H

millennia institute

2023 End-of-Year Exam
Pre-university 3

Biology Higher 2 — 9744/01

Paper 1 Multiple Choice — **21 September 2023**
1 hour

Additional Materials: Optical Answer Sheet

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.
Write your name, Adm No. and class on all the papers you hand in.

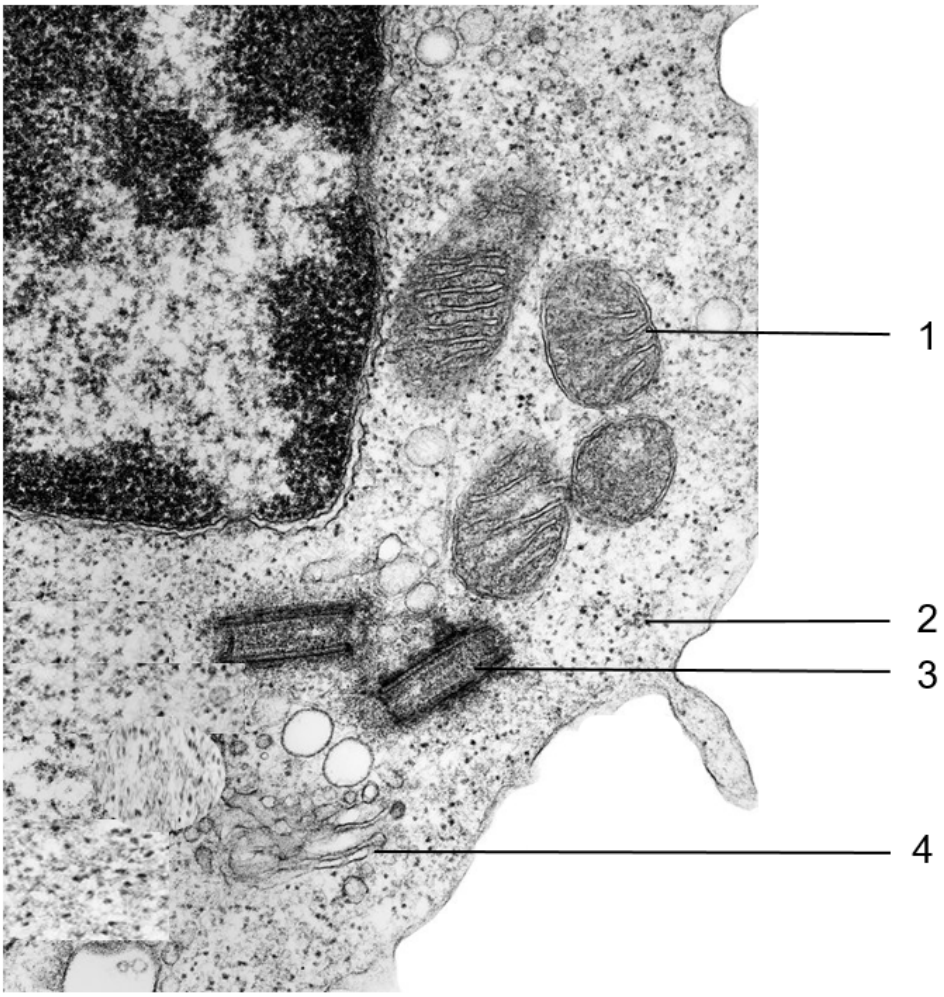
There are **thirty** questions in this paper. Answer **all** questions. For each question, there are four possible answers, **A**, **B**, **C** and **D**.

Choose the one you consider correct and record your choice in soft pencil on the separate answer sheet.

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

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

1 A part of a cell is shown in the electron micrograph below.



Which of the following correctly describes the labelled organelles?

	membrane-bound	contains nucleic acids	found in both animal and plant cells
A	1, 4	1	2, 3, 4
B	1, 4	1, 2	1, 2, 4
C	1, 2, 3	2, 3	3, 4
D	1, 2, 4	1	1, 2, 3, 4

2 It is possible for a bacterium to synthesise a eukaryotic protein.

This involves introducing a eukaryotic gene into the bacterial DNA. The eukaryotic gene is then expressed into protein by the bacterium.

Which of the following explains why a bacterial cell can produce a eukaryotic protein but cannot produce a eukaryotic glycoprotein?

A Bacteria do not have rough endoplasmic reticulum.
B Bacteria do not have nuclear envelope.
C Bacteria do not have mitochondria.
D Bacteria do not have Golgi bodies.

3 Which of the following correctly describes starch, glycogen and cellulose?

	starch	glycogen	cellulose
A	Can be easily hydrolysed to release α-glucose monomers	Angle of α-(1,4)-bonds and CH_2OH side chains results in helical chains	Made up of long linear chains due to 180° rotation of alternate β-glucose
B	Insoluble due to the –OH groups projecting into the interior of helices	Made up of α-glucose monomers with (1,4)-glycosidic bonds resulting in highly branched chains	Cellulose chains are organised into microfibrils and macrofibrils
C	Highly branched amylose due to α-(1,6)-glycosidic bonds	Highly compacted molecule that serves as a good energy storage in animal cells	Provides structural support and prevents cells from bursting when turgid
D	Highly compacted molecule that serves as a good energy storage in plant cells	Made up of β-glucose units with (1,4)-glycosidic bonds resulting in highly branched chains	High tensile strength is due to the accumulative strength of the covalent cross linkages between cellulose chains

4 The table compares three molecules, X, Y and Z, which contain the elements carbon, hydrogen and oxygen only. The percentage of carbon, hydrogen and oxygen atoms in each molecule are shown below.

molecule	% carbon	% hydrogen	% oxygen
X	25.0	50.0	25.0
Y	28.5	47.7	23.8
Z	34.6	61.6	3.8

Which row correctly identifies the three molecules?

	molecule		
	X	Y	Z
A	monosaccharide	disaccharide	polysaccharide
B	monosaccharide	polysaccharide	triglyceride
C	polysaccharide	triglyceride	monosaccharide
D	triglyceride	monosaccharide	polysaccharide

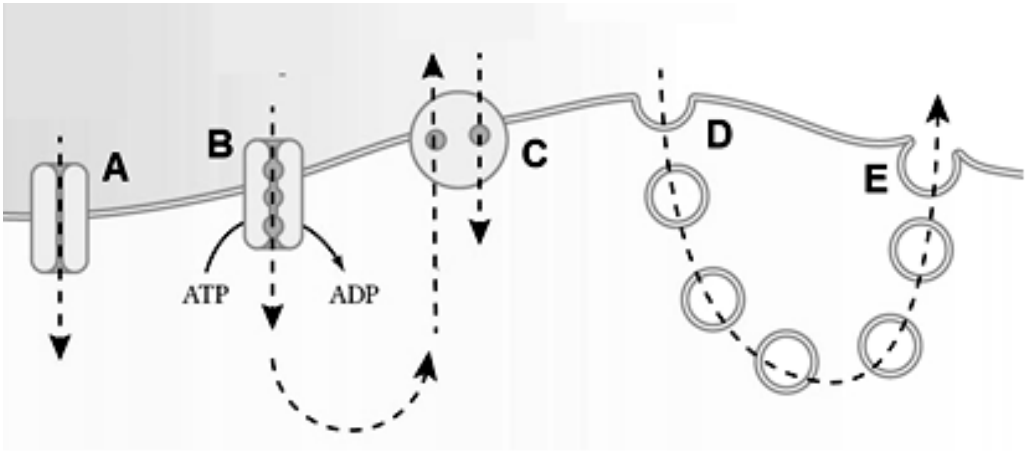
5 The activity of an enzyme, E, is measured under different conditions. The same amount and concentration of enzyme was used in each set up.

Set up	Activity of E (A.U.)
10% substrate, 30ºC	5
10% substrate, 40ºC	10
10% substrate, 50ºC	13
10% substrate, 1% inhibitor, 40ºC	7
20% substrate, 1% inhibitor, 40ºC	6

Which row correctly shows a statement that can be concluded and the supporting evidence?

	Statement	Supporting evidence
A	The optimum temperature of the enzyme is 50ºC.	It is the temperature with the highest enzyme activity.
B	There is end-product inhibition.	At higher substrate concentration and at the same temperature, the enzyme activity is lower.
C	The inhibitor binds to the active site of the enzyme.	An increase in substrate concentration did not overcome the inhibition.
D	The inhibitor changes the active site of the enzyme.	Enzyme activity did not increase at higher substrate concentration.

6 The figure below shows different mechanisms of transport across membrane, labelled **A** to **E**.



Which of the following correctly categorises the mechanisms based on their features?

A	passive process	active process
	A	B, C, D, E
B	transport polar molecules	transport non-polar molecules
	A, B, C	B, D, E
C	transport molecules down concentration gradient	transport molecules against concentration gradient
	A, C	B, C, D, E
D	transport large molecules	transport small molecules
	A, B, C	A, D, E

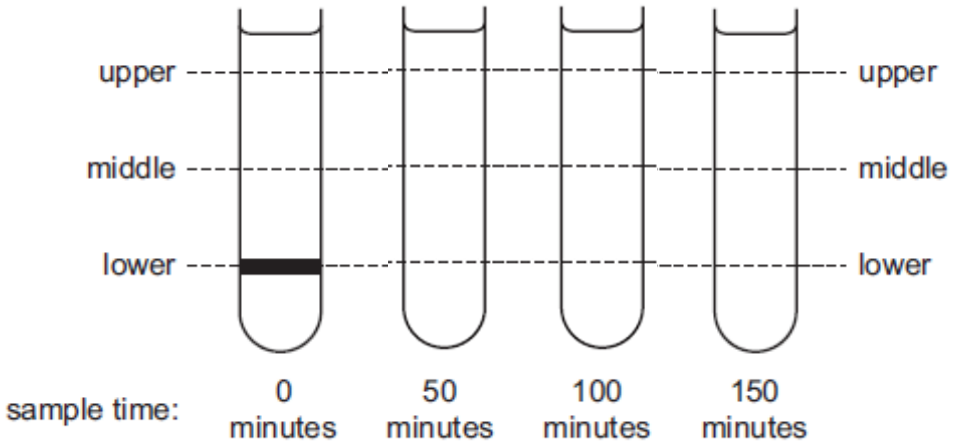
7 The bacterium *Escherichia coli,* or *E. coli,* divides once every 50 minutes.

E. coli were grown on a medium containing only heavy nitrogen, ^{15}N, until all of the bacterial DNA contained heavy nitrogen. This was counted as sample time of 0 minutes.

Some of the bacteria were moved from a heavy nitrogen medium and cultured in a medium with only light nitrogen, ^{14}N.

After every generation, some bacteria were collected, and their DNA was extracted and centrifuged.

The diagram shows the possible positions (upper, middle, lower) of the bands of DNA. The actual position of bands in the first sample is shown.



What proportion of the DNA of the sample taken at 150 minutes will be at the upper position?

A 25%

B 50%

C 75%

D 100%

8 A population of bacteria is exposed to the antibiotic penicillin. Most of the bacteria die.

However, after a few generations, bacteria that were found to survive were found to have an allele coding for an enzyme that breaks down penicillin.

Which could explain how some of these bacterial cells could have acquired this allele?

1 A mutation during DNA replication.
2 Transcription error that leads to a different mRNA being formed.
3 Ribosomes failing to associate with mature mRNA during translation.

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

9 If DNA is damaged, checkpoints in the cell cycle can either trigger DNA repair, allowing the cell to progress through the cell cycle or, if this cannot be carried out, divert the process to programmed cell death, also known as apoptosis.

Damaged DNA can be repaired using proteins like p53 and Chk1. About half of all cancer cells have non-functional p53 proteins.

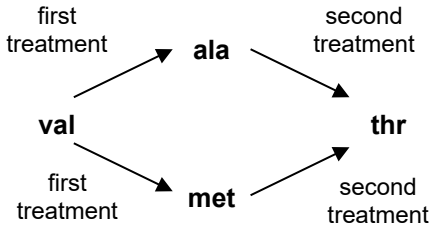
An inhibitor for Chk1 protein has been developed as a treatment for cancer patients to improve tumour shrinkage during radiation treatment.

How would this Chk1 inhibitor benefit these patients?

A *Chk1* genes would be damaged and unable to repair DNA.
B Fewer healthy cells would have damaged DNA.
C More cells with non-functional p53 protein would undergo apoptosis.
D The radiation treatment would kill all the tumour cells.

10 A bacteria colony produces a normal protein with a known amino acid sequence.

The bacteria colony was treated with the same chemical mutagen twice. This gave rise to two mutant strains of bacteria where each had a single nucleotide change at a particular mRNA codon resulting in a change of amino acid as shown in the diagram.

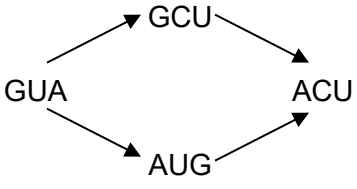


The mRNA codons for some amino acids are shown in the table.

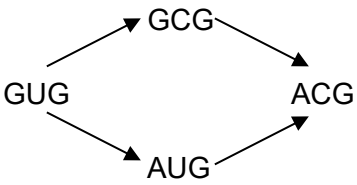
alanine (ala)	leucine (leu)	threonine (thr)	valine (val)
GCU	UUU	ACU	GUU
GCC	UUC	ACC	GUC
GCA	UUA	ACA	GUA
GCG	UUG	ACG	GUG

Assuming that both treatments resulted in a single nucleotide change each, which diagram correctly shows the codons that were translated into alanine, methionine, threonine and valine?

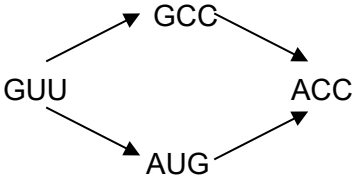
A



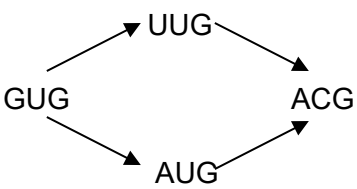
B



C



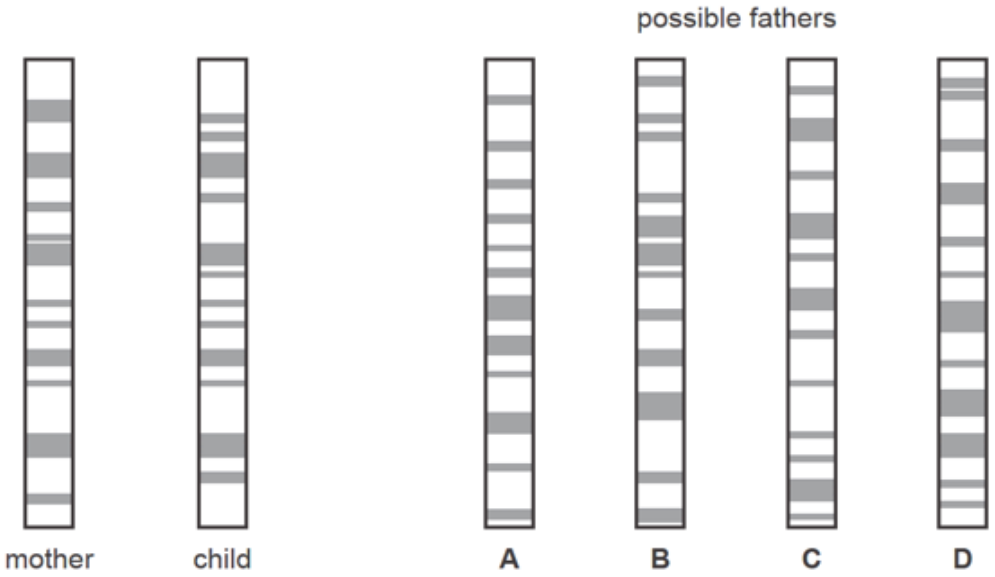
D



11 The paternity of a child can be determined through genetic profiling. This is achieved by cutting the DNA of the mother and the child into fragments, separating them by gel electrophoresis and visualising them by staining these fragments.

The diagram shows the genetic profiles of a mother and child, and four possible fathers.

Which of the following is most likely the father?



12 Which of the following statement comparing the human immunodeficiency virus (HIV) and lambda phage is **incorrect**?

A The HIV enters by receptor-mediated endocytosis, but the lambda phage infects bacterial cells by injecting its DNA.

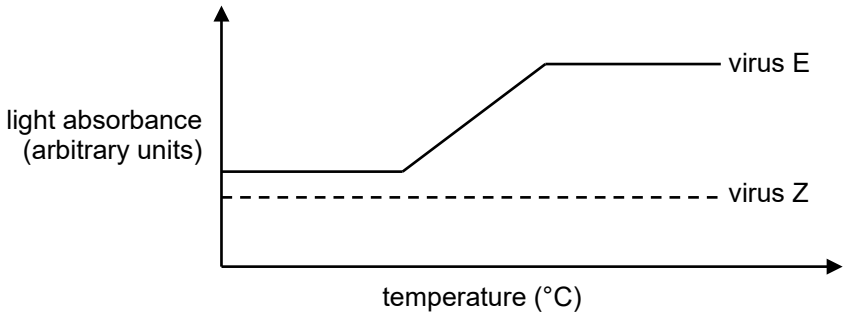
B The capsid of the HIV enters the host cell, but the capsid of the lambda virus does not.

C The genome of the HIV must be processed before it is integrated into the host chromosome, but the genome of the lambda virus can be directly integrated.

D New HIV are released from the host cell via budding, but new lambda virus are released via cell lysis.

13 Two new viruses, E and Z, which infect eukaryotic cells, have been identified.

In one experiment, the nucleic acid from each virus is isolated and analysed over a range of temperatures. The light absorbance of nucleic acids increases when denaturation occurs. The behaviour of the nucleic acid from each virus is shown in the graph.

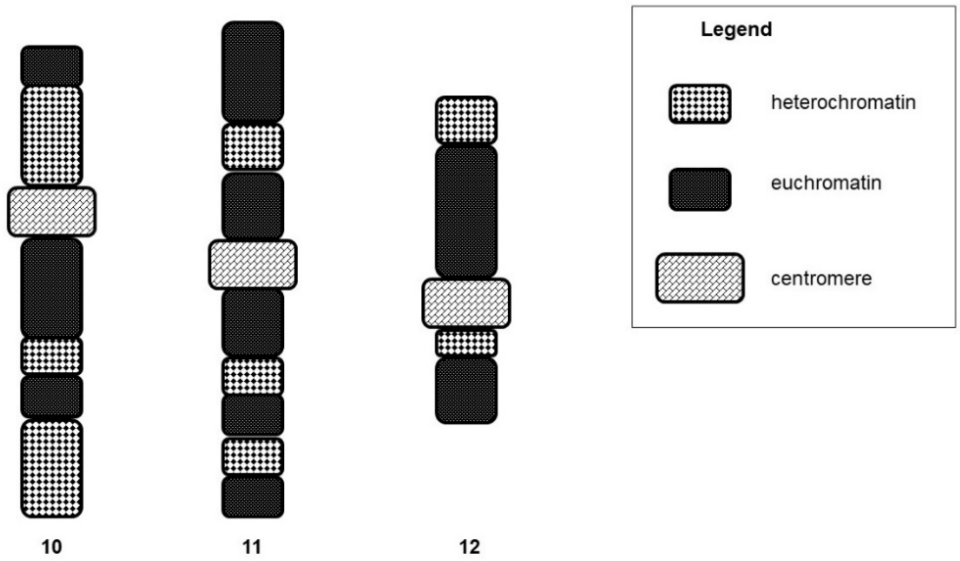


In a second experiment, virus E and Z were treated with reverse transcriptase inhibitors and DNA synthesis inhibitors. Both types of inhibitors blocked the ability of virus Z to infect cells, but only DNA synthesis inhibitors could block the infection by virus E. Reverse transcriptase inhibitors had no effect on virus E.

Which of the following about the type of nucleic acid is consistent with the information provided above?

	Genome of virus E	Genome of virus Z
A	Single-stranded RNA	Double-stranded DNA
B	Double-stranded DNA	Single-stranded RNA
C	Double-stranded RNA	Single-stranded DNA
D	Double-stranded DNA	Double-stranded RNA

14 A chromosome mapping exercise was carried out on a DNA sample extracted from liver cells of a healthy donor. The distribution of heterochromatin and euchromatin in several chromosomes in represented in a model shown in the figure below.



Which of the following statements can be deduced from the chromosome map?

A Chromosome 11 has increased number of intron regions compared to chromosome 12.

B A greater proportion of chromosome 10 being organised as heterochromatin enables the most number of genes to be compacted in it.

C The position of the centromeres along the chromosome is independent of the distribution of the heterochromatin and euchromatin regions.

D Chromosome 12 will express the greatest amount of proteins in all the cell types of the organism as it has a greater proportion of the chromosome organised as euchromatin.

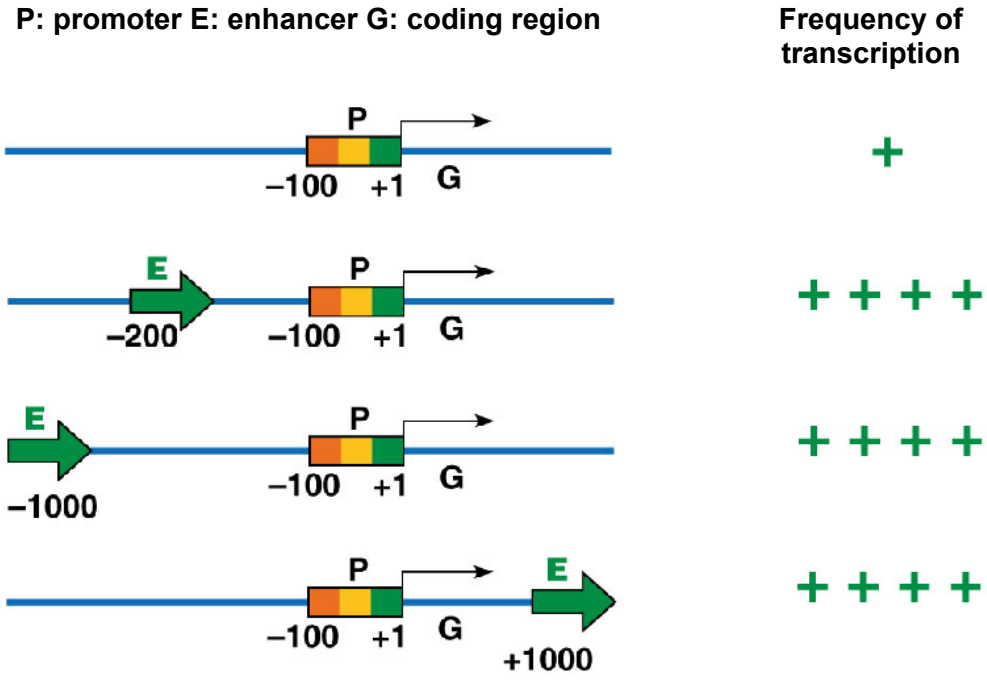
15 The following statements are related to the regulation of gene expression in a eukaryotic cell.

1 The recruitment of transcription factors to the promoter.
2 Inhibition of histone acetylase.
3 A chemical is added to inhibit the activity of poly(A) polymerase.
4 Binding of translational repressor protein to 5'UTR and 3'UTR.

Which of them could lead to an increase in gene expression?

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

16 To study the effects of control element position on the rate of transcription, recombination DNA techniques can be used to alter the location of control elements within DNA sequences. The diagram shows the relative position of the promoter, enhancer and coding region. The number of nucleotides in between the promoter and the enhancer is also illustrated. The number of '+' indicates the relative frequency of transcription.



Which of these statements are valid conclusions that can be made from the diagram?

A The frequency of transcription is increased when the enhancer is located upstream of the promoter.

B An enhancer is required for transcription.

C Orientation of the enhancer does not affect the frequency of transcription.

D The relative distance between promoter and enhancer has no effect on the frequency of transcription.

17 The bone marrow is commonly harvested for its ability to produce two main types of stem cells, haematopoietic stem cells and mesenchymal stem cells. Haematopoietic stem cells eventually differentiate into the lineages that give rise to all blood types, and mesenchymal stem cells will differentiate into lineages that give rise to bone cells, cartilage cells, muscle cells and adipocytes.

Haematopoietic stem cells have also been found to have the ability to differentiate into bone cells and cartilage cells, but mesenchymal stem cells have only been proven to be able to differentiate into cells of the mesenchymal linages.

Base on the information provided, which of the following is a valid conclusion?

A Mesenchymal stem cells have the same differentiation potential as the stem cells found in the zygote.
B Haematopoietic stem cells have a higher potency than mesenchymal stem cells.
C In the human body, haematopoietic stem cells do not have the genes required for mesenchymal stem cells.
D When exposed to appropriate molecular signals, bone cells will be able to differentiate into white blood cells.

18 Induced pluripotent stem cells (iPSCs) are derived from the molecular reprogramming of adult somatic cells.

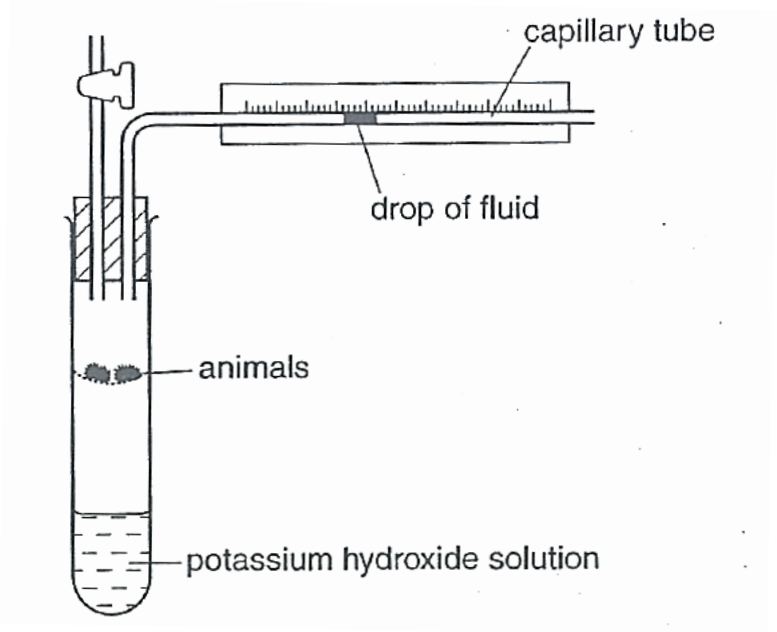
Which of the following statements about iPSCs is/are true?

1 iPSCs are self-renewing and can give rise to cells that can differentiate into specialised cells.
2 There are no ethical concerns with iPSCs as they are able to overcome the problem of rejection by the patient's immune system.
3 An induced pluripotent stem cell has the same genetic make-up as an embryonic stem cell.

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

19 A respirometer was set up to investigate the rate of respiration of animals as shown below. The animals were provided with a constant flow of oxygen.

At the end of the experiment, it was found that the drop of fluid moved significantly to the left more than expected. Mitochondria from the animals were isolated to investigate the cause.



Which of the following could be a possible reason about the mitochondria that could best explain the results?

A Cytochrome b in the electron transport chain was non-functional.

B There was a higher-than-normal amount of cristae.

C The proton pump was decoupled from the electron carriers.

D ATP synthase was non-functional.

20 The taste and texture of fruits, such as apples, can be stored in a controlled atmospheric condition for up to a year.

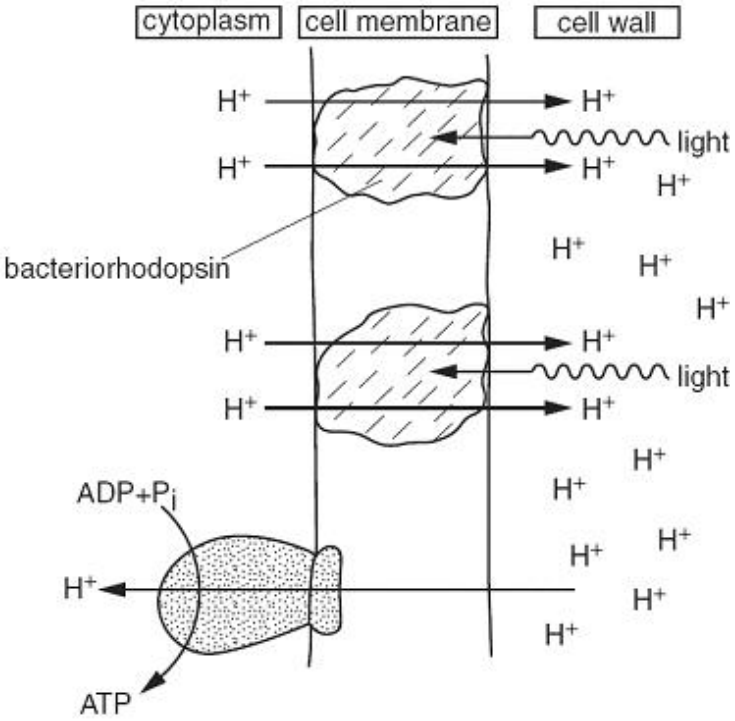
The storage conditions needed include a low temperature, higher carbon dioxide concentration and low oxygen concentration. These are maintained to reduce the production of a fruit-ripening plant hormone while limiting the build-up of ethanol.

Which of the following statements explains why these conditions are needed?

1 Low oxygen concentration favours anaerobic respiration.
2 Enzyme activity is reduced.
3 Conversion of sugar to ethanol is minimised.
4 High carbon dioxide concentration promotes photosynthesis.

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

21 The figure illustrates the process of chemiosmosis in a photosynthetic bacterium.



How many of the following statements can be inferred from the diagram?

1 Bacteriorhodopsin acts as a light harvesting complex to harness solar energy.

2 ATP formed in the cytoplasm will be used by the bacterium mainly for growth and repair of the bacterium.

3 H^+ diffuses down their concentration gradient from the cytoplasm to the cell wall for the eventual production of ATP.

4 H^+ diffuses down the concentration gradient back into the cytoplasm via ATP synthase complex, resulting in the phosphorylation of ADP to ATP.

A 1

B 2

C 3

D 4

22 Tortoiseshell coat colour in domestic cats is controlled by two genes. One gene is on an autosome and the dominant allele, **B**, is expressed as a black coat colour while recessive allele **b** is expressed as a brown coat colour.

Another gene is sex-linked, where the dominant allele $\mathbf{X^G}$ is expressed as ginger coat colour, and recessive allele $\mathbf{X^g}$, is expressed as the absence of ginger colour. $\mathbf{X^G}$ is expressed even in the presence of **B** allele.

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

A male non-ginger cat heterozygous for black coat colour mated with a female tortoiseshell cat heterozygous for black coat colour.

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

A 0.1875
B 0.25
C 0.5
D 0.75

23 Wild-type fruit flies, *Drosophila melanogaster,* have red eyes. The red pigment, drosopterin, is derived from the amino acid tryptophan in two steps, each controlled by a different gene.

Flies that were each heterozygous for both genes were mated. The offspring had three different eye colours in a ratio of 9 red-eyed flies : 3 brown-eyed flies : 4 cinnabar-eyed flies.

Which cross between the respective parental fruit flies is **unable** to produce the offspring listed?

	parents		offspring	
A	brown-eye	cinnabar-eye	cinnabar-eye	red-eye
B	cinnabar-eye	cinnabar-eye	red-eye	brown-eye
C	red-eye	brown-eye	brown-eye	cinnabar-eye
D	brown-eye	red-eye	red-eye	red-eye

24 Pure breeding plants of contrasting traits were cross fertilised and the seeds were planted in pots of soil containing equal proportion of fertiliser. The pots were then exposed to different light conditions for 60 days. Throughout the investigation, the plants were watered with equal amount of water, twice daily.

At the end of the investigation, the plants' height, length of leaves and colour of leaves were measured and summarised in the table below.

	No light	Dim Light	Bright light
Height/cm	10.3 ± 0.3	8.1 ± 0.5	6.6 ± 0.4
Length of leaves/cm	1.7 ± 0.3	1.7 ± 0.2	1.6 ± 0.1
Colour of leaves	Yellow	Pale green	Dark green

Which of the following statement can be explained by the data?

A The colour of the leaves resulted in a higher absorption of light energy, and therefore affected the height of the plant.

B The genes involved in chlorophyll pigment synthesis are activated by light.

C The additive effect of genes is responsible for the continuous variation observed in the height and length of leaves.

D Leaf colour is controlled by a gene locus whereby heterozygotes have pale green leaves.

25 Which of the following gives an accurate comparison between intracellular receptors and cell surface receptors?

	Intracellular receptors	**Cell surface receptors**
A	May act as regulatory proteins and bind to DNA	May catalyse the phosphorylation of intracellular proteins
B	Functions as the second messenger to activate other relay proteins	Binding of ligand always trigger the production of second messengers
C	Ligands can be water-soluble or lipid-soluble	Ligands must be lipid-soluble
D	Made up of only hydrophobic amino acids to allow the interaction with lipid-soluble ligands	Made up of hydrophobic amino acids which interact with the phospholipids of the membrane

26 What is the main purpose of the second messengers in signal transduction pathways?

A They allow for long distance signalling between cells by being activated when they bind to extracellular molecules.

B They amplify the signal without involving protein kinase cascade.

C They can always cross the membranes of the organelles to initiate cellular processes.

D They relay a signal from the cell surface membrane to the cytoplasm by sudden increase of their cytosolic concentration.

27 Regressive evolution is a change in a population over time that involves the loss of certain phenotypic characteristics. It is thought to be caused by either genetic drift or natural selection. An example of regressive evolution is the loss of eyes in one form of the Mexican cavefish, *Astyanax mexicanus*. These eyeless cavefish live in caves that are in total darkness.

There are three theories to explain how the loss of eyes in the cavefish has occurred.

Theory 1

There is no advantage to having eyes in a cave that is in total darkness, where energy sources are scarce. Having eyes is a disadvantage as there may be an energy cost.

Theory 2

A mutation has occurred in a single gene. This mutation has two effects:

- A lack of eye development
- An increase in the number of chemoreceptors on the skin.

Theory 3

Various mutations occurred in the genes responsible for eye development over a period of time. By chance, these mutations increased in frequency in small, isolated populations. Eventually this produced a population of eyeless cavefish.

Which option has the correct combination of theories that describe natural selection and/or genetic drift?

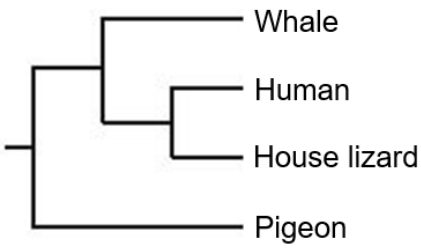
	Theory that describes genetic drift	Theory that describes natural selection
A	3 only	2 only
B	2 only	3 only
C	3 only	1 and 2 only
D	1 and 2 only	1 and 3 only

28 The phylogenetic relationship between four different species, human, whale, pigeon and house lizard, was investigated. Part of the amino acid sequence for the cytochrome c protein found in the different species was analysed and is shown in the following table. Each letter represents an amino acid.

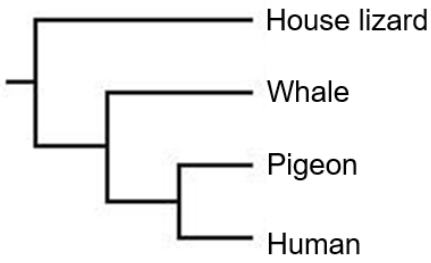
Species	Amino acid sequence of cytochrome c
Human	I F V G I K K K E E R A D L I A Y L K K A T N E
Whale	I F A G I K K K G E R A D L I A Y L K K A T N E
Pigeon	I F A G I K K K A E R A D L I A Y L K Q A T A K
House Lizard	I F A G I K K K A E R A D L I A Y L K D A T S K

Which of the following phylogenetic tree of the four species can be concluded with the available evidence?

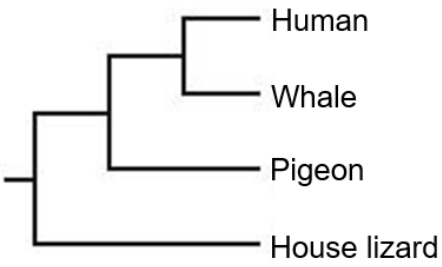
A



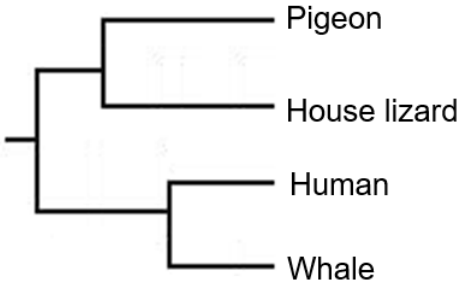
C



B



D



29 There is a large variation in the specificity of antibodies to different antigens.

Which of the following statements describes the genetic basis of this large variation?

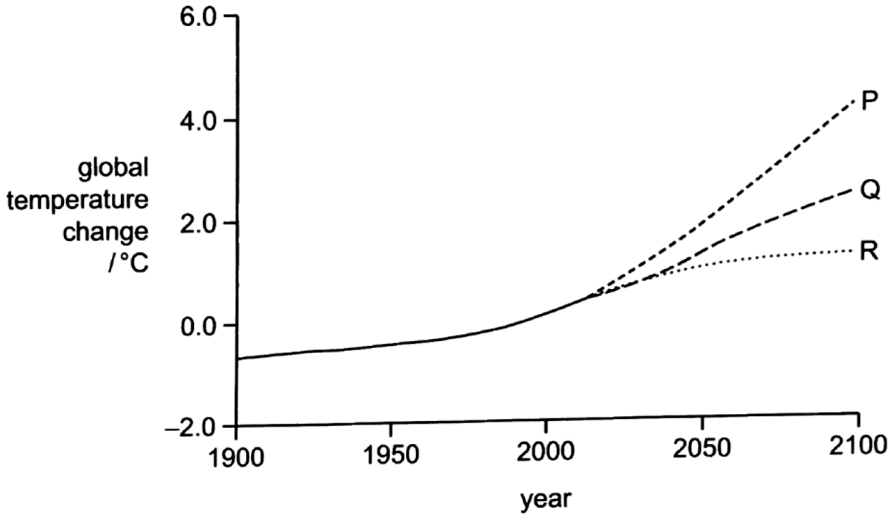
A There is a set of different gene loci in the germline cells and random selection of gene segments for recombination.

B There is a set of different gene loci in the germline cells and programmed selection of gene segments for recombination to create the specific receptors depending on the encountered antigen.

C There is a set of different gene loci in the germline cells and somatic hypermutation occurs at each of the gene loci in the germline cells to create different specificity to different antigens.

D There is an infinite number of different gene loci in germline cells, each coding for a different specificity to different antigens.

30 The graph below shows three different models, **P**, **Q** and **R**, which predict changes in global temperature. Model **Q** assumes that there are no new factors that are influencing the rate of climate change.



The predictions based on models **P** and **R** can be explained using the following statements.

1 An increased global temperature and reduced rainfall will lead to an increase in forest fires.

2 Permanently frozen soil and sediment in the Arctic will begin to thaw as global temperature increase.

3 Rising sea temperature will cause increase growth of photosynthetic algae.

4 Rising sea temperatures will reduce the solubility of greenhouse gases in the oceans.

Which of these statements support models **P** and **R**?

	statements that support model **P**	statements that support model **R**
A	1 and 3	2 and 4
B	1, 2 and 4	3
C	2	1, 3 and 4
D	3 and 4	1 and 2

END OF PAPER