# VICTORIA JUNIOR COLLEGE
# JC 2 PRELIMINARY EXAMINATION
# 2022
# HIGHER 2

**NAME:** .....

**CT CLASS:** .....

## BIOLOGY
Paper 1 Multiple Choice

**9744 / 01**

**23/09/2022**

**1 hour**

Additional Materials: Multiple Choice Answer Sheet

---

**READ THESE INSTRUCTIONS FIRST**

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name and class on the Answer Sheet in the spaces provided.
**WRITE and SHADE your EXAM NUMBER** on the Answer Sheet in the spaces provided.

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

**Read the instructions on the Answer Sheet very carefully.**

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

---

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

[Turn over]

1 Four students were asked to match the function with the appearance of some cell structures in an animal cell.

The functions were listed by number.

1 mRNA passes through to the ribosome
2 synthesis of lipids
3 packaging of hydrolytic enzymes that will remain in the cell

The appearances were listed by letter.

V membrane enclosing an inner cavity
W non-membrane-bound, spherical structures
X a double membrane interspersed with pores
Y non-membrane-bound, cylindrical structures
Z membrane-bound sacs, arranged as a flattened stack

Which student correctly matched the numbered function with the appearance of the cell structure?

| | 1 | 2 | 3 |
|---|---|---|---|
| **A** | V | Z | W |
| **B** | W | V | Z |
| **C** | X | Y | V |
| **D** | X | V | Z |

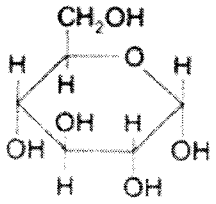
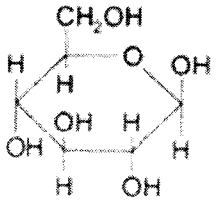
2 A scientist observed the following under the microscope.

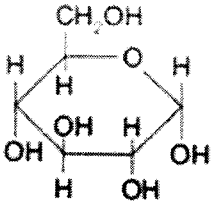
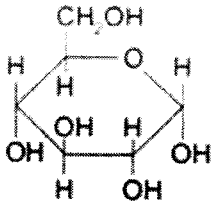
1 Heart muscle cells contract in a synchronised manner.
2 Mature red blood cells do not have nuclei.
3 Spermatogonia undergo mitotic cell division.
4 Tissue samples from endocrine glands contain many cells of different shapes and sizes.

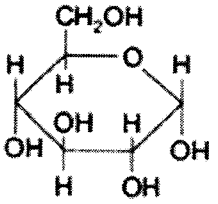
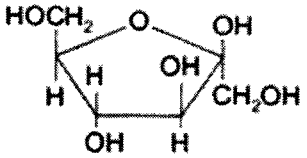
Which of his observations support the cell theory?

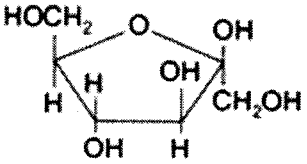
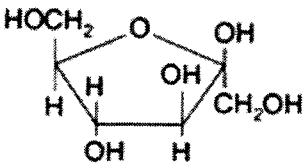
**A** 1 and 2
**B** 3 and 4
**C** 1 and 3
**D** 2 and 4

3 Which pair of monosaccharides form a non-reducing sugar?

A  

B  

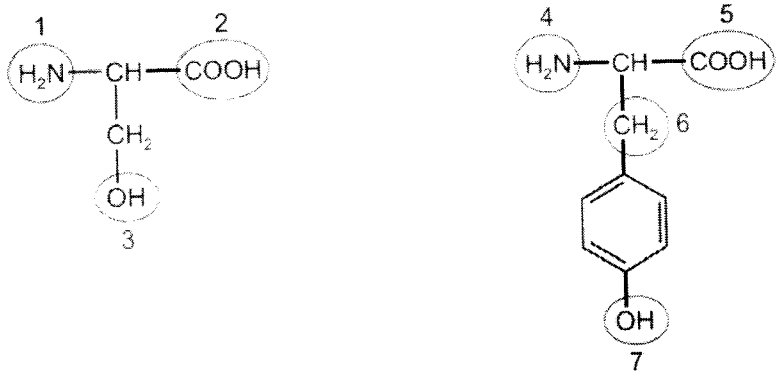
C  

D  

4 Which of the following is true about triglycerides and phospholipids?

**A** They may have either saturated or unsaturated fatty acids.
**B** A triglyceride has a glycerol but a phospholipid has a phosphate group instead of a glycerol.
**C** All triglycerides have saturated fatty acids while phospholipids have unsaturated fatty acids to maintain membrane fluidity.
**D** They are formed through hydrolysis reactions.

**5** The diagram shows the structures of two amino acids.

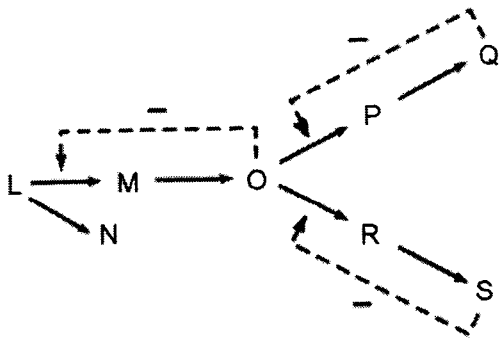



These amino acids will form part of a protein that has a tertiary structure.

Which numbered groups could form bonds to maintain the tertiary structure of the protein?

| | numbered groups | type of bond |
|---|---|---|
| **A** | 2 and 4 | peptide bond |
| **B** | 1 and 5 | hydrogen bond |
| **C** | 3 and 6 | hydrophobic interaction |
| **D** | 3 and 7 | hydrogen bond |

**6** In the following branched metabolic pathway, a dotted arrow with a minus sign symbolises inhibition of a metabolic step by an end product.

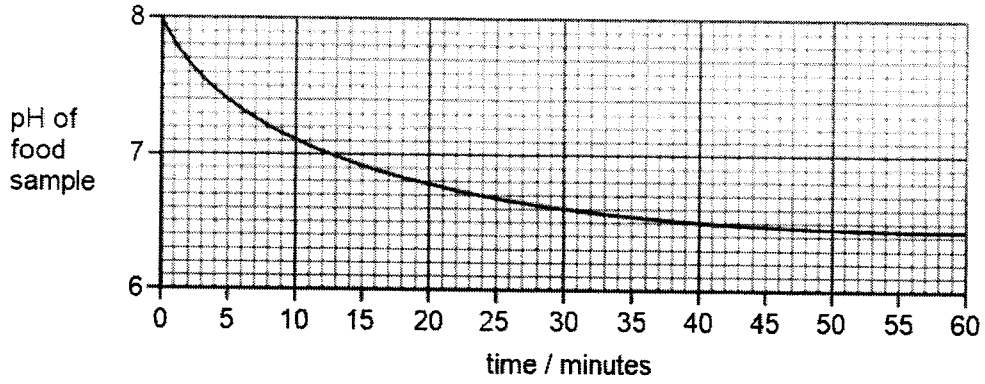



Which reaction would continue if both Q and S were present in the cell in high concentrations?

**A** L → M
**B** M → O
**C** R → S
**D** L → N

**7** Lipase is an enzyme that catalyses the hydrolysis of lipids. An experiment was carried out to investigate changes in pH when lipase is added to a food sample containing a high proportion of lipids.

The results are shown in the graph.

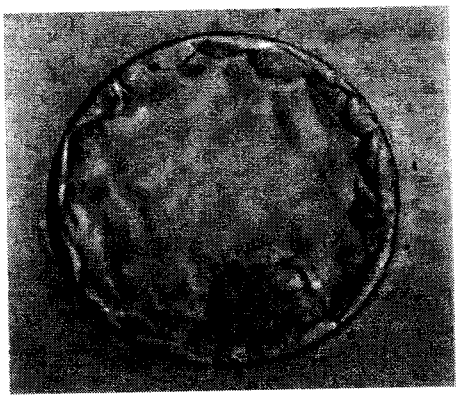



Which statements are possible explanations of the results of the experiment between 50 minutes and 60 minutes?

1 Enzyme concentration becomes the limiting factor.
2 Substrate concentration becomes the limiting factor.
3 All the enzyme active sites are occupied.
4 Denaturation of the enzyme by the products takes place.
5 There is end-product inhibition.

**A** 1, 2 and 3
**B** 1, 4 and 5
**C** 2, 3 and 4
**D** 2, 4 and 5

8 The diagram below shows a micrograph of a multicellular structure formed several days after fertilisation of an egg by a sperm. A type of stem cell can be extracted from this structure.



Which of the following correctly describe the stem cell that can be extracted from this structure?

1 It does not exhibit contact inhibition, thus forms a mass of cells.
2 It is totipotent and is able to differentiate into almost all cell types.
3 It is undifferentiated and does not express tissue-specific structures.
4 It expresses telomerase to maintain the length of telomeres.
5 It is metabolically inactive as it does not serve tissue-specific functions.

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

9 The DNA sequence CCAAGAAGTCGACAAACA codes for the amino acid chain gly-ser-ser-ala-val-cys.

As a result of a single-base substitution, the sequence length of the amino acid chain is shortened from six to two amino acids.

Which base in the DNA sequence was changed by the mutation?

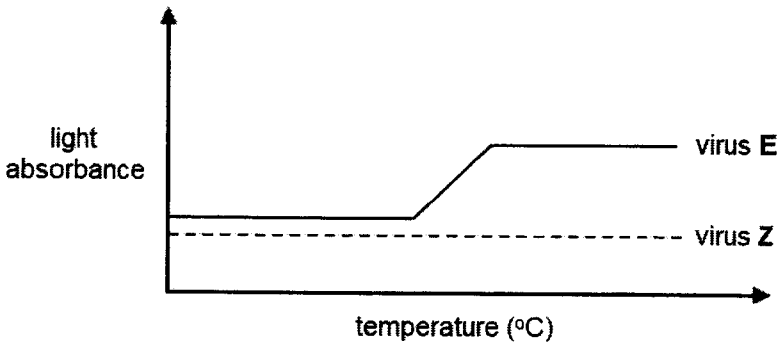
**A** A
**B** C
**C** G
**D** T

**10** Which of these steps in protein synthesis involves complementary base pairing?

**A** Amino acid and tRNA form a tRNA-amino acid complex.
**B** A ribosome moves along the mRNA by one codon.
**C** A release factor occupies the ribosome at the stop codon.
**D** Amino acids are correctly aligned in a ribosome.

**11** 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 changes when denaturation or annealing occurs. The behaviour of the nucleic acid from each virus is shown in the graph.

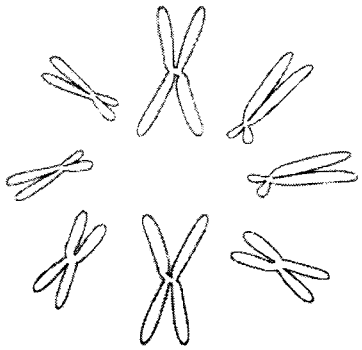



In a second experiment, it is found that treatment with reverse transcriptase inhibitors or with inhibitors of DNA synthesis blocks the ability of virus **Z** to infect cells. In contrast, reverse transcriptase inhibitors have no effect on the ability of virus **E** to infect cells but DNA synthesis inhibitors block infection by virus **E**.

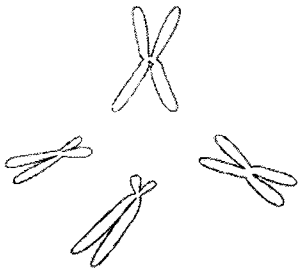
Which of the following conclusions can be drawn from both the experiments?

**A** Genome of virus **E** is single-stranded RNA and that of virus **Z** is double-stranded DNA.
**B** Genome of virus **E** is double-stranded DNA and that of virus **Z** is single-stranded RNA.
**C** Genome of virus **E** is double-stranded RNA and that of virus **Z** is single-stranded DNA.
**D** Genome of virus **E** is double-stranded DNA and that of virus **Z** is double-stranded RNA.

12 Figures (A) and (B) below show the chromosomes of a plant cell undergoing two different stages of cell divisions, viewed from the pole.



(A)

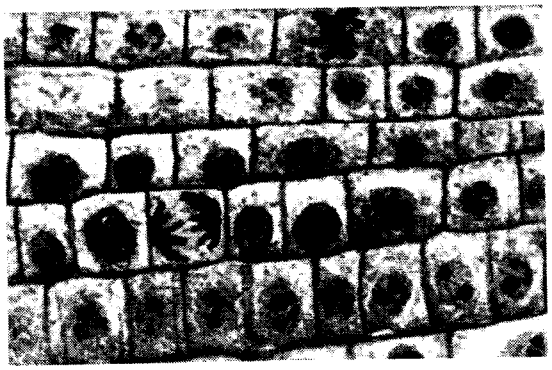


(B)

Which of the following correctly describes the stage of cell division shown in (A) and (B), as well as the diploid number of the plant cell?

| | stage of cell division shown in (A) | stage of cell division shown in (B) | diploid number of plant cell |
|---|---|---|---|
| **A** | prophase | anaphase | 4 |
| **B** | metaphase I | telophase II | 8 |
| **C** | prophase I | prophase II | 4 |
| **D** | metaphase | metaphase II | 8 |

13 The diagram below shows a micrograph of the onion root tip.

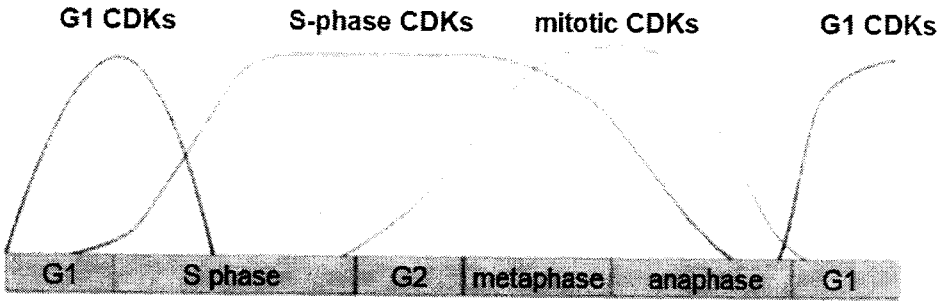


How many of the cells in the diagram are undergoing mitosis?

**A** 2
**B** 3
**C** 20
**D** 30

**14** Cyclins are regulatory proteins that associate with cyclin-dependent kinases (CDKs) to control the different stages of the cell cycle. The right type and amount of cyclins and CDKs must be present at the different stages to ensure regulation of the cell cycle.

The diagram shows the concentrations of the different CDKs.




How could the levels of the different CDKs be regulated during these stages?

1 binding of repressor to operator
2 formation of heterochromatin
3 length of mRNA poly(A) tail
4 ubiquitination of CDKs

**A** 1 and 2
**B** 1 and 3
**C** 2 and 4
**D** 3 and 4

**15** The following statements are about eukaryotic control elements:

1 Attachment of RNA polymerase at the TATA box is achieved with the help of a series of specific transcription factors.
2 The DNA binding site on general transcription factors and specific transcription factors is the same.
3 When the histones found in part of a chromosome are methylated, the control elements of a gene are easily accessed.
4 Repressors bind to regions of DNA far upstream of promoters to repress transcription.

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

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

**16** Proteins X and Y play a role in regulating gene expression.

Protein X forms a complex with GTP and mediates the binding of methionyl aminoacyl-tRNA to the small ribosomal subunit which then binds to the 5' end of mRNA and scans for the first AUG codon. When an AUG codon is recognised, protein X hydrolyses bound GTP to GDP and it is released from the small ribosomal subunit. A complete ribosome then forms and protein synthesis begins.

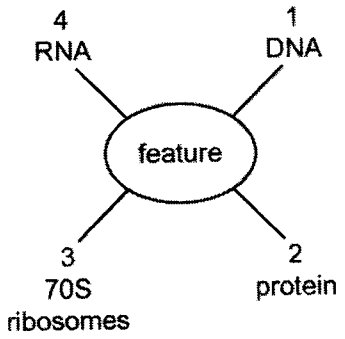
Protein Y is required to cause GDP release from protein X so that it can be reused. The reuse of protein X is inhibited when it is phosphorylated because phosphorylated X binds to protein Y tightly and inactivates protein Y.

Which of the following statements can be concluded?

1 Proteins X and Y control gene expression by regulating translational control.
2 Protein X is a translational initiation factor that has catalytic activity.
3 Inactivation of protein Y will inhibit translation.
4 Active protein kinases will decrease overall protein synthesis.

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

**17** The diagram shows some features that occur in organisms.




Which features can be present in viruses?

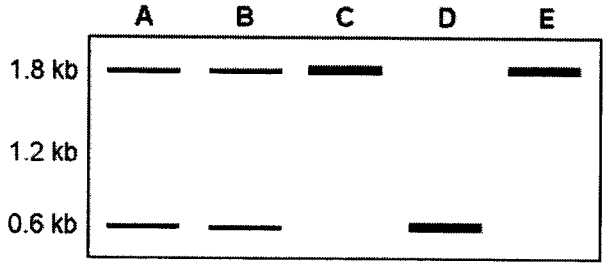
**A** 2 and 4 only
**B** 1, 2, and 4
**C** 1, 3 and 4
**D** 2, 3 and 4

**18** A family exhibits a rare autosomal recessive disease, which is caused by a point mutation in a gene. This mutation also removes an *Eco*R1 restriction site in the gene, such that the *Eco*R1 restriction enzyme cannot cleave the DNA at this mutated site.

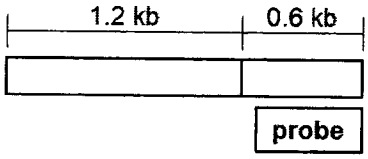
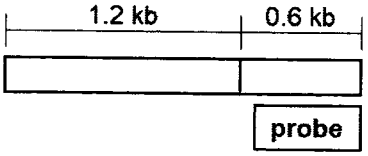
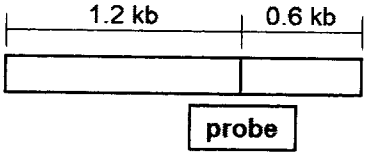
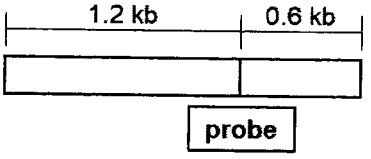
To ascertain the genotype of family members, researchers did the following:

1 amplify a 1.8 kb long DNA sequence containing the gene using PCR
2 cut the PCR products with *Eco*R1 restriction enzyme
3 separate the DNA fragments using an agarose gel
4 autoradiography using a radioactively-labelled probe

The result of this experiment is shown in the figure below, using DNA obtained from each of the five family members.




Which of the following shows correctly where the probe binds to, and the family members who have the disease?

| | where the probe binds to | family members who have the disease |
|---|---|---|
| **A** |   | **A** and **B** |
| **B** |   | **C** and **E** |
| **C** |   | **A** and **B** |
| **D** |   | **C** and **E** |

**19** Bacterial cells divide by a process called binary fission.

Which macromolecules must be synthesised for binary fission?

1 cell membrane proteins and RNA
2 DNA and peptidoglycan
3 enzymes and cellulose

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

**20** A flowering plant has either white, yellow or red flowers. Flower colour is controlled by two independently assorting genes. The dominant allele of gene **A** codes for an enzyme that catalyses the synthesis of a yellow pigment, while the dominant allele of gene **B** codes for another enzyme that converts the yellow pigment into a red pigment. The recessive alleles of both genes code for non-functional enzymes.

A plant with white flowers was crossed with another plant with yellow flowers. All of the F1 progeny plants had red flowers. One of the F1 progeny plants was then back-crossed with the parent plant with white flowers.

What is the probability of obtaining a F2 plant with white flowers?

**A** 25%
**B** 50%
**C** 75%
**D** 100%

**21** In a genetic study of brinjal plants, a test cross was made between a variety of plant producing purple and long brinjal, and another variety producing green and short brinjal. The results of the F1 generation are shown below.

| phenotypes | number |
|---|---|
| purple, long | 28 |
| purple, short | 30 |
| green, long | 26 |
| green, short | 34 |
| total number | 118 |

The formula for chi-squared test and table of probabilities are shown below:

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

key:
$\sum$ = 'sum of'
O = observed values
E = expected values

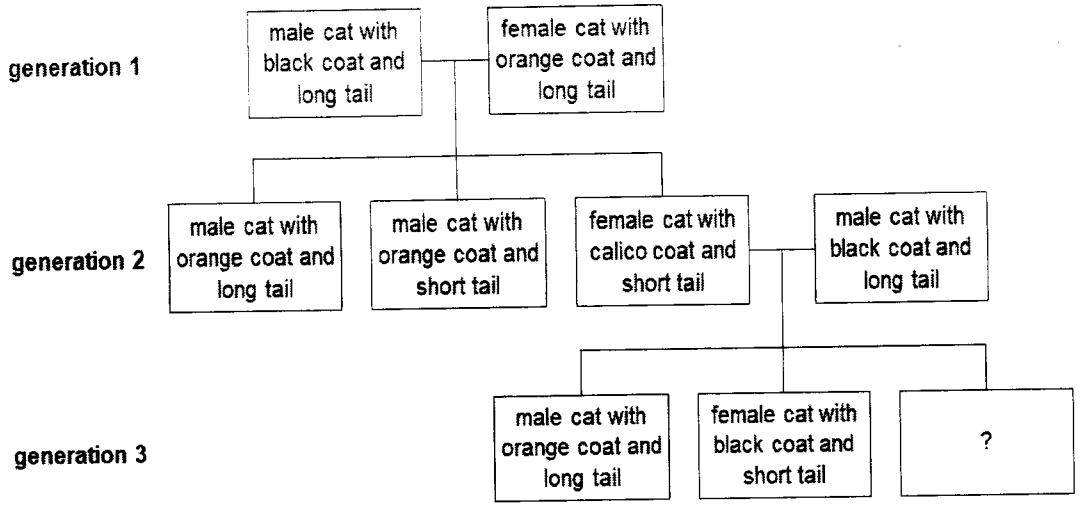
| degree of freedom | probability | | | | |
|---|---|---|---|---|---|
| | 0.10 | 0.05 | 0.02 | 0.01 | 0.001 |
| 1 | 2.71 | 3.84 | 5.41 | 6.64 | 10.83 |
| 2 | 4.61 | 5.99 | 7.82 | 9.21 | 13.82 |
| 3 | 6.25 | 7.82 | 9.84 | 11.35 | 16.27 |
| 4 | 7.78 | 9.49 | 11.67 | 13.28 | 18.47 |

Which of the following statements is false?

**A** Probability that differences between the observed and expected numbers is due to chance is greater than 10%.
**B** The two genes coding for the colour and shape are not linked.
**C** Differences between the observed and expected numbers are not statistically significant.
**D** The calculated $\chi^2$ value is greater than the critical $\chi^2$ value.

**22** Coat colour in cat is controlled by a gene with two codominant alleles. Male cats are either black or orange in colour. Female cats may be black, orange or have both colours (known as calico). Tail length in cat is controlled by another gene with dominant-recessive alleles.

The pedigree below shows a family of cats with different coat colours and tail lengths.




What is the probability that the generation 3 offspring will be a female cat with calico coat and long tail?

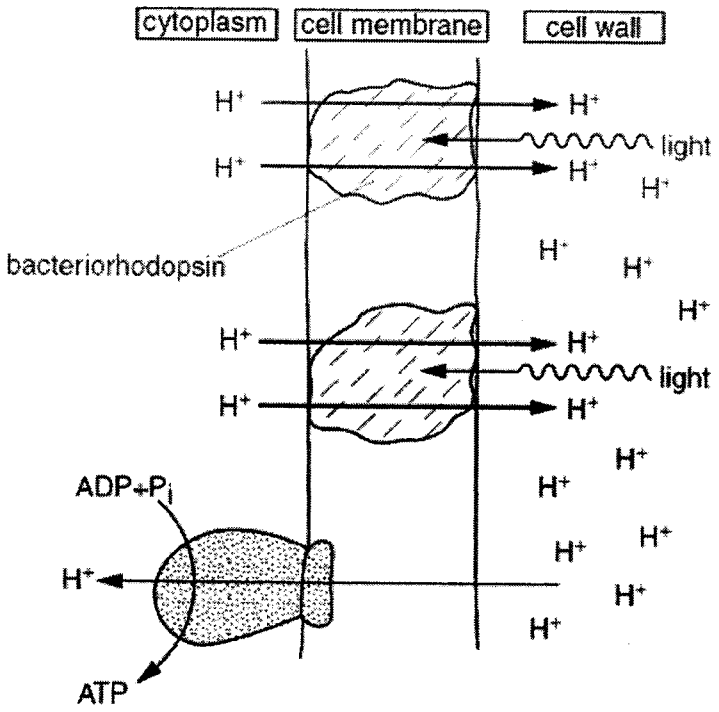
**A** 0.125
**B** 0.25
**C** 0.5
**D** 0.625

**23** Mature red blood cells lack organelles such as nuclei and mitochondria.

Which of the following processes occur during respiration in mature red blood cells?

**A** hydrolysis of glucose
**B** synthesis of nucleotides such as ATP
**C** oxidation of FAD
**D** reduction of oxygen

**24** The figure illustrates the process of chemiosmosis in a recently discovered photosynthetic bacterium in the Dead Sea.



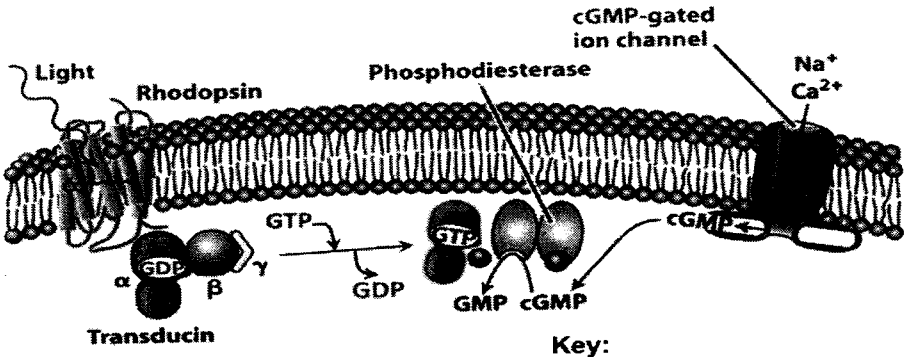

Which of the following statements can be concluded about this photosynthetic bacterium?

1 Bacteriorhodopsin acts as a light harvesting complex to harness the energy from the sun.
2 The ATP formed in the cytoplasm will be used by the bacterium for cellular activities.
3 Protons diffuse 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. This results in the phosphorylation of ADP to ATP.

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

**25** Vision is based on the absorption of light by photoreceptor cells in the eye. Detection of light by photoreceptor cells is mediated by a transmembrane receptor protein, rhodopsin. Absorption of light by rhodopsin initiates a cascade of events that closes an ion-channel, causing a change in voltage (difference in charges) across the cell membrane, producing a signal which is communicated to the brain.

The figure below illustrates the signalling events that take place in a photoreceptor cell upon light stimulation.




**Key:**
GMP = guanosine monophosphate
cGMP = cyclic guanosine monophosphate

Which of the following correctly describes the role of the proteins in rhodopsin signalling?

| | rhodopsin | transducin | phosphodiesterase | cGMP-gated ion channel |
|---|---|---|---|---|
| **A** | a G-protein linked receptor which changes conformation upon light absorption | a G-protein which is activated when the bound GDP replaced by GTP | activated by GTP-bound transducin and converts cGMP to GMP to terminate the transduction | closes when cGMP dissociates, preventing ions from entering the photoreceptor cell |
| **B** | a G-protein which changes conformation upon light absorption | a relay protein which is activated when the bound GDP replaced by GTP | converts cGMP to CMP, which is a second messenger that brings about a response | closes when cGMP dissociates, preventing ions from entering the photoreceptor cell |
| **C** | a G-protein linked receptor which changes conformation upon binding to G protein | a G-protein which is activated when the bound GDP is phosphorylated to GTP | activated by GTP-bound transducin and converts cGMP to GMP to terminate the transduction | opens when cGMP dissociates, allowing ions to enter the photoreceptor cell |
| **D** | a G-protein which changes conformation upon binding to G protein | a relay protein which is activated when the bound GDP is phosphorylated to GTP | converts cGMP to CMP, which is a second messenger that brings about a response | opens when cGMP dissociates, allowing ions to enter the photoreceptor cell |

**26** The chart below shows the taxonomic classification of a particular horse species, *Equus caballus*.

Animalia → Chordata → Mammalia → Perissodactyla → Equidae → *Equus* → *Caballus*

Identify the Family and Class taxa of the horse.

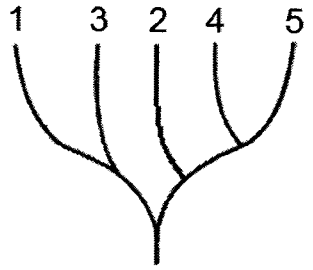
| | Family | Class |
|---|---|---|
| **A** | Chordata | Equidae |
| **B** | Chordata | Mammalia |
| **C** | Equidae | Mammalia |
| **D** | Perissodactyla | Equidae |

**27** The table below shows a sequence of 22 amino acid residues of cytochrome c protein from five different species.

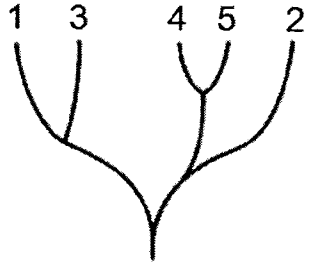
| species | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | G | D | V | E | K | G | K | K | I | F | V | Q | K | C | A | Q | C | H | T | V | E | K |
| 2 | G | D | I | E | K | G | K | K | I | D | V | Q | K | C | S | Q | C | H | T | V | E | K |
| 3 | G | D | V | E | K | G | K | K | I | F | V | Q | K | C | A | Q | C | H | T | V | E | N |
| 4 | G | N | E | D | A | G | A | K | L | F | K | Q | R | C | A | Q | C | H | T | V | Q | A |
| 5 | G | N | P | D | A | G | A | K | L | F | K | Q | C | C | A | Q | C | H | T | V | D | A |

Using the information above, a suitable phylogenetic diagram would be

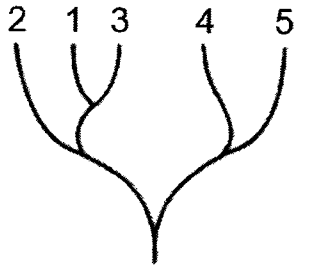
**A**



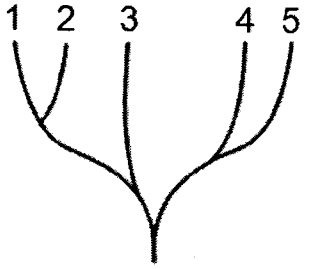

**B**




**C**




**D**



**28** The following statements describe different cells of the immune system.

1 Express cell-surface receptor.
2 Release inflammatory cytokines.
3 Mature in the thymus.
4 Each cell recognises a different antigen.
5 Are derived from haematopoietic stem cells.
6 Cell functions need to be activated.
7 Express MHC class I molecules.
8 Actively undergo phagocytosis.

How many of the above statements relate only to macrophage, helper T cell or both?

| | number of statements relating to macrophage | number of statements relating to helper T cell | number of statements relating to both cells |
|---|---|---|---|
| **A** | 1 | 3 | 4 |
| **B** | 2 | 2 | 4 |
| **C** | 2 | 3 | 3 |
| **D** | 3 | 2 | 3 |

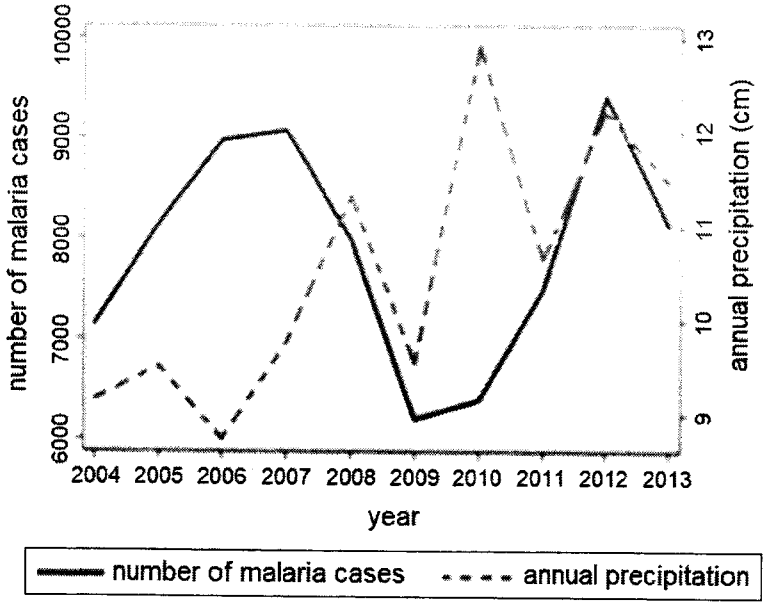
**29** While greenhouse effect is a natural phenomenon, today's climate change is a concern.

Which statements support the need to be concerned about today's climate change?

1 A small increase in greenhouse gas concentration can have a large effect of increased warming.
2 Humans have altered a natural process and exaggerated changes that might normally occur over millions of years.
3 Once released into the atmosphere, greenhouse gases remain potent for many years, making it difficult to reverse the process.
4 Abrupt changes to the climate system may have unintended outcomes that pose challenges for societies, like more extreme weather, spread of diseases, a decline in marine life, or an alteration of ocean circulation patterns.

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

**30** The graph below shows the relationship between malaria cases and precipitation from 2004 to 2013 of a certain African country.




Which of the following conclusions can be made from the graph?

1 Increases in temperature, humidity, and rainfall (all caused by climate change) are helping to proliferate the mosquito population at higher altitudes.
2 The geographical distribution of the disease widened, allowing it to emerge in new locations which had previously not supported mosquito populations.
3 Increases in temperatures at lower altitudes, where mosquitoes and malaria are already prevalent, have the impact of adjusting the growth cycle of the parasite that causes the mosquito to carry the disease, allowing it to develop malaria faster and, therefore, increasing transmission rates.
4 Additional rainfall that can result from changes to the El Niño cycle can provide good breeding conditions in locations that are usually dry, allowing the insect and therefore, the disease to proliferate in new regions.
5 Droughts caused by changes to weather patterns in conjunction with increased humidity can also result in the proliferation of the mosquito populations. In this case, rivers can be converted into strings of pools which provide the optimal breeding site for mosquitoes.
6 Changes to the El Niño cycle that cause areas that are significantly impacted by malaria to become drier can lead to increases in malaria cases due to the loss of heavy rainfall that can wash away mosquito breeding sites.

**A** 1, 2, 3 and 4
**B** 1, 2 and 4 only
**C** 3, 4 and 5 only
**D** 4, 5 and 6 only

# VICTORIA JUNIOR COLLEGE
# JC 2 PRELIMINARY EXAMINATION
# 2022
# HIGHER 2

**NAME:** .....

**CT CLASS:** .....

## BIOLOGY
Paper 2 Structured Questions

**9744 / 02**

**14/09/2022**

**2 hour**

Candidates answer on the Question Paper.
No Additional Materials are required.

---

**READ THESE INSTRUCTIONS FIRST**

Write your name and CT class in the spaces at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper.

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

You may lose marks if you do not show your working or if you do not use appropriate units.

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

| Question | Marks |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| 9 | |
| 10 | |
| Total | |

---

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

[Turn over]

Answer **all** questions.

**1** The islet of Langerhans, made up of beta cells, is an example of endocrine tissues found in the pancreas.

Fig. 1.1 shows the structure of an islet of Langerhans, and Fig. 1.2 shows the structure of a beta cell, viewed under the microscope.

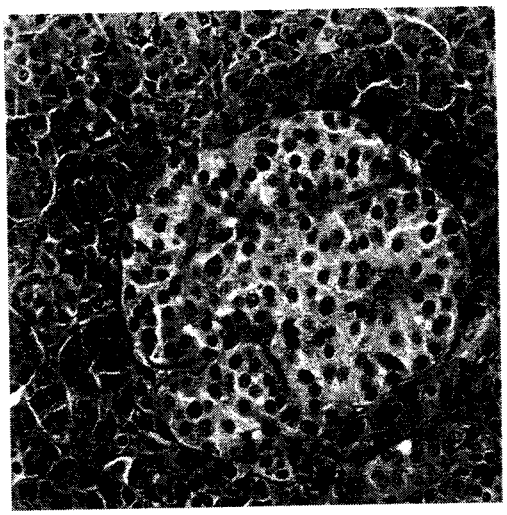


**Fig. 1.1**

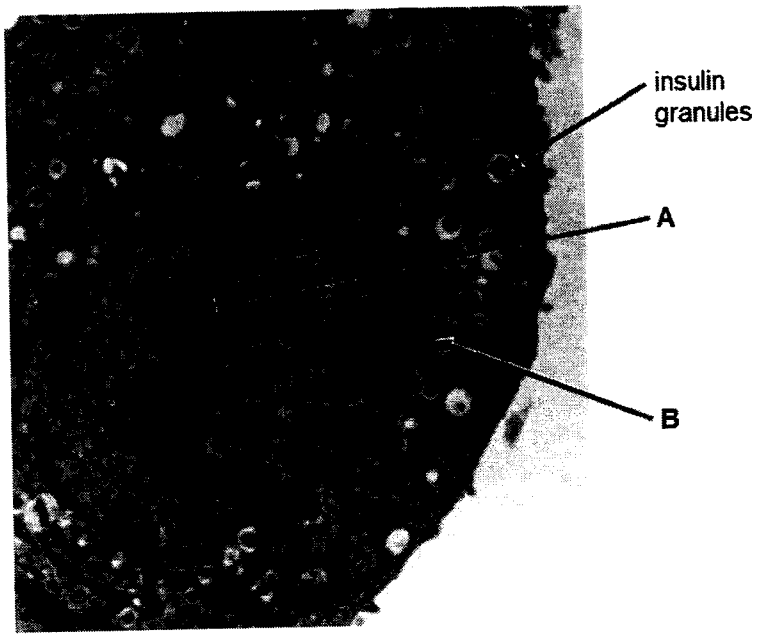



**Fig. 1.2**

**(a) (i)** Identify organelles **A** and **B** and explain their roles in beta cells.

.....

.....

.....

.....

.....

..... [3]

**(ii)** With reference to Fig. 1.1 and 1.2, explain how the cell theory is supported.

.....

.....

.....

..... [2]

**(iii)** Outline the roles of the intermembrane system in the synthesis of insulin within beta cells.

.....

.....

.....

.....

.....

..... [3]

**(iv)** Describe how insulin is released by beta cells.

.....

.....

.....

..... [2]

**(b)** Fig. 1.3 shows the structure of insulin.

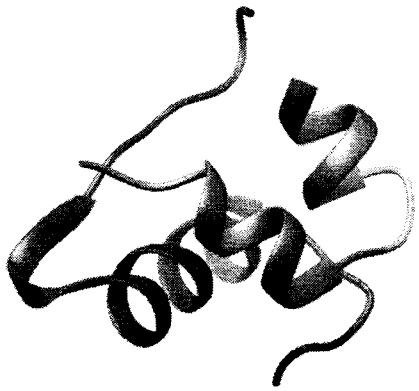


**Fig. 1.3**

With reference to Fig. 1.3, explain how the structure of insulin is significant to its role in the body.

.....

.....

.....

.....

.....

..... [3]

[Total: 13]

**2** Whole cow's milk contains about 87% water. The remaining 13% consists of proteins, lipids, carbohydrates, vitamins and minerals. A type of lipid found in milk is the triglyceride.

**(a)** Using a labelled diagram, show how a triglyceride molecule is hydrolysed.

[3]

**(b)** Fatty acid β-oxidation is a multi-step process by which fatty acids are broken down to produce energy. An overview of the process is shown in Fig. 2.1.

Fatty acids primarily enter a cell via fatty acid transporters on the cell surface.

Once inside the cell, a CoA group is added to the fatty acid by fatty acyl-CoA synthase (FACS), forming long-chain fatty acyl-CoA.

The long-chain fatty acyl-CoA enters the fatty acid β-oxidation pathway, which results in the production of one acetyl-CoA from each cycle of fatty acid β-oxidation.

This acetyl-CoA then enters the mitochondrial tricarboxylic acid (TCA) cycle (also known as Krebs cycle). The NADH and $FADH_2$ produced by both fatty acid β-oxidation and TCA cycle are used by the electron transport chain to produce ATP.

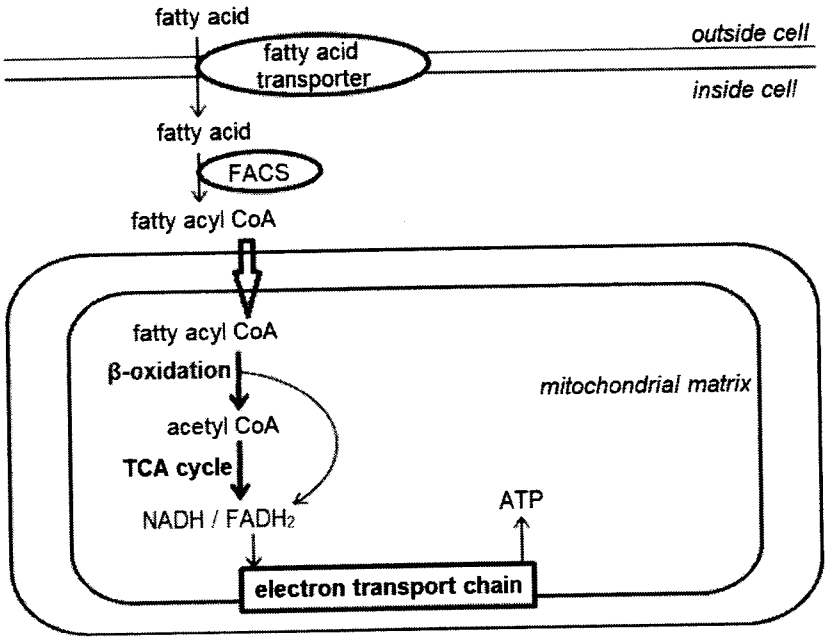



**Fig. 2.1**

**(i)** Describe the structure of the fatty acid transporter and explain how it supports its role.

.....

.....

.....

.....

.....

..... [3]

**(ii)** Account for the number of ATP molecules produced for each acetyl CoA that enters the TCA (Krebs) cycle.

.....

.....

.....

.....

.....

..... [3]

**(iii)** Explain why, for the same mass of glucose and triglyceride respired, a lot more ATP is produced from the triglyceride.

.....

.....

.....

..... [2]

[Total: 11]

3 Fig. 3.1 below depicts the structure of a commonly found DNA polymerase III.

**Fig. 3.1**

**(a)** Briefly describe the role of DNA polymerase III in a eukaryotic cell.

.....

.....

.....

..... [2]

**(b)** Table 3.1 below shows the percentage efficiency of three different DNA polymerases at three different temperatures. The percentage efficiency is measured against the maximal efficiency of each enzyme, which is taken as 100%. The table also details the optimal pH of each enzyme.

**Table 3.1**

| | type of polymerase | temperature | | | optimal pH |
|---|---|---|---|---|---|
| | | 30 °C | 70 °C | 90 °C | |
| percentage efficiency (%) | P-Alpha | 45 | 93 | 0 | 7.2 |
| | P-Beta | 98 | 53 | 12 | 11.9 |
| | P-Omega | 26 | 71 | 96 | 3.2 |

**(i)** With reference to their molecular structures, explain why the three polymerases have a different optimal pH.

.....

.....

.....

..... [2]

**(ii)** Explain why P-Omega has a high percentage efficiency at 90 °C.

.....

.....

.....

..... [2]

**(c)** A researcher wishes to replicate DNA in a lab. He has to use one of the three polymerases indicated in Table 3.1. The buffer solution in which he has placed the DNA is highly alkaline. The procedure he wishes to employ to replicate the DNA involves heating it to 85 °C to separate the two polynucleotide strands, before lowering the temperature to 68°C to allow replication to occur.

**(i)** Suggest which polymerase the researcher should choose to replicate his DNA. Explain the reasons behind your choice.

.....

.....

.....

..... [2]

**(ii)** The three polymerases indicated in Table 3.1 are from different sources, with P-Beta being extracted from microbes living in Bonnevile Salt Flats in Utah, USA.

Fill up Table 3.2 below to indicate the types of polymerase from each of the sources.

**Table 3.2**

| type of polymerase | origin of polymerase |
|---|---|
| | yeast |
| P-Beta | microbes from Bonneville Salt Flats |
| | volcanic lake in New Zealand |

[1]

[Total: 9]

4 The Hayflick limit, or Hayflick phenomenon, is the number of cell division a normal somatic, differentiated human cell can undergo before cell division stops.

(a) Using your knowledge on DNA replication in cells, explain how the Hayflick limit occurs.

.....

.....

.....

.....

.....

.....

.....

..... [4]

**(b)** Differences in global levels of histone acetylation can be observed between normal and cancer cells, although the reason why cells regulate these levels has been unclear.

Fig. 4.1 illustrates the extent of histone acetylation and the corresponding intracellular pH (pHi) in the cytoplasm of the cell. Acetyl groups can be broken down into acetate and $H^+$.

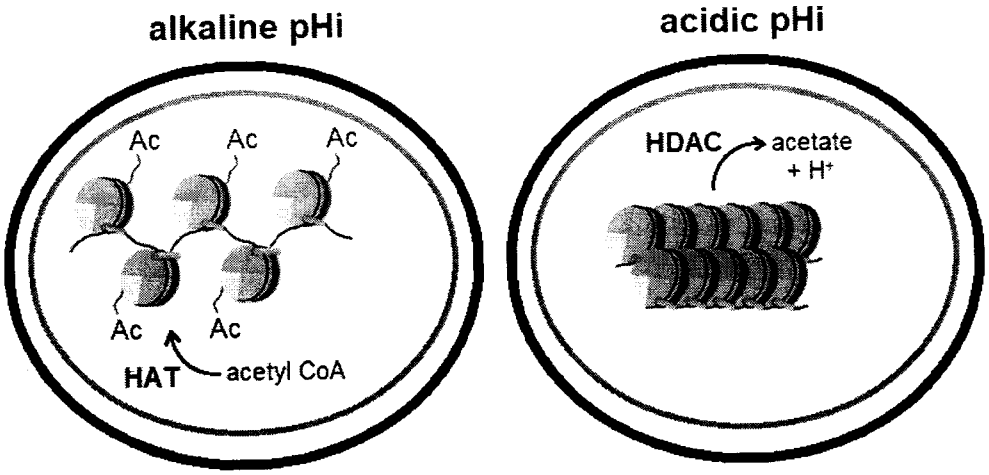



**Fig. 4.1**

**(i)** With reference to Fig. 4.1, describe how pHi becomes acidic.

.....

.....

.....

.....

.....

..... [3]

**(ii)** Suggest a role for such changes in histone acetylation other than transcriptional regulation.

.....

..... [1]

**(c)** Fig. 4.2 shows the synthesis and post-translational modifications of G protein-coupled receptors (GPCRs).

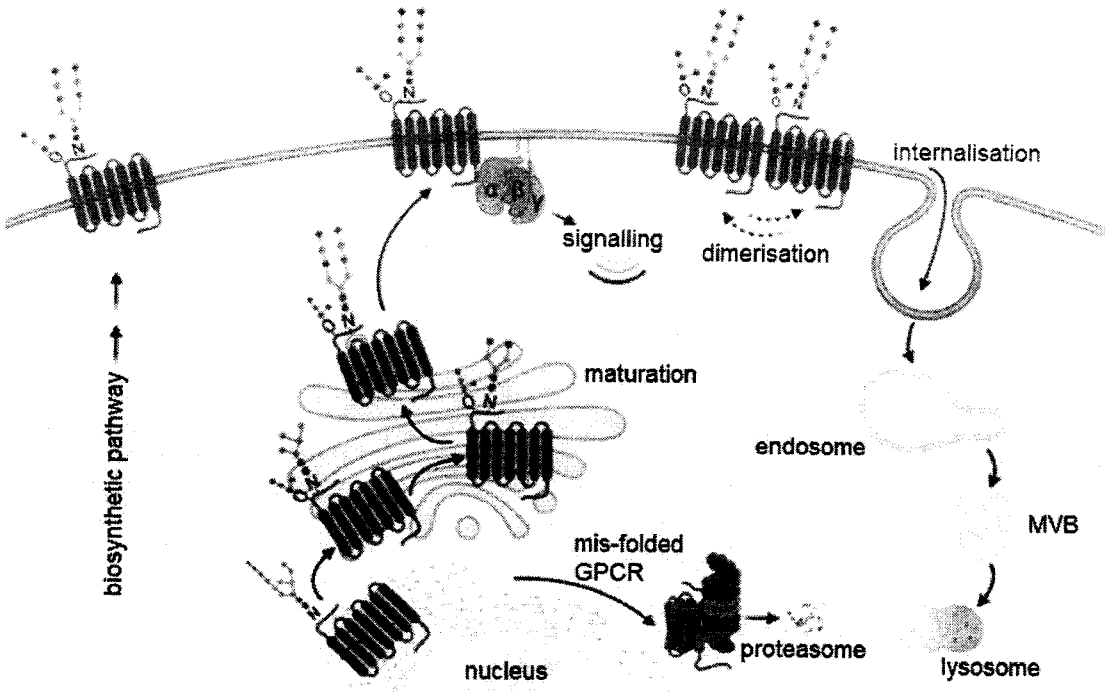



**Fig. 4.2**

With reference to Fig 4.2, identify and describe the post-translational control of the amount of functional GPCRs.

.....

.....

.....

.....

.....

.....

.....

..... [4]

[Total: 12]

5 Reverse transcription polymerase chain reaction (RT-PCR) is a molecular technique which combines the reverse transcription of RNA into complementary DNA (cDNA), as well as the amplification of specific DNA targets using polymerase chain reaction (PCR). It is primarily used to measure the amount of a specific RNA for analysis of gene expression.

**(a)** Account for the difference between the cDNA obtained from the RT-PCR of a eukaryotic mRNA and the gene from which the mRNA was transcribed.

.....

.....

.....

..... [2]

**(b)** An experiment is conducted on several bacterial mutants to study the effect of mutations on the expression of the *trp* operon. Each mutant has a single base-pair substitution in a single component of the *trp* operon. RT-PCR is used to quantify the mRNA transcribed from the *trpE, trpD, trpC, trpB and trpA* genes of each bacterial mutant. These genes code for five enzymes E, D, C, B and A, which catalyse the synthesis of tryptophan.

The RT-PCR levels for the enzymes E, D, C, B and A in the bacterial mutants is shown in Table 5.1.

**Table 5.1**

| enzymes | RT-PCR level for enzymes / units | | | | | |
|---|---|---|---|---|---|---|
| | mutant 1 | | mutant 2 | | mutant 3 | |
| | Trp absent | Trp present | Trp absent | Trp present | Trp absent | Trp present |
| E | 700 | 700 | 700 | 0 | 0 | 0 |
| D | 700 | 700 | 0 | 0 | 0 | 0 |
| C | 700 | 700 | 700 | 0 | 0 | 0 |
| B | 700 | 700 | 700 | 0 | 0 | 0 |
| A | 700 | 700 | 700 | 0 | 0 | 0 |

(i) State which mutant has a phenotype consistent with a loss-of-function mutation in the *trpR* gene. Explain your answer.

.....

.....

.....

.....

.....

..... [3]

(ii) State the component of the *trp* operon in mutant 3 in which a loss-of-function mutation has occurred. Explain your answer.

.....

.....

.....

..... [2]

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

.....

.....

.....

.....

.....

..... [3]

[Total: 10]

6 Studies of cell cultures of fibroblasts have revealed that progress between the phases of cell cycle is normally controlled by 'checkpoints'. If these fail, tumours may develop.

**(a)** The M checkpoint occurs during mitosis of the cell cycle. Explain the significance of this checkpoint.

.....

.....

.....

..... [2]

**(b)** The $G_1$ checkpoint functions to regulate the entry of cells into S phase, hence controlling the rate of cell proliferation. This checkpoint can be regulated by a few factors, including proto-oncogenes and tumour suppressor genes. Table 6.1 shows the results of cell counts from normal tissues of the Indian Barking Deer, in which the stages of mitosis are scored separately from cells in interphase. Table 6.2 shows the results obtained when tumour cells from the same deer are cultured.

**Table 6.1**

| stage | number of cells | % of cells at each stage |
|---|---|---|
| interphase | 924 | 87.3 |
| prophase | 46 | 4.4 |
| metaphase | 48 | 4.5 |
| anaphase | 8 | 0.8 |
| telophase | 32 | 3.0 |

**Table 6.2**

| stage | number of cells | % of cells at each stage |
|---|---|---|
| interphase | 60 | 42.9 |
| prophase | 17 | 12.1 |
| metaphase | 32 | 22.9 |
| anaphase | 16 | 11.4 |
| telophase | 15 | 10.7 |

With reference to Table 6.1, account for the differences in percentage distribution of cells at each stage.

.....

.....

.....

..... [2]

**(c)** Using information from Table 6.1 and 6.2, explain the effect of oncogenes on cell division.

.....

.....

.....

..... [2]

**(d)** Suggest why it is important to use percentage values when comparing data from the normal and tumour cell cultures.

.....

..... [1]

[Total: 7]

7 In a species of moth, sex is determined by the ZO system, in which there is only one sex chromosome, Z. Males have two Z chromosomes (ZZ) and females have one Z chromosome (ZO).

Two genes, **A** and **B**, are found on the Z chromosome (denoted as $Z^{A}_{B}$). Gene **A** codes for synthesis of a yellow pigment, giving rise to yellow body, while gene **B** codes for long antenna.

A pure-breeding male moth with yellow body and long antenna was mated with a female moth with white body and short antenna. All the F1 moths had yellow body and long antenna. A F1 male moth was then mated with another female moth with white body and short antenna. The following were obtained in the F2 generation:

| | |
|---|---|
| male moth with yellow body and long antenna | 46 |
| female moth with yellow body and long antenna | 44 |
| male moth with yellow body and short antenna | 5 |
| female moth with yellow body and short antenna | 6 |
| male moth with white body and long antenna | 5 |
| female moth with white body and long antenna | 4 |
| male moth with white body and short antenna | 43 |
| female moth with white body and short antenna | 47 |

**(a) (i)** State the genotypes of the F1 male moth and the F2 female moth with white body and long antenna.

..... [1]

**(ii)** Explain how the F2 female moth with white body and long antenna is obtained.

.....

.....

.....

.....

.....

..... [3]

**(b)** Gene **D**, located on an autosomal chromosome, codes for an enzyme that converts the yellow pigment into a brown pigment, giving rise to brown body. The recessive allele codes for a non-functional enzyme.

The F1 male moth in **(a)** was crossed with another female moth with white body. The following were obtained in the offspring:

| | |
|---|---|
| male moth with brown body | 48 |
| female moth with brown body | 51 |
| male moth with white body | 50 |
| female moth with white body | 51 |

In the space provided below, draw a genetic diagram of the above cross to show the expected phenotypic ratio of the offspring.

You do not have to include gene **B** or antenna length in the diagram.

[4]

[Total: 8]

**8** In each species of finch, there is a variation in beak depth. Fig. 8.1 shows how beak depth is measured.

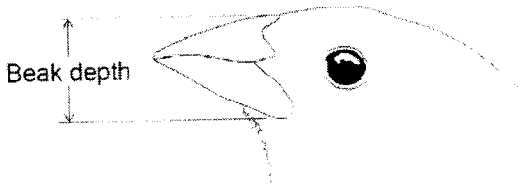



**Fig. 8.1**

Fig. 8.2 shows the relationship between the beak depth of parent birds and the beak depth of their offspring.

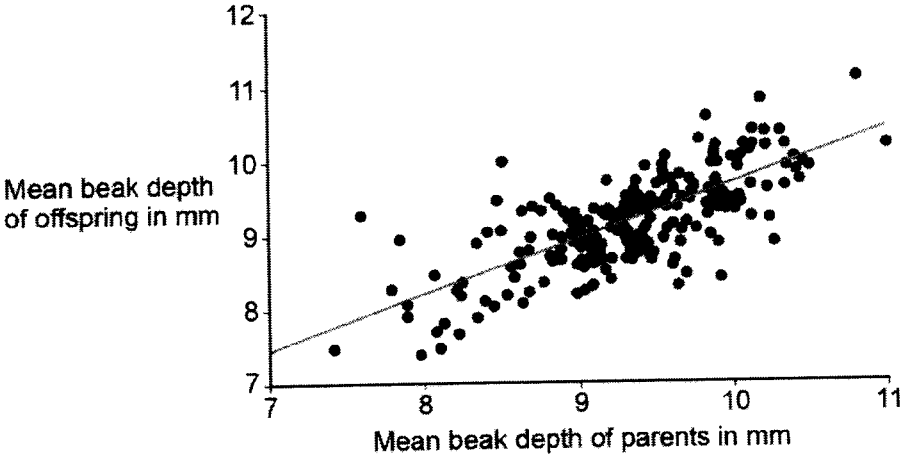



**Fig. 8.2**

**(a)** With reference to Fig. 8.2, comment whether

**(i)** beak depth is an inherited characteristic.

.....

.....

.....

..... [2]

**(ii)** more than one gene controls beak depth.

.....

..... [1]

**(b)** Fig. 8.3 is a map of the Galapagos Islands.

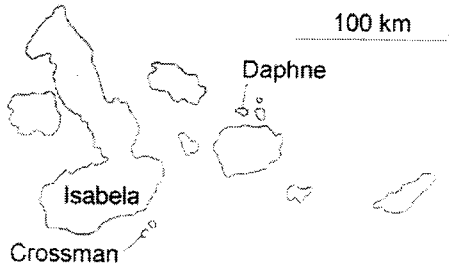



**Fig. 8.3**

On Isabela Island, the medium ground finch **and** the small ground finch are found. On Daphne Island, only the medium ground finch is found. On Crossman Island, only the small ground finch is found.

The medium ground finch and the small ground finch both feed on seeds. The size of seeds eaten by each bird depends on the depth of the bird's beak.

Fig. 8.4 shows how the beak depth of each species varies on each island.

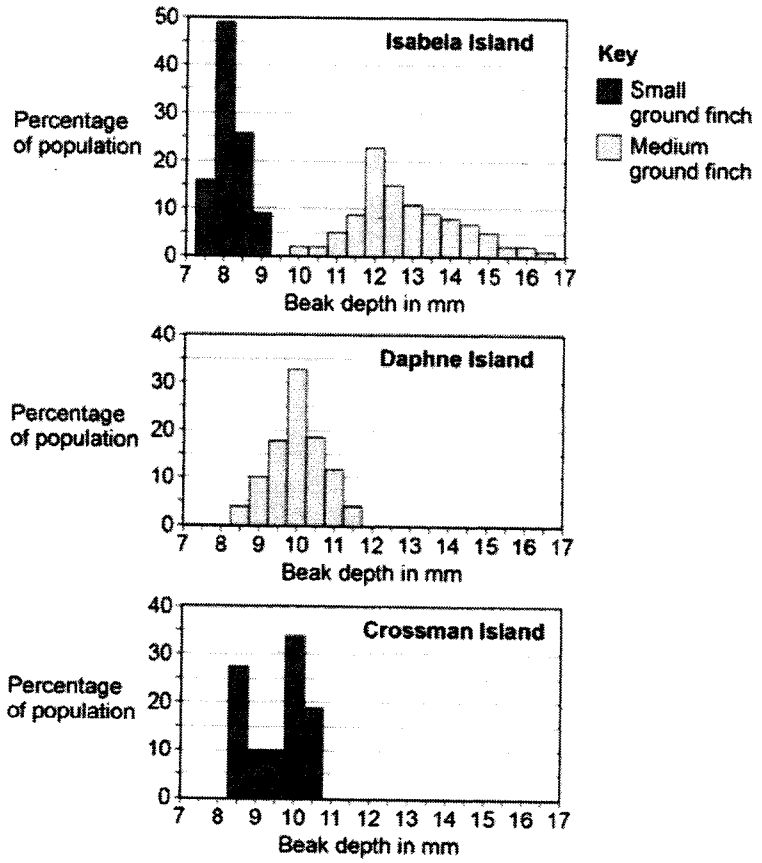



**Fig. 8.4**

(i) Explain why the range of beak depth of the medium ground finch on Isabela Island is different from those on Daphne Island.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [5]

(ii) Outline how the medium ground finch on Daphne Island may evolve as a distinct species thousands of years in the future.

.....

.....

.....

.....

.....

..... [3]

(iii) Suggest why both species of finches are found on Isabela Island while only one is found on the other islands.

.....

..... [1]

[Total: 12]

9 **(a)** Contrast between an antigen and an antibody.

.....

.....

.....

..... [2]

**(b)** Vaccination stimulates the immune system to develop immunological memory against the actual pathogen. Antigen presenting cells, such as dendritic cells, play a significant role in this process by activating specific helper T cells.

**(i)** Explain how the structure of the cell surface membrane of dendritic cell allows its role as an antigen presenting cell.

.....

.....

.....

.....

.....

..... [3]

**(ii)** Outline how immunological memory is developed after activation of specific helper T cells.

.....

.....

.....

.....

.....

.....

.....

..... [4]

[Total: 9]

**10** With global warming reaching unprecedented levels, world famous iconic places like the Swiss Alps are losing the beauty of snow-capped mountain tops (Fig. 10.1).

The chart in Fig. 10.2 shows the impact of climate change on the annual temperature on the snowy mountains of Switzerland.

**Fig. 10.1**

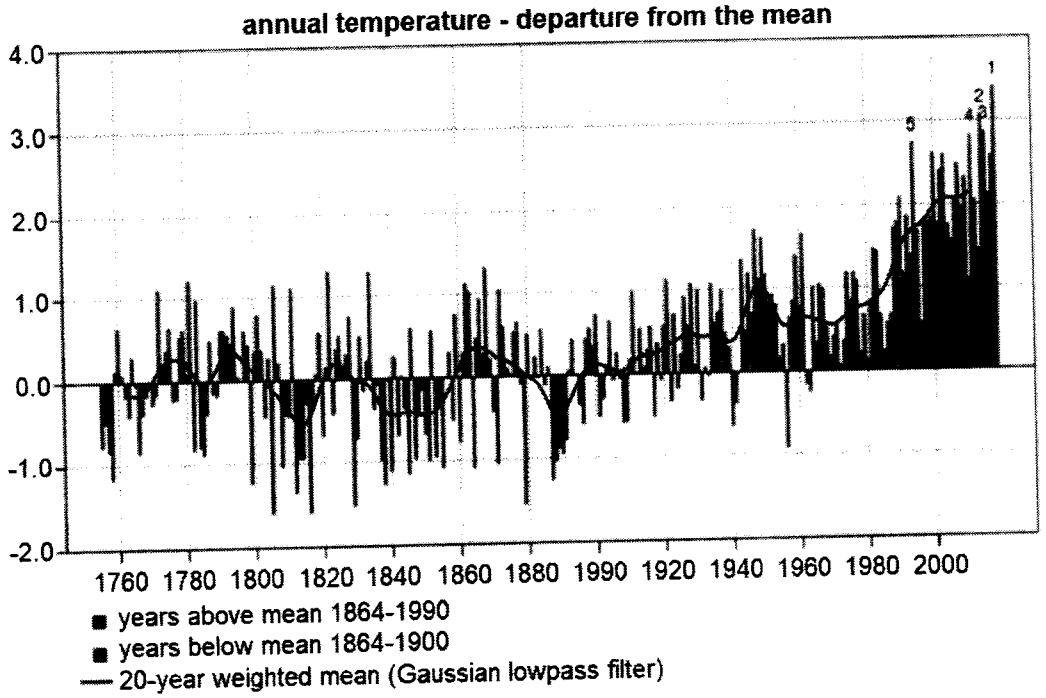



**Fig. 10.2**

**(a)** With reference to Fig 10.1 and 10.2, other than missing ice caps, predict how the natural landscape of the Swiss Alp would change in the next decade.

.....

.....

.....

.....

.....

..... [3]

**(b)** Fig. 10.3 shows the influence of increasing temperatures on the relationship between the rates of respiration and photosynthesis on stone pine seedlings found in the Swiss Alps. Gross photosynthesis refers to the carbon fixed by the plant and net photosynthesis is the measurement of carbon fixed after subtracting carbon lost via respiration (in the form of $CO_2$).

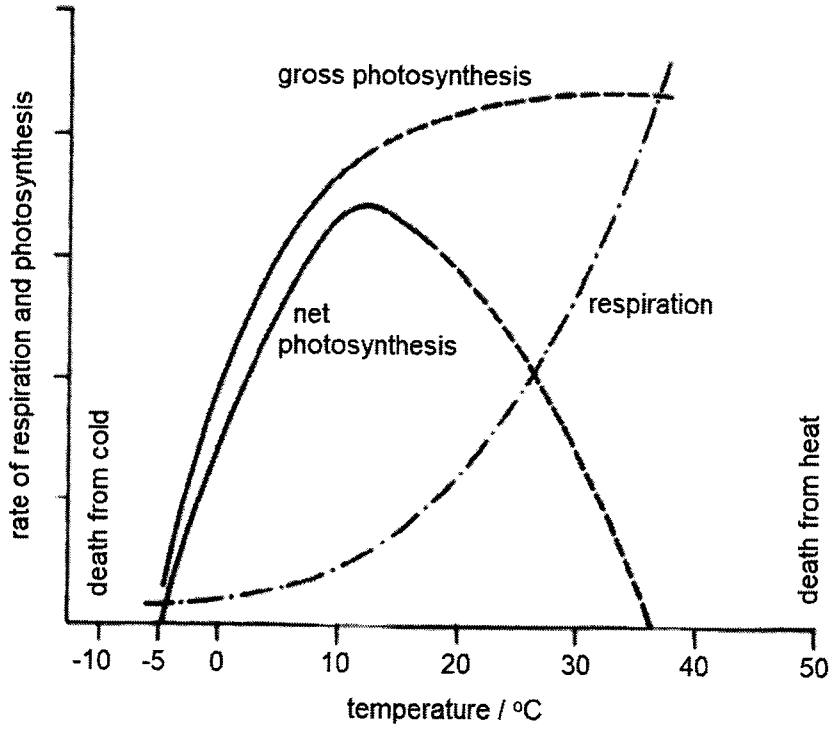



**Fig. 10.3**

**(i)** State the optimal temperature for growth and development of the stone pine seedlings

..... [1]

(ii) With reference to Fig 10.3, describe the change in rates between the gross and net photosynthesis before 35°C.

.....

.....

.....

..... [2]

(iii) With your knowledge on photosynthesis, explain the change observed in **(bii)**.

.....

.....

.....

.....

.....

..... [3]

[Total: 9]

# VICTORIA JUNIOR COLLEGE
# JC 2 PRELIMINARY EXAMINATION
# 2022
# HIGHER 2

**NAME:** .....

**CT CLASS:** .....

## BIOLOGY
Paper 3 Long Structured and Free-response Questions

**9744 / 03**

**21/09/2022**

**2 hour**

Candidates answer on the Question Paper.
No Additional Materials are required.

---

**READ THESE INSTRUCTIONS FIRST**

Write your name and CT class in the spaces at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

**Section A**
Answer **all** questions in the spaces provided on the Question Paper.

**Section B**
Answer any **one** question in the space provided on the Question Paper.

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

You may lose marks if you do not show your working or if you do not use appropriate units.

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

| Question | Marks |
|---|---|
| **Section A** | |
| 1 | |
| 2 | |
| 3 | |
| **Section B** | |
| | |
| **Total** | |

---

This document consists of **18** printed pages.

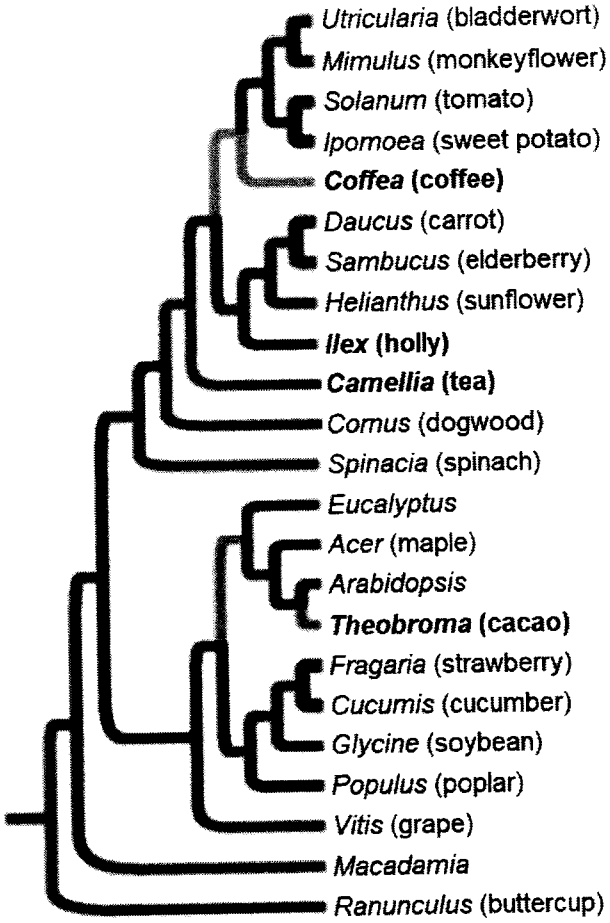
[Turn over]

## Section A

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

1 Caffeine is a bitter, white crystalline alkaloid produced by a wide range of plants, like tea, coffee, cacao, guarana, holly, and some citrus plants.

Fig. 1.1 shows a phylogenetic tree involving some caffeine-producing plants, constructed by the comparison of the amino acid sequence of ribulose bisphosphate carboxylase (Rubisco) extracted from the plants.




*Genus of caffeine-producing plants are bolded.

**Fig. 1.1**

**(a) (i)** State, as precisely as you can, where Rubisco is found in the plants.

..... [1]

**(ii)** Outline the significance of Rubisco to the plants.

.....

.....

.....

.....

.....

..... [3]

With reference to Fig. 1.1,

**(iii)** of all the caffeine-producing plants, state the genus of the least related one.

..... [1]

**(iv)** deduce if the evolution of caffeine in plants shows divergent evolution. Give a reason for your answer.

.....

.....

.....

..... [2]

**(v)** An evolutionary biologist commented that the use of amino acid sequence of Rubisco in the construction of the phylogenetic tree in Fig. 1.1 is reliable. However, reliability of the phylogenetic tree can be improved.

Justify the claim of the scientist that the phylogenetic tree is reliable and suggest an improvement to the reliability.

.....

.....

.....

..... [2]

**(b)** The global consumption of coffee has been increasing steadily, as shown in Fig. 1.2.

Fig. 1.3 shows the consumption of coffee in different regions around the world.

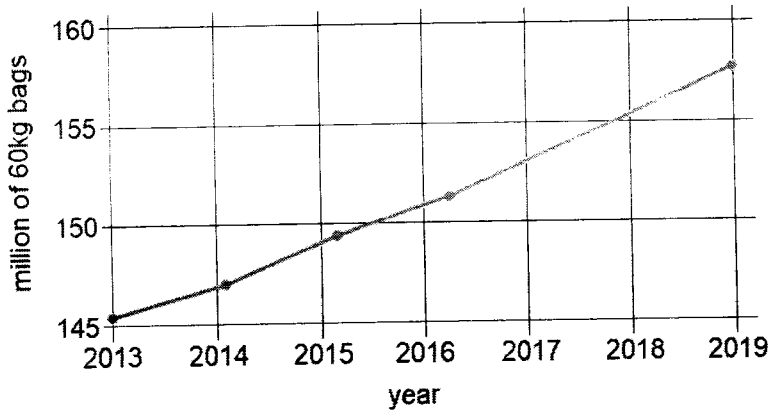



**Fig. 1.2**

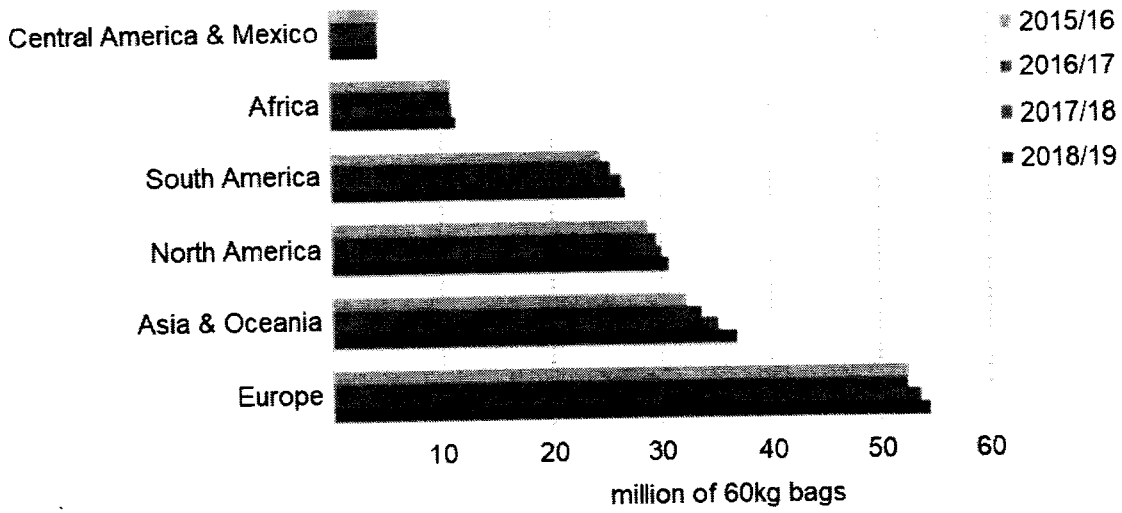



**Fig. 1.3**

With reference to Fig. 1.2 and 1.3,

**(i)** calculate the rate of increase in global consumption of coffee between 2015 and 2019. Show your working below.

[1]

**(ii)** state the region that contributed the most to the increase in the global consumption of coffee. Give a reason for your answer.

.....

.....

.....

..... [2]

**(c)** One reason for the increasing consumption of coffee is due to the benefits of caffeine as a cognitive enhancer, as it increases alertness and attentional performance of individuals who consume coffee.

Adenosine is a chemical found in the brain. Its concentration has been shown to increase when we are awake and active during the day. It binds to specific receptors on neurones, which causes the feeling of drowsiness. The number of receptors bound by adenosine increases throughout the day, resulting in increasing feeling of drowsiness.

Fig. 1.4 shows the signalling pathway of adenosine, and Fig. 1.5 shows the structure of adenosine and caffeine.

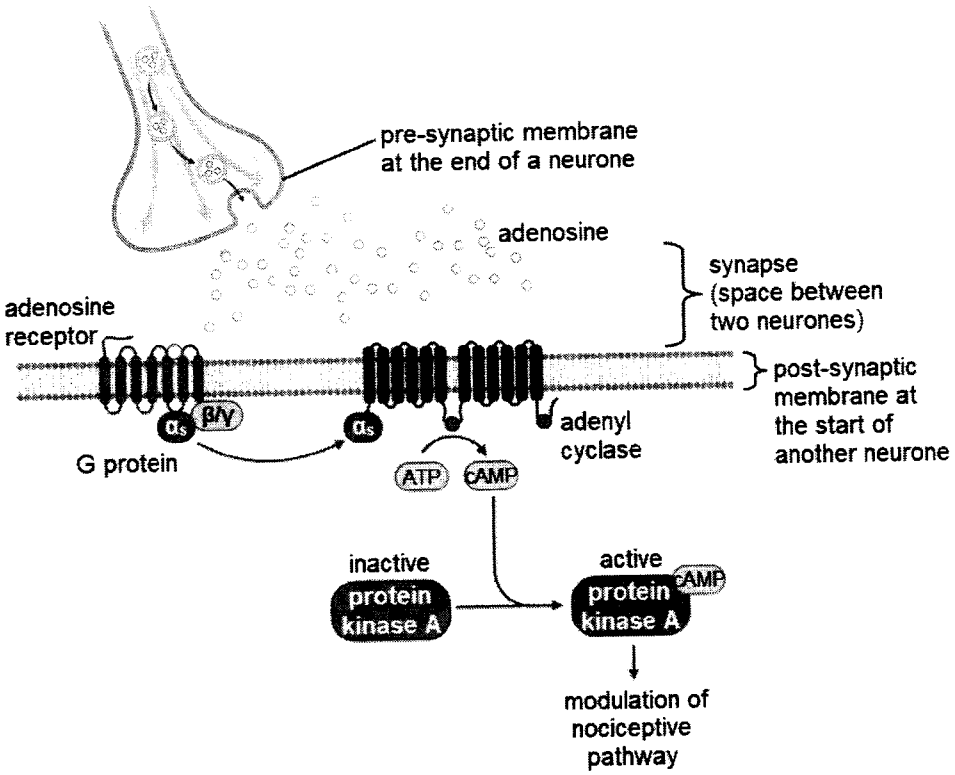



**Fig. 1.4**

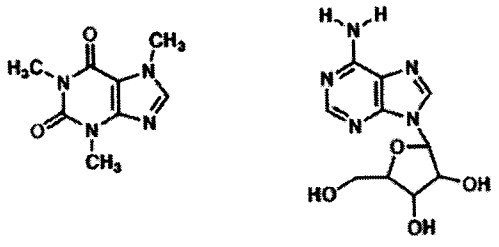



**Fig. 1.5**

With reference to the information provided,

**(i)** explain how the structure of adenosine aids in its movement across the synapse.

.....

.....

.....

..... [2]

**(ii)** explain the significance of cAMP in adenosine signalling.

.....

.....

.....

.....

.....

..... [3]

**(iii)** explain how caffeine functions as a cognitive enhancer.

.....

.....

.....

.....

.....

..... [3]

**(iv)** suggest two reasons for the need of repeated consumption of coffee throughout the day in order to prevent feeling of drowsiness.

.....

.....

.....

..... [2]

**(d)** While caffeine serves as a cognitive enhancer in humans, it serves important functions in plants. In high concentrations, it plays a pesticidal role against many insects, snails, slugs, even some fungi and bacteria. However, the presence of low concentrations of caffeine in nectar increases the chance of pollination as pollinators like bees have been observed to preferentially visit the flowers of caffeine-producing plants.

However, a species of beetle known as coffee berry borer, is able to consume the fruits and leaves of coffee plants despite the high concentration of caffeine. The resistance to caffeine in the beetle is due to the symbiotic relationship with a species of bacteria in its gut, which is able to utilise caffeine as a food source.

**(i)** Outline the symbiotic relationship between coffee berry borer and its gut bacteria.

.....

.....

.....

.....

.....

..... [3]

**(ii)** Explain how coffee berry borer may be classified as a distinct species.

.....

.....

.....

..... [2]

[Total: 27]

2 The cancer stem cell (CSC) theory, where scientists believe that in every tumour, a small group of cancer cells exhibit stem cell-like behaviours and properties, is gaining increasing attention from researchers and has become an important focus of cancer research.

**(a) (i)** Outline how cancer cells can be 'stem cell-like'.

.....

.....

.....

..... [2]

Under natural circumstances in the body, another group of cells, the germ line cells, also exhibit stem cell-like properties. However, they are not the same as cancer cells.

**(ii)** Describe the differences that can be seen in cancer cells compared with normal germ line cells.

.....

.....

.....

.....

.....

..... [3]

**(b)** A bone marrow transplant is also known as a stem cell transplant. Transplantation can be used to treat certain types of cancer, such as leukaemia, myeloma, and lymphoma, as well as other blood and immune system diseases that affect the bone marrow. In medical procedures, stem cells for an **autologous transplant** come from the patient's own body.

Sometimes, cancer is treated with high-dose, intensive chemotherapy or radiation therapy treatment.

**(i)** Suggest a reason why doctors remove the patient's stem cells from their blood or bone marrow before the cancer treatment begins.

.....

..... [1]

In blood cancer treatment, bone marrow transplant often yielded positive outcomes in many clinical trials, with over 50% of the patients surviving without remission.

A team of doctors decided to incorporate this treatment with high doses of chemotherapy in a new clinical trial. Fig 2.1 shows the Kaplan-Meier Estimates of the overall survival of patients with metastatic breast cancer, who were randomly assigned to treatment with either conventional-dose chemotherapy alone, or with high-dose chemotherapy plus autologous haematopoietic stem-cell transplantation.

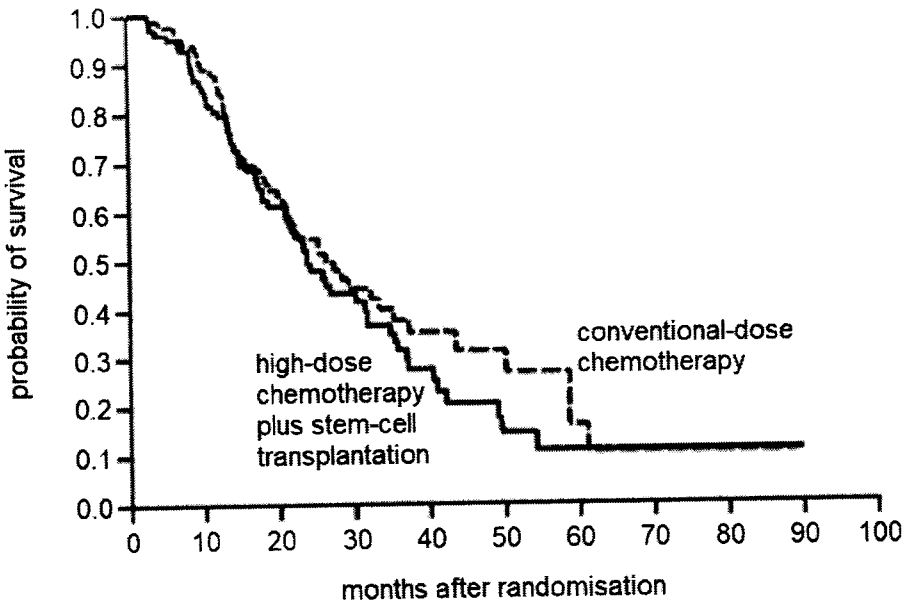



**Fig. 2.1**

**(ii)** With reference to Fig 2.1, give a conclusion for the effectiveness of the two treatment methods for breast cancer in women. Justify your answer.

.....

.....

.....

.....

.....

..... [3]

[Total: 9]

**3** Coronavirus disease (COVID-19) is an infectious disease caused by the SARS-CoV-2 virus. Most people infected with the virus will experience mild to moderate respiratory illnesses and recover without requiring special treatment. However, some individuals will become seriously ill and require medical attention. Older people and those with underlying medical conditions like cardiovascular diseases, diabetes, chronic respiratory diseases, or cancer are more likely to develop serious illnesses. Anyone can get infected with COVID-19 and become seriously ill or die at any age.

The understanding of the structure of the SARS-CoV-2 virus is important for the production of drugs and vaccines.

Fig. 3.1 shows the general structure of the SARS-CoV-2 virus.

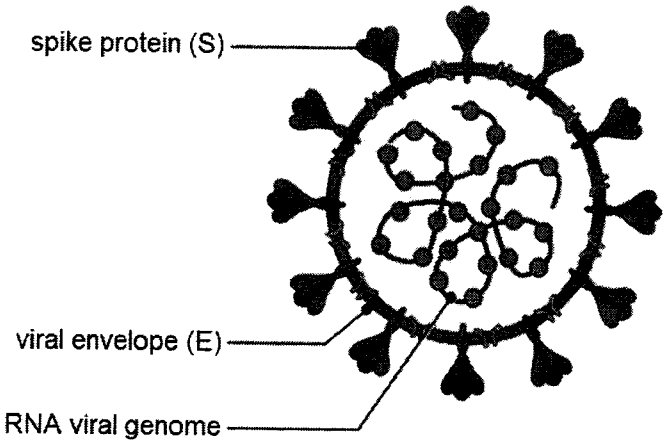



**Fig. 3.1**

**(a)** With reference to Fig. 3.1, contrast the structure of SARS-CoV-2 with that of HIV.

.....

.....

.....

..... [2]

**(b)** Researchers looked at COVID-19 patients and found that they had much higher levels of antibodies against SARS-CoV-2 than those without the disease.

Describe three ways in which the structure of antibodies contributes to their functions.

.....

.....

.....

.....

.....

..... [3]

**(c)** Fig. 3.2 shows the structure of immunoglobulin genes which code for antibodies.

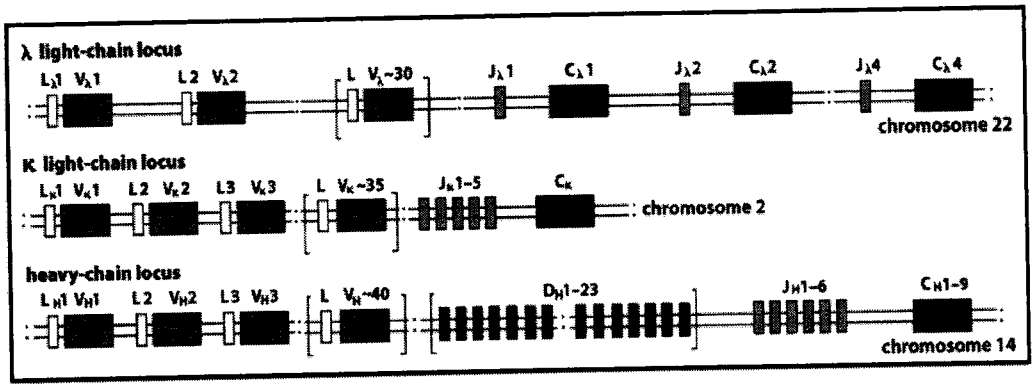



**Fig. 3.2**

With reference to Fig. 3.2, explain how variability at the DNA level result in variability in the antigen-binding sites of antibodies.

.....

.....

.....

.....

.....

..... [3]

**(d)** mRNA COVID-19 vaccines are currently being administered as a measure to reduce the severity of illnesses brought about by the infection. The vaccine contains an mRNA which codes for a spike protein. When the vaccine is injected into the upper arm muscle, the mRNA enters a cell and gets translated into a spike protein. The protein is then displayed on the cell surface membrane and gets recognised as 'foreign' by the immune cells. This triggers the production of antibodies against the spike protein.

Explain how the vaccine triggers the production of antibodies and how the antibodies confer protection against the virus.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [5]

**(e)** While COVID-19 vaccines took several months to be developed, no effective HIV vaccine has been developed after almost 40 years. Scientists that are involved in the research and development of the HIV vaccine say that the problem lies not in the lack of funding but in the HIV virus itself.

Suggest why scientists have not been able to create an effective vaccine against HIV.

.....

..... [1]

[Total: 14]

## Section B

Answer **one** question in this section.

Write your answers in the lined paper provided at the end of this Question Paper.

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 parts **(a)** and **(b)**, as indicated in the question.

**4** **(a)** Epigenetics is the study of changes in organisms that are caused by modifications of gene expression rather than alteration of the genetic code. Describe how such modifications can be achieved. [15]

**(b)** Using relevant examples, discuss the significance of regulating gene expression. [10]

[Total: 25]

**5** **(a)** Respiration produces ATP. Describe the role of ATP in living organisms. [15]

**(b)** Using relevant examples, discuss the significance of complementarity in the production of ATP. [10]

[Total: 25]