Write your **student number** in the boxes above. **Letter**

Biology ¾

Question and Answer Book - SOLUTIONS

VCE Examination (Term 1 Mock) - April 2025

- Reading time is **15 minutes**.
- Writing time is **2 hours 30 minutes**.

Materials Supplied

- Question and Answer Book of 42 pages.
- Multiple-Choice Answer Sheet.

Instructions

- Follow the instructions on your Multiple-Choice Answer Sheet.
- At the end of the examination, place your Multiple-Choice Answer Sheet inside the front cover of this book.

Students are **not** permitted to bring mobile phones and/or any unauthorised electronic devices into the examination room.

Contents

Student's Full Name: _____

Student's Email: _____

Tutor's Name: _____

Marks (Tutor Only): _____

Section A

Instructions

- Answer **all** questions in pencil on the Multiple-Choice Answer Sheet.
- Choose the response that is **correct** or that **best answers** the question.
- A correct answer scores 1; an incorrect answer scores 0.
- Marks will **not** be deducted for incorrect answers.
- No marks will be given if more than one answer is completed for any question.
- Unless otherwise indicated, the diagrams in this book are not drawn to scale.

Learning Objective [1.4.1] Define & compare primary, secondary, tertiary & quaternary structures of proteins.

Question 1 D1

A researcher is studying the enzyme **hexokinase**, which catalyses the phosphorylation of glucose to form glucose-6-phosphate in the first step of glycolysis. The researcher observes that specific amino acids in the enzyme's active site play a key role in binding glucose and catalysing the reaction. Modifying certain amino acids in the active site significantly reduces the enzyme's efficiency.

Which of the following best explains the role of the variable side chain (R-group) in determining the properties and function of these amino acids?

A. The R-group forms peptide bonds, which stabilise the enzyme's structure.

B. The R-group dictates the chemical reactivity and interactions of the amino acid, impacting enzyme activity.

C. The R-group determines the structure of the amino acid backbone, which is critical for enzyme folding.

D. The R-group does not affect the biochemical interactions or function of the amino acid in the enzyme.

Question 2 D1

Learning Objective [1.2.4] Identify & practically apply the characteristics of the genetic code - universal, unambiguous, degenerate, triplet - to real life examples.

How does the degeneracy of the genetic code contribute to minimising the impact of mutations?

A. It prevents mutations from occurring.

B. It allows multiple codons to code for the same amino acid, reducing the likelihood of a harmful mutation.

C. It ensures that all mutations lead to the same amino acid change, allowing consistency in gene expression.

D. It restricts the types of mutations that can occur, ensuring they fall within given bounds to prevent unexpected harm to proteins.

Question 3 D1

Learning Objective [1.3.2] Describe the processes of transcription, mRNA processing, & translation, recognising the significance of each step to the final product.

Which of the following incorrectly identifies a step during transcription?

A. The stop codon is reached, and the polypeptide chain then detaches.

B. RNA polymerase binds to the promoter region.

C. The DNA double helix begins to unwind.

D. The terminator sequence is reached and mRNA detaches.

Question 4 D1

Learning Objective [1.2.1] Identify & compare the characteristic features of the structures of nucleic acids & their monomers, including DNA, mRNA, tRNA & rRNA, including base pairing.

Which one of the following correctly identifies both the structure and a possible role of an RNA molecule in a eukaryotic cell?

	Conclusion	Possible role
A.	Is single-stranded and contains uracil	Serves as a template for protein synthesis during translation
B.	Consists of nucleoti ribose and phosphat	Consists of nucleotides with ribose and phosphate groups | carries genetic information from the DNA to the ribosome for protein synthesis
C.	Contains a double helix and pairs adenine with thymine	Acts as a structural component of ribosomes
D.	Contains ribose sugar and is double-stranded	Stores genetic information in the nucleus

Question 5 D1

Research methods **[5.1.?]**

You are designing an experiment to test the effect of pH on enzyme activity. Which of the following steps would best improve the reliability and validity of your results?

A. Repeating the experiment multiple times and averaging the results.

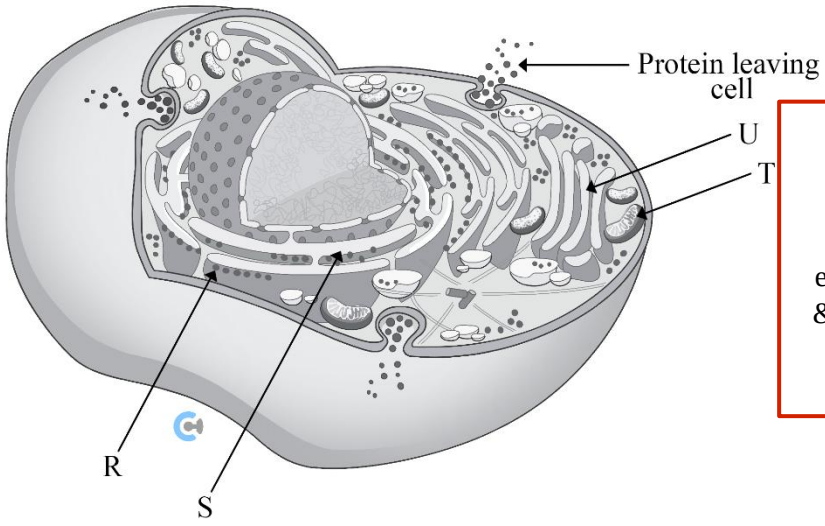
B. Including both a positive control and a negative control.

C. Calibrating the pH meter before each measurement.

D. Using a larger variety of pH levels in your tests.

Question 6 D1

The diagram below represents a mammalian cell undergoing the process of exocytosis.



Source: adapted from Soleil Nordic/Shutterstock.com

Learning Objective [1.4.2] Identify & describe the roles of ribosomes, rough endosplasmic reticulum & golgi apparatus in the transport & export of proteins from a cell.

In the process of exocytosis, the role of:

A. Organelle R is to synthesise the proteins.

B. Organelle S is to modify, sort, and package proteins for secretion.

C. Organelle T is to transport proteins to their destination within or outside the cell.

D. Organelle U is to generate ATP required for cellular activities.

The following information applies to the two questions that follow.

Question 7 D1

Learning Objective [1.2.1] Identify & compare the characteristic features of the structures of nucleic acids & their monomers, including DNA, mRNA, tRNA & rRNA, including base pairing.

A sequence of single-stranded nucleic acid containing both exons and introns would most likely be:

A. Mature mRNA

B. Pre-mRNA

C. cDNA

D. DNA

Learning Objective [1.3.2] Describe the processes of transcription, mRNA processing, & translation, recognising the significance of each step to the final product.

Question 8 D1

Learning Objective [1.2.1] Identify & compare the characteristic features of the structures of nucleic acids & their monomers, including DNA, mRNA, tRNA & rRNA, including base pairing.

This would most likely be found in the:

A. Rough Endoplasmic Reticulum

B. Golgi Apparatus

C. Nucleus

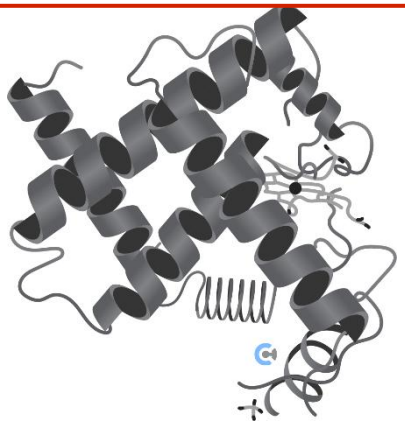
D. Ribosome

Learning Objective [1.3.2] Describe the processes of transcription, mRNA processing, & translation, recognising the significance of each step to the final product.

Question 9 D1

Myoglobin is a protein with a three-dimensional shape and only one polypeptide. What is the highest level of protein structure in myoglobin?

Learning Objective [1.4.1] Define & compare primary, secondary, tertiary & quaternary structures of proteins.



A. Primary

B. Secondary

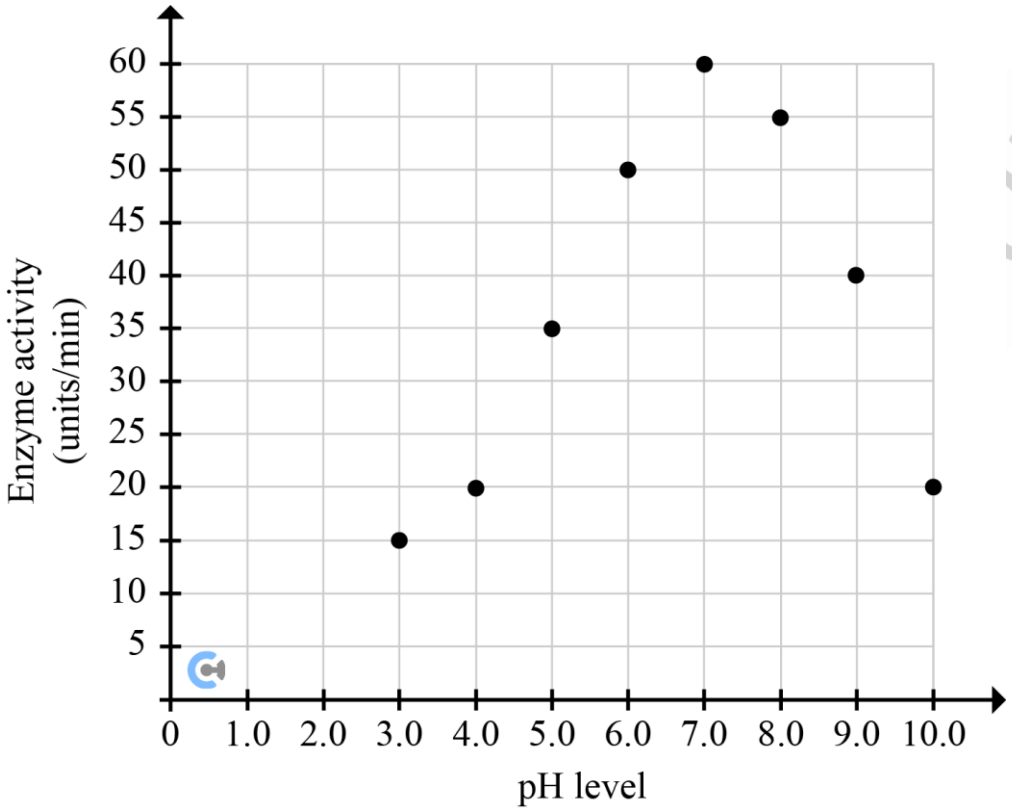
C. Tertiary

D. Quaternary

Question 10 D1

A team of researchers conducted an experiment to measure the activity of an enzyme under different pH levels. The enzyme activity was measured in units of product formed per minute. The data collected is summarised in the table below:

Learning Objective [1.4.4] Explain how enzymes change/denature in different pH & at different temperatures.



Based on the data, which pH level is closest to the enzyme's optimal pH, and what does this imply about the enzyme's activity in a biological context, such as the human digestive system?

A. pH 3.0; The enzyme is most active in highly acidic environments similar to the stomach.

B. pH 6.0; The enzyme's activity peaks at a slightly acidic environment, indicating it might be functional in the small intestine.

C. pH 7.0; The enzyme has the highest activity in neutral pH, suggesting it is most active in environments like the blood.

D. pH 8.0; The enzyme works best in slightly basic conditions, indicating it might function well in environments such as the pancreas.

The correct answer is C. pH ; The enzyme has the highest activity in neutral pH, suggesting it is most active in environments like the blood. This implies that the enzyme is likely to be one that functions optimally.

D1

Question 11 Learning Objective [2.2.1] Recall the inputs, outputs & locations of all stages of aerobic cellular respiration.

A biochemical analysis of the bat muscle cells showed a high level of lactic acid. Which one of the following is a valid conclusion for a high level of lactic acid in the bat muscle cells?

	Conclusion	Reason for conclusion
A.	Oxygen is being efficiently used by the cells.	Lactic acid is produced only when oxygen is available.
B.	The cells are undergoing aerobic respiration.	Aerobic respiration produces lactic acid as a byproduct.
C.	There is no oxygen in the cells.	Anaerobic respiration occurs in the absence of
D.	NADH is being recycled.	pyruvate into lactic acid, allowing glycolysis to continue.

NADH is being recycled. | NADH is used in anaerobic respiration to convert pyruvate into lactic acid, allowing glycolysis to continue.

Question 12 D1

Learning Objective [1.6.6] Define & describe the bioethical concepts of integrity, respect, beneficence, non-maleficence & justice as elaborated in the VCAA study design.

A pharmaceutical company is conducting a clinical trial for a new medication aimed at treating a rare genetic disorder. The trial includes a diverse group of participants from various age groups and health backgrounds. The company has implemented extensive safety measures to minimise potential risks and has ensured that the potential benefits of the medication are well-communicated to the participants.

Which ethical principle is the company prioritising by focusing on minimising risks and maximising benefits?

A. Integrity
B. Justice
C. Respect
D. Beneficence

Learning Objective [1.6.6] Define & describe the bioethical concepts of integrity, respect, beneficence, non-maleficence & justice as elaborated in the VCAA study design.

Question 13 D1

Learning Objective [2.2.8] Explain how yeast can be used to produce bioethanol from biomass.

Some species of bacteria can be added to biomass to produce bioethanol, a renewable energy source. The production of bioethanol involves the breakdown of starch:

A. By glycolysis followed by alcoholic fermentation.
B. Via aerobic respiration followed by carbon dioxide production.
C. Through the Kreb's cycle followed by lactic acid fermentation.
D. In the presence of oxygen followed by fermentation.

Question 14 D1

Learning Objective [1.6.4] Describe the function & compare the guide RNA (gRNA) & single guide RNA (sgRNA).

The function of guide RNA in the CRISPR-Cas9 system is:

A. Unwind the target DNA.

B. Provide bacteria with innate immunity.

C. Identify the position where the target DNA is to be cut.

D. Cut the double-stranded DNA at the site upstream from the PAM sequences.

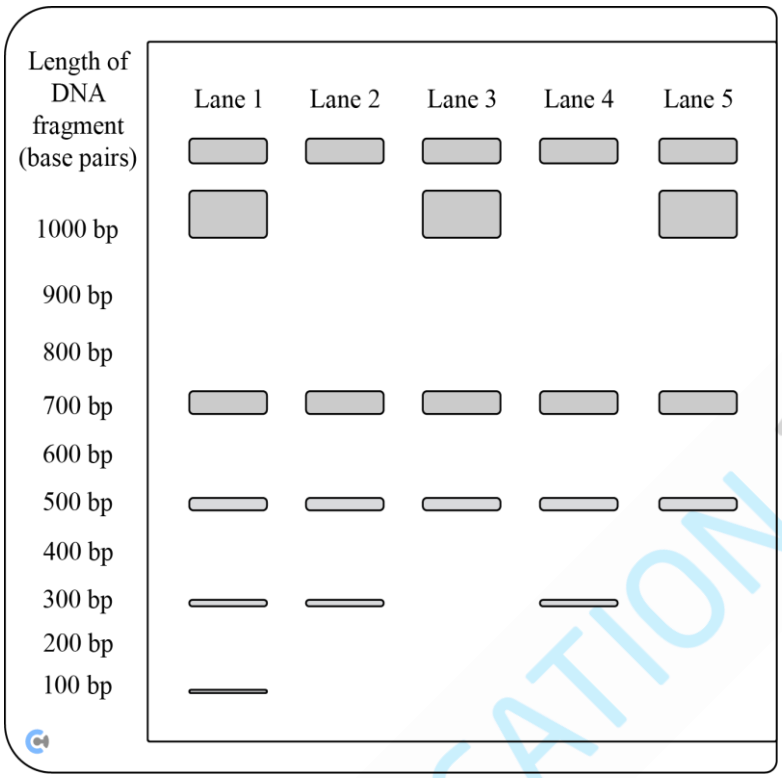
The following information applies to the two questions that follow.

A forensic team is analysing DNA samples from a crime scene to identify the suspect. They run gel electrophoresis on the DNA samples, which include the suspect's DNA, the victim's DNA, and DNA samples were collected from the crime scene. The results of the gel electrophoresis are shown below:

Gel Electrophoresis Results:

Lane	Sample	Band Pattern (in *bp*)
1	DNA Ladder	1000, 700, 500, 300, 100
2	Suspect's DNA	700, 500, 300
3	Victim's DNA	1000, 700, 500
4	Crime Scene DNA Sample 1	700, 500, 300
5	Crime Scene DNA Sample 2	1000, 700, 500

Schematic of the Gel:



Question 15 D1

Learning Objective [1.5.3] Describe the process of gel electrophoresis, & describe how it may be used to differentiate DNA samples or to obtain a "DNA profile".

Based on the gel electrophoresis results, which DNA sample(s) match the suspect's DNA?

A. Only Crime Scene DNA Sample 1.

B. Only Crime Scene DNA Sample 2.

C. Both Crime Scene DNA Sample 1 and Crime Scene DNA Sample 2.

D. Neither Crime Scene DNA Sample 1 nor Crime Scene DNA Sample 2.

Question 16 D1

Learning Objective [1.5.3] Describe the process of gel electrophoresis, & describe how it may be used to differentiate DNA samples or to obtain a "DNA profile".

What is the significance of the DNA ladder in Lane 1, and how does it help in interpreting the gel results?

A. It serves as a control to ensure the experiment was performed correctly.

B. It provides a reference for estimating the size of DNA fragments in other lanes.

C. It contains the suspect's DNA for comparison with crime scene samples.

D. It shows the DNA from the victim to identify any contamination.

Question 17 D1

Learning Objective [1.2.3] Define the key components of a gene, including a comparison between the structure of genes in eukaryotes & prokaryotes.

Identify the correct statement below.

A. Plasmids are found in the eukaryotic mitochondria.

B. Plasmids are sections of DNA part of the prokaryotic genome.

C. Plasmids are technically not considered part of the genome.

D. Plasmids are enzymes that protect bacteria from viral infections.

Question 18 D1

Learning Objective [1.7.1] Describe the role of plasmids as a vector to transform bacteria & other cells.

Learning Objective [1.7.2] Explain how a gene of interest is isolated & inserted into a plasmid.

Recombinant DNA technology is used in many applications to produce human proteins in bacteria, for use in primarily medical applications. Which of the following correctly identifies the type of cut required from an endonuclease to a plasmid in the process of adding the gene of interest to it?

A. Sticky ends, as the complementary ends allow for specificity in the orientation of the insertion of the gene of interest.

B. Blunt ends, as most plasmids do not have the correct recognition sites for insertion.

C. Sticky ends, as they allow the plasmid to rejoin itself via DNA ligase, while blunt ends do not.

D. Blunt ends, as they allow for any end to join without specificity, which means you can keep trying until you get the join the right way around.

Question 19 D1

Learning Objective [2.2.1] Recall the inputs, outputs & locations of all stages of aerobic cellular respiration.

The final electron acceptor during the electron transport chain is:

A. Oxygen

B. Water

C. Carbon dioxide

D. ATP

Question 20 D1

Learning Objective [2.1.1] Recall the inputs, outputs, & locations, & the relationship between both stages of photosynthesis.

Thirty minutes later, ^{18}O is provided to photosynthesising plants in water molecules, it will be found as:

A. Glucose

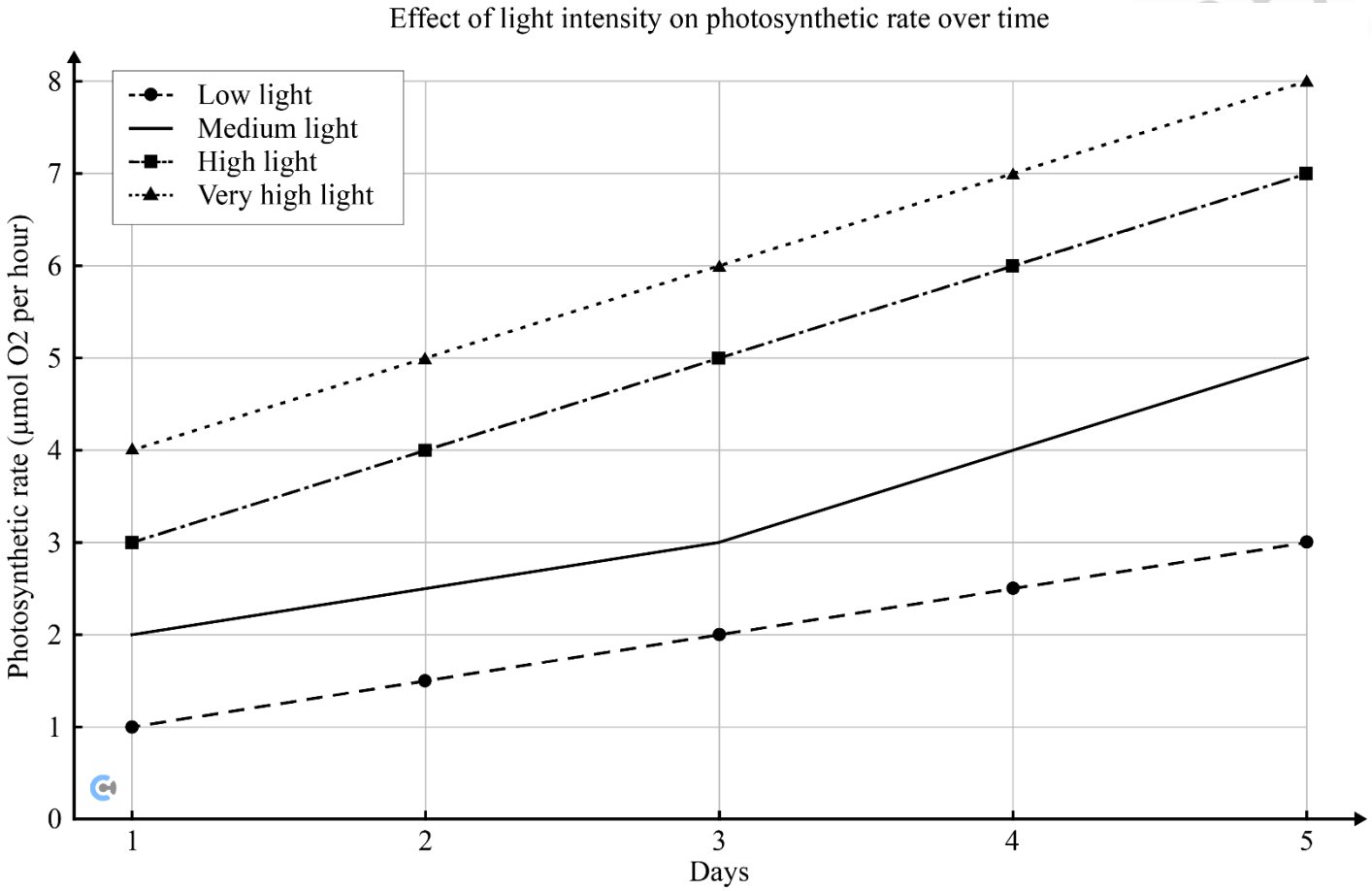
B. Carbon dioxide

C. Gaseous oxygen

D. Starch

The following information applies to the two questions that follow.

A new experiment is conducted on the effect of light intensity on the photosynthetic rate of a plant over a five-day period. The plant is subjected to four different light intensity levels: **low, medium, high**, and **very high**. The Y-axis measures the **photosynthetic rate** (measured in $\mu mol\ O_2$ released per hour) and the X-axis represents the days of the experiment (Day 1, Day 2, Day 3, Day 4, and Day 5).



Question 21 D1

Learning Objective [2.1.6] Identify & explain the factors - light colour, intensity, CO2 concentration, temperature, water availability - that affect the efficiency of photosynthesis.

Which of the following conclusions can be drawn from the graph of light intensity v/s photosynthetic rate?

A. The photosynthetic rate increased consistently under all light intensities over the five days.

B. The photosynthetic rate was highest under the "very high" light intensity on day 5.

C. The "medium" light intensity showed the lowest rate of photosynthesis across all time points.

D. The photosynthetic rate under "low" light intensity was higher than under "high" light intensity by day 5.

Question 22 D1

Which of the following would be a reasonable controlled variable in this experiment?

Learning Objective [2.1.6] Identify & explain the factors - light colour, intensity, CO_2 concentration, temperature, water availability - that affect the efficiency of photosynthesis.

A. Temperature at which the plant is kept.

B. The type of plant used in the experiment.

C. The intensity of the light used.

D. The length of time the experiment lasts.

Question 23 D1

Learning Objective [1.4.5] Explain function of competitive & non-competitive enzyme inhibitors & how they affect rate of reaction, & how they may/may not be overcome.

Methotrexate is a medication used to treat a variety of conditions, such as rheumatoid arthritis, due to its ability to bind to and competitively inhibit dihydrofolate reductase, an enzyme that facilitates cell division by binding to folic acid. Based on this information, it would be reasonable to conclude that:

A. Increasing the dose of Methotrexate (ignoring toxicity) would block more dihydrofolate reductase active sites, causing a reduction in cell division.

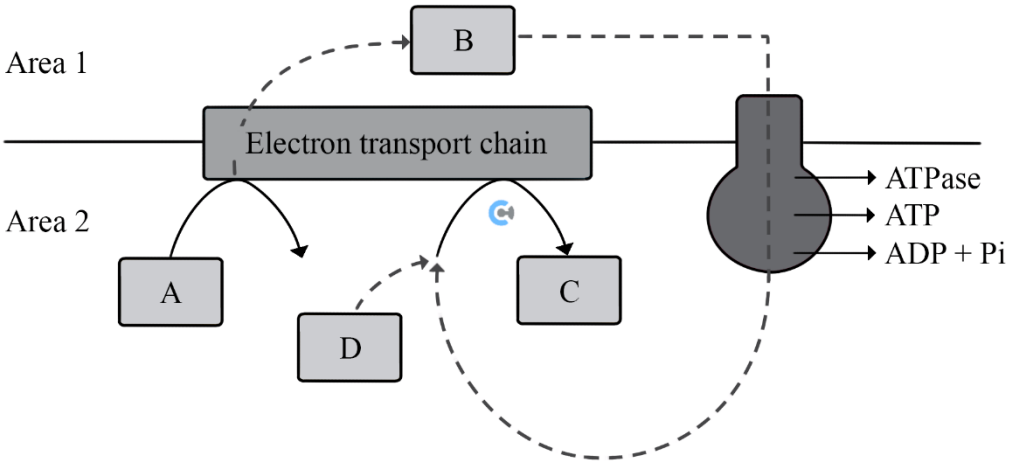
B. Methotrexate would be more effective than a non-competitive inhibitor in the same scenario.

C. A low dose of methotrexate would allow for the treatment to be successful because all the active sites would be occupied.

D. Methotrexate and folic acid have the same three-dimensional shape.

The following information applies to the three questions that follow.

The diagram below shows a reaction that occurs in most eukaryotic cells. Chemicals A-D are involved in the process.



Learning Objective [2.2.1] Recall the inputs, outputs & locations of all stages of aerobic cellular respiration.

Question 24 D1

Which one of the following identifies chemicals A-C?

	Chemical A	**Chemical** B	**Chemical** C
A.	NADPH	Hydrogen	Oxygen
B.	Oxygen	NADH	Water
C.	Water	Carbon dioxide	Oxygen
D.	NADH	Hydrogen	Water

Question 25 D1

Which one of the following identifies Area 1 and Area 2?

	Area 1	**Area** 2
A.	Cytosol	Matrix
B.	Intermembrane space	Matrix
C.	Nucleoplasm	Cytoplasm
D.	Matrix	Intermembrane space

Learning Objective [2.2.1] Recall the inputs, outputs & locations of all stages of aerobic cellular respiration.

Question 26 D1

Identify the ATP yield for the reaction depicted in the diagram.

A. 26 or 28

B. 30 or 32

C. 32 or 34

D. 36 or 38

Learning Objective [2.2.1] Recall the inputs, outputs & locations of all stages of aerobic cellular respiration.

Question 27 D1

Learning Objective [2.1.9] Explain how CRISPR-Cas9 can be used to increase photosynthetic efficiency.

CRISPR-Cas9 technology has been used to improve the efficiency of photosynthesis in crop plants. There are two main methods that successfully change the genome of a plant.

- Method 1 aims to disable an undesired gene in a plant, which may lead to a commercial advantage.
- Method 2 aims to insert a gene into a plant without disrupting other genes.

Which one of the following assumptions could be made about methods 1 and 2?

A. Method 1 is easier than Method 2 as it only involves cutting DNA, whereas Method 2 involves both cutting and pasting DNA.

B. Method 2 is faster to complete than Method 1.

C. Method 1 is easier than Method 2 as it involves cutting RNA, which has only one nucleic acid strand, whereas Method 2 involves cutting DNA, which has two nucleic acid strands.

D. Method 1 and 2 are equally visible for future use, but CRISPR-Cas9 technology will never be widely implemented due to the ethical concept of non-maleficence.

Question 28 D1

Learning Objective [1.4.3] Explain the lock-&-key model, the induced fit model & why enzymes are specific & only catalyse one reaction.

Enzymes play an important role in metabolic pathways. Which one of the following statements about enzymes is **incorrect**?

Learning Objective [1.4.4] Explain how enzymes change/denature in different pH & at different temperatures.

A. All enzymes are affected by changes in pH.

B. More enzymes have a limited number of substrates.

C. Enzymes increase the average energy of reactant molecules.

D. Enzymes lower the activation energy of the reactions they catalyse.

Question 29 D1

Learning Objective [1.3.5] Describe the regulation of the trp operon through the action of the repressor protein.

The *lac* operon is an example of a regulatory process in *E.coli* that is regulated by the action of repressor proteins.

Where on the operon will the repressor protein bind?

A. Operator region

B. Terminator region

C. Promoter region

D. The TATA box

D1

Question 30

Learning Objective [1.7.1] Describe the role of plasmids as a vector to transform bacteria & other cells.

If a plasmid is cut and has restriction sites for 3 restriction enzymes, how many fragments will remain after it has been cut?

A. 2

B. 3

C. 4

D. 5

Question 31 D1

Learning Objective [2.2.2] Recall the inputs, outputs & locations of all stages of anaerobic cellular respiration, including lactic acid & alcoholic fermentation.

When exercising, to make up for the extra energy that is required by the body, another reaction pathway takes place alongside cellular respiration. Which of the following is true about this pathway?

A. Produces ethanol.

B. Decreases the pH of the blood.

C. Produces CO_2.

D. Results in the formation of water.

Question 32 D1

What would happen if the electrode were placed at the incorrect end during gel electrophoresis?

A. There would be no separation of the fragments as they all collect at the end with the wells.

B. The fragments would all move at the same speed.

C. Cannot tell what happens.

D. Forms a phosphodiester bond.

Learning Objective [1.5.4] Explain the factors that affect the movement of fragments in gel electrophoresis.

The following information applies to questions 33 to 36.

The use of genetically modified soybeans is becoming increasingly popular, especially with the adoption of this standard by the Growers Association for Soybeans in Australia. This is a genetically modified crop, as it includes a pesticide-resistance gene from a soil bacterium.

Question 33 D1

Which of the following correctly describes this soybean?

A. Transgenic

B. Cisgenic

C. Cyborg

D. Monogenic

Learning Objective [1.6.9] Compare transgenic, cisgenic & genetically modifed organisms.

Question 34 D1

"The pesticide resistance nature results in over spraying of insecticide."

Which of the following correctly identifies the ethical concept relating to this statement?

A. Integrity

B. Justice

C. Beneficence

D. Non-maleficence

Learning Objective [1.6.6] Define & describe the bioethical concepts of integrity, respect, beneficence, non-maleficence & justice as elaborated in the VCAA study design.

Question 35 D1

These seeds are only present to the farmers with the financial means of accessing them, particularly in Western nations. Which of the following correctly identifies the ethical concept relating to this statement?

A. Justice

B. Respect

C. Non-maleficence

D. Integrity

Learning Objective [1.6.6] Define & describe the bioethical concepts of integrity, respect, beneficence, non-maleficence & justice as elaborated in the VCAA study design.

D1

Question 36

There is no legal requirement to publish products that are made from GMO soybeans. Which of the following correctly identifies the ethical concept relating to this statement?

Learning Objective [1.6.6] Define & describe the bioethical concepts of integrity, respect, beneficence, non-maleficence & justice as elaborated in the VCAA study design.

A. Respect

B. Justice

C. Beneficence

D. Non-maleficence

D1

Learning Objective [2.1.1] Recall the inputs, outputs, & locations, & the relationship between both stages of photosynthesis.

Question 37

In the light-independent reactions (Calvin Cycle) of photosynthesis, ATP and NADPH are used in the reduction of 3-phosphoglycerate to glyceraldehyde-3-phosphate. Which of the following correctly describes the roles of ATP and NADPH in these reactions?

A. ATP provides the energy for converting ribulose-1,5-bisphosphate to 3-phosphoglycerate, while NADPH carries the electrons required for carbon fixation.

B. ATP supplies the energy needed to convert 3-phosphoglycerate into glyceraldehyde-3-phosphate, while NADPH donates electrons and protons to reduce 3-phosphoglycerate.

C. ATP is used to regenerate ribulose-1,5-bisphosphate, while NADPH carries energy for carbon fixation.

D. ATP is used to phosphorylate ribulose-1,5-bisphosphate, while NADPH supplies electrons for the reduction of carbon dioxide.

D1

Question 38

Certain plants combine carbon dioxide with a three-carbon compound (C3) to produce a four-carbon compound (C4) during the night, which can be used in photosynthesis during daylight hours. This kind of plant is called a:

Learning Objective [2.1.4] Describe the adaptations of C4 & CAM plants for reducing photorespiration, as compared to C3 plants, including structural & physiological differences.

A. C3 plant.

B. CAM plant.

C. C4 plant.

D. Rubisco plant.

D1

Learning Objective [1.7.5] Explain the significance of beta-galactosidase, other reporter genes, & antibiotic resistance genes in the selection of transformed, recombinant bacterial cells.

Question 39

In the process of making recombinant plasmids, the role of the reporter gene and the antibiotic-resistance genes can be used for:

A. Making sure the colonies survive after transformation.

B. To determine which bacterial colony has been transformed with the recombinant plasmid.

C. To determine which bacterial colony has been transformed with the non-recombinant plasmid.

D. To help purify the protein product produced by the bacterial cell.

Question 40 D1

Consider the conversion of isocitrate into α-ketoglutarate. When ATP is produced in excess amounts for the needs of this cell, some ATP attaches to isocitrate dehydrogenase. The role of the ATP that attaches to isocitrate dehydrogenase is to act as a:

Learning Objective [1.4.5] Explain function of competitive & non-competitive enzyme inhibitors & how they affect rate of reaction, & how they may/may not be overcome.

A. Catalyst

B. Coenzyme

C. Source of hydrogen ions

D. Non-competitive inhibitor

Section B

Instructions

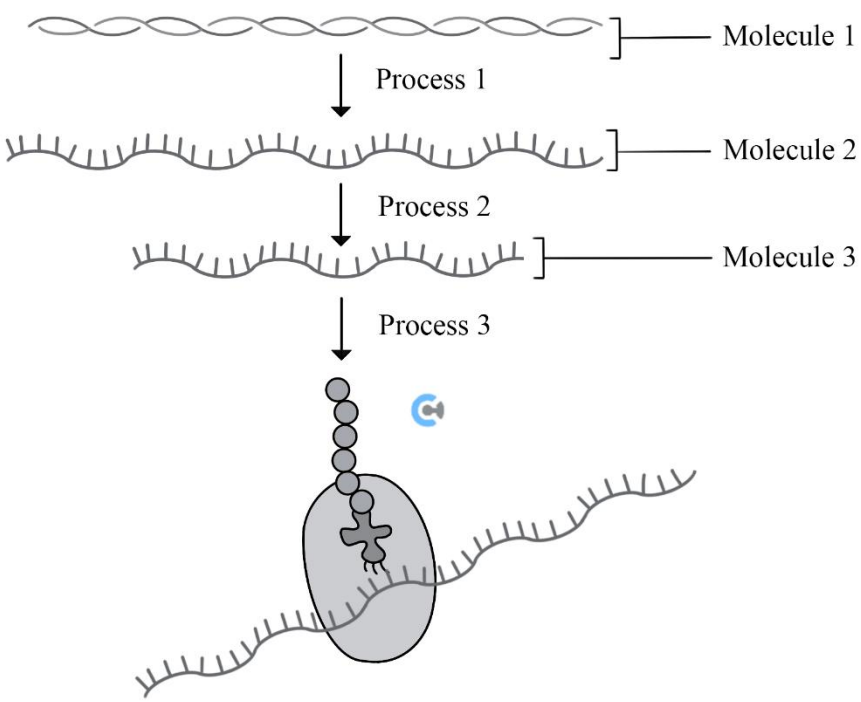
- Answer all questions in the spaces provided.
- Unless otherwise indicated, the diagrams in this book are not drawn to scale.

Question 1 (11 marks)

In a small village, there lived a family with a rich history of farming. The youngest child, Elena, a lively and spirited five-year-old, began to show signs of muscle weakness. Her parents, noticing her difficulty in walking and frequent falls, grew increasingly concerned. Visits to local doctors provided little insight, as the symptoms seemed perplexing and out of place for a child so young.

After months of uncertainty, they decided to seek help from a specialist in a nearby city. Dr. Patel, a renowned neurologist, conducted a series of genetic tests. The results revealed that Elena had spinal muscular atrophy (SMA), a genetic disorder characterised by the loss of motor neurons and progressive muscle wasting. Dr. Patel explained that SMA is caused by a deficiency in the survival motor neuron (SMN) protein due to a mistake in process 2 of the SMN2 gene.

The diagram below shows the steps of normal gene expression sequence that occur to produce the SMN protein. The process and molecules (1-3) involved in the sequence are indicated.



D1

a. Complete the table below by naming the processes and molecules indicated in the diagram. 3 marks

Learning Objective [1.3.2] Describe the processes of transcription, mRNA processing, & translation, recognising the significance of each step to the final product.

Process	Process name	Molecule	Molecule name
1	Transcription	1	DNA
2	mRNA processing	2	pre mRNA
3	Translation	3	mature mRNA

D2

b. Describe the steps of process 1. 3 marks

Learning Objective [1.3.2] Describe the processes of transcription, mRNA processing, & translation, recognising the significance of each step to the final product.

RNA polymerase binds to the promoter region and the DNA double helix unwinds and unzips
RNA polymerase then catalyses the production of the mRNA strand in the 5′ to 3′ direction by joining together complementary RNA nucleotides via condensation polymerisation. mRNA is complementary to the DNA template strand - adenine pairs with uracil in RNA instead. Continues until a termination or stop sequence is reached.
mark for each of the above points, student must include one of DIRECTION or CONDENSATION reaction to obtain full marks.

c. Describe how a mistake in process 2 could lead to the production of a defective SMN protein. 3 marks

D3

Learning Objective [1.3.2] Describe the processes of transcription, mRNA processing, & translation, recognising the significance of each step to the final product.

1. Process is mRNA processing.
2. This involves the splicing of exons and the removal of introns, or in some cases may be 'alternative splicing', involving exons and introns being shuffled around.
3. An error in this process may result from incorrect splicing, thus impacting the mature mRNA produced.
4. This will be translated incorrectly, producing a defective SMN polypeptide which differs from the normal SMN protein.

No marks are awarded for the incorrect process, and for naming mRNA processing.

d. Name the location and level of protein structure that is present at the completion of process 3, in a patient with normal SMN. 2 marks

D2

1M Learning Objective [1.4.1] Define & compare primary, secondary, tertiary & quaternary structures of proteins.

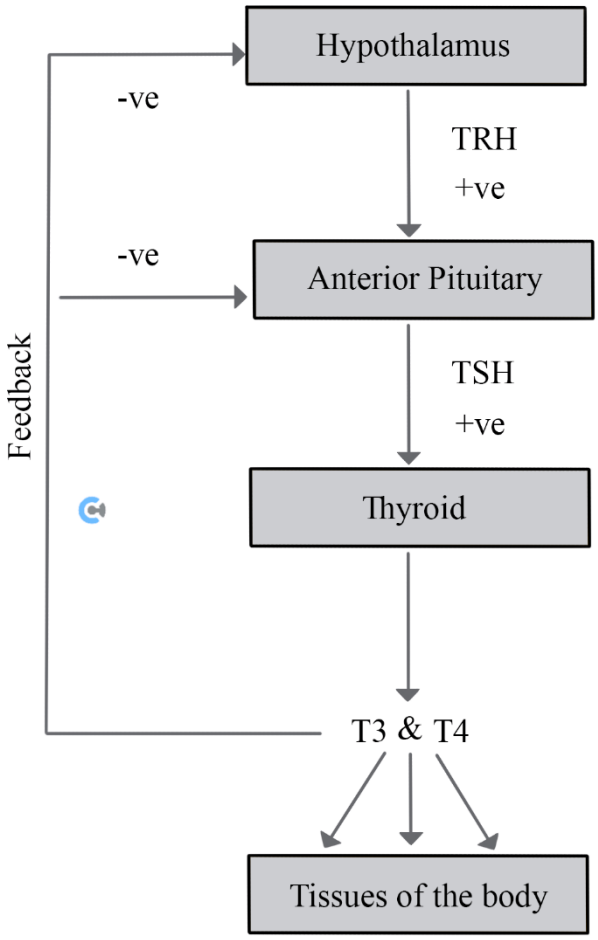
1M Learning Objective [1.4.2] Identify & describe the roles of ribosomes, rough endoplasmic reticulum & golgi apparatus in the transport & export of proteins from a cell.

Ribosome/Cytosol – Primary Structure

mark for each of the above

Question 2 (7 marks)

Hyperthyroidism occurs when there is an issue in the TRH-TSH-T3/T4 axis as mediated by the hypothalamus, anterior pituitary gland and thyroid gland respectively, resulting in excess production of thyroid hormone (T3/T4). This is a diagram representing the relationship between the different hormones.



a. What would happen in the body if there is an increase in the level of TSH in the body? D2 2 marks

If there are increased levels of TSH in the body, then this means that there will be an increased production of hormones, as TSH directly acts on the thyroid.

However, this will also cause negative feedback of the TSH to the hypothalamus, reducing the production of TRH and subsequently TSH and as well.

Thyroxine (T4) is synthesised by the follicular cells of the thyroid gland before being exported out of the cell.

b. Describe the steps and organelles that are involved in the export of thyroxine from the follicular cells of the thyroid gland. D2 3 marks

Learning Objective [1.4.2] Identify & describe the roles of ribosomes, rough endoplasmic reticulum & Golgi apparatus in the transport & export of proteins from a cell.

- The polypeptide primary structure of thyroxine (T4) undergoes folding in the Rough Endoplasmic 1 mark
- It is then further modified in the Golgi Apparatus and packaged into secretory vesicles for export. 1 mark
- The T4, now in the secretory vesicle merges with the plasma membrane to exit the cell via exocytosis (using energy) and allows the T4 to be exported from the follicular cells of the thyroid gland. 1 mark

Enzymes that are known as deiodinases are responsible for the conversion of $T4$ into $T3$ (which is actually responsible for the function of thyroid hormone). Some medications work by acting as inhibitors.

c. Compare competitive and non-competitive enzyme inhibition. D2 2 marks

Learning Objective [1.4.5] Explain function of competitive & non-competitive enzyme inhibitors & how they affect rate of reaction, & how they may/may not be overcome.

Competitive inhibition is when the inhibitor binds to the active site, compared to non - competitive where it binds to the allosteric site.

Competitive inhibition can be reversible, whereas generally non-competitive inhibition is irreversible.

Question 3 (14 marks)

The *trp* operon is the process by which bacteria are able to regulate the production of the amino acid tryptophan in the cell.

a. What is meant by an operon, and why might they be useful? D2 2 marks

Learning Objective [1.3.4] Identify & recall the general principles & reasons for gene regulation in both prokaryotes & eukaryotes.

Operons are where multiple structural genes are under the control of a single promoter and operator, and this may be useful in gene regulation as many genes can be regulated simultaneously, conserving regulatory resources compared to having separate repressors and activators for each individual gene.

Operons allow the whole pathway to be controlled efficiently.

b. Explain how, through the action of repressor proteins, *E. coli* is able to regulate the production of tryptophan. Include a labelled diagram in your answer. D3 5 marks

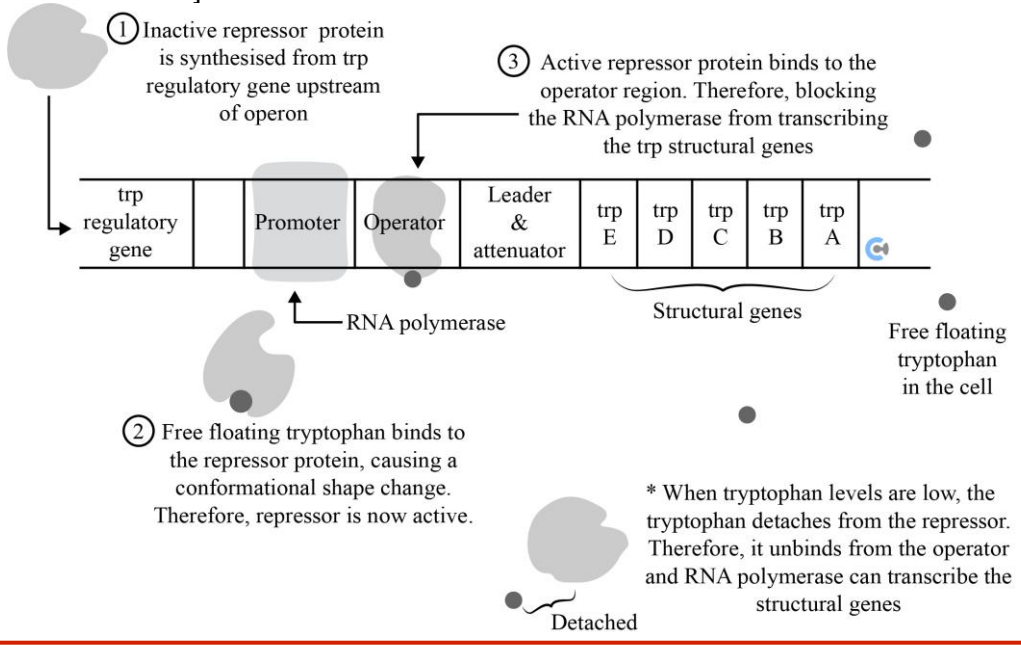
Learning Objective [1.3.5] Describe the regulation of the trp operon through the action of the repressor protein.

Repressor proteins bind to the operator region of the operon, blocking RNA polymerase from transcribing the downstream genes when tryptophan levels are high.

When tryptophan is present, it binds to the repressor protein, causing a conformational change that allows the repressor to bind to the operator.

When tryptophan levels are low, the repressor protein cannot bind to the operator, allowing RNA polymerase to transcribe the genes needed for tryptophan synthesis.

[Labelled diagram should show the repressor protein binding to the operator and the conformational change with and without tryptophan. MUST depict conformational shape change of the repressor protein to obtain full marks.]



c. Explain, through the process of attenuation, how post-transcriptional regulation of tryptophan can occur. 4 marks

D2

Learning Objective [1.3.6] Describe the regulation of the trp operon through attenuation in high trp environments.

In prokaryotes, transcription and translation can occur simultaneously due to a lack of processing and a nucleus.

In between the operator and the structural genes, there is a leader sequence.

This leader sequence contains the code for two trp residues. If there are low levels of tryptophan, then the ribosome will be stalled while translating this sequence.

Following the leader sequence, there is an attenuator. If the ribosome is stalled, then this attenuator will form an anti-terminator loop and allow transcription to occur.

If there are high levels of trp, then the ribosome will not be stalled, thus resulting in a terminator loop to be formed, preventing full transcription of the structural genes.

d. Why cannot the process described in **part c.** be performed by eukaryotes? In your answer, compare the process of gene expression in prokaryotes such as *E. coli* and eukaryotes. 3 marks

D3

1M Learning Objective [1.3.2] Describe the processes of transcription, mRNA processing, & translation, recognising the significance of each step to the final product.

2M Learning Objective [1.3.4] Identify & recall the general principles & reasons for gene regulation in both prokaryotes & eukaryotes.

This cannot be performed by eukaryotes due to the fact that they do not have the ability to simultaneously do transcription and translation.

This is made possible in prokaryotes which do not have a nucleus, allowing ribosomes to access mRNA directly, rather than wait for processing as is the case in eukaryotes.

Students must clearly identify the LACK of the nucleus (and thus lack of processing required for the mRNA) as the key reason why.

Question 4 (16 marks)

CRISPR-Cas9 is an exciting and revolutionary gene-editing tool that has recently been isolated from bacteria, ushering in a new age of medical treatments. The CRISPR system is part of the bacterial immune response, where it provides resistance to viral infections. Researchers have adapted this natural process to allow for precise gene editing in a variety of organisms, including humans.

a. Describe the process by which CRISPR-Cas9 functions in bacteria. 3 marks

D2

Learning Objective [1.6.1] Describe the function & process of CRISPR-Cas9 as an adaptive defence against viruses in bacteria.

A virus inserts its DNA into a bacteria, and a spacer is cut out and incorporated into the CRISPR locus.

This is then transcribed to form crRNA which is then combined with tracrRNA to form guideRNA.

This will form a CRISPR-Cas complex with Cas enzyme and float around the cell until it encounters complementary viral DNA.

Viral DNA is cleaved and inactivated.

b. Describe the significance of the PAM sequence in bacterial CRISPR-Cas9 function, identifying two reasons. 2 marks

D3

Learning Objective [1.6.3] Describe & compare the function of the PAM sequence in bacteria & gene editing applications of CRISPR-Cas9 technology.

Safety: Prevents the bacterial chromosome from being cut (allows for the determination of self v/s non-self)

Efficiency: Allows for efficient searching for a match with the guide RNA, resulting in faster function.

PAM serves as the recognition site for Cas9 to bind to its target DNA

Recent trials are investigating the use of CRISPR-Cas9 directly infused into patients for a hereditary blindness condition known as Lemer's congenital amaurosis, caused by a single mutation in the CEP290 gene coding for a photoreceptor. This is expressed in the retina, preventing accurate reception of light. Research has shown that accurate vision can still be maintained with an absent photoreceptor, as opposed to the mutated version. This is the first time CRISPR-Cas9 has been injected into a patient, with previous trials focusing on taking cells out, editing them *ex vivo* and then returning them to the patient.

c. Describe how scientists could use CRISPR-Cas9 technology to cure Lemer's congenital amaurosis. 4 marks

Learning Objective [1.6.2] Explain the process of using CRISPR-Cas9 as a gene editing tool, including silencing, knock-ins & knock-outs.

D3

Identify a target sequence for a cut in the and develop a synthetic (SINGLE) guide RNA (sgRNA) complementary to it.

Combine this with the Cas9 enzyme, altered with a PAM to suit the target.

Inject this into a target cell (the embryo), and then the sgRNA will bind to the target DNA and then signal the cut.

Cell repair mechanisms can either silence the gene, preventing the expression of the CEP290 gene, with no photoreceptor expressed – curing the blindness.

James and Marcus are discussing the delivery of the CRISPR-Cas9 complex into a patient's bloodstream to treat a genetic disorder involving the CEP290 gene. James is concerned that the infusion might edit cells outside the retina, as the CEP290 gene is found in all cells. Marcus disagrees, suggesting that only the retina will be affected, as the proteome (the proteins expressed in cells) determines which cells will be impacted by the editing.

d. Who is correct, James or Marcus, and why? D3 3 marks

In your answer, explain the difference between the genome and proteome, and how this affects the CRISPR-Cas9 system's impact on different cells.

Learning Objective [1.3.3] Explain how a single gene can give rise to multiple proteins.

Expected Answer:

Marcus is correct. While the **CEP290 gene** is present in all cells (the **genome** is the same across the body), the gene may only be **expressed** (i.e., used to make proteins) in certain cells, such as those in the retina. The **proteome** refers to the set of proteins produced in a specific cell type, and this determines whether the CRISPR-Cas9 system will have an effect. Even if the gene is present in other cells, if it is not expressed, editing the gene will have no functional impact on those cells. In contrast, in the retina, where the gene is expressed, CRISPR-Cas9 editing could impact eye function.

Some enterprising individuals have seen this evolution of CRISPR-Cas9 technology and realised it may be an opportunity to create a gene-editing service targeted to immigrant parents allowing them to edit their child so they get straight raw 50s in all their VCE subjects.

e. Using the ethical concepts you have studied this year, discuss using a consequences-based approach to the ethics of genetically editing humans for 'designer', or non-medically necessary edits. 4 marks

D3

Learning Objective [1.6.5] Apply bioethical principles to the use of CRISPR-Cas9 technology.

1M Learning Objective [1.6.7] Define & describe the three ethical approaches as elaborated in the VCAA study design.

Potential Health Risks and Long-Term Effects:

Consequences: Genetic editing for non-medical reasons could lead to unforeseen health issues or genetic abnormalities that may not manifest until later in life. The long-term consequences could include increased susceptibility to diseases or adverse reactions.

Analysis: The potential negative health outcomes outweigh the immediate benefits of aesthetic or non-essential genetic modifications.

Social Inequality and Access:

Consequences: Access to genetic editing for 'designer' traits is likely to be limited to those who can afford it, exacerbating social inequality. This could lead to a societal divide where only the wealthy can enhance their children's traits, potentially leading to discrimination.

Analysis: The social harm and increased inequality resulting from unequal access to genetic enhancements could destabilise societal cohesion and fairness.

Psychological Impact on Individuals:

Consequences: Individuals who are genetically edited for non-medical reasons may experience psychological effects, including identity issues and pressure to meet certain expectations. They might feel they need to live up to the enhanced traits or struggle with their sense of self.

Analysis: The potential for psychological harm and identity crises suggests that the negative emotional and mental health outcomes could outweigh the perceived benefits of genetic enhancements.

Generational Effects and Ethical Legacy:

Consequences: Genetic edits made for non-medical reasons can be passed on to future generations, potentially leading to unintended consequences for descendants. This raises ethical concerns about consent, as future generations cannot consent to the genetic changes imposed on them.

Analysis: The ethical implications of making irreversible changes that affect future generations without their consent are profound, potentially causing long-term harm and ethical dilemmas.

Reduction in Acceptance of Natural Human Variability:

Consequences: Emphasising genetic perfection through designer edits may reduce societal acceptance of natural human variability and diversity. This could lead to increased stigmatisation and marginalisation of individuals with natural traits.

Analysis: The societal harm of reducing acceptance of diversity and increasing stigmatisation and discrimination against those with natural traits is significant and undermines the values of inclusion and equality.

Potential for Misuse and Ethical Slippery Slope:

Consequences: Allowing genetic editing for non-medical reasons could open the door to more extreme uses and misuse of the technology. This could include enhancements for intelligence, physical abilities, or other traits, leading to an ethical slippery slope where the line between acceptable and unacceptable uses becomes blurred.

Analysis: The risk of misuse and the ethical slippery slope highlight the potential for technology to be used in ways that are harmful and morally questionable, necessitating strict regulations and ethical guidelines.

Question 5 (13 marks)

In an effort to become closer to his cultural roots, Micah chooses to undergo genetic testing and profiling. He takes a sample of his DNA and sends it off to the lab, as he goes off to buy a kurta, confident that he'll have at least 25% brown DNA (owing to his grandfather).

Unfortunately for Micah, the police intercepted his sample and are instead using it to test him as a prime suspect in a spree of international bank robberies.

a. Describe, the process that the forensic scientists could use in order to increase his DNA sample. Reference the significance of each step in your answer. 4 marks

D2

Learning Objective [1.5.2] Identify the ingredients required, describe the process, & recall key applications of PCR.

PCR - Polymerase Chain Reaction

Denaturation - heat to 95 degrees Celsius, as this will allow the hydrogen bond between the strands to break, separating them.
Annealing - cool the solution to 50 – 55 degrees Celsius, as this will allow for the primers to anneal whilst allowing for the strands to remain separate.
Elongation - heat the solution to 72 degrees Celsius, as this will allow for the optimal function of TAQ polymerase to extend the complementary DNA strands.

Once they do have a large sample of his DNA, they need to compare it with the rest of the samples that they have received, including the samples collected from the crime scene. They achieve this using gel electrophoresis techniques, which involve cutting the DNA into fragments with the same endonuclease prior to running the gel.

b. What property of DNA allows it to move through the gel? 1 mark

D1

Learning Objective [1.5.3] Describe the process of gel electrophoresis, & describe how it may be used to differentiate DNA samples or to obtain a "DNA profile".

Negative charge

c. Describe two factors that influence the rate at which the fragments move through the gel. 2 marks

D2

There could be many factors:
Ion concentration
Voltage/current applied
Density of the gel
Size

Learning Objective [1.5.4] Explain the factors that affect the movement of fragments in gel electrophoresis.

d. Explain how gel electrophoresis can be used to tell the difference between two DNA samples. 3 marks

Learning Objective [1.5.3] Describe the process of gel electrophoresis, & describe how it may be used to differentiate DNA samples or to obtain a "DNA profile".

D2

Each sample is cut with the same endonuclease.
Assuming that the strands are different, this means that they will be cut at the different places producing fragments of different sizes.
In the gel, after staining, the different fragments will move different lengths.
The band pattern will be identical for samples that are the same.

With the results of the gel now back, it becomes clear that Micah was in fact responsible for the crimes. In court, however, choosing to be his own lawyer, he states:

"These Interpol dogs have actually acted unethically by getting the genetic testing company to send them my sample! I would NEVER have given up my DNA at all!"

e. With reference to the ethical concepts studied, such as integrity, respect and beneficence, discuss the ethics of Interpol using this DNA sample as part of their investigation to put away a bank robber. 3 marks

D2

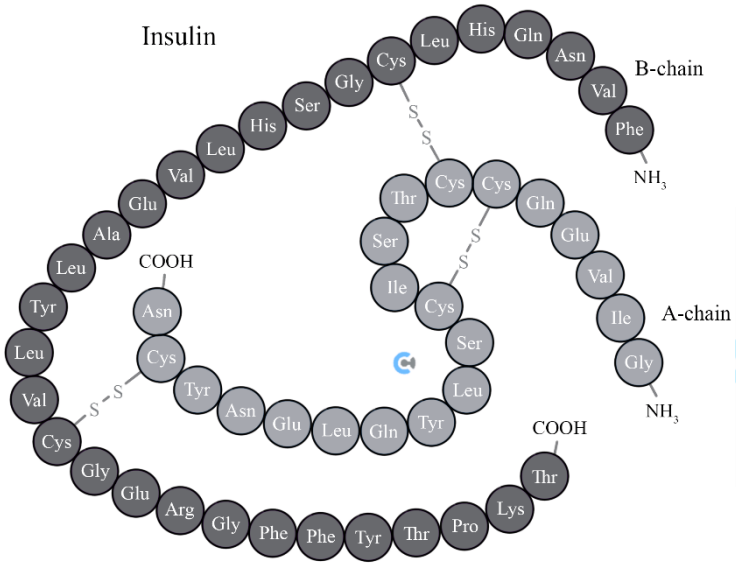
Learning Objective [1.6.6] Define & describe the bioethical concepts of integrity, respect, beneficence, non-maleficence & justice as elaborated in the VCAA study design.

Integrity - being honest with one's intentions in a scenario, in this case, Interpol were dishonest with their intentions in getting Micah to send over a sample of his DNA.
Beneficence - doing the best, Micah's impacts on banks around the world being prevented could be construed as a positive action.
Respect - Micah only consented to having his DNA being checked for the genetic testing, not the criminal testing.

Question 6 (5 marks)

Insulin is an incredibly important protein that is required for many functions in the body, most notably the uptake of glucose by cells via glucose transporters in order to reduce the blood glucose level.

The structure of insulin is given below:



a. What level of protein structure is insulin? D1 1 mark

Learning Objective [1.4.1] Define & compare primary, secondary, tertiary & quaternary structures of proteins.

Quaternary

Recombinant plasmids have been widely floated as a way to get synthetically produced human insulin.

b. Explain 2 methods that could be used to insert a plasmid into a bacterial cell. D2 2 marks

Learning Objective [1.7.3] Explain electroporation & heat shock as methods to transform bacterial cells.

Electroporation – an electric current is passed through the bacterial membrane to increase its permeability to plasmids.

Heat Shock – the bacteria is placed on ice, heated to, and placed on ice again in a solution of ions to increase membrane permeability to plasmids.

A lack of insulin can lead to cell death due to a lack of energy, despite hyperglycaemia (high blood glucose) being present.

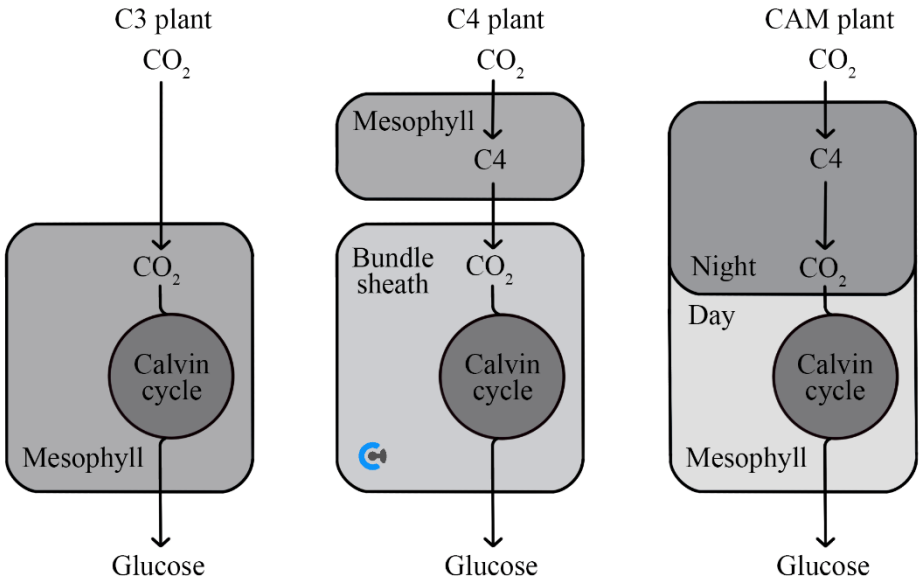
c. Account for this, with reference to the pathway by which human cells produce energy. D3 2 marks

Learning Objective [2.2.1] Recall the inputs, outputs & locations of all stages of aerobic cellular respiration.

Although high glucose hyperglycaemia may indicate that there is enough energy present, cells use energy in the form of ATP only. This requires cellular respiration to occur, and it cannot happen if glucose cannot enter the cytosol of cells.

Question 7 (4 marks)

Plants have the unique ability to photosynthesise and utilise sunlight. They are able to produce high-energy-containing molecules that fix carbon dioxide (CO_2) into forms of carbohydrates that can be stored or used by the plant cells. Most plants use C3 pathways to fix CO_2 and some use the C4 pathways. A small group of plants use a combination of both pathways. This smaller number of plants is called CAM plants.



Condition	Plant Type	Photosynthesis Rate $(\mu mol\ CO_2/m^2/s)$	Water use Efficiency $(\mu mol\ CO_2/mmol\ H_20\ )$	Biomass Production (g/m^2)
Cool and Wet	C3	25	2.5	600
	C4	30	4.5	650
	CAM	15	5.0	400
Warm and Wet	C3	20	2.0	500
	C4	35	4.8	700
	CAM	18	5.2	450
Hot and Dry	C3	10	1.5	300
	C4	25	5.0	600
	CAM	22	8.0	500

With reference to the data, explain why C3 plants are poorly adapted for hot and dry conditions as compared to C4 and CAM plants. D3

2M Learning Objective [2.1.4] Describe the adaptations of C4 & CAM plants for reducing photorespiration, as compared to C3 plants, including structural & physiological differences.

2M Learning Objective [2.1.3] Explain the function of Rubisco in photosynthesis, & describe the factors that increase its affinity for O_2.

Under hot and dry conditions, C3 plants are poorly adapted compared to C4 and CAM plants, primarily due to differences in their photosynthetic pathways.

C3 plants utilise a basic form of photosynthesis where carbon dioxide is directly fixed into a 3-carbon compound, a process that becomes inefficient under heat and water stress due to increased photorespiration, as Rubisco begins to bind to oxygen.

This inefficiency is reflected in their lower photosynthesis rate of and minimal biomass production of $300\ g/m^2$ under these conditions.

In contrast, C4 plants separate photosynthesis into two cells, so, carbon dioxide effectively concentrates at the site of the Calvin cycle, reducing oxygen binding to Rubisco and thus photorespiration and enhancing water use efficiency, shown by their rate of efficiency.

CAM plants adapt even further by fixing carbon dioxide at night when temperatures are cooler and humidity higher, minimising water loss and maximising usage, evident from their high-water use efficiency of and stable biomass production. Fixing carbon dioxide at night enables them to maintain a high concentration to be released during the day for photosynthesis.

Question 8 (10 marks)

As part of their practical investigation into cellular respiration, a group of students decided to test germinating wheat seeds under varying temperature conditions. For their experimental setup, they placed a CO_2 sensor inside each of four sealed containers, each containing 100 germinating wheat seeds. The containers were then placed in different controlled environments, with temperatures set to $10℃$, $20℃$, $30℃$, and $40℃$ respectively. The CO_2 sensors were used to measure the concentration of carbon dioxide produced by the seeds over a 30-minute period, indicating the rate of cellular respiration. The data collected from the experiment is presented in the table below: D2

Time (min)	CO_2 **Concentration** (ppm) **at** $10℃$	CO_2 **Concentration** (ppm) **at** $20℃$	CO_2 **Concentration** (ppm) **at** $30℃$	CO_2 **Concentration** (ppm) **at** $40℃$)
0	400	400	400	400
5	410	420	430	450
10	420	440	460	500
15	430	460	490	550
20	440	480	520	600
25	450	500	550	650
30	460	520	580	700

a. Explain and describe a possible hypothesis for this experiment. 2 marks

Learning Objective [2.2.6] Apply experimental design principles to create methodologies to test factors that affect cellular respiration.

It is hypothesised that as the temperature of the container increases, the rate of cellular respiration in germinating wheat seeds will also increase.

This expectation is based on the premise that higher temperatures will enhance the enzymatic reactions involved in cellular respiration, thereby accelerating the metabolic processes and resulting in increased carbon dioxide production.

b. Describe and explain the results of this experiment, with reference to concepts studied this year. 4 marks

Learning Objective [2.2.6] Apply experimental design principles to create methodologies to test factors that affect cellular respiration.

D3

Learning Objective 2.2.4] Identify & describe factors - such as temperature, glucose availability, & oxygen concentration - on the rate of cellular respiration.

The data from the experiment indicate that the concentration increases over time in each temperature setting, with the highest rates of increase observed at.

Specifically, concentrations at increased from to, at from to, at from to, and at from to over minutes.

This trend supports the hypothesis, showing that higher temperatures significantly boost the rate of cellular respiration, as evidenced by the steeper rise in levels at elevated temperatures.

This is because increasing temperatures increase the kinetic energy and activity of the enzymes that help facilitate cellular respiration.

After their investigation of cellular respiration, one particularly bright student wonders if modifications to another biochemical pathway can be used to usher in a new form of renewable energy in our vehicles and homes, using biomass from plants.

c. D2

i. Naming this biochemical process, explain how fuels may be produced from biomass. 2 marks

1M Learning Objective [1.3.6] Describe the regulation of the trp operon through attenuation in high trp environments.

1M Learning Objective [2.2.8] Explain how yeast can be used to produce bioethanol from biomass.

Anaerobic fermentation of the biomass using yeast, as they undergo alcoholic fermentation.
Glucose in biomass can be fermented to produce ethanol which can be used as bioethanol

ii. List two advantages of biofuel production using this process. D1 2 marks

Learning Objective [2.2.8] Explain how yeast can be used to produce bioethanol from biomass.

Environmental Sustainability: Producing biofuel through anaerobic fermentation leverages plant biomass, a renewable resource. This method reduces dependency on non-renewable fossil fuels, which are major contributors to environmental degradation and pollution.
Carbon Neutrality: Biofuels such as bioethanol, produced from anaerobic fermentation, are considered carbon-neutral. The carbon dioxide released during the combustion of these biofuels is offset by the carbon dioxide absorbed by the plants during their growth phase, thereby not contributing to an increase in atmospheric levels.

Extra space for responses

Clearly number all responses in this space.