the kinetochore complex to allow attachment of spindle fibres;**

@ 1m

[2]

In normal cells, the ends of chromosomes do not normally fuse with each other. However, in senescent cells where the ends of chromosomes are eroded to a critical length due to the end-replication problem, chromosomes may undergo end-to-end fusions. Fig. 2.2 shows how the ends of two sister chromatids may fuse and subsequently break during cell division at a location other than the point of fusion.

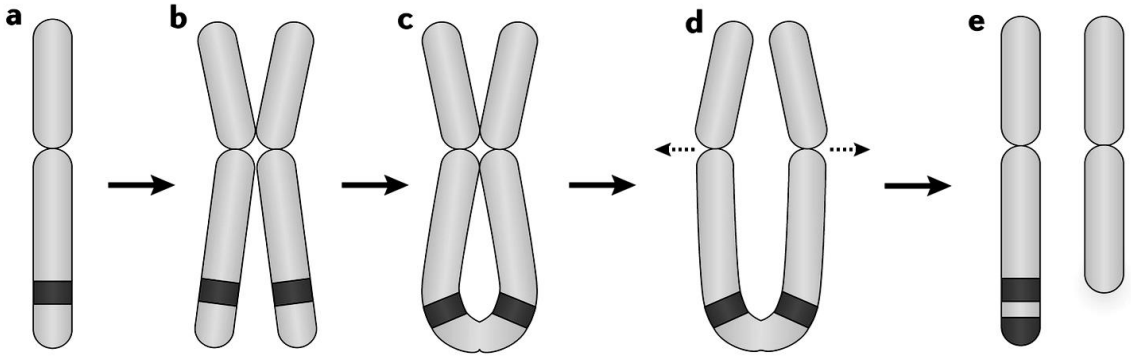


Fig. 2.2

(6) (i) Describe the result of the chromosomal mutation on the chromosomes shown in Fig. 2.2I.

A deletion on one chromosome and a duplication on the other chromosome;
R! translocation mutation **@ 1m**

[1]

(ii) Suggest how the ends of chromosomes are normally protected from end-to-end fusions.

1. **Telomeres form loops at the ends of chromosomes, hence there are no free ends for fusion to occur;**
2. **Proteins bind to telomeres at the ends of chromosomes, preventing the fusion of these ends;**

@ 1m, max 1

[1]

(iii) Explain how the end-replication problem will lead to the erosion of the ends of chromosomes.

1. **During the replication of DNA, the RNA primer at the 5' end of the lagging strand is removed;**
2. **but the gap cannot be filled with complementary deoxyribonucleotides;**
3. **Due to the absence of an existing 3'–OH group for DNA polymerase I to add nucleotides to / DNA polymerase I can only elongate a strand in a 5' to 3' direction;**
4. **Hence, over repeated cycles of DNA replication, there will be a gradual shortening of the ends of chromosomes;**

@ 1m

[3]

[Total: 11m]

For examiner's use

3 **(a)** A new type of influenza drug has been shown to be effective against drug-resistant strains of the flu virus, according to a study led by University of British Columbia researchers in 2013. This drug works by inhibiting newly-formed influenza viruses from leaving the cell surface membrane of host cells, thus preventing the infection of other host cells.

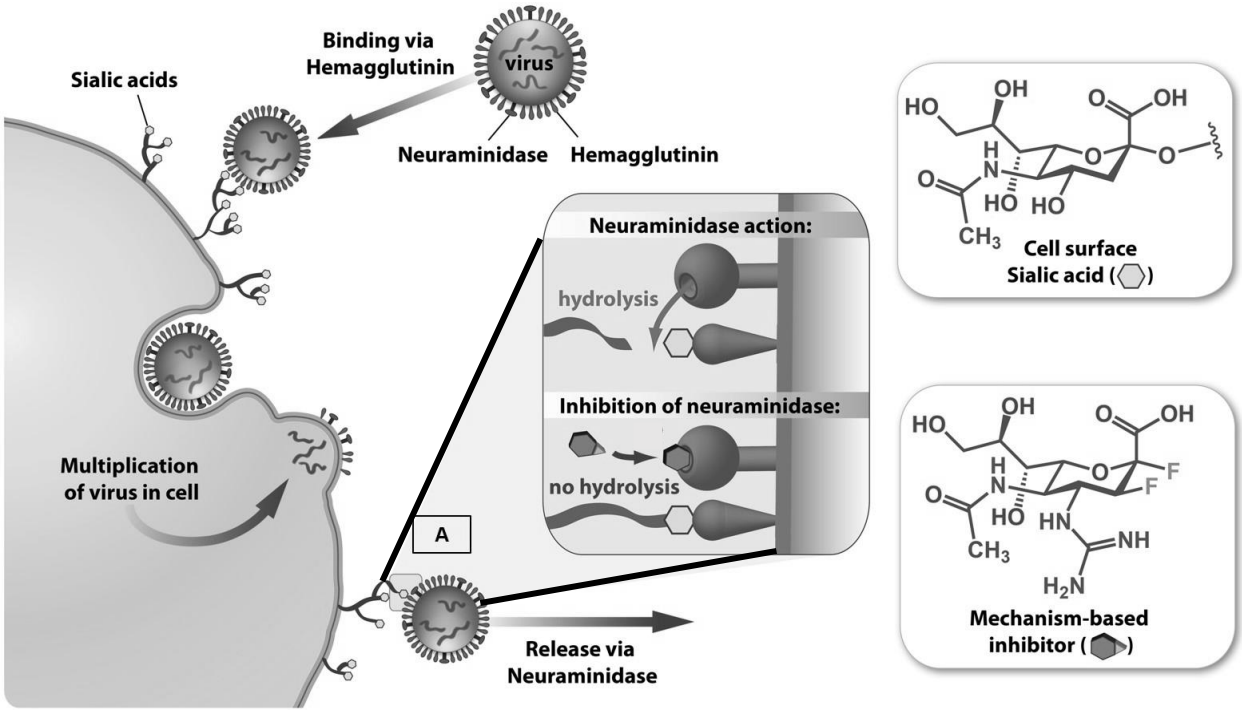


Fig. 3.1

(i) Describe the process by which influenza viruses replicate in host cells.

1. **Viral RNA genome is transcribed to mRNA by viral RNA-dependent RNA polymerase inside nucleus;**
2. **The mRNA is transported to the cytoplasm and translated to viral structural proteins and viral enzymes by host cell ribosomes;**
3. **The mRNA in the nucleus is also used as a template to replicate new RNA genomes for new influenza viruses;**
4. **Capsid proteins are transported back to the nucleus to bind with viral RNA to form ribonucleoproteins (RNPs);**
5. **Neuraminidase and haemagglutinin are transported through the Golgi apparatus and incorporated onto the cell surface;**

@ 1m, max 4 [4]

For examiner's use

(ii) With reference to Fig. 3.1, describe how the drug prevents the newly formed influenza viruses from infecting other host cells in the process labelled **A**.

1. **The drug is a competitive inhibitor of neuraminidase as it is structurally similar to the cell surface sialic acid,;**
2. **Hence the drug binds to the complementary active site on neuraminidase instead of sialic acid;**
3. **This prevents neuraminidase from hydrolysing the sialic acid receptors which are attached to the viral haemagglutin, from the cell surface membrane and hence viruses cannot be released;**

@ 1m [3]

(iii) Suggest a limitation of using this type of influenza drug.

1. **Concentration of inhibitors may not be high enough to target all neuraminidase/ large number of host cells, difficult to ensure inhibitors reach <u>all</u> the host cells;**
2. **Antigenic drift/shift/mutation in neuraminidase gene will result in a different 3D conformation of neuraminidase, so drug needs to be continually updated;**

AVP; **@ 1m** [1]

(6) Describe the differences between the lysogenic life cycle of a lambda phage and the life cycle of an influenza virus.

	Lysogenic life cycle	Influenza life cycle
1.	Use tail tip to bind to specific receptors on bacterial cells	Use haemaglutinin to bind to sialic acid receptors on epithelial cells;
2.	Only DNA is injected into host cell /Capsid left outside host cell	Capsid and viral RNA enters host cell;
3.	Viral DNA integrated into host cell genome directly	Viral RNA transcribed into mRNA by RNA-dependent RNA polymerase directly;
4.	Occurs in host cell bacteria	Occurs in epithelial cells;
5.	Do not result in death of the host cell	Release of influenza virus by budding may result in death of host cell;

AVP; **@1m, max 2**

[2]

[Total: 10m]

For examiner's use

4 The most common type of lung cancer is non-small cell lung cancer (NSCLC) which affects between 75% to 85% of all lung cancer patients. The *c-Met* gene which is located on chromosome 7 has been implicated in NSCLC.

To investigate the role of *c-Met* gene in NSCLC, researchers studied the level of expression of c-Met receptor tyrosine kinase protein in several NSCLC cancer cell lines.

cDNA was generated from mRNA samples from the cancer cell lines and subsequently sequenced. Fig. 4.1a shows the normal cDNA. The corresponding protein regions it codes for are labelled. Fig. 4.1b shows two mutant cDNAs and the corresponding protein regions they code for. The corresponding regions shown in the mutant cDNA may or may not be translated to functional protein structures.

Normal cDNA:

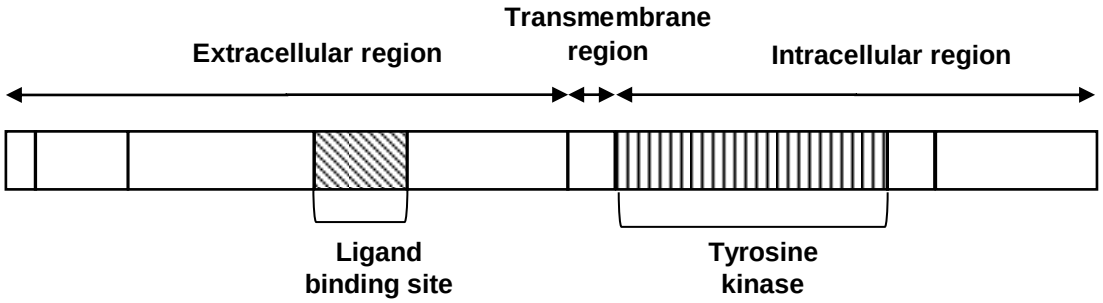


Fig. 4.1a

Mutant 1 cDNA:

Mutant 2 cDNA:

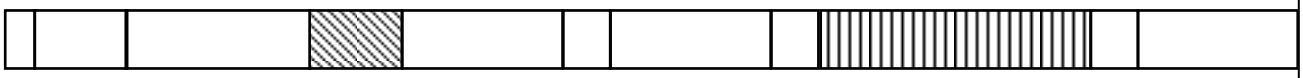


Fig. 4.1b

With reference to Fig. 4.1a and 4.1b,

(a) (i) State and explain the types of mutation in the *c-Met* gene that could have resulted in mutant 1 and mutant 2.

Mutant 1: (max 2)

1. **Insertion/deletion/substitution of nucleotide(s);**
2. **Such that there is the creation of a new splice site in the mRNA;**
3. **Spliceosome deletes one or more exons resulting in a shortened sequence coding for the extraceullar region of the protein;**

OR

4. **Deletion of several nucleotides;**
5. **In the exon;**
6. **Hence, shorter exon resulting in a shortened sequence coding for the extracellular region of the protein;**

Mutant 2: (max 2)

7. **Duplication/insertion of a part of the gene sequence;**
8. **Such that exons were duplicated/inserted;**
9. **Resulting in a lengthened sequence coding for a part of the extracellular and transmembrane region.;**
   OR
10. **Insertion/deletion/substitution of nucleotide(s);**
11. **Such that there is the deletion of a splice site in the mRNA;**
6. **Spliceosome does not delete one or more introns resulting in a lengthened sequence coding for a part of the extracellular and transmembrane region.;**

@1m, max 4

[4]

Fig. 4.2 shows the cell signaling pathway of the c-Met receptor tyrosine kinase protein.

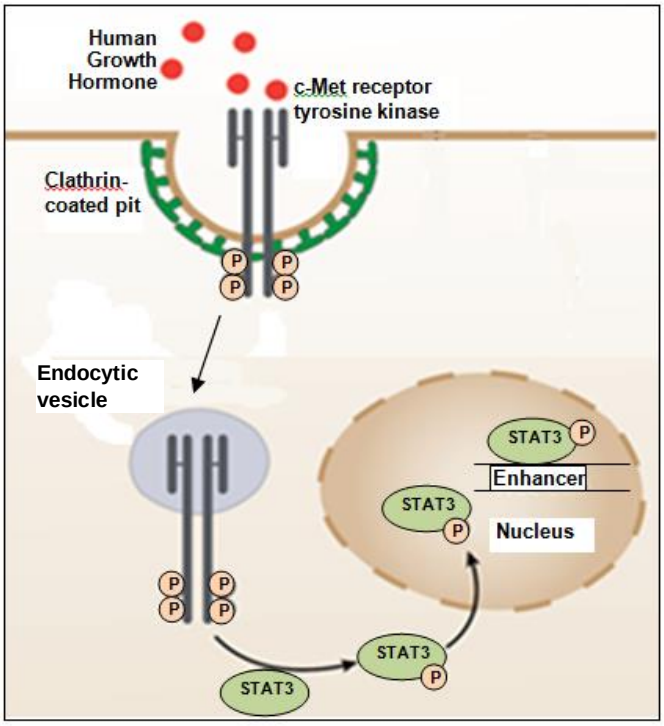


Fig. 4.2

(6) With reference to Fig. 4.2, describe the mechanism by which STAT3 controls the expression of genes involved in cell division.

1. **STAT 3 is an activator;**
2. **Upon phosphorylation, STAT3 changes its 3D conformation and is activated and travels into the nucleus via the nuclear pore;**
3. **It is complementary in conformation/configuration to the enhancer sequence and binds to it.;**
4. **A DNA-bending protein is recruited and causes DNA bending, (which brings STAT3 closer to the promoter.);**
5. **Other general transcription factors, (mediator proteins) and RNA polymerase**

are also recruited to the promoter.;

6. **STAT3 binds to the above, forming a transcription initiation complex.;**

7. **Hence, transcription of genes involved in cell division occurs at an optimal/ increased/higher rate.;**

@1m, max 4

Reference to phosphorylation of STAT3 is required for awarding of full marks.

[4]

(c) Many cells are shown to have a mutation in the *c-Met* gene resulting in a hyperactive c-Met receptor tyrosine kinase. However, not all of these cells develop into cancerous cells. Explain why.

1. **A loss of function mutation in both alleles of a tumour suppressor gene is also required.;**
2. **For the cell to divide excessively.;**
3. **Allowing for an accumulation of mutations in other genes involved in cancer development (e.g. telomerase, genes involved in angiogenesis etc.)**
4. **In a single cell lineage;**
5. **Cancer is a multistep process.;**

@1m, max 4

[4]

[Total: 12m]

For examiner's use

5 (a) A geneticist is interested in studying eye and body pigmentation in *Drosophila*. The genes for eye colour and body colour are located 11 cM apart on chromosome 3. Purple eye is produced by a dominant mutation that is lethal in a homozygous state.

Female flies with purple eyes (**E**) and ebony bodies (**b**) were mated with male flies which were true-breeding for red eyes (**e**) and yellow bodies (**B**). All the F_1 offspring of this cross had yellow bodies. F_1 female flies which had purple eyes were chosen and test-crossed with male flies. 200 flies were present in the F_2 generation. There were equal numbers between the two parental phenotypes and equal numbers between the recombinant phenotypes.

(i) Draw a genetic diagram of the F_1 cross to show the observed results, indicating clearly the numbers of individuals in each different phenotypic class in the F_2 offspring.

F_1 phenotypes	**female with purple eyes and yellow body**	**X**	**male with red eyes and ebony body**	
F_1 genotypes	**(Eb)(eB)**	**X**	**(eb)(eb)**	**;**
Gametes	**(Eb)** **(eB)** **(EB)** **(eb)**		**(eb)**	**;**

F_2 genotypes	**(Eb)(eb)**	**(eB)(eb)**	**(EB)(eb)**	**(eb)(eb)**	**;**
F_2 phenotypes	**purple eyes ebony body**	**red eyes yellow body**	**purple eyes yellow body**	**red eyes ebony body**	**;**
	89	**89**	**11**	**11**	**;**
	parental phenotypes		**recombinant phenotypes**		

[5]

For examiner's use

In many other crosses, the proportion of recombinant offspring obtained is lower than the one observed in (a)(i). One possible cause is the occasional occurrence of a double cross-over in female *Drosophila*, as shown in Fig. 5.1 for a doubly heterozygous female.

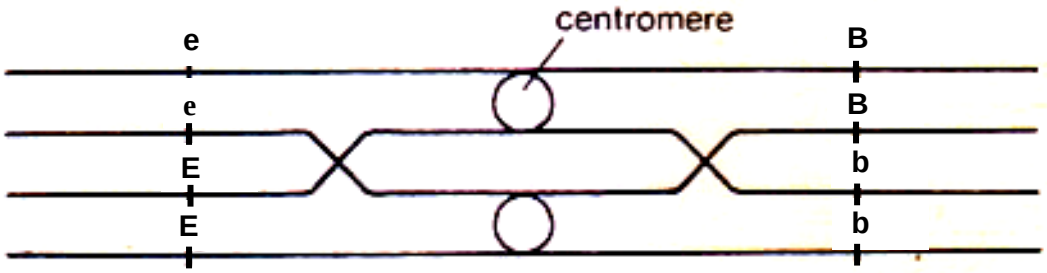


Fig. 5.1

(ii) Assuming that a double cross-over does occur between the two genes, suggest why the recombination frequency between the two loci would be lower than the predicted percentage.

A double cross-over returns / restores the grouping of the linked alleles to the parental combination; OWTTE [1]

In a separate experiment, the geneticist decides to investigate the chromosomal positions of genes controlling body pigmentation and wing shape in *Drosophila*. The alleles for these traits are shown below.

B: Allele for grey body **b:** Allele for black body
C: Allele for straight wings **c:** Allele for curved wings

He carried out a cross between a female fly heterozygous for both loci with a homozygous recessive black-bodied, male fly with curved wings and obtained a large number of offspring. Table 5.1 shows the results.

Table 5.1

Phenotype	**Number of offspring**
Grey-bodied, straight wings	35
Black-bodied, straight wings	37
Grey-bodied, curved wings	35
Black-bodied, curved wings	33

A chi-squared test was used to find out if there is any significant difference between the observed and expected ratios.

The table of probabilities is given as follows:

degrees of freedom	probability, p				
	0.10	**0.05**	**0.02**	**0.01**	**0.001**
1	2.71	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.67	13.28	18.47

For examiner's use

(b) The calculated χ^2 value is found to be 0.229. Using the chi-squared (χ^2) test and the information given above, state the conclusion that may be drawn from the result.

1. **Calculated χ^2 value of 0.229 is less than the critical χ^2 value of 7.82;**
2. **At df =3;**
3. **<u>p> 0.05</u>;**
4. **Difference between observed ratio and expected ratio is not significant and probably due to chance;**
5. ***The genes controlling body pigmentation and wing shape are not linked / are found on separate chromosomes;**

***compulsory pt @ 1m** [4]

[Total: 10m]

For examiner's use

6 Fig. 6.1 shows an electron micrograph of a plant cell.

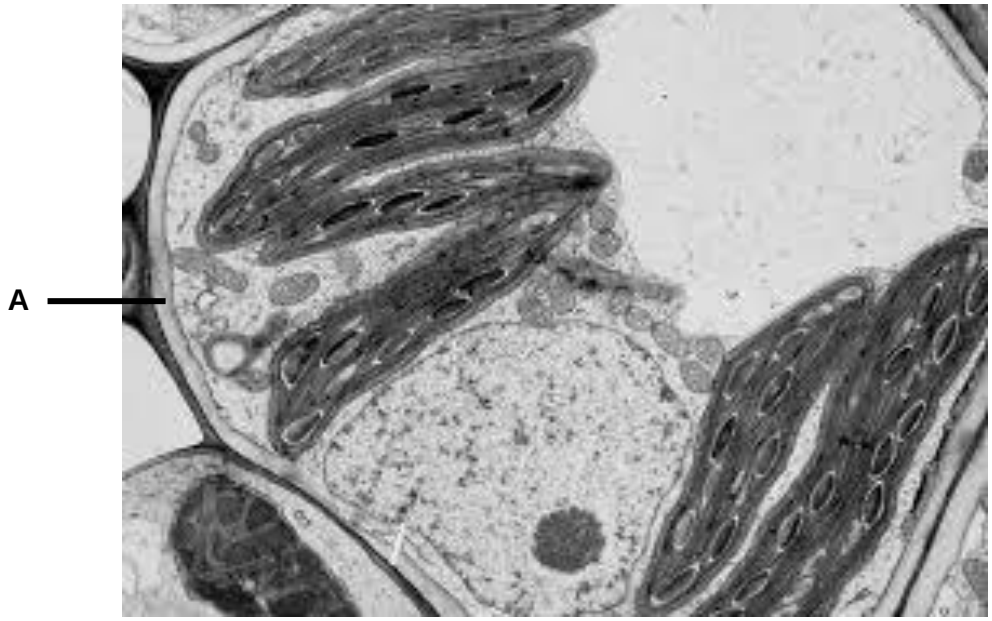


Fig. 6.1

(6) (i) Name the macromolecule which makes up structure **A**.

Cellulose; [1]

(ii) Describe how the structure of the named macromolecule in (a)(i) gives rise to its fibrous nature.

1. **Polymer of β glucose residues with alternate glucose residues rotated 180°;**
2. **OH groups found on both sides of the chain enables crosslinking / formation of H bonds with other chains;**
3. **Chains associate to form microfibrils which are arranged in larger bundles to form macrofibrils (idea of bundling is important);**
4. **Chains form long strands/fibres;** **@ 1m, max 3** [3]

Fig. 6.2 shows how a seed undergoes germination to form a seedling.

Fig. 6.2

(b) (i) State what is meant by respiratory quotient (RQ).

1. RQ is the ratio of carbon dioxide given out to oxygen taken in during respiration;

[1]

(ii) In some pea plants, the RQ has been found to be between three and four at the start of germination. Suggest a reason to explain the high RQ obtained at the early stages of germination.

1. The testa or seed coat still covers the seed/seed is embedded deep in the soil, making it difficult for oxygen to penetrate inside;
2. Respiration in seed is partly anaerobic (hence, the RQ > 1);

[2]

(6) Following root growth, leaves will develop and this is necessary for the seedling to harvest energy from the sun. Light intensity plays a role in determining the rate of photosynthesis. State why the rate of photosynthesis remains constant even at high light intensity.

Light is no longer limiting / another factor e.g. CO_2 or temperature is now limiting/ light saturation has been reached; **@ 1m** [1]

[Total: 8m]

For examiner's use

7 The Fluid Mosaic Membrane Model of biological membrane structures was proposed as a basic framework model to describe the basic structures of biological membranes.

Synapses are unique cell junctions found between a neurone and another cell that serve to conduct signals in a neural pathway. A chemical synapse is cholinergic if it uses acetylcholine as its neurotransmitter.

(6) Explain the significance of the Fluid Mosaic Model of membrane structures in the transmission of signals across a cholinergic synapse.

1. Fluid: phospholipids free to move within the membrane;

2. allow synaptic vesicles containing neurotransmitters to fuse with plasma membrane of pre-synaptic neurone to be released into the synaptic cleft/ allow membrane proteins to change conformation even when embedded in membrane;

3. Mosaic: Presence of (a variety of) proteins scattered on/in the membrane;

4. Voltage-gated Ca2+ ion channels which allow Ca2+ influx across pre-synaptic membrane upon membrane depolarisation/ Chemically-gated Na+ ion channels which allow Na+ influx across post-synaptic membrane upon binding of neurotransmitters (to their specific receptors);

[4]

Transmission at the neuromuscular junctions takes place in the same way as synapses between nerve cells. Fig. 7.1 shows a chemical synapse formed by the contact between a motor neurone and a muscle cell at the neuromuscular junction.

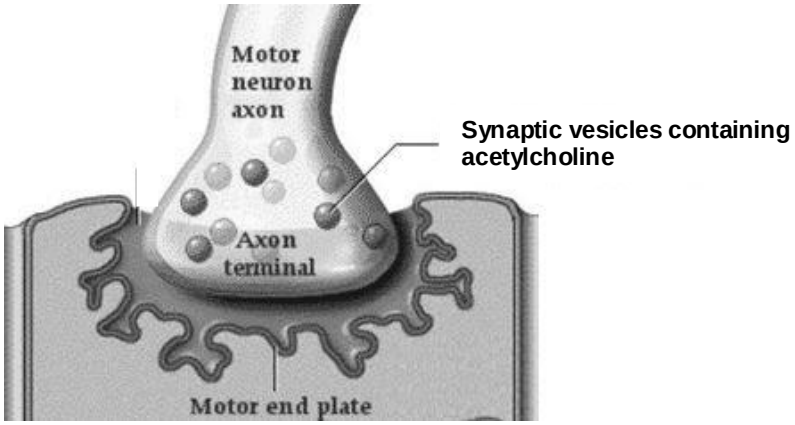


Fig. 7.1

Suxamethonium is a drug that mimics the action of acetylcholine (Ach) at acetylcholine receptors of the motor end plate. Unlike Ach, it cannot be hydrolysed by acetylcholinesterase.

(b) With reference to the above information, explain the effect of suxamethonium on the muscles.

1. Suxamethonium is structurally similar to acetylcholine;

2. Hence, it <u>competes</u> for binding to the Ach receptors at the motor end plate; (R! Competitive inhibition)

3. Because it cannot be hydrolysed by acetylcholinesterase, this results in prolonged opening of the chemically-gated Na^+ ion channels ;

4. Influx of Na+ ions results in depolarization of the motor end-plate;

5. the end plate remains depolarised/ cannot be repolarize;

6. Muscles remained contracted/ cannot relax/ OWTTE;

[4]

[Total: 8m]

For examiner's use

8 (a) The camelids are a group of mammals that share a large numbers of homologies. Recognisable camelids have been found fossilized in rock that are 45 million years old. Modern camelids have a discontinuous distribution. Guanacos and vicunas are found in South America together with the domesticated llamas and Alpacas. Bactrian Camels and Dromedaries are found in the Asian and South African deserts.

(i) Explain how homologies in camelids supports Darwin's theory of descent with modification.

1. Presence of homologous structures in all the camelids shows that they inherited a common set of genes from common ancestor;
2. Ref to anatomical, embryological and molecular homologies;
3. (Modification arises due to) natural selection selecting for better adapted traits/ phenotypes in each population;
4. Due to different selection pressure found in different geographical location;

[4]

(ii) Without considering the theory of continental drift, explain how discontinuous distribution of modern day camelids poses a problem to Darwin's theory of descent with modification.

1. Different species which are descendants of a common ancestors should be found close in geographical proximity;
2. As their range is limited by geographical barriers, the ocean between continents;
3. Hence being found on different continents in present day suggest modern camelids may not descended from a common ancestor;

[2]

For examiner's use

(b) Fig. 8.1 is a graph which shows the relationship between the number of amino acid changes of the protein haemoglobin with respect to the number of years since two organisms diverged from their common ancestor.

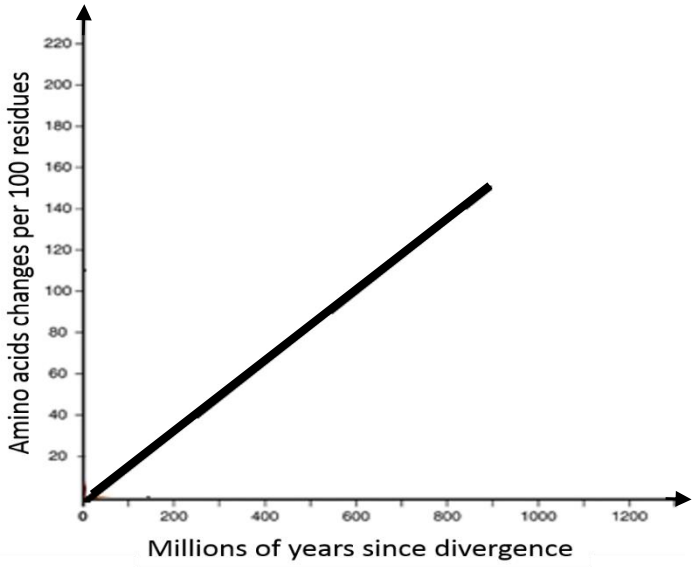


Fig. 8.1

(i) Explain the significance of the shape of the graph shown in Fig. 8.1.

1. **The linear graph shows mutation accumulates at a <u>constant rate</u> over time;**
2. **Shows that most mutation / amino acid differences between organisms are <u>neutral mutation / silent mutation</u>;**
3. **As the mutation does not come under selection pressure;**
4. **Frequency of the mutation in the population changes mainly due to <u>genetic drift</u>;**
5. **Elaborate genetic drift;**
6. **Use data as molecular clock to calculate no. of years since divergence of a species from ancestral species;**

[4]

(ii) Compare neutral mutation and silent mutation.

1. **Both does not affect the fitness of the organism;**
2. **Both involve a change in nucleotide sequence;**
3. **However silent mutation does not involve a change to the amino acid sequence of the polypeptide;**
4. **While neutral mutation includes changes to the amino acid sequence;**
5. **Both do not change the phenotype of an organism;**

[3]

[Total: 13m]

For examiner's use

Section B

Answer **EITHER 9 OR 10**.

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

EITHER

9 **(a)** Using the induced-fit hypothesis, explain the mode of action of enzymes. [6]

1. **Enzyme lowers activation energy/ alternative pathway of lower activation energy;**
2. **Ref. to *mechanisms e.g. 'proximity effect', 'strain effect' and 'orientation surface'* (any one)**
3. **Enzyme <u>specific</u> in its action;**
4. **due to <u>complementary</u> 3D configuration/conformation of <u>active site</u> to that of substrate;**
5. **The induced fit model suggests that the enzyme and the substrate do not fit together exactly;**
6. **<u>Effective</u> collisions between enzymes and (specific) substrate molecules result in substrate binding to active site of enzyme;**
7. **The enzyme undergoes a 3D conformation change, which improves the fit between substrate and enzyme;**
8. **to form enzyme-substrate (ES) complexes;**
9. **Product formed that no longer fits into active site and is released;**
10. **Enzyme remains unchanged at the end of the reaction (and can be reused);**

For examiner's use

(b) With reference to haemoglobin, explain the significance of bonds in maintaining the protein's structure and function. [8]

Compulsory points (must be seen for full marks):

1. **The primary structure is maintained by peptide bonds between amine groups and carboxyl groups of amino acids;**
2. **The secondary structure which refers to the α helix is maintained by hydrogen bonds between –CO and –NH groups of the polypeptide backbone;**
3. **The tertiary structure which refers to the overall 3D configuration/ globular shape of the subunit that is maintained by hydrogen bonds, ionic bonds and hydrophobic interactions (any 2) between the R groups of amino acid residues.;**
4. **The quaternary structure which refers to the association of the two polypeptide chains in each dimer and association of the two dimers are held together by mainly hydrophobic interactions and weak hydrogen and ionic bonds respectively; (give for quaternary structure if student describes either association within or between dimers)**

N.B. If there is none of the above points, max 4 marks can be awarded.

Description of tertiary structure:

5. **Globular structure allows for the packing of many haemoglobin in red blood cells;**
6. **Each globin polypeptide is folded such that the bulk of the hydrophobic amino acid residues are buried in the interior of the globular structure;**
7. **Ref. to haem binding pocket lined with hydrophobic amino acids to provide a hydrophobic environment for hydrophobic haem group to bind;**
8. **Ref. to presence of Fe^{2+} to allow for reversible binding of O_2;**
9. **Hydrophilic amino acid residues are on the outside (to form hydrogen bonds with water);**
10. **Haemoglobin is soluble in aqueous medium and hence a good transport protein for oxygen in blood;**

Description of quaternary structure:

11. **(Association of two dimers with weak hydrogen and ionic bonds) results in the ability of the two dimers to move with respect to each other;**
12. **This allows for cooperativity;**
13. **When an oxygen molecule binds to/is released from 1 haemoglobin subunit, the binding/ release induces a conformational change in the remaining subunit;**
14. **Which increases/ lowers the affinity for oxygen of the remaining three oxygen binding sites respectively;**
15. **Hence facilitates the loading and unloading of oxygen;**

For examiner's use

(c) Compare competitive and non-competitive inhibition of enzyme action. [6]

Similarities:

1. **At <u>low substrate concentration</u>, rate of reaction in the presence of inhibitors is slower than that in the absence of inhibitor;**

Features	Competitive	Non-competitive
Structure of inhibitor	**2. Resembles substrate;**	**Does not resemble substrate;**
Binding site of inhibitor	**3. Binds to active site of enzyme;**	**Binds to enzyme at a region other than the active site/ allosteric site;**
Mechanism of inhibition	**4. Blocks substrates from binding to active site of the enzyme;**	**Blocks substrates from binding to active site by changing the conformation of the active site;**
Effect of high substrate concentration on inhibition	**5. Inhibition can be reversed at high substrate concentration;** **6. V_{max} in the presence of inhibitor can be very close to that of reaction in the absence of inhibitor;**	**Inhibition cannot be reversed at high substrate concentration;** **V_{max} in the presence of inhibitor is less than that of reaction in the absence of inhibitor;**

[Total: 20m]

OR

10 (a) Explain the roles of the key components of the homeostatic control system. . [6]

1. **It consists of the following components: detector, control centre and effector;**
2. **The detector/ receptor senses the stimuli and the information is relayed to the control centre;**
3. **The control centre (receives the information and) compares it with the set-point of that parameter;**
4. **Which is the optimal level of that specific parameter;**
5. **When there is a deviation in the parameter from the set point, the control centre initiates an appropriate response *(to restore conditions back to the set point);**
6. **This action is conveyed to the effector through the communication systems/nervous & endocrine systems in the body;**
7. **The effector will carry out the response (initiated by the control centre to restore conditions to the set point);**
8. **Ref to negative feedback mechanism;**

*** Ref to be made at least once in answer**

@ 1m, max 6

(b) With the use of named examples, describe the role of hormones in the regulation of blood glucose concentration in humans. [8]

<u>Insulin:</u>

1. **When blood glucose concentration is higher than the set point of 80-90mg/100ml;**
2. **The change is detected by <u>β cells</u> (α and β cells of the islets of Langerhans) and are stimulated to secrete (more) insulin (and secretion of glucagon by α cells is inhibited);**
3. **Insulin binds to cell-surface insulin receptors on the plasma membrane of effector cells e.g. liver, skeletal muscles and adipose cells (at least one);**
4. **(Upon binding of insulin,) the insulin receptor, which is a receptor tyrosine kinase, phosphorylates intracellular enzymes to bring about the following effects:;**
5. **Acceleration of the rate of glucose uptake via facilitated diffusion;**
6. **By increasing the number of glucose transporters in the plasma membrane of cells (but not in liver cells);**
7. **Rate of glycolysis is increased, glycogenesis is stimulated, glycogenolysis is inhibited, stimulates amino acid absorption and protein synthesis, inhibits gluconeogenesis, stimulates lipogenesis.; (any two)**

[max 4 marks]

Glucagon:

8. **When the blood glucose concentration is lower than the set point of 80 - 90mg/100ml;**
9. **The change is detected by α cells (α and β cells of the islets of Langerhans) and are stimulated to secrete (more) glucagon (and secretion of insulin by β cells is inhibited);**
10. **Glucagon binds to the cell-surface glucagon receptors on the plasma membrane of effector cells e.g. liver;**
11. **Upon binding of glucagon to its receptor, a G-protein coupled receptor, adenylate cyclase is activated to produce cyclic AMP (cAMP) from ATP to bring about the following effects:;**
12. **Stimulates glycogenolysis, gluconeogenesis and lipolysis.; (any two)**

[max 4 marks]

13. **Hence, the opposite actions of both hormones help to maintain the blood glucose concentration about a set point;**
14. **The ratio of the amounts of both hormones determines the net effect.;**

(c) Explain the significance of cell signalling pathways in homeostasis. [6]

1. **Cell signaling pathways allows for cellular response by an extracellular signal.;**
2. **Such that a constant internal environment can be maintained.;**
3. **It allows for signal amplification;**
4. **Since at each catalytic step in the cascade, the number of activated products is much greater than in the preceding step.;**
5. **A small number of extracellular signal molecules is sufficient to elicit a large cellular response.;**
6. **Ref to a small number of glucagon molecules binding to receptors on the surface of an effector cell can lead to the release of hundreds of millions of glucose molecule from glycogen.;**

[max 2]

7. **It allows for coordination and regulation (to information coming from different sources in a body).;**
8. **A pathway that is triggered by a single kind of signal can diverge to produce two or more cellular responses.;**
9. **Ref. to receptor tyrosine kinases which can activate multiple relay proteins or second messengers which can regulate numerous proteins.;**
10. **Different signal transduction pathways can also converge to modulate a signal response;**

[max 2]

11. It contributes to the specificity of the response;
12. Because of the specific constitution of proteins within target cell such as signalling proteins, receptors, relay proteins to carry out the response in a particular cell type.;
13. A specific signal molecule must bind to a specific receptor with a specific complementary conformation to elicit a specific reaction via a specific pathway;
14. Ref. to muscle cells responding to insulin but not glucagon;
15. Hence, two cells can respond differently to the same signal / Multiple responses in different cells to one signal molecule because 1 ligand can trigger multiple signal transduction pathways to elicit different responses;
16. Ref. to Insulin causes increase in glucose uptake in muscle and fat cells but not in liver cells because liver cells do not express a specific type of glucose transporter.;

[max 2]

17. The hormone may be carried in the blood stream and cells in all parts of the body will be exposed to the hormone;
18. Hence, as long as the cells have the appropriate receptor, many cells in different parts of the body can be activated and they respond simultaneously;
19. Ref. to Insulin causes increase in glucose uptake in muscle and fat cells in different parts of the body;

[max 2]

N.B. Students have to discuss at least 3 of the 4 areas to be awarded the full marks.

[Total: 20m]

Name	Subject Class	Class	Candidate Number
	2BI		

BIOLOGY **9648/03**

Applications Paper and Planning Question **26 Aug 2016**

PAPER 3 **2 hours**

Additional Materials: Writing Paper

READ THESE INSTRUCTIONS FIRST

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

Answer **all** questions.

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

FOR EXAMINER'S USE	
1	
2	
3	
4	
5	
TOTAL	**72**

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

1 The first restriction enzyme was discovered in *Escherichia coli* in the 1960s, and thousands more have been discovered since. These enzymes opened the path to powerful research tools which scientists use to sequence genomes through the process of genetic engineering.

(a) Compare the roles of restriction enzymes occurring naturally in bacteria and those used in genetic engineering.

.....

.....

.....

..... [2]

(b) A gene, *URA3*, was discovered to be a potential marker gene for genetic engineering. This gene is obtained from yeast and codes for orotidine 5'-phosphate decarboxylase, which converts 5-fluoroorotic acid (5-FOA) into the toxic compound 5-fluorouracil, so any cells carrying the *URA3* gene will not survive in the presence of 5-FOA.

In an investigation of the effectiveness of *URA3* as a marker gene, researchers created a plasmid vector shown in Fig. 1.1.

A eukaryotic gene was inserted into this plasmid and the mixture was added to competent *Escherichia coli* for transformation to take place. These bacteria were then grown on agar plates containing X-gal and 5-FOA.

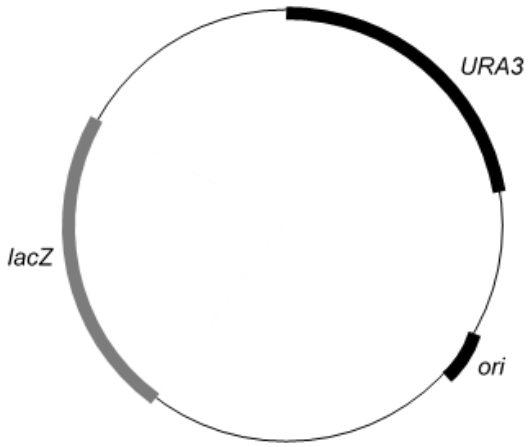


Fig. 1.1

(i) The researchers observed that recombinant bacteria appeared as blue colonies on agar plates containing X-gal and 5-FOA. Using this information, draw a cross (**X**) on the plasmid in Fig. 1.1 to indicate where the eukaryotic gene was inserted. [1]

(ii) Account for the observations stated in **b(i)**.

[4]

(iii) State the purpose of the *lacZ* gene.

[1]

(iv) Explain why the bacteria containing the recombinant plasmid should be further subjected to gene probing.

[3]

(c) The differences between the formation of genomic and cDNA libraries are due to the original source of genetic material used. In genomic libraries, the genetic material used is the genome of a haploid cell while in cDNA libraries, mRNA from a specialised cell is extracted.

(i) Describe two differences in the processes involved in the formation of these libraries.

.....

.....

.....

..... [2]

(ii) State two applications of cDNA libraries.

.....

.....

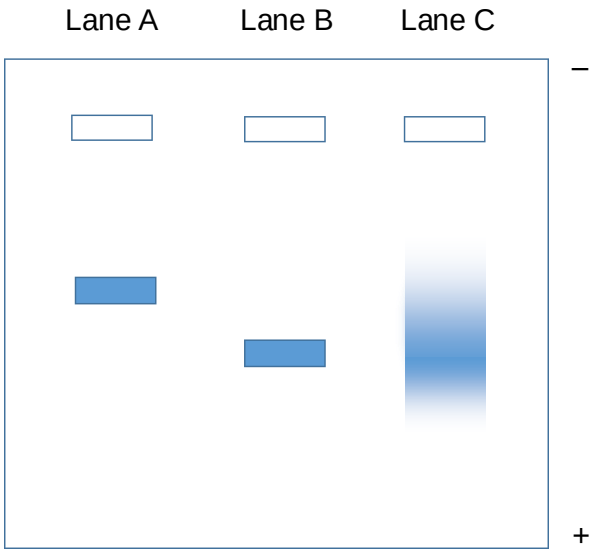
.....

..... [2]

[Total: 15m]

2 Gel electrophoresis is a technique that is widely used in molecular biology to separate DNA fragments based on molecular mass. The molecular mass of DNA fragments may differ due to the number of nucleotides present in the DNA fragment as well as chemical modifications made to the DNA.

Fig. 2.1 shows the gel electrophoregram of the DNA fragments taken from three sources. DNA fragments from all three samples are known to have equal lengths.



Key

Lane A: DNA fragments comprising insulin gene isolated from liver cells

Lane B: DNA fragments comprising insulin gene isolated from Islets of Langerhans

Lane C: Linear DNA isolated from many lambda phages

Fig. 2.1

(a) Describe the role of the buffer solution in gel electrophoresis.

.....

.....

.....

..... [2]

(b) (i) Describe and explain the position of the band in lane A with respect to the band in lane B.

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..... [3]

For Examiner's Use

(ii) Fig. 2.2 shows the DNA of a lambda phage.

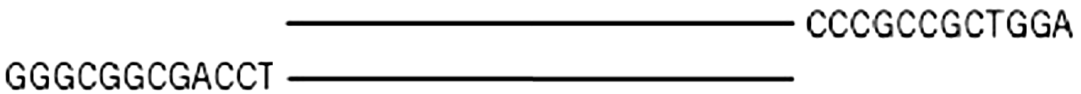

Fig. 2.2

Describe and explain the band pattern of the lambda phage DNA in lane C.

[4]

Cyclopselemia is a new genetic disease recently discovered in a small town called X-mansion. A patient suffering from cyclopselemia has red eyes and cannot control the amount of light entering his eyes. They have to constantly wear sun glasses. Scientists used information from a pedigree chart as well as RFLP analyses of the individuals in the pedigree chart to determine the allele that is responsible for this genetic disease.

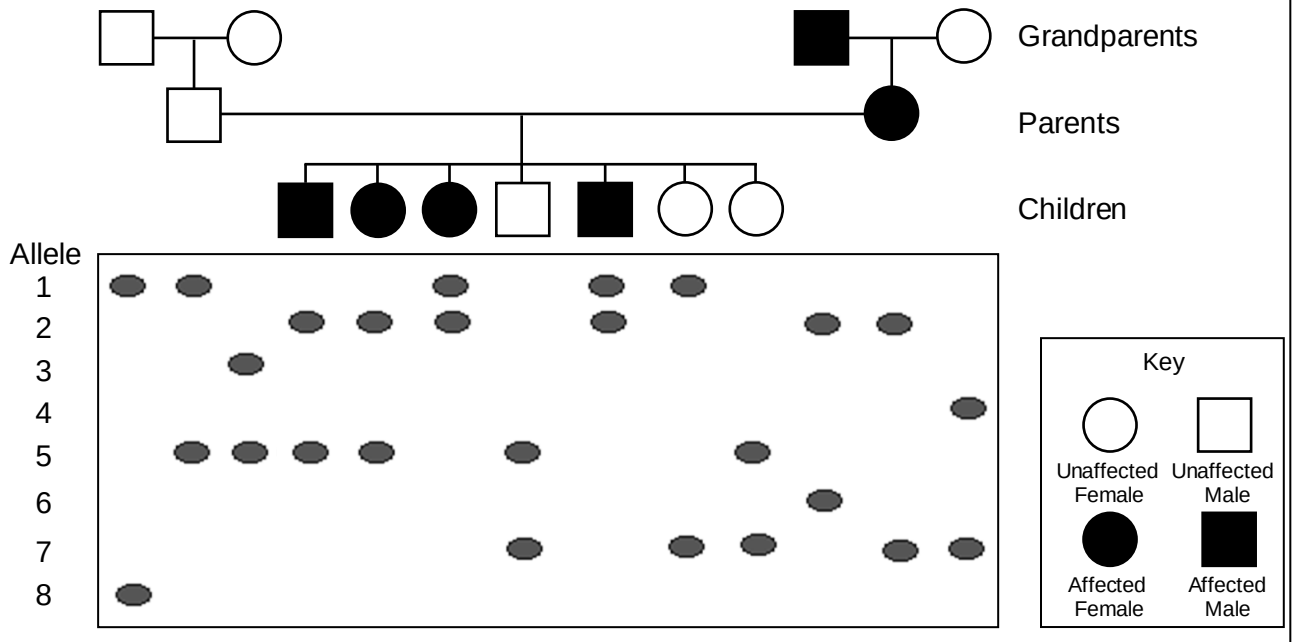

Fig. 2.3

For Examiner's Use

(c) Outline the process that can be used to determine the presence of cyclopselemia in a foetus.

[5]

[Total: 14m]

3 Embryonic stem cells, which are derived from the inner cell mass of mammalian blastocysts, are used in research to understand disease development and develop future cell-based therapies for currently untreatable diseases.

In 2006, a team of scientists led by Shinya Yamanaka discovered that differentiated cells can be isolated and modified to an embryonic-like state. These cells, subsequently known as induced pluripotent stem cells (iPSCs), have been hailed as an effective replacement for human embryonic stem cells for its usefulness in regenerative medicine. Fig. 3.1 shows a potential application of human iPSCs in gene therapy.

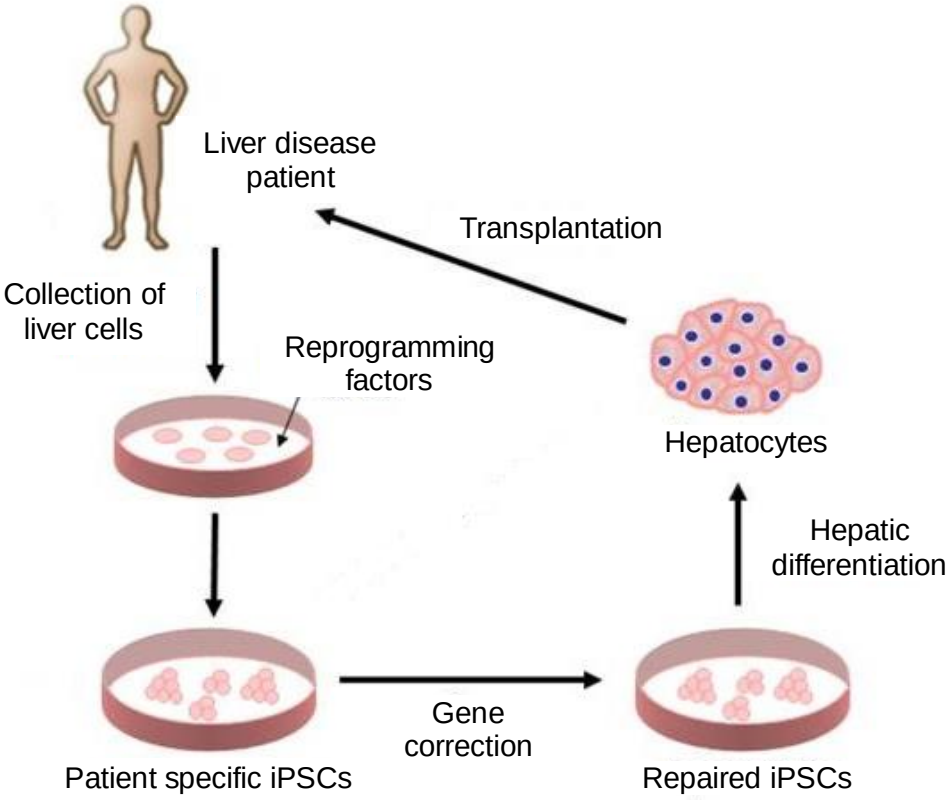

Fig. 3.1

(a) (i) State two similarities in the features of embryonic stem cells and iPSCs.

.....

.....

.....

..... [2]

(ii) State and explain two advantages of using iPSCs over embryonic stem cells in gene therapy.

[4]

Yamanaka's research team studied 24 genes expressed by embryonic stem cells in mice to identify genes that can induce pluripotency. They discovered that four genes, notably *Oct4*, *Sox2*, *Klf4* and *c-Myc*, encode transcription factors which could be used to reprogramme differentiated cells to form iPSCs. These genes can be introduced into differentiated somatic cells via viral transduction or the introduction of non-integrating plasmids. This process is shown in Fig. 3.2.

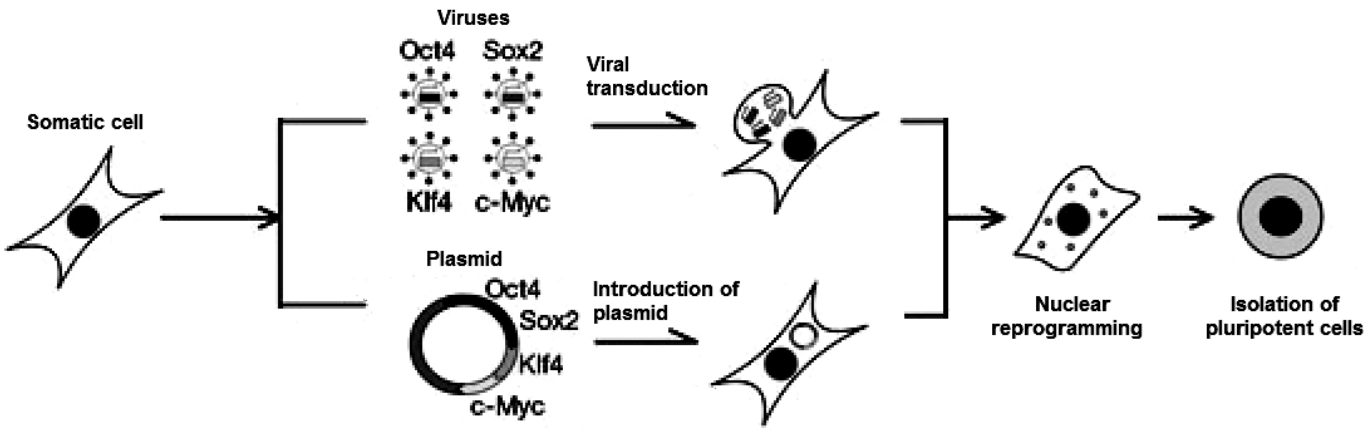

Fig. 3.2

(b) (i) Suggest why it is necessary to introduce these four genes into somatic cells in iPSC formation.

[1]

(ii) Describe two advantages and one disadvantage of introducing the four genes via non-integrating plasmids over viral transduction using retroviruses.

[3]

(iii) Before iPSCs are stimulated to undergo cellular differentiation, the introduced genes must be removed from the cells. Suggest why this process is necessary.

[1]

[Total: 11m]

4 Planning question

The visking tubing is a semi-permeable membrane which allows smaller molecules such as water and glucose to pass through, but not larger molecules like sucrose and proteins. The tubing is to be supported in a boiling tube as shown in Fig. 4.1.

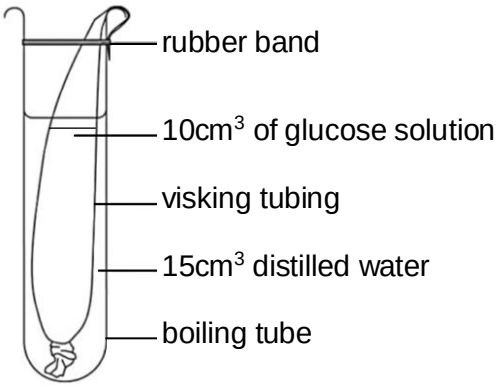

Fig. 4.1

The presence of glucose can be detected using the Benedict's test for reducing sugars.

Using this information and your own knowledge, design an experiment to investigate the effect of glucose concentration on its rate of diffusion across the visking tubing.

You must use:
- 5 pieces of visking tubing (each knotted at one end, and open at the other), soaked in a beaker of distilled water
- 5 boiling tubes and 5 rubber bands
- 2.0 moldm^{-3} glucose solution
- Benedict's solution
- weighing balance and weighing paper
- filter paper and funnel
- distilled water
- thermostatically-controlled water bath

You should select from the following apparatus:
- any normal laboratory glassware e.g. test-tubes, beakers, measuring cylinders, glass rods
- tripod stand, bunsen burner and lighter
- test-tube holder
- stopwatch
- 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,
- be illustrated by relevant diagrams, if necessary,
- 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,
- include layout of results tables and graphs with clear headings and labels,
- use the correct technical and scientific terms,
- include reference to safety measures to minimise any risks associated with the proposed experiment.

[Total: 12m]

For Examiner's Use

For Examiner's Use

5 Free-response Question

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

Your answers:

- 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.

(a) Describe the steps and advantages of plant tissue culture. [8]

(b) Discuss the benefits and ethical issues related to the use of a named genetically-modified animal. [6]

(c) Discuss the goals and benefits of the human genome project. [6]

[Total: 20m]

Name	Subject Class	Class	Candidate Number
	2BI		

ANGLO-CHINESE JUNIOR COLLEGE
Preliminary Examination 2016

BIOLOGY **9648/03**

Applications Paper and Planning Question **26 Aug 2016**

PAPER 3 **2 hours**

Additional Materials: Writing Paper

READ THESE INSTRUCTIONS FIRST

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Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
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Answer **all** questions.

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

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1	
2	
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TOTAL	**72**

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

1. The first restriction enzyme was discovered in *Escherichia coli* in the 1960s, and thousands more have been discovered since. These enzymes opened the path to powerful research tools which scientists use to sequence genomes through the process of genetic engineering.

(a) Compare the roles of restriction enzymes occurring naturally in bacteria and those used in genetic engineering. [2]

1. **Similarity 1 – Both cut dsDNA at specific sites which have complementary 3D conformation to the restriction enzyme;**
2. **Similarity 2 – Cut phosphodiester bonds between adjacent nucleotides;**
3. **Difference – Restriction enzymes found naturally in bacteria cut/cleave/hydrolyse foreign/viral DNA to destroy them while those used in genetic engineering cut/cleave/hydrolyse vectors/gene of interest to allow gene of interest to be inserted into the vector;**

Note: students need to have 1 similarity and 1 difference to score full marks

(b) A gene, *URA3*, was discovered to be a potential marker gene for genetic engineering. This gene is obtained from yeast and codes for orotidine 5'-phosphate decarboxylase, which converts 5-fluoroorotic acid (5-FOA) into the toxic compound 5-fluorouracil, so any cells carrying the *URA3* gene will not survive in the presence of 5-FOA.

In an investigation of the effectiveness of *URA3* as a marker gene, researchers created a plasmid vector shown in Fig. 1.1.

A eukaryotic gene was inserted into this plasmid and the mixture was added to competent *Escherichia coli* for transformation to take place. These bacteria were then grown on agar plates containing X-gal and 5-FOA.

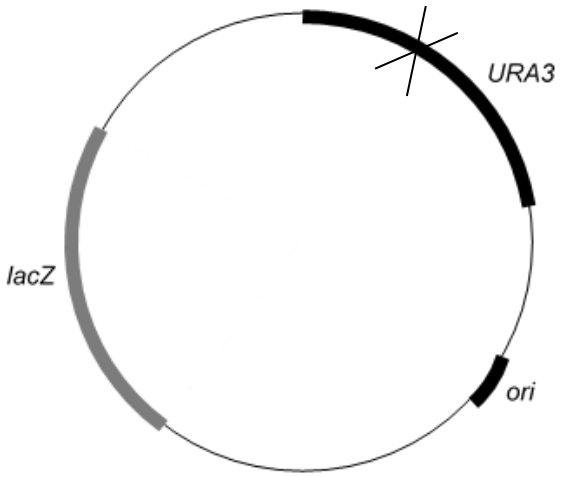


Fig. 1.1

(i) The researchers observed that the recombinant bacteria appeared as blue colonies on agar plates containing X-gal and 5-FOA. Using this information, draw a cross (**X**) on the plasmid in Fig. 1.1 to indicate where the eukaryotic gene was inserted. [1]

The cross should be within the *URA3* gene.

(ii) Account for the observations stated in **b(i)**. [4]

1. **The *URA3* gene will be disrupted because the gene of interest has been inserted into the plasmid within the *URA3* gene;**

2. **5-FOA will not be converted into the toxic compound <u>5-fluorouracil, and so there will be growth of bacteria colonies on the agar plates;</u>**
3. **Bacteria with the recombinant plasmid will express a *lacZ* gene/*lacZ* gene is intact;**
4. **X gal will be hydrolysed to form blue compound → colonies appear blue;**

(iii) State the purpose of the *lacZ* gene. [1]

Select for transformed bacteria (and not untransformed bacteria);

(iv) Explain why the bacteria containing the recombinant plasmid should be further subjected to gene probing. [3]

1. **To confirm the presence of the eukaryotic gene in the plasmid;**
2. **A gene probe, which is single-stranded radioactive DNA complementary to the gene of interest → will specifically bind to the (denatured) gene of interest;**
3. **Bacteria colonies with the gene of interest will expose photographic film (owtte);**

OR

1. **DNA other than the gene of interest could have been inserted into the vector/(for marking only: mutation could have occurred in the URA3 gene);**
2. **A gene probe, which is single-stranded radioactive DNA complementary to the gene of interest → will not bind to any DNA segment in the bacteria (which has been denatured);**
3. **Bacteria colonies will therefore not expose the photographic film (owtte);**

(c) The differences between the formation of genomic and cDNA libraries are due to the original source of genetic material used. In genomic libraries, the genetic material used is the genome of a haploid cell while in cDNA libraries, mRNA from a specialised cell is extracted.

(i) Describe two differences in the processes involved in the formation of these libraries. [2]

Basis of comparison	**Genomic library**	**cDNA library**
Addition of DNA linkers	**1. No**	**Yes;**
Use of DNA ligase	**2. Once – formation of recombinant vector/DNA**	**Twice – Add linkers to ds cDNA and formation of recombinant vector/DNA;**
Reverse transcription/ Use of enzymes involved in reverse transcription	**3. No**	**Yes – reverse transcriptase, RNase H, DNA Pol;**

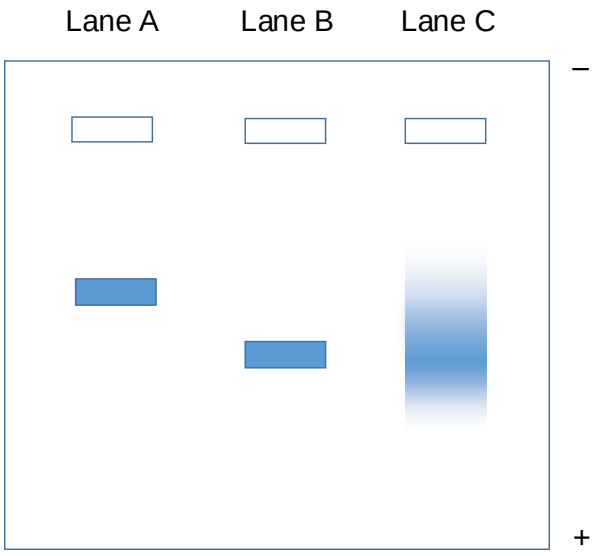
(ii) State two applications of cDNA libraries. [2]

1. **To study gene expression;**
2. **To locate a gene of interest to be inserted into a cloning vector;**
3. **To use as a gene probe;**
4. **To use as a primer for PCR;**

[Total: 15m]

2. Gel electrophoresis is a technique that is widely used in molecular biology to separate DNA fragments based on molecular mass. The molecular mass of DNA fragments may differ due to the number of nucleotides present in the DNA fragment as well as chemical modifications made to the DNA.

Fig. 2.1 shows the gel electrophoregram of the DNA fragments taken from three sources. DNA fragments from all three samples are known to have equal lengths.



Key

Lane A: DNA fragments comprising insulin gene isolated from liver cells

Lane B: DNA fragments comprising insulin gene isolated from Islets of Langerhans

Lane C: Linear DNA isolated from many lambda phages

Fig. 2.1

(a) Describe the role of the buffer solution in gel electrophoresis. [2]

1. **To maintain the pH;**
2. **So that charge on DNA will not change, affecting the migration rate of DNA;**
3. **To conduct electricity across the gel by providing ions (for the separation of DNA fragments);**

(b) (i) Describe and explain the position of the band in lane A with respect to the band in lane B. [3]

1. **DNA fragment migrated shorter distance than in lane B/ to a position of higher kilo basepair than in lane B/vice versa; (compulsory point to obtain full marks)**
2. **DNA fragment that contain insulin gene from the liver cell may be highly methylated ;**
3. **as it is not expressed in liver cell / found in heterochromatin region / region of transcriptionally inert DNA;**
4. **hence it slows down the movement of the DNA fragment due to the size of the methyl groups;**

(ii) Fig. 2.2 shows the DNA of a lambda phage.

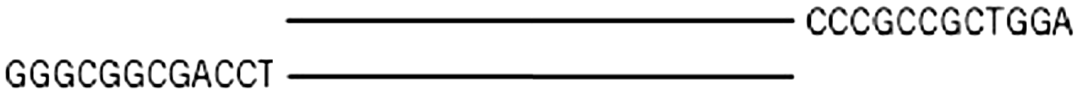


Fig 2.2

Describe and explain the band pattern of the lambda phage DNA in lane C. [4]

1. ***Lambda DNA resulted in 1 <u>smear</u> / owtte; (compulsory point to obtain full marks)**
2. **DNA of lambda phage has (long) <u>sticky ends</u>;**
3. **Hence they can <u>anneal</u> with <u>other</u> lambda DNA by <u>complementary base pairing</u>;**
4. **Ref to multiple annealing can produce <u>fragments of many different sizes/lengths</u> (resulting in the smear)/ Annealing of complementary sticky ends at both strands, forming <u>circular</u> DNA;**
5. **Small size of circular DNA migrated faster (through the pores of the agarose gel)**;

(c) Cyclopselemia is a new genetic disease recently discovered in a small town called X-mansion. A patient suffering from cyclopselemia has red eyes and cannot control the amount of light entering his eyes. They have to constantly wear sun glasses. Scientists used information from a pedigree chart as well as RFLP analyses of the individuals in the pedigree chart to determine the allele that is responsible for this genetic disease.

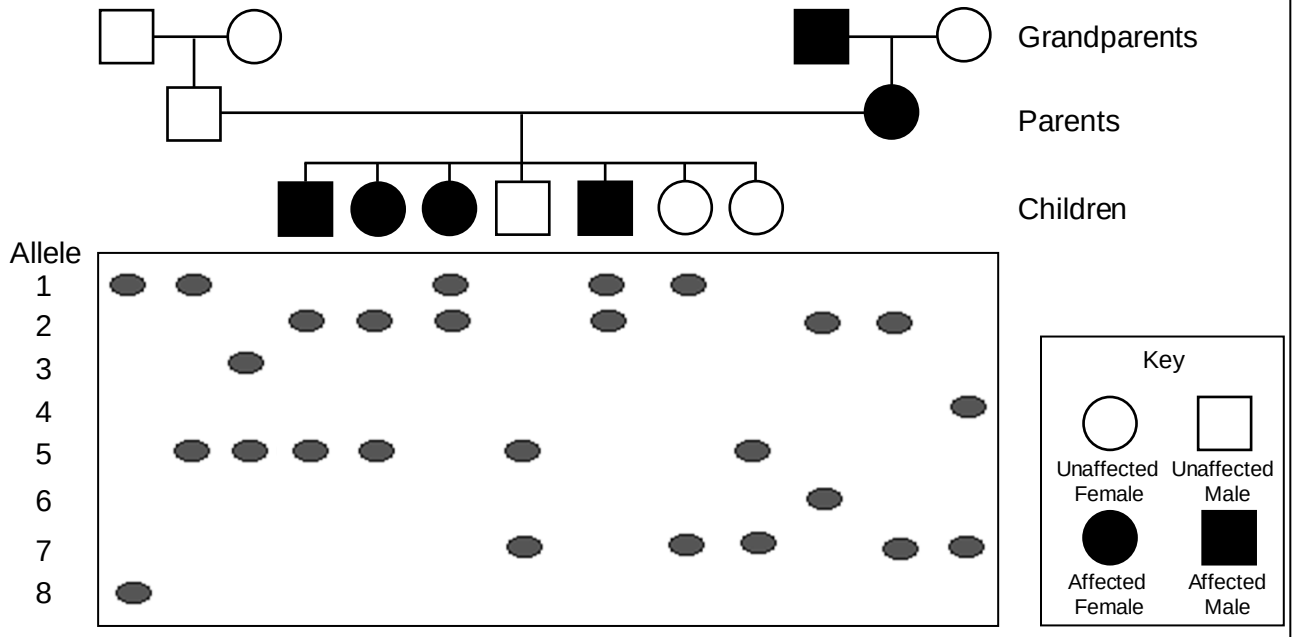


Fig. 2.3

Outline a process that can be used to determine the presence of cyclopselemia in a foetus. [5]

1. **Isolate DNA from foetus and amplify via PCR;**
2. **Subject to restriction digest with the same restriction enzyme <u>used in the RFLP analysis above</u>;**
3. **Separate restriction fragment via gel electrophoresis;**
4. **Ref to southern blotting / Transfer fragment to nitrocellulose membrane;**
5. **Single-stranded <u>radioactive</u> probe binds/anneals to region of interest (via complementary base pairing);**
6. **Bands are visualised via autoradiography;**
7. ***Presence of one RFLP allele 2 indicates presence of disease; (compulsory point to obtain full marks)**

[Total: 14m]

For Examiner's Use

3. Embryonic stem cells, which are derived from the inner cell mass of mammalian blastocysts, are used in research to understand disease development and develop future cell-based therapies for currently untreatable diseases.

In 2006, a team of scientists led by Shinya Yamanaka discovered that differentiated cells can be isolated and modified to an embryonic-like state. These cells, subsequently designated as induced pluripotent stem cells (iPSCs), have been hailed as an effective replacement for human embryonic stem cells for its usefulness in regenerative medicine. Fig. 3.1 shows a potential application of human iPSCs in gene therapy.

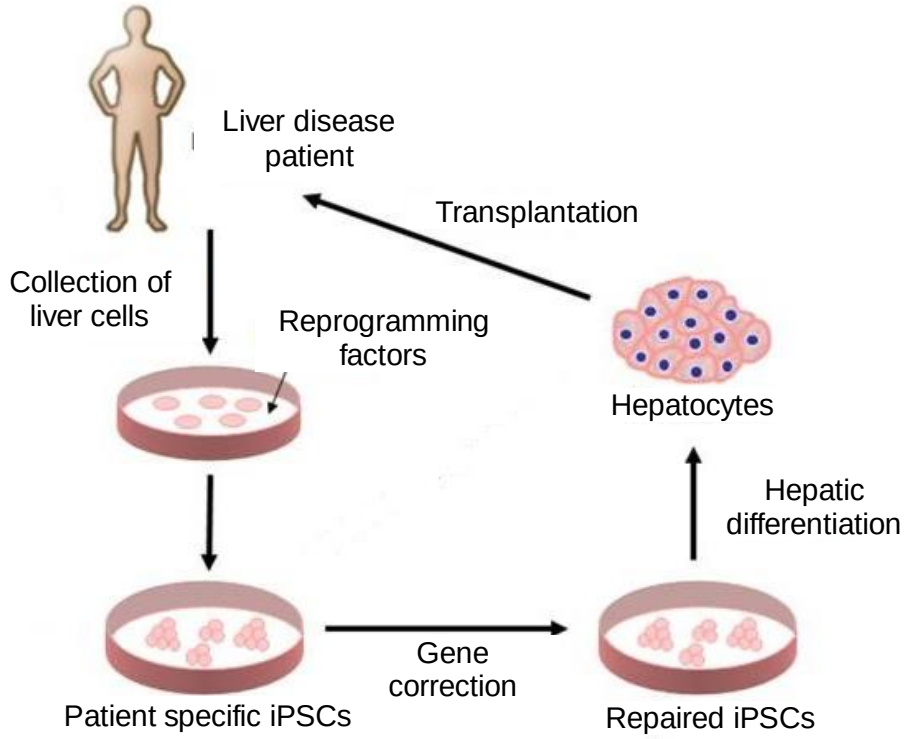


Fig. 3.1

(a) (i) State two similarities between the features of embryonic stem cells and iPSCs. [2]

1. **Both are pluripotent (and can be multipotent, but not totipotent);**
2. **Both have the potential to become any cell type in the adult body but not those of the extra-embryonic membranes;**
   R! Only stating 'both can differentiate' without elaboration
3. **Both have self-renewing capabilities / active telomerase / can divide continually via mitosis;**
4. **Both are unspecialised/undifferentiated;**
5. **Both have similar DNA methylation patterns;**

(ii) State and explain two advantages of using iPSCs over embryonic stem cells in gene therapy. [4]

1. **iPSCs can be obtained directly from transplant recipient (and will therefore be genetically identical to the patient);**
2. **Hence there is reduced immune incompatibility between donor cells and recipient / lower chance of rejection of transplanted cells;**
   R! Tissue rejection
3. **iPSCs are not derived from human embryos / does not involve isolation and subsequent death of embryos;**
4. **Hence avoiding ethical issues associated with usage of embryos in scientific research (and scientists are more likely to obtain federal funding and support);**
5. **It also has fewer ethical issues involved, as genetic makeup of patient's descendants are not altered, unlike in germ-line gene therapy;**
6. **It is easier to obtain iPSCs in greater numbers compared to embryonic stem cells;**
7. **iPSCs can be obtained from any differentiated somatic cell while embryonic stem cells can only be obtained from the inner cell mass of the blastocyst;**

Yamanaka's research team studied 24 genes expressed by embryonic stem cells in mice to track down genes that can induce pluripotency. They discovered that four genes, notably *Oct4*, *Sox2*, *Klf4* and *c-Myc*, encode transcription factors which could be used to reprogram differentiated cells to form iPSCs. These genes can be introduced into differentiated somatic cells via viral transduction or the introduction of non-integrating plasmids in Fig. 3.2.

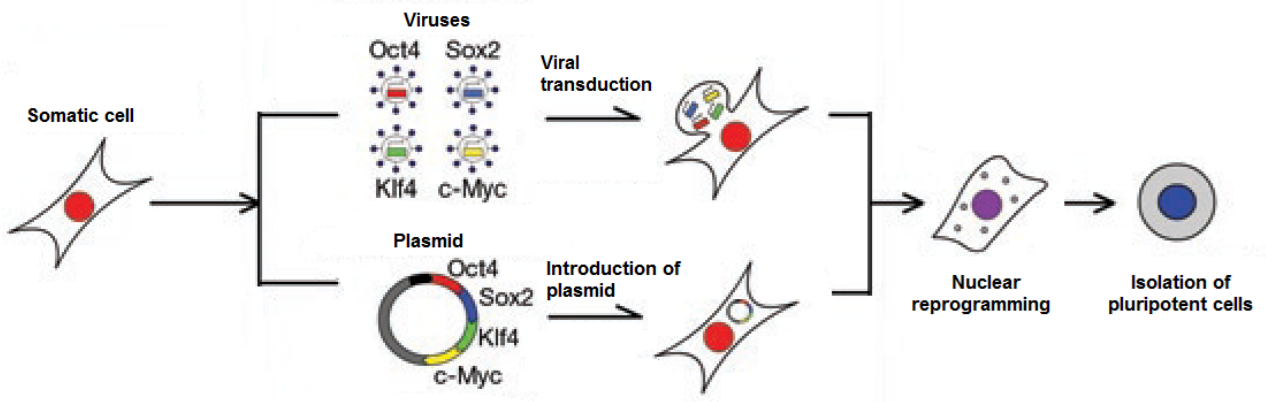


Fig 3.2

(b) (i) Suggest why it is necessary to introduce these four genes into somatic cells in iPSC formation. [1]

These four genes are not expressed / methylated in differentiated (somatic) cells;
R! Genes are not found in somatic cells

(ii) Describe two advantages and one disadvantage of introducing the four genes via non-integrating plasmids over viral transduction using retroviruses. [3]

1. **Advantage #1: Plasmids do not integrate into the genome, hence it does not cause insertional mutagenesis which can facilitate cancer development;**
2. **Advantage #2: Lower risk of stimulating immune response;**

3. **Advantage #3: Do not cause disease / lower risk of pathogenicity;**
4. **Disadvantage #1: Plasmids do not integrate into the genome, hence expression of transgenes is short-lived / cells may only achieve pluripotency temporarily / require multiple rounds of introduction of plasmid;**
   R! Gene therapy is short-lived (irrelevant context)
5. **Disadvantage #2: Lower efficiency of transferring transgenes into cells;**

Note: Students must have 2 advantages and 1 disadvantage to get full marks.

(iii) Before iPSCs are stimulated to undergo cellular differentiation, the introduced genes must be removed from the cells. Suggest why this process is necessary. [1]

1. **Transcription factors encoded by transgenes allow cells to remain pluripotent which impedes differentiation;**
2. **To remove the risk of insertional mutagenesis if transgenes are integrated into cells (via retroviral transfection);**

[Total: 11m]

4. Planning question

The visking tubing is a semi-permeable membrane which allows smaller molecules such as water and glucose to pass through, but not larger molecules like sucrose and proteins. The tubing is to be supported in a boiling tube as shown in Fig. 4.1.

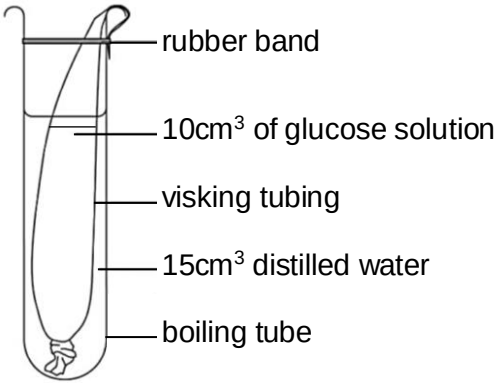


Fig. 4.1

The presence of glucose can be detected using the Benedict's test for reducing sugars.

Using this information and your own knowledge, design an experiment to investigate the effect of glucose concentration on its rate of diffusion across the visking tubing.

You must use:
- 5 pieces of visking tubing (each knotted at one end, and open at the other), soaked in a beaker of distilled water
- 5 boiling tubes and 5 rubber bands
- 2.0 moldm^{-3} glucose solution
- Benedict's solution
- weighing balance and weighing paper
- filter paper and funnel
- distilled water
- thermostatically-controlled water bath

You should select from the following apparatus:
- any normal laboratory glassware e.g. test-tubes, beakers, measuring cylinders, glass rods
- tripod stand, bunsen burner and lighter
- test-tube holder
- stopwatch
- 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,
- be illustrated by relevant diagrams, if necessary,
- 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,
- include layout of results tables and graphs with clear headings and labels,
- use the correct technical and scientific terms,
- include reference to safety measures to minimise any risks associated with the proposed experiment.

[Total: 12m]

Answer Scheme

1. Theoretical consideration or rationale of the plan to justify the practical procedure (1 mark)

A. How would the independent variable (glucose concentration) affect the dependent variable (rate of diffusion)?

(a) As **concentration of glucose** in the visking tubing **increases**, the **rate of diffusion of glucose molecules across the membrane increases** (over a fixed amount of time)**;**

B. How would the dependent variable (rate of diffusion) be measured?

(b) The rate of diffusion can be **measured by weighing the amount of precipitate** formed from reacting the solution in the boiling tube with **Benedict's solution** to test for presence of reducing sugars.

(c) As a result, **mass of precipitate (g) formed will increase with an increase** in the **rate of diffusion**.

2 The correct use of technical and scientific terms (throughout the write-up, 1 mark)
(a) down/along concentration gradient,
(b) precipitate

Procedure [max 9 m]

Independent Variable	**3. Identification** of **independent variable: concentration of glucose solutions.;**
	4. At least 5 concentration of glucose solutions with **regular interval** ranging from 0.4, 0.8, 1.2, 1.6, 2.0moldm^{-3} not inclusive of 0.0moldm^{-3}
	5. Dilution table to make up different concentrations of glucose solutions (volume of water, volume of glucose solutions, concentration of glucose solutions must be indicated, total volume is the same for all concentrations) Note for markers: Precision does not need to be seen, but if incorrect units penalize.
Dependent Variable	**6. Use of filter funnel and filter paper to obtain precipitate**
	7. Determination of dependent variable: rate of diffusion **measured by measuring the mass of precipitate formed using a weighting balance** from reacting glucose with Benedict's solution
	8. Description of Benedict's test: **(a) Equal volume of Benedict's solution and test solution** **(b) Boiling water bath**
Constant Variables (Points 9 to 14, max 2)	Constant vol. of glucose solution 10cm^3 (stated in qn, no marks awarded) Constant vol of distilled water 15cm^3 (stated in qn, no marks awarded) **9. Constant vol of solution taken from boiling tube to react with Benedict's solution** e.g. 1-5cm^3 **10. Constant volume of Benedict's solution used** e.g. 1-5cm^3 **11. Fixed amount of time for diffusion to occur** e.g. 5-30min **12. Fixed amount of time for heating Benedict's solution with sample solution** e.g. 1-5min **13. Constant temperature** (suitable temperature: 25-35^{o}C) **at which diffusion takes place** (maintained thermostatically-controlled water bath)

Equilibration	**14.** Place the (visking tubing in the beaker of distilled water)**, the glucose solutions and a beaker of distilled water separately** in a **thermostatically controlled water bath** for **fixed time** e.g. 5 minutes at **fixed temperature** e.g. 25-30°C.
Control	**15.** Description of control experiment: **(a)** Replace glucose solution with **10.0cm^3** of **distilled water**. (as long as present in dilution table, award) **(b)** Subject the control tube to the same experimental conditions. **(c)** Ref to rationale of control: This shows that without glucose, red precipitate is not observed as there is **no diffusion of glucose** across the visking tubing.
Table of results	**16.** Table of results with **clear headings and units**. (**Concentration** of glucose solution/moldm^{-3}, Weight of ppt/g, **average rate of diffusion** of glucose across membrane/gmin^{-1}). Note for markers: ECF. If theory is incorrect, marks can still be awarded.
Repeats and replicates	**17.** **(a)** Repeat experiment twice to get replicate readings (at least 3 replicates) **(b)** Repeat entire experiment twice for repeat readings (at least 2 repeats)
Data Analysis & Graph	**18.** **(a)** Plot graphs of average rate of diffusion (gmin-1) against concentration of glucose (moldm-3) **(b)** Sketch expected trend, straight line positive gradient graph R: Plateau Note for markers: ECF. If theory is incorrect, marks can still be awarded. However, the y axis of the graph must follow the table seen in 16.
~~Labelled Diagram~~	Not required since it is already provided

Points 3-18 max 9 marks

19 Safety Precautions (1 mark)

a. Handle the boiling water bath with care as **hot** water can scald / Handle the lit Bunsen burner with care as it can burn/ Handle the test-tubes in the boiling water bath with test-tube holders as the test-tubes can burn
b. Wear gloves when handling the Benedict's solution as it is a possible skin irritant.
c. Use dry hands when handling the power socket/supply of the thermostatically controlled water bath/ electrical appliances to prevent electrocution.

Procedure

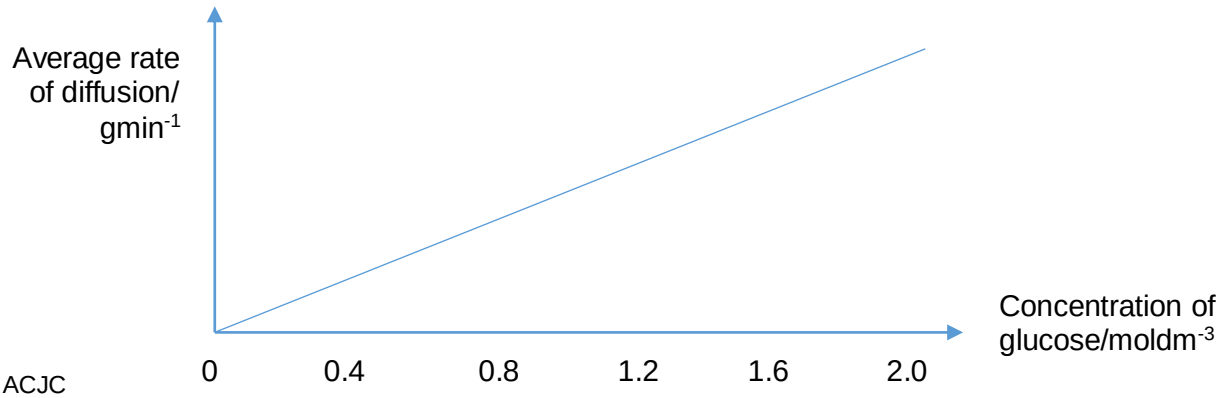
1. Label 5 test-tubes 0.4, 0.8, 1.2, 1.6 and 2.0moldm^{-3} glucose.
2. Using a 10.0cm^3 syringe, dilute the glucose solution, as shown, to obtain the following glucose concentrations:

Conc of glucose solution/moldm^{-3}	Volume of 2.0 moldm^{-3} glucose solution added/cm^3	Volume of distilled water added/cm^3	Total volume/cm^3
0.4	2.0	8.0	10.0
0.8	4.0	6.0	10.0
1.2	6.0	4.0	10.0
1.6	8.0	2.0	10.0
2.0	10.0	0.0	10.0

3. Equilibrate the visking tubing in the beaker of distilled water, the 2.0moldm^{-3} glucose solution and a beaker of distilled water separately in a thermostatically controlled water bath for 5 minutes at 30°C.
4. Remove a visking tubing from the distilled water and squeeze it to remove as much distilled water as possible.
5. Using a 10.0cm^3 syringe, place 10.0cm^3 of the 2.0moldm^{-3} glucose solution into the visking tubing and set up the experiment as shown in Fig. 4.1.
6. Start the stopwatch once you place the visking tubing into the boiling tube filled with distilled water and leave the set-up for 10 minutes.
7. After 10min, use a 10.0cm^3 syringe to transfer 2.0cm^3 of the solution in the boiling tube into test-tube labelled 2.0 moldm^{-3}.
8. Using a 10.0 cm^3 syringe, add 2.0cm^3 of Benedict's solution to the test-tube.
9. Mix the contents thoroughly and place the test-tubes in a beaker of boiling water for 3 minutes.
10. Remove the test-tube from the boiling water with a test-tube holder.
11. Let it cool before pouring the contents into a funnel lined with filter paper. Use the glass rod to remove all remaining precipitate in the test-tube onto the filter paper.
12. Let the filtrate drip into the sink. When the filtrate stops dripping, remove the filter paper from the funnel.
13. Tare the weighing balance with a clean sheet of weighing paper.
14. Using the glass rod, gently scrap as much of the precipitate from the filter paper onto the weighing boat.
15. Record the weight of the precipitate in a table as shown:

Concentration of glucose solution/moldm^{-3}	Weight of precipitate / g				Average rate of diffusion of glucose across membrane/gmin^{-1}
	Replicate 1	Replicate 2	Replicate 3	Average	
0.4					
0.8					
1.2					
1.6					
2.0					

16. Do two more replicates by repeating steps 3 to 15.
17. Repeat steps 3 to 16 for the other glucose concentrations.
18. Repeat the entire experiment twice.
19. To set up the control, repeat steps 3 to 16 using 10.0cm^3 of distilled water instead of glucose. Subject the control tube to the same experimental conditions. This shows that without glucose, red precipitate is not observed as there is no diffusion of glucose across the visking tubing.
20. Calculate the average rate of diffusion of glucose across the visking tubing membrane: average weight of precipitate divided by 10min.
21. Plot a graph to show how average rate of diffusion increases with concentration of the glucose.



Safety Precautions:

d. Handle the boiling water bath with care as hot water can scald / Handle the lit Bunsen burner with care as it can burn.
e. Wear gloves when handling the Benedict's solution as it is a possible skin irritant.

For Examiner's Use

5. Free-response Question

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

Your answers:

- 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.

(a) Describe the steps and advantages of plant tissue culture.

[8]

Techniques (max. 6)

1. **Plant tissue culture is performed under aseptic conditions (in a laminar flow hood to prevent bacterial and fungal contamination);**
2. **A small piece of plant tissue / explant is taken from the meristematic tissue of a stock plant that possess desirable characteristics;**
3. **Explants are sterilized with bleach / sodium hypochlorite;**
4. **Explant cells are cultured in a growth medium containing plant growth regulators such as auxin and cytokinin and other nutrients such as sucrose, amino acids, vitamins and inorganic ions (name any 2 nutrients);**
5. **To allow cells to divide by mitosis to form a callus;**
6. **Callus is subcultured into separate culture vessels to produce more plantlets;**
7. **Specific ratio of plant growth regulators such as auxin and cytokinin is then added to induce differentiation of callus into a plantlet;**
8. **Plantlet is transferred into soil and allowed to grow under controlled conditions in a greenhouse (until plant is hardy enough to survive in the field);**

Advantages (max. 4)

9. **Production is not affected by weather or environmental conditions;**
10. **Plants that are difficult to germinate from seeds (e.g., orchids) can be easily produced via tissue culture;**
11. **Less space is required to grow plants in the lab as compared to the field;**
12. **Disease-free plants can be produced;**
13. **Mass production of many copies of genetically identical plants with desirable traits is possible, hence increasing yield of crop;**
14. **Plant cultures stored in culture flasks are easier to transport (via air freight);**

@ 1m, max. 8

(b) Discuss the benefits and ethical issues related to the use of a named genetically modified animal. [6]

1. GM salmon;

<u>Beneficial considerations:</u>

2. GM Salmon can produce growth hormones all year round and achieve a faster growth rate to increase yield/ grow to marketable size in half the time required;
3. Make fish farming more environmentally sustainable as reduction in the time required to raise salmon means supply could be increased without proportionately increasing the use of coastal waters;
4. Increase in food conversion rates means that fewer natural resources are required to produce the fish;

<u>Negative ethical implications:</u>

5. Some argue that producing GMOs is tampering with nature as foreign genes are introduced into an organism's genome;
6. Concerns that human genetic modification for enhancement may one day occur;
7. Concerns that genetically modifying salmon may cause suffering or pain or distress / welfare of animals is compromised in the process;
8. There could be unexpected undesirable outcomes / side-effects in the well-being of animals due to unpredictable interaction of the transgenes with its own DNA;
9. Companies (AquaBounty Technologies) have sought to patent GM Salmon that they have developed, and some argue that it reduces animals to the level of objects;
10. Labelling of products on sale to indicate that genetic engineering was involved in their production is not mandatory in some countries;
11. Consumers may thus unknowingly consume products that could be harmful to them / consumption of GM Salmon may produce unintended harmful secondary by-products that lead to potential health risks;
12. GM salmon might upset ecological balance; if the fast-growing salmon escape into the sea, they might affect balance of wild salmon populations as GM salmon may be more aggressive and better at competing with the wild salmon populations for resources;
13. Companies monopolise the technology hence dominating the market because innovations in research are not shared;

(Max. 3)
@ 1m

R: Answers that discuss a named plant organism (awarded 0 marks).
Answers that do not give a named organism, will still be awarded marks for relevant points.

(c) Discuss the goals and benefits of the human genome project. [6]

Goals

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

Max 3

Benefits

8. **Genetic testing - Improve diagnosis of disease; predict the risk of future disease in healthy individuals or their progeny**
9. **Pharmacogenetics - Customised medication and treatment based on your unique genome;**
10. **Gene therapy - Delivering specific genes into cells to treat disease;**
11. **Risk assessment of individuals upon exposure to toxic agents - Genetic differences make some people more susceptible and others more resistant to such agents → Assess health damage and risks to individuals caused by exposure to radiation exposure and carcinogens → Evaluate if individuals are suitable to work in those areas with exposure to radiation and carcinogens;**
12. **Understanding human evolution - Study evolution through germline mutations in lineages/ Compare breakpoints in the evolution of mutations with ages of populations and historical events/ Study migration of different population groups based on female genetic inheritance (mitochondrial DNA) and male genetic inheritance (Y chromosome);**
13. **DNA forensics - Catch criminals / Identify victims of crimes, disasters / Establish family relationships / Match organ donors and recipients / Identify endangered/protected species / Determine pedigree for seed or livestock / Authenticate consumables such as caviar and wine;**

NOTE: each point requires elaboration and can be owtte

Max 3