Unit 3 Biology Practice Exam 2023 – Assessment Guide

Section A

VCAA Key Knowledge	Question	Answer Guide
amplification of DNA using polymerase chain reaction and the use of gel electrophoresis in sorting DNA fragments, including the interpretation of gel runs for DNA profiling	**Question 1** Gel electrophoresis is a process used to isolate particular segments of DNA. Electrophoresis works on the premise that **A.** DNA is positively charged. **B.** longer fragments of DNA move faster through the electrophoresis gel. **C.** DNA is negatively charged. **D.** strands of DNA can be separated by heating the DNA.	***C*** *In electrophoresis, DNA moves through the gel towards the positive terminal because DNA is negatively charged.* *B is incorrect because the shorter fragments, not the longer fragments, move further through the gel.* *D relates to PCR, not electrophoresis.*
nucleic acids as information molecules that encode instructions for the synthesis of proteins: the structure of DNA, the three main forms of RNA (mRNA, rRNA and tRNA) and a comparison of their respective nucleotides	**Question 2** Protein synthesis describes the process by which the information encoded in a gene is used to produce a protein. The following options describe various steps/processes that occur in eukaryotic cells during protein synthesis followed by protein export from a cell; however, only one option describes the processes correctly and in the correct order. Which option is correct? **A.** DNA polymerase moves along the template strand, creating a molecule with a complementary RNA sequence; post-transcriptional modification occurs; the mRNA molecule attaches to a ribosome **B.** all exons are removed from the pre-mRNA molecule during post-transcriptional modification; mRNA codons align with their complementary tRNA anticodons at the ribosomes; enzymes fold the protein into its tertiary structure **C.** the protein is packaged into a vesicle; a condensation polymerisation reaction joins amino acids together to form a peptide chain; the protein is exported from the cell through exocytosis **D.** a pre-mRNA molecule is produced through transcription; introns are spliced out during post-transcriptional modification; the protein-containing vesicle fuses with the cell membrane during export from the cell	***D*** *Only option D correctly describes steps in the processes of protein synthesis and export from the cell in the correct order.* *A is incorrect because, although the processes are in the correct order, it is RNA polymerase, not DNA polymerase, that creates the pre-mRNA molecule during transcription.* *B is incorrect because, although the processes are in the correct order, it is the introns that are removed during post-transcription modification, not the exons.* *C is incorrect because, although each process is described correctly, the amino acids are joined together before the protein is packaged into a vesicle.*

the use of enzymes to manipulate DNA, including polymerase to synthesise DNA, ligase to join DNA and endonucleases to cut DNA

Question 3

A particular endonuclease has the following recognition site:

5′. . . G|AATTC . . . 3′
3′. . . CTTAA|G . . . 5′

This endonuclease is mixed with the following section of DNA.

5′ TTGGCCAGTAAATTCCATAGAGAATTCATAGTGTGATCCTATGACGAATTCAGATCGTTAGGGACCCATATCCCG 3′

The resultant DNA is amplified and run through an electrophoresis tank. Assuming that the DNA strand is cut by the endonuclease, which of the following would be observed in the electrophoresis output?

A. two bands of DNA, with one located close to the positive terminal and the other located close to the negative terminal
B. three bands of DNA, located quite close to each other
C. one single band of DNA
D. four bands of DNA spread evenly throughout the gel

B *There are two recognition sites for this endonuclease in the section of DNA; therefore, the DNA will be cut into three pieces. Since the three sections are of similar nucleotide length, they will be located quite close to each other.*

nucleic acids as information molecules that encode instructions for the synthesis of proteins: the structure of DNA, the three main forms of RNA (mRNA, rRNA and tRNA) and a comparison of their respective nucleotides

Question 4

DNA and RNA both play critical roles in the function of cells and the production of proteins. Which option below correctly describes the structures of DNA and RNA?

A. RNA contains uracil while DNA does not and DNA contains ribose while RNA does not
B. the sugar in RNA contains one fewer oxygen atoms than the sugar in DNA
C. DNA contains thymine while RNA does not and the sugar contained in DNA contains one fewer oxygen atoms than the sugar in RNA
D. in RNA, uracil and thymine form base-pairs, while, in DNA, thymine and adenine form base-pairs

C *In RNA, uracil replaces thymine. The sugar in DNA, deoxyribose, has one fewer oxygen atoms than the ribose sugar found in RNA (hence the name 'de'-oxyribose).*

A is incorrect because DNA contains deoxyribose, not ribose.

B is incorrect because the sugar in RNA contains one additional oxygen atoms, compared to deoxyribose.

D is incorrect because uracil and thymine do not form a base pair.

amino acids as the monomers of a polypeptide chain and the resultant hierarchical levels of structure that give rise to a functional protein	Question 5 The HBB gene contains the instructions to make the protein beta-globin, which is composed of a single polypeptide chain. Beta-globin is a subunit of the protein haemoglobin, which is essential to the transport of oxygen around the body. What can be concluded regarding these proteins? A. beta-globin has a quaternary structure B. a mutation in the HBB gene would have little effect on the capacity of cells to aerobically respire C. the sequence of bases that is translated at the ribosomes is shorter than the sequence of bases in the HBB gene D. haemoglobin does not have a quaternary structure	*C* *During post-transcriptional modification, introns are removed from the pre-mRNA strand. So, the original HBB gene is longer as it contains introns and exons, while the mRNA at the ribosomes contains only exons.* *A and D are incorrect as the reverse is true; beta-globin does not have a quaternary structure, while haemoglobin does.* *B is incorrect because, as the function of haemoglobin is to transport oxygen, a mutation in the HBB gene is likely to affect oxygen transport around the body and, thus, the capacity of cells to undergo respiration.*

inputs, outputs and locations of the light dependent and light independent stages of photosynthesis in C3 plants (details of biochemical pathway mechanisms are not required)	Question 6 Photosynthesis involves a number of complex biochemical reactions. These are broadly divided into light-dependent and light-independent reactions. Which of the following is a light-dependent reaction? A. the energy of sunlight splits water molecules into oxygen and hydrogen in the stroma B. NADPH coenzymes are unloaded to provide energy for the synthesis of glucose C. oxygen gas is produced in the grana and released through the stomata of the leaf D. NAD+ molecules are loaded	*C* *In light-dependent reactions, which occur at the thylakoid membranes, the energy of sunlight is used to split water into hydrogen ions and oxygen. Oxygen is not needed for light-independent reactions and, instead, diffuses out of chloroplasts and then out of the leaf through the stomata.* *A is incorrect because light-dependent reactions occur at the thylakoid membranes, not in the stroma.* *B is incorrect because glucose is synthesised through light-independent reactions.* *D is incorrect because NAD+ and NADH are involved in cellular respiration, not photosynthesis.*

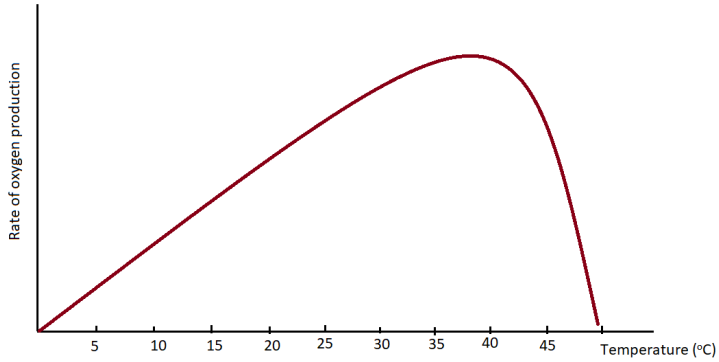
the location, inputs and the difference in outputs of anaerobic fermentation in animals and yeasts	Question 7 During heavy exercise, human muscle cells may switch to anaerobic respiration due to a lack of oxygen supply. For muscle cells undergoing anaerobic respiration A. the majority of ATP is produced in the electron transport chain. B. two net molecules of ATP are produced per molecule of glucose. C. the process of anaerobic respiration produces more molecules of ATP per molecule of glucose, compared to aerobic respiration. D. the process of anaerobic respiration is less complex than aerobic respiration.	*B* *Anaerobic respiration in animal cells consists only of glycolysis, in which two net molecules of ATP are produced for every glucose molecule.* *A is incorrect because anaerobic respiration does not include the electron transport chain.* *C is incorrect, as anaerobic respiration only produces two molecules of ATP per molecule of glucose, which is less than aerobic respiration.* *D is incorrect, as anaerobic respiration is less complex than aerobic respiration, given that it does not involve the Krebs cycle or electron transport chain.*

the factors that affect the rate of photosynthesis: light availability, water availability, temperature and carbon dioxide concentration

Question 8

A student sets up an experiment to investigate the effect of temperature on the rate of photosynthesis in a particular plant. The rate of photosynthesis was measured through the rate of oxygen production.

The results obtained by the student showed the following trend:



Which statement best explains the shape of this graph?

A. at approximately 40°C, the active sites of the enzymes controlling the photosynthesis reactions became altered

B. at approximately 40°C, the active sites of the enzymes controlling photosynthesis reactions became saturated

C. enzyme activity slowed down as temperature increased, reaching a minimum at approximately 40°C

D. at approximately 40°C, the enzymes controlling the photosynthesis reactions underwent reversible inhibition

A

The best explanation for the shape of the graph is that, at 40°C, the enzymes controlling the process became denatured. Denaturation permanently alters the shape of the enzyme's active site so that it can no longer catalyse the reaction.

B is incorrect because if the active sites of the enzymes were all full, then the rate of reaction would proceed at a steady rate, not reduce.

C is incorrect because enzyme activity increased with increasing temperature up to approximately 40 °C.

D is incorrect because denaturation is not reversible.

uses and applications of anaerobic fermentation of biomass for biofuel production

Question 9

The production of biofuels from biomass is a growing area of research and interest given the issues associated with the use of non-renewable fuels. One possible form of biofuel is bioethanol. Bioethanol is formed through which of the following processes?

A. the anaerobic fermentation of plant sugars

B. the aerobic fermentation of plant sugars

C. the conversion of carbon dioxide into glucose

D. the combustion of crude oils

A

Bioethanol is formed through the anaerobic fermentation of plant sugars.

B is incorrect because the fermentation process is anaerobic.

C is incorrect as it describes an aspect of the process of photosynthesis.

the basic elements of gene regulation: prokaryotic trp operon as a simplified example of a regulatory process	**Question 10** In some prokaryotes, such as *E. coli*, there are two mechanisms that regulate the expression of the structural genes of the *trp* operon: repression and attenuation. In repression **A.** the repressor protein binds to the promoter region. **B.** the initiation of transcription is blocked. **C.** translation begins but stops prematurely. **D.** RNA polymerase binds to the operator.	***B***	*In repression, RNA polymerase is blocked from carrying out transcription, due to the repressor protein binding to the operator.* *A and D are incorrect because the repressor protein binds to the operator. C is incorrect because translation does not occur at all during repression.*

amplification of DNA using polymerase chain reaction and the use of gel electrophoresis in sorting DNA fragments, including the interpretation of gel runs for DNA profiling	**Question 11** Polymerase chain reaction (PCR) is a process that is used to amplify DNA. Which of the following options accurately describes some of the steps of the PCR process in the correct order? **A.** DNA is heated to 95°C to separate the two strands; RNA polymerase extends each complementary strand of DNA **B.** DNA is heated to 95°C to separate the two strands; the mixture is cooled to 55°C and primers are added **C.** DNA is heated to 72°C to separate the two strands; DNA polymerase extends each complementary strand of DNA **D.** DNA is heated to 72°C to separate the two strands; the mixture is cooled to 55°C and primers are added	***B***	*DNA is heated to 95°C to separate the two strands, and the mixture is cooled to 55°C to allow the primers to anneal to the strands.* *A is incorrect as it is DNA polymerase, not RNA polymerase, that extends each complementary strand. D and C contain incorrect temperature values.*

Use the following information to answer Questions 12 – 14.

Two students, Caitlin and Asher, are investigating the effect of light colour on the relative rates of photosynthesis and respiration in *Elodea*, an aquatic plant. Six samples of *Elodea* are divided between six test tubes. The test tubes are filled with water and are stoppered. Three test tubes are wrapped in red cellophane and three are wrapped in green cellophane. The six samples are then left on a windowsill for 24 hours.

A product of aerobic respiration is carbon dioxide; carbon dioxide dissolves in water to form carbonic acid, creating acidic conditions. Conversely, oxygen produced from photosynthesis dissolves in water to form hydroxide (OH^-) ions, creating alkaline conditions.

After 24 hours, Caitlin and Asher measure the pH of the water in each of the test tubes. They produce the following results:

Test Tube #	Cellophane Colour	pH After 24 hours
1	Red	7.4
2	Red	7.1
3	Red	7.3
4	Green	6.2
5	Green	5.8
6	Green	6.9

characteristics of the selected scientific methodology and method, and appropriateness of the use of independent, dependent and controlled variables in the selected scientific investigation

Question 12

Identify the independent variable in this experiment.

A. the colour of light to which the *Elodea* samples were exposed

B. the temperature at which the test tubes were kept

C. the final pH of the water

D. the rate of photosynthesis of the samples

A

The independent variable is the one that is deliberately altered by the experimenter. In this experiment, this is the colour of light to which the samples were exposed.

B is incorrect - the temperature would be a controlled variable in this experiment.
The pH of the water is the dependent variable as this is the variable that is measured. The rates of photosynthesis in the samples could also be considered a dependent variable; the pH of the water was used as an indirect method to measure the rates of photosynthesis.

the key findings and implications of the selected scientific investigation

the factors that affect the rate of photosynthesis: light availability, water availability, temperature and carbon dioxide concentration

Question 13

What can be inferred from the results regarding the effect of light colour on rates of photosynthesis in *Elodea*?

A. *Elodea* is more efficient at utilising green light for photosynthesis than red light
B. high rates of respiration relative to photosynthesis result in more acidic water
C. samples of *Elodea* that are exposed to red light will photosynthesise at higher rates than those exposed to white light
D. an *Elodea* plant that is only exposed to green light will experience higher rates of respiration relative to photosynthesis than an *Elodea* plant that is only exposed to red light

D

According to the results, green light resulted in water with a lower pH (more acidic); thus, it may be inferred that there was more carbon dioxide released into the water in these samples, indicating higher rates of respiration than photosynthesis.

A is incorrect because, according to the results, red light resulted in higher rates of photosynthesis, as indicated by a higher (more alkaline) pH.

B is incorrect because, although high rates of respiration will result in more acidic water, this was not inferred from the results; this is the assumption that the experiment was based on.

C is incorrect because none of the samples were exposed to white light so no comparison can be made.

the accuracy, precision, reproducibility, repeatability and validity of measurements

Question 14

Caitlin discovers that the pH meter was incorrectly calibrated, resulting in pH readings that were consistently 0.2 points higher than the actual pH of the water. This type of error is best described as a

A. random error, reducing both accuracy and precision.
B. random error, reducing accuracy only.
C. systematic error, reducing both accuracy and precision.
D. systematic error, reducing accuracy only.

D

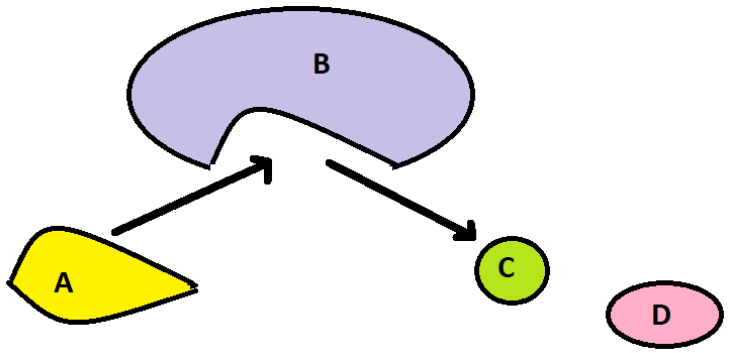
The type of error that results from incorrectly calibrated equipment is a systematic error.

In this case, the accuracy was reduced given that the readings were consistently too high; however, precision (how similar each reading is) was not affected.

the general role of enzymes and coenzymes in facilitating steps in photosynthesis and cellular respiration

Question 15

Catalase is an enzyme in the liver that converts hydrogen peroxide into oxygen and water. The image below depicts this process:



Which of the following statements is true for this process?

A. molecule B is hydrogen peroxide
B. molecule D is the substrate
C. molecule A binds to the allosteric site of molecule B
D. this enzyme-catalysed reaction would not proceed at a temperature of 95°C

D

In this image, A represents hydrogen peroxide, B represents catalase, and molecules C and D represent the products oxygen and water. At high temperatures, enzymes in the body denature, changing the shape of the active site. This means that the enzyme will no longer be able to catalyse its reaction.

B is incorrect because molecule D is a product, not the substrate.

C is incorrect because, according to the image, hydrogen peroxide is binding to the active site, not an allosteric site.

the function of CRISPR-Cas9 in bacteria and the application of this function in editing an organism's genome

Question 16

CRISPR is a sequence in bacteria that has been used to produce a gene-editing technology that offers a lot of potential for genetic engineering. The CRISPR-Cas9 complex is found naturally in some bacteria and evolved as a defence against bacteriophages (viruses that infect bacteria). What is the purpose of the PAM sequence in CRISPR?

A. to indicate to the Cas9 enzyme where the cutting point is
B. to recognise the DNA sequence of interest and direct the Cas9 enzyme there
C. to cut the DNA at a specific recognition sequence
D. to make a complementary copy of the viral DNA

A

The PAM sequence is a short sequence of nucleotides just downstream of the cutting site. Cas9 recognises the PAM sequence and, thus, will cut the bacteriophage DNA.

B is incorrect as this describes single guide RNA.

C is incorrect as it is the Cas9 enzyme that actually cuts the viral DNA.

D is incorrect as the PAM sequence does not make a complementary copy of the viral DNA.

Use the following information to answer Questions 17 – 19.

Collagen is a protein that provides strength and support to several of our body tissues, such as cartilage, bones, tendons and skin.

Type I collagen is a protein composed of two pro-α1 chains and one pro-α2 chain which are encoded by the COL1A1 and COL1A2 genes respectively.

Source: https://medlineplus.gov/genetics/gene/col1a1/

amino acids as the monomers of a polypeptide chain and the resultant hierarchical levels of structure that give rise to a functional protein

Question 17

Type I collagen would best be described as

A. a structural protein with a tertiary structure.
B. a regulatory protein with a tertiary structure.
C. a structural protein with a quaternary structure.
D. a regulatory protein with a quaternary structure.

C *Type I collagen is a structural protein because its function is to build and provide support to bodily tissues, rather than to regulate biochemical processes. It has a quaternary structure because it is composed of more than one polypeptide chain (two pro-α1 chains and one pro-α2 chain).*

the genetic code as a universal triplet code that is degenerate and the steps in gene expression, including transcription, RNA processing in eukaryotic cells and translation by ribosomes

Question 18

How would the DNA template strand of the COL1A1 gene compare to the corresponding mRNA strand that is used to translate the genetic instructions into a pro-α1 polypeptide at the ribosomes?

A. the mRNA strand would contain the same number of nucleotides as the template strand but would be complementary and would contain uracil rather than thymine
B. the mRNA strand would be shorter than the template strand and would contain thymine rather than uracil
C. the mRNA strand would be shorter than the template strand and would have a guanine cap at the 5' end
D. the mRNA strand would be shorter than the template strand and would have a guanine cap at the 3' end

C *The mRNA strand will be shorter than the template strand because the introns have been spliced out during RNA processing. A guanine cap is also added during RNA processing.*

A is incorrect because the mRNA strand is shorter than the template strand.

B is incorrect because mRNA contains uracil, not thymine.

D is incorrect because the guanine cap is added to the 5' end of the mRNA strand.

the role of rough endoplasmic reticulum, Golgi apparatus and associated vesicles in the export of proteins from a cell via the protein secretory pathway	Question 19 Following the synthesis of the pro-α1 and one pro-α2 chains, what else occurs before the type I collagen protein is secreted from the cell? A. the protein chains are folded into their required 3D shape and are exported to the ribosomes before being packaged into a vesicle and exported from the cell via exocytosis B. the protein chains are folded into their 3D shape and are transported to the Golgi apparatus before being packaged into a vesicle and exported from the cell via exocytosis C. the protein chains are folded into their 3D shape and are transported to the Golgi apparatus before being packaged into a vesicle and exported from the cell via endocytosis D. the protein chains are folded into their 3D shape and are transported to the smooth endoplasmic reticulum before being packaged into a vesicle and exported from the cell via exocytosis	*B* *Once the three polypeptide chains are synthesised, various enzymes fold the protein into its final quaternary structure. This process requires energy. The protein is transported to the Golgi apparatus, where it is packaged into a vesicle, and exported from the cell. Bulk transport out of the cell is called exocytosis.* *A is incorrect because the protein chains are formed at the ribosomes, not exported to the ribosomes after being formed.* *C is incorrect because bulk transport out of the cell is called exocytosis, while endocytosis refers to bulk transport into the cell.* *D is incorrect because the smooth endoplasmic reticulum is not involved in protein export.*

inputs, outputs and locations of the light dependent and light independent stages of photosynthesis in C3 plants (details of biochemical pathway mechanisms are not required)

the factors that affect the rate of photosynthesis: light availability, water availability, temperature and carbon dioxide concentration

Question 20

Mayah is attempting to grow broad beans. She wishes to optimise the rate of photosynthesis in her seedlings. Mayah understands that carbon dioxide is a key input to photosynthesis, so she sets up the seedlings in a tank with a carbon dioxide concentration that is higher than atmospheric levels. However, while increasing carbon dioxide concentration increases the rate of photosynthesis initially, as she further increases carbon dioxide concentrations, the rate of photosynthesis plateaus. Which of the following is *not* a possible explanation for the plateau?

A. the active sites of the enzymes that catalyse the reactions that synthesise glucose in the light-dependent reactions are all occupied

B. although there is excess carbon dioxide available for glucose synthesis, the rate of NADPH supply from the light-dependent reactions limits the rate of photosynthesis

C. the rates at which the light-independent reactions can proceed are limited by the concentration of enzymes in the stroma

D. the light intensity, and thus the amount of light energy available, cannot produce enough H+ ions in the light-dependent reactions to continue to increase the rate of photosynthesis

A *Carbon dioxide is an input into the light-independent reactions, where glucose is synthesised, not the light-dependent reactions.*

Although carbon dioxide levels are high, if the active sites of the enzymes catalysing these reactions are all occupied, the rate of reaction cannot proceed any further. Likewise, the energy for the light-independent reactions is provided by the light-dependent reactions. This energy is limited, so the rate of photosynthesis cannot increase indefinitely, even if there is plenty of carbon dioxide available.

Use the following information to answer Questions 21 and 22.

Recombinant plasmids are used to transform bacteria with the purpose of producing large quantities of certain genes, such as the human insulin gene.

Insulin consists of two polypeptide chains that are referred to as the alpha and beta subunits. Therefore, to produce insulin, two different recombinant plasmids are required: one producing the alpha subunit and one producing the beta subunit.

A suitable plasmid is mixed with two restriction enzymes, EcoR1 and BAMHI, and the subunit A gene. The subunit A gene is flanked by recognition sites for one of these restriction enzymes. This plasmid contains two antibiotic resistant genes: the amp^R gene, which encodes for antibiotic resistance to ampicillin, and the tet^R gene, which encodes for antibiotic resistance to tetracycline. The tet^R gene has a recognition site for one of the restriction enzymes inside it, while the amp^R gene does not.

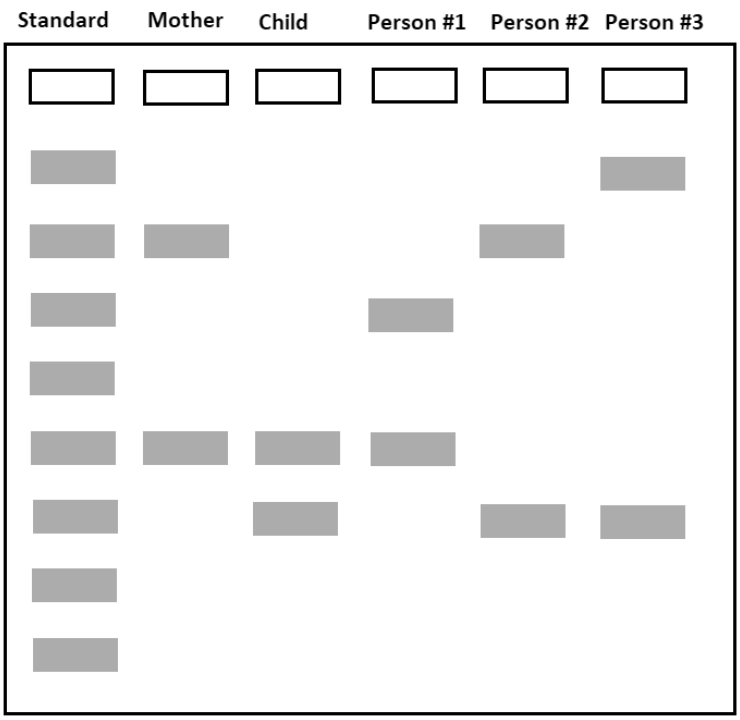
the use of recombinant plasmids as vectors to transform bacterial cells as demonstrated by the production of human insulin	Question 21 When the plasmids are mixed with the restriction enzymes and subunit A gene, some plasmids will incorporate the subunit A gene. What else must be added to the mixture to join the fragments of DNA together? **A.** free nucleotides **B.** DNA ligase **C.** DNA polymerase **D.** RNA polymerase	*B*	*DNA ligase is an enzyme that joins the sugar-phosphate backbone of the DNA fragments together.*

the use of recombinant plasmids as vectors to transform bacterial cells as demonstrated by the production of human insulin	Question 22 The plasmids are then mixed with bacteria, which are stimulated to take up the plasmids; however, not all of the bacterial cells will take up plasmids and, of those that do, not all of the plasmids will be recombinant plasmids. The bacteria that successfully take up the recombinant plasmids only will be resistant to **A.** both ampicillin and tetracycline. **B.** neither ampicillin nor tetracycline. **C.** ampicillin but not to tetracycline. **D.** tetracycline but not to ampicillin.	*C*	*The plasmids contain both antibiotic genes, but, in the recombinant plasmids, the tet^R gene will have been cut by a restriction enzyme. Therefore, bacteria that have taken up the recombinant plasmids will not be resistant to tetracycline, as these genes will not be able to be transcribed; they will, however, be resistant to ampicillin because the amp^R gene is located away from the restriction sites and, so, will be unaffected.* *Bacteria that have taken up non-recombinant plasmids will be resistant to both antibiotics because the tet^R gene will still be intact in these bacteria.* *Bacteria that have not taken up any plasmids will not be resistant to either antibiotic.*

amplification of DNA using polymerase chain reaction and the use of gel electrophoresis in sorting DNA fragments, including the interpretation of gel runs for DNA profiling

Question 23

In a paternity case, short tandem repeats (STRs) were used to identify the father of a child. A particular STR site was compared between the child, the mother, and three potential fathers. The following electrophoresis output was produced.



Which of the following conclusions can be made from this information?

A. none of the three people tested could possibly be the father
B. only person #2 could be the father
C. all three people tested could potentially be the father
D. persons #2 or #3 could be the father

D *Both persons #2 and #3 have one chromosome with an STR of the same number of repeats as the child, which is different from the STR inherited from the mother.*

amplification of DNA using polymerase chain reaction and the use of gel electrophoresis in sorting DNA fragments, including the interpretation of gel runs for DNA profiling

Question 24

Polymerase chain reaction (PCR) is a method used to amplify DNA. If a gene of interest undergoes four cycles of PCR, how many pieces of DNA will exist after these cycles?

A. 4
B. 8
C. 16
D. 32

C *Each subsequent cycle of PCR doubles the amount of DNA; therefore, after four cycles there would be 2^4 times the original amount of DNA, which is 16 times the original amount.*

the role of Rubisco in photosynthesis, including adaptations of C3, C4 and CAM plants to maximise the efficiency of photosynthesis	Question 25 Plants can be categorised as C3, C4 or CAM plants based on differences in how they capture and store carbon for photosynthesis. Which statement correctly compares C3, C4 and CAM plants? A. the stages of photosynthesis are identical between all three types of plants, but the role of rubisco varies B. all three types of plants use the same amount of energy in photosynthesis C. the light-dependent stage is the same for all three types of plants, but the light-independent stage differs D. CAM plants use the least amount of energy in photosynthesis	*C* *The light-independent stage is the same for all three types of plants, but the light-independent stage varies significantly. In C4 plants, carbon fixation is separated from the rest of the Calvin cycle spatially and, in CAM plants, it is separated temporally.* *A is incorrect because the light-independent stage differs between the three types of plants.* *B and D are incorrect because CAM plants use the most amount of energy in photosynthesis, followed by C4 plants and, finally, C3 plants.*

Section B

VCAA Key Knowledge	Question	Answer Guide

A pair of biology students set up an experiment to investigate the effect of temperature on the rates of photosynthesis in spinach leaves. Twelve beakers of four different temperatures (three beakers per temperature) were prepared, each containing 30 spinach leaf discs in bicarbonate solution, with the air removed. The solution in each beaker was kept at a constant temperature. After 10 minutes, the number of floating leaf discs was recorded. Three beakers were prepared for each of the following temperatures:

Temperature 1: 10°C
Temperature 2: 20°C
Temperature 3: 30°C
Temperature 4: 40°C

White light was shone on each beaker, using 12 identical lamps of the same light intensity. The relative rates of photosynthesis in the spinach leaves were determined by counting the number of floating leaf discs after 10 minutes. Assume that the floating discs are *not* floating due to the production of carbon dioxide gas. The following results were obtained:

Temperature	Number of Floating Discs After 10 Minutes			
	Beaker 1	Beaker 2	Beaker 3	Average
10°C	14	14	15	14.3
20°C	25	29	24	26.0
30°C	18	15	20	17.7
40°C	4	1	2	2.3

characteristics of the selected scientific methodology and method, and appropriateness of the use of independent, dependent and controlled variables in the selected scientific investigation	**Question 1a** (2 marks) Identify the independent and dependent variables in this experiment. Independent variable: Dependent variable:	**Answer:** • Independent variable: *Temperature of the bicarbonate solution.* • Dependent variable: *Number of floating discs after 10 minutes OR Rate of photosynthesis.* **Marking protocol:** One mark for each of the above points. Note: The rate of photosynthesis may be accepted as the dependent variable, as this was being inferred from the number of floating discs.

inputs, outputs and locations of the light dependent and light independent stages of photosynthesis in C3 plants	**Question 1b** (2 marks) In relation to photosynthesis, what was causing the discs to float?	**Answer:** • *Oxygen gas caused the discs to float (because oxygen is less dense than water).* • *Oxygen is a product of photosynthesis; therefore, a floating disc indicated the production of oxygen and, thus, indicated that photosynthesis was occurring in the leaf disc.* **Marking protocol:** One mark for each of the above points.

inputs, outputs and locations of the light dependent and light independent stages of photosynthesis in C3 plants	**Question 1c** (2 marks) Identify the stage of photosynthesis that results in the formation of the product identified in Question 1b and name the structure in the chloroplasts at which this occurs.	**Answer** • *Oxygen gas is produced in the light-dependent stage of photosynthesis.* • *This occurs at the thylakoid membranes OR grana.* **Marking protocol:** One mark for each of the above points.

the accuracy, precision, reproducibility, repeatability and validity of measurements	**Question 1d** (2 marks) For which temperature was the most precise set of results obtained? Justify your answer.	**Answer** • *The most precise results were obtained at 10 °C.* • *This is because the three results for this temperature were the most similar/had the least variation.* **Marking protocol:** One mark for each of the above points.

techniques of primary quantitative data generation relevant to the selected scientific investigation	**Question 1e** (1 mark) Using data, what conclusion can be drawn from the results regarding the optimal temperature for photosynthesis in spinach leaves?	**Answer** • *The optimal temperature for photosynthesis in spinach leaves is approximately 20°C, as indicated by the highest average number of floating discs at this temperature, that being 26.* **Marking protocol:** One mark for the above point, including justification.

inputs, outputs and locations of the light dependent and light independent stages of photosynthesis in C3 plants *the factors that affect the rate of photosynthesis: light availability, water availability, temperature and carbon dioxide concentration*	**Question 1f** (2 marks) Suggest reasons for the low numbers of floating discs at 10°C and at 40°C.	**Answer** • *At low temperatures, molecules have less kinetic energy and move around less; therefore, the enzymes that catalyse the reactions for photosynthesis come into contact with their substrate less frequently, leading to low rates of photosynthesis. This causes a low rate of oxygen production, which was indicated by low numbers of floating discs.* • *At high temperatures, the enzymes that control photosynthesis become denatured and cannot combine with their substrates, resulting in little or no photosynthesis. This causes low rates of oxygen production and, therefore, few floating discs.* **Marking protocol:** One mark for each of the above points.

the factors that affect the rate of photosynthesis: light availability, water availability, temperature and carbon dioxide concentration *characteristics of the selected scientific methodology and method, and appropriateness of the use of independent, dependent and controlled variables in the selected scientific investigation*	**Question 1g** (2 marks) Identify two controlled variables that were not identified in the experiment description.	**Answer** • *Size of beakers.* • *pH of water.* • *Size of leaf discs.* • *Volume of solution.* • *The specific spinach plant from which the leaf discs were obtained.* **Marking protocol:** One mark for any of the above points, to a maximum of two.

Golden Rice is a variety of genetically engineered rice designed to combat vitamin A deficiencies in certain parts of the world. Golden Rice is engineered to biosynthesise beta-carotene, which is then converted into vitamin A in the gut.

Golden Rice is created by transforming rice with two beta-carotene genes: *Psy* (phytoene synthase) from daffodils (*Narcissus pseudonarcissus*) and *Crt1* (carotene desaturase) from the bacterium *Erwinia uredovora.*

The restriction enzyme EcoR1 is used to cut out the desired genes from both the daffodil DNA and the bacterial DNA. EcoR1 has the following restriction site:

5′. . . G|AATTC . . . 3′
3′. . . CTTAA|G . . . 5′

The *Psy* and *Crt1* genes are isolated, amplified and transferred into the *Ti* plasmid of the bacterium *Agrobacterium tumefaciens*, which then goes on to infect the rice embryos. The embryos then grow into mature rice plants with the desired traits.

Source: med.nyu.edu

the use of genetically modified and transgenic organisms in agriculture to increase crop productivity and to provide resistance to disease	**Question 2a** (2 marks) Would Golden Rice be described as a transgenic organism? Explain your answer.	**Answer:** • *Yes, it is a transgenic organism…* • *…because it contains foreign DNA, this DNA being from Narcissus pseudonarcissus and Erwinia uredovora.* **Marking protocol:** One mark for each of the above points, including the identification of the foreign species.

the use of enzymes to manipulate DNA, including polymerase to synthesise DNA, ligase to join DNA and endonucleases to cut DNA	**Question 2b** (1 mark) Consider a different section of double-stranded DNA:  How many fragments of DNA would there be after this section of DNA is mixed with the EcoR1 enzyme?	**Answer:** • *Three.* **Marking protocol:** One mark for stating the correct number of fragments. Note: There are two recognition sites, resulting in three fragments, but an explanation is not required for a mark.

the use of enzymes to manipulate DNA, including polymerase to synthesise DNA, ligase to join DNA and endonucleases to cut DNA	**Question 2c** (1 mark) When an endonuclease cuts a section of DNA, it can leave sticky or blunt ends. Explain the difference between the two.	**Answer** • *Sticky ends mean that the DNA is cut in such a way that leaves overhanging, or unpaired, bases. Blunt ends do not have unpaired bases.* **Marking protocol:** One mark for the above point.

the use of enzymes to manipulate DNA, including polymerase to synthesise DNA, ligase to join DNA and endonucleases to cut DNA	**Question 2d** (4 marks) The *Psy* and *Crt1* genes, once isolated, are amplified using PCR. Describe the steps involved in one cycle of the PCR process.	**Answer** • *DNA is heated to 95°C to separate the molecule into two single strands.* • *It is then cooled to 55°C, and primers are added, which anneal to the single strands of DNA and act as an attachment site in the replication process.* • *Taq polymerase and free nucleotides are added.* • *It is heated to 72°C and Taq polymerase extends each complementary strand beyond the primers, resulting in two double stranded DNA molecules that are identical to the original DNA molecule.* **Marking protocol:** One mark for each of the above points.

the use of enzymes to manipulate DNA, including polymerase to synthesise DNA, ligase to join DNA and endonucleases to cut DNA	**Question 2e** (1 mark) Explain why *Taq* polymerase, rather than mammalian DNA polymerase, is used for the process of PCR.	**Answer** • *Taq polymerase is active at high temperatures (72°C used in PCR), whereas mammalian DNA polymerase would denature at the temperatures required for PCR.* **Marking protocol:** One mark for the above point.

the use of recombinant plasmids as vectors to transform bacterial cells as demonstrated by the production of human insulin

Question 2f (2 marks)

The desired genes are mixed with the *Ti* plasmids, which are then incorporated into the *Agrobacterium tumefaciens* bacteria. It is important that these plasmids contain two antibacterial resistant genes; one located away from an EcoR1 restriction site and the other containing an EcoR1 restriction site within its sequence.

Describe the purpose of these two antibacterial-resistant genes in identifying the successfully transformed bacteria.

Answer

- *The antibacterial-resistant gene located away from any recognition sites is used to identify the bacteria that have successfully taken up a plasmid. (When treated with the corresponding antibiotic, these bacteria will be unaffected).*
- *The antibacterial-resistant gene that contains a recognition site within its sequence is used to identify the bacteria that have successfully incorporated (not just a plasmid) a recombinant plasmid. (When treated with the corresponding antibiotic, these bacteria will be affected, as the gene coding for antibiotic resistance has been cut, so will not be expressed).*

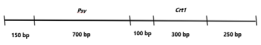
Marking protocol:

One mark for each of the above points. Note: the points in brackets are not required, but some students may include this information in their answer.

amplification of DNA using polymerase chain reaction and the use of gel electrophoresis in sorting DNA fragments, including the interpretation of gel runs for DNA profiling

Question 2g (2 marks)

The figure below shows the EcoR1 restriction sites of the section of rice DNA in which the two desired genes are incorporated.



Consider a plant that has incorporated the *Psy* gene but not the *Crt1* gene. Describe the electrophoresis output when this section of DNA is mixed with EcoR1 then run through an electrophoresis gel. Explain your answer.

Answer

- *The electrophoresis output would show the following: one band at 100 bp; one band at 150 bp; one band at 250 bp; and one band at 700 bp (the Psy gene).*
- *Since the Crt1 gene does not exist, there will be a single restriction site between the 100 bp and 250 bp sections in the figure, and therefore no 300 bp band.*

Marking protocol:

One mark for each of the above points.

the genetic code as a universal triplet code that is degenerate and the steps in gene expression, including transcription, RNA processing in eukaryotic cells and translation by ribosomes	**Question 2h** (1 mark) Explain how the universality of the genetic code allows for the genetic modification of the rice embryos to produce Golden Rice.	**Answer** • *Because the genetic code is universal (i.e. the same codon will code for the same amino acid regardless of the organism), it allows for the gene of one organism, in this case, the Psy gene from daffodils and the Crt1 gene from* Erwinia uredovora *to be expressed in another organism, the rice.* **Marking protocol:** One mark for the above point. NB: The answer must reference the process of producing Golden Rice.

Calandrinia balonensis is an Australian flowering plant found in arid regions west of the Great Diving Range, and throughout central Australia. It is well-adapted to its warm climate and is usually found growing in red sandy soils and spinifex zones. Like many plants that are adapted to a hot, dry climate, *C. balonensis* utilises the CAM pathways of photosynthesis.

Source: https://www.anbg.gov.au/gnp/interns-2013/calandrinia-balonensis.html

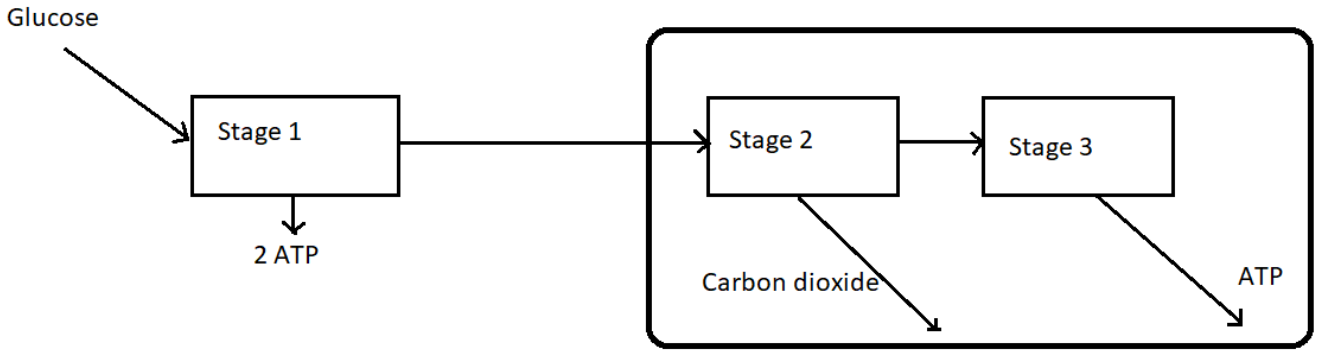
the role of Rubisco in photosynthesis, including adaptations of C3, C4 and CAM plants to maximise the efficiency of photosynthesis	**Question 3a** (2 marks) Describe how the adaptations of *C. balonensis* maximise the efficiency of photosynthesis in a warm, arid environment.	**Answer:** • *In CAM plants, stomate are closed during the day to limit water loss.* • *CO_2 is fixed into a 4-carbon compound at night (when stomata are open) and then released during the day (when the stomata are closed) to allow for photosynthesis.* **Marking protocol:** One mark for each of the above points.

the role of Rubisco in photosynthesis, including adaptations of C3, C4 and CAM plants to maximise the efficiency of photosynthesis	**Question 3b** (2 marks) Briefly describe the role of Rubisco in synthesising glucose in photosynthesis and outline how coenzymes are involved in this process.	**Answer:** • *Rubisco fixes the carbon (from CO_2) to make glucose.* • *Coenzymes (ATP and NADPH) from the light-dependent stage provide the energy and hydrogen atoms needed to do this.* **Marking protocol:** One mark for each of the above points.

the role of Rubisco in photosynthesis, including adaptations of C3, C4 and CAM plants to maximise the efficiency of photosynthesis	**Question 3c** (2 marks) Referring to the role of Rubisco, explain why photorespiration is more likely to occur at higher temperatures.	**Answer** • *High oxygen levels can occur when plants close their stomata to reduce water loss at higher temperatures. Since the stomata are the means by which oxygen exits the leaf, this can result in a build-up of oxygen, increasing Rubisco's affinity for oxygen.* • *If oxygen levels are high and carbon dioxide levels are low, then Rubisco is more likely to bind to oxygen, which causes photorespiration. (Carbon dioxide also has lower solubility at high temperatures.)* **Marking protocol:** One mark for each of the above points.

the role of Rubisco in photosynthesis, including adaptations of C3, C4 and CAM plants to maximise the efficiency of photosynthesis	**Question 3d** (3 marks) Like CAM plants, C4 plants are adapted to hot climates. Compare the process of photosynthesis in C4 and CAM plants.	**Answer** • *In CAM plants, initial carbon fixation is separated from the rest of the Calvin cycle over time. In C4 plants, the initial carbon fixation is separated from the rest of the Calvin cycle over space, rather than time.* • *In CAM plants, during the night, the plants open their stomata to take in CO_2 and use it to produce glucose during the day when their stomata are closed. C4 plants have their stomata open during the day.* • *In C4 plants, initial carbon fixation occurs in a mesophyll cell and the rest occurs in bundle-sheath cells. In CAM plants, only mesophyll cells are involved.* **Marking protocol:** One mark for each of the above points.

The figure below depicts an essential process that occurs in most eukaryotic cells. Note that not all of the inputs and outputs of each stage are shown.



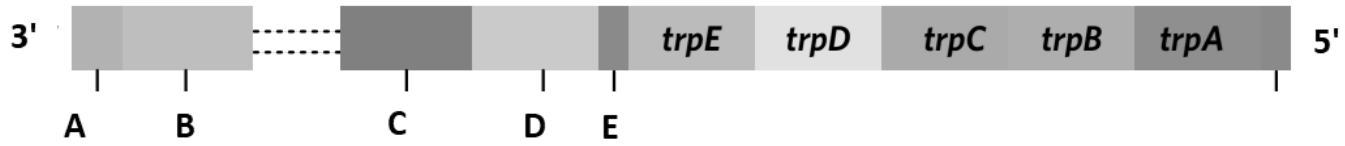
the main inputs, outputs and locations of glycolysis, Krebs Cycle and electron transport chain including ATP yield	**Question 4a** (1 mark) Name Stages 1, 2 and 3.	**Answer:** • *Stage 1 is glycolysis.* • *Stage 2 is the Krebs cycle (citric acid cycle is also accepted).* • *Stage 3 is the electron transport chain.* **Marking protocol:** One mark for all three of the above points. Note: Students should recognise that the process is aerobic cellular respiration and, thus, be able to identify the three main stages.

the main inputs, outputs and locations of glycolysis, Krebs Cycle and electron transport chain including ATP yield	**Question 4b** (1 mark) Identify two outputs from Stage 1.	**Answer:** • *Pyruvate.* • *ATP.* • *NADH.* **Marking protocol:** One mark for naming any two of the above outputs.

the main inputs, outputs and locations of glycolysis, Krebs Cycle and electron transport chain including ATP yield	**Question 4c** (2 marks) In which organelle and in which parts of the organelle do Stages 2 and 3 occur?	**Answer:** • *Stage 2 occurs in the mitochondrial matrix of the mitochondria.* • *Stage 3 occurs on the inner membrane (cristae) of the mitochondria.* **Marking protocol:** One mark for each of the above points.

the location, inputs and the difference in outputs of anaerobic fermentation in animals and yeasts	**Question 4d** (4 marks) When human muscle cells are subjected to heavy exercise and, thus, limited oxygen, they may switch from the process depicted above to a different biochemical process. Name this process and describe how this alternate biochemical process differs from the one shown above, in terms of location and outputs.	**Answer:** • *Human muscle cells may switch to anaerobic (lactic acid) fermentation (a form of anaerobic respiration).* • *This process only occurs in the cytosol and does not involve the mitochondria (like aerobic respiration does).* • *The outputs of anaerobic fermentation in animals are two net molecules of ATP and lactic acid, per molecule of glucose.* • *Whereas, the outputs of aerobic respiration are a net output of 30/32 molecules of ATP, carbon dioxide and water, per molecule of glucose.* **Marking protocol:** One mark for each of the above points.

An example of gene regulation in prokaryotes like *E. coli* is the *trp* operon. The transcription and translation of the five structural genes in this operon forms part of the process of the production of the amino acid tryptophan. The figure below shows the general structure of the *trp* operon.



the basic elements of gene regulation: prokaryotic trp operon as a simplified example of a regulatory process	**Question 5a** (2 marks) Identify part D and describe its function in regulating the transcription of structural genes.	**Answer:** • *Part D is the operator region.* • *The operator region is the binding site of the repressor. When tryptophan levels in the cell are high, the repressor will bind to the operator, preventing RNA polymerase from transcribing the structural genes.* **Marking protocol:** One mark for each of the above points.

the basic elements of gene regulation: prokaryotic trp operon as a simplified example of a regulatory process	**Question 5b** (3 marks) There are two ways in which the *trp* operon regulates the transcription of structural genes: repression and attenuation. Describe what occurs during attenuation when levels of tryptophan are high.	**Answer:** • *The attenuator sequence contains codons for two tryptophan amino acids. The ribosome arrives at this sequence, and translates these codons, adding tryptophan to the peptide chain.* • *This causes the mRNA molecule to fold and form a terminator hairpin loop.* • *This folding causes the mRNA molecule to separate from the DNA template strand and causes RNA polymerase to detach. Protein synthesis then ceases.* **Marking protocol:** One mark for each of the above points.

the basic elements of gene regulation: prokaryotic trp operon as a simplified example of a regulatory process	**Question 5c** (1 mark) In prokaryotic cells, the DNA is not located in a nucleus. Explain why this allows for attenuation to occur in prokaryotic cells.	**Answer:** • *Attenuation is made possible in prokaryotes because transcription and translation take place very close to each other in the cytoplasm, as the two processes are not separated by a nuclear membrane.* **Marking protocol:** One mark for the above point.

VCE Unit 3 BIOLOGY
Written Examination
ANSWER SHEET – 2023

Student name:	

Use a **PENCIL** for **ALL** entries. For each question, shade the box which indicates your answer.

Marks will **NOT** be deducted for incorrect answers.

NO MARK will be given if more than **ONE** answer is completed for any question.

If you make a mistake, **ERASE** the incorrect answer – **DO NOT** cross it out.

1	A	B	**C**	D
2	A	B	C	**D**
3	A	**B**	C	D
4	A	B	**C**	D
5	A	B	**C**	D
6	A	B	**C**	D
7	A	**B**	C	D
8	**A**	B	C	D
9	**A**	B	C	D
10	A	**B**	C	D
11	A	**B**	C	D
12	**A**	B	C	D
13	A	B	C	**D**
14	A	B	C	**D**

15	A	B	C	**D**
16	**A**	B	C	D
17	A	B	**C**	D
18	A	B	**C**	D
19	A	**B**	C	D
20	**A**	B	C	D
21	A	**B**	C	D
22	A	B	**C**	D
23	A	B	C	**D**
24	A	B	**C**	D
25	A	B	**C**	D