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Draw a cross through the box (☒) if you have NOT written in this booklet

NZQA

Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Level 2 Biology 2024

91159 Demonstrate understanding of gene expression

Credits: Four

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of gene expression.	Demonstrate in-depth understanding of gene expression.	Demonstrate comprehensive understanding of gene expression.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–16 in the correct order and that none of these pages is blank.

Do not write in the margins (▨). This area will be cut off when the booklet is marked.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

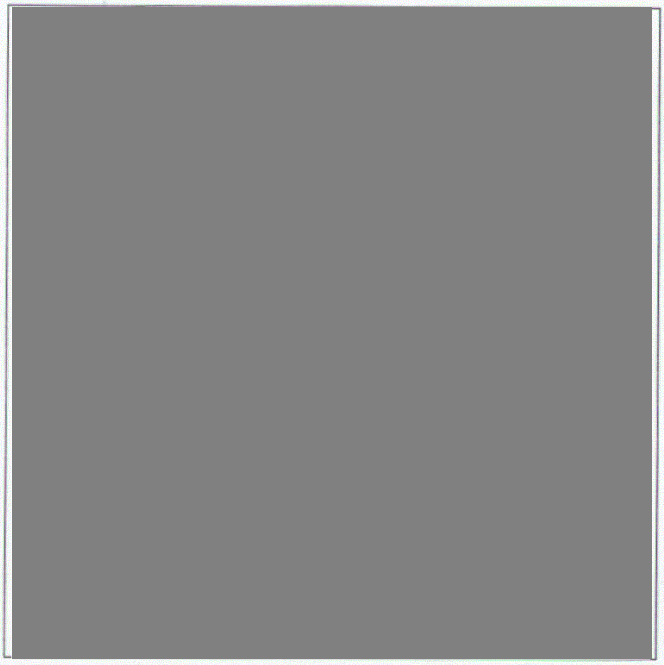
Merit

TOTAL 16

QUESTION ONE: Protein synthesis

(a) Complete the table below to describe three ways in which mRNA and DNA are different from each other.

Difference	DNA	mRNA
1	A Double stranded helix making it too large to exit the nucleus	A single stranded Helix capable of leaving the nucleus due to its smaller stature
2	DNA only comes in a single form Deoxyribonucleic Acid	RNA has three seperate forms Messenger RNA : mRNA Ribosome RNA : rRNA Transport RNA : tRNA
3	DNA uses 4 bases • Adenine • Guanine • Thymine • Cytosine	RNA also uses 4 bases except replaces Thymine with Uracil when copying the template strand in transcription



Overview of protein synthesis.

Compared to mRNA, the structure of tRNA increases its stability, which increases the period of time that tRNA lasts in the cytoplasm. In contrast, the majority of mRNA molecules break down within a few hours after their release from the nucleus into the cytoplasm.

(b) Compare mRNA and tRNA, including their function, structure, stability, and role in protein synthesis.

In your answer, include discussion of:

- the function of both mRNA and tRNA
- how mRNA and tRNA work together to carry out protein synthesis
- the significance of tRNA being stable and mRNA being unstable.

Messenger RNA is produced through transcription and serves as transport to the information to create a specific protein in translation as DNA cannot leave the nucleus as it risks damage. Transport RNA serves also as transport but to amino acids to pair with one another during translation. They both possess a variation of ~~one another~~ bases with mRNA having codons which are a set of three bases on a mRNA strand and are complimentary to the DNA triplets and tRNA anticodons, while tRNA has anticodons which are a set of three bases on the tRNA strand and are complimentary to the mRNA codons. While both are

different to one another they are both equally important during translation as one without the other is equally useless. During translation mRNA transports the information to create a amino acid chain which turns into a polypeptide chain that folds into a protein, this is where we need tRNA which carries amino acids into the ribosome to be deposited correctly according to mRNA's instructions, this is correctly carried out due to each anticodon carrying a specific AA (amino acid) the AA is only deposited on the codons that are complimentary to its anticodons therefore requiring each other to successfully carry out translation. Stability is a concern when dealing with chemicals which is basically our entire body, but when it comes to mRNA and tRNA the reason that mRNA is less stable and only breaks down after a couple of hours is because it is easily and readily made as opposed to tRNA which takes a bit of time, where mRNA is fairly easily mass produced in the nucleus' safety tRNA must exist in the "harsher" cytoplasm with the amino acids

QUESTION TWO: Mutations

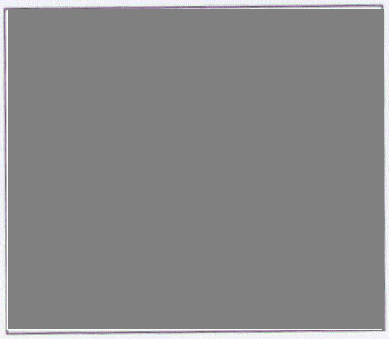
The table below shows the abbreviations for some of the amino acids and DNA triplets that code for them.

Sneaky ******** (I use this jokingly)

Amino acid	Abbreviation	Triplets on the DNA template strand
Valine	val	CAA, CAC, CAG, CAT
Proline	pro	GGA, GGC, GGG, GGT
Threonine	thr	TGA, TGC, TGG, TGT
Histidine	his	GTA, GTG
Glutamic acid	glu	CTC, CTT
Leucine	leu	AAC, AAT, GAA, GAC, GAG, GAT

One function of haemoglobin is to assist with transport of oxygen.

There are many different variants of haemoglobin.
The sequence of bases in DNA for the normal gene and for the mutated version that codes for the β-globin polypeptide are shown in table (i) below.



Haemoglobin molecule.

(a) Complete the following TWO tables to show the mRNA, tRNA, and amino acid sequences, using the resource information above.

(i) Code for **normal** β-globin polypeptide

Triplet number	1	2	3	4
DNA template strand	TGA	GGA	CTC	CTC
mRNA (codon)	ACU	CCU	GAG	GAG
tRNA (anticodon)	UGA	GGA	CUC	CUC
Amino acid	Thr	Pro	[illegible] Glu	[illegible] Glu

(ii) Code with **mutated** β-globin polypeptide

Triplet number	1	2	3	4
DNA template strand	TGA	GGA	CAC	CTC
mRNA (codon)	ACU	CCU	GUG	GAG
tRNA (anticodon)	UGA	GGA	CAC	CUC
Amino acid	Thr	Pro	Val	[illegible] Glu

(b) Discuss the effect of this mutation on the amino acid sequence and the functioning of the final β-globin polypeptide.

In your answer, include discussion of:

- the causes of mutations
- the mutation type and the severity of this type of mutation compared to other types
- the effect of this mutation on the functioning of the final haemoglobin beta polypeptide.

A mutation is a change to the DNA base sequence that is the only source for new alleles. Mutations can occur from exterior forces called mutagens which are environmental factors that increase the frequency of mutations. These mutagens are things we expose ourselves to like UV rays and X-rays both of these being mutagens and contributing to mutation frequency. This specific mutation on the haemoglobin is only affecting a singular triplet not the entire chain, this leads me to believe a substitution mutation has taken place, where no new bases have been subtracted or added to the triplet chain instead a single base is swapped in a triplet with a different base which can have different effects on the process of transcription and translation. In the case of this mutated haemoglobin we can see the 2nd base of the third triplet has been substituted from T (Thymine) to A (Adenine), This has had a domino effect where now a different codon and anticodon are produced from that CAC triplet meaning a different amino acid is now coded for. This change of amino acid is called a missense mutation and is one of the 3 possible effects of a substitution mutation, A missense mutation is when a change in the DNA triplets due to a substitution mutation leads to it coding for a different amino acid in this case the normal haemoglobin 3rd base coded for the GLU amino acid but the mutated haemoglobin coded for a new VAL amino acid showing that the mutation changed the coded for amino acid. Whereas

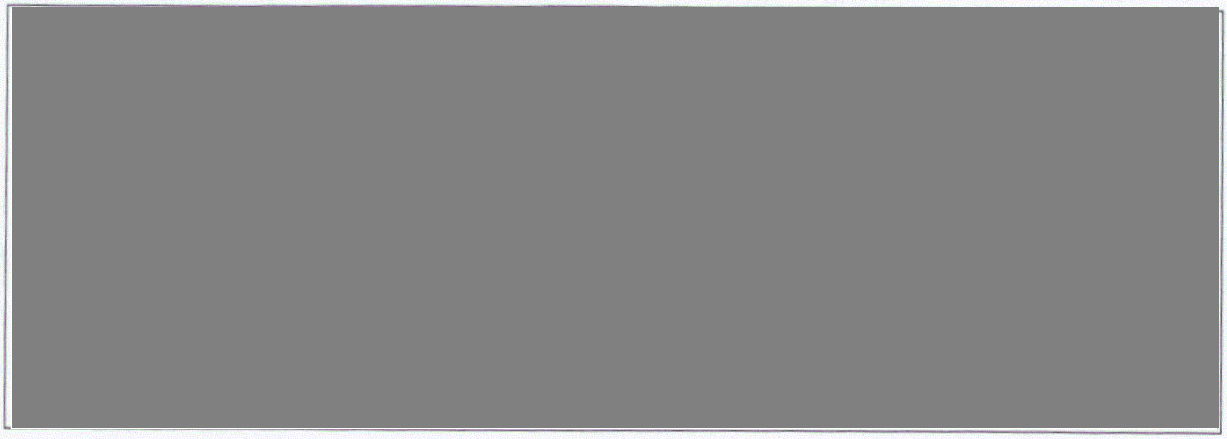
the other mutations a substitution reaction can cause would show different results, A Nonsense mutation would be for if the substitution mutation had coded the amino acid for an early stop triplet (Terminator) in the case of the haemoglobin should the 1st C (Cytosine) been replaced with A (Adenine) in the triplet it would have produced the UAG codon during transcription which doesn't code for an amino acid therefore causing the process to finish prematurely this would the lead to a shorter polypeptide chain during translation which would fold differently producing a non-functional protein. Where the final possible mutation from a substitution is a Silent mutation when the substitution occurs but does not code for a new amino acid rather still coding for the same one due to degeneracy, which is where multiple codons code for the same amino acid cause there are 64 codons and only 20 amino acids. In this case the 3rd triplet of the haemoglobin if the 3rd C (cytosine) swapped to a T (Thymine) it would still code for GLU and therefore have little effect on the process of transcription and translation. Our current missense mutation does cause us some issues during the process of translation because the amino acid is different to the original haemoglobin acid it means the polypeptide will fold differently during translation this could result in the ~~protein~~ haemoglobin produced being non-functional and being harmful to survival as it affects the transport of oxygen through the body. Refering back to the other possible mutations there are 2 other main mutations which could occur them being the addition of a base to the strand called insertion mutation or the subtraction of a base from the strand called a deletion mutation. Both of these mutations are catastrophic for the strand as both produce an effect called a reading frameshift mutation, this RFS mutation is dangerous due to its affect on the bases

I believe that is a stop codon but I don't have a sheet

QUESTION THREE: Environment and gene expression

Anaemia is a condition that develops when a person's blood produces a lower-than-normal amount of healthy red blood cells.

Iron is an essential element in all living cells. Approximately 75% of an individual's total iron is associated with a compound called 'haem' (a part of haemoglobin found in red blood cells), which is responsible for oxygen transport. Part of the metabolic pathway for haem synthesis is shown below.



Haem synthesis.

A lack of iron and high levels of lead in the body can limit the synthesis of haem. Lead is a known poison that inhibits enzymes. If haem synthesis does not occur when needed, anaemia can develop.

Discuss how genes, enzymes and materials in the environment can change the rate of haem production.

In your answer, include discussion of:

- a metabolic pathway
- how the metabolic pathway for haem synthesis occurs, using the terms: substrate, enzyme, gene, and final product
- how DNA mutations, low iron, and high lead can all cause anaemia.

A metabolic pathway is a series of enzyme-controlled reactions where the product of one reaction is the reactant of the next in this case that intermediate substrate is the product of the previous reaction but is also the reactant with iron to produce Haem. The production of Haem occurs as the final product of this metabolic pathway signalling its end and the creation of a helpful protein, this comes to be through the use of substrates and enzymes where substrates are molecules capable of being put to use but require chemical catalysation and enzymes are catalysts capable of

Catalysing these substrates through their active sites which ~~are created by a gene that~~ have a very specific shape to them allowing them to catalyse one specific substrate and no others the information for the production of these specific enzymes is found on genes in the DNA which can be affected by mutations. Ounce the intermediate substrates have been catalyzed we reach our final product Haem which is a protein beneficial to survival and signals the end of the MP (metabolic pathway). We have been told that lead inhibits the enzymes used for catalyzing iron into Haem which would result in a build up of our intermediate substrate and a lack of our final product this is called a metabolic block, this is dangerous for us since we lack the beneficial final product leading to anaemia but also results in the build up of intermediate substrate which could be toxic and cause further damage. Lead, however, is not the only way a metabolic block can occur as both mutations and other environmental factors can inhibit the production of Haem. Firstly if a mutation occured in the DNA specifically affecting the gene which produces the specific enzyme needed to catalyse either intermediate substrates it would lead to enzymes being produced with denatured active sites that would no longer fit their specific substrate leading to another metabolic block in the MP cause now we lack the specific enzymes to catalyze the IS (intermediate substrates). This can also occur from environmental factors in this case diet, if we do not consume enough iron then it doesn't matter wether or not our enzymes are natured and we have lov lead levels we still cannot produce the haem without sufficient iron levels leading to another MB (metabolic block) with the beneficial protein (haem)

not being produced and a possible build up of a toxic intermediate substrate which will lead to anaemia.

Extra space if required.
Write the question number(s) if applicable.

QUESTION NUMBER

Q2 Part b - where it will shift all of the bases to the left or right completely disrupting the entire strand for example we use our normal haemoglobin sample

TGA GGA CTC CTC

and we introduce an insertion mutation

T GAG GAC TGC CTC

↑

That G (Guanine) has been added and shifted all the based to the left therefore completely disrupting the order and changing the amino acids which will now be a completely different order therefore changing the polypeptide chain which will create a non-functional protein

Merit

Subject: Biology

Standard: 91159

Total score: 16

Q	Grade score	Marker commentary
One	M6	This response explains the function of mRNA, noting that it carries a gene from the DNA to the ribosome. It also explains the complementary nature of codons and anticodons and acknowledges the importance of tRNA's stability.
Two	E7	This response explains what a mutation is, giving two examples. It explains that a substitution mutation causes a change in one amino acid and links this to a slight change in the polypeptide sequence. The candidate discusses the effect of the substitution mutation on the amino acid sequence and links this to the shape and function of haemoglobin.
Three	A3	This response describes a metabolic pathway. It identifies that lead inhibits enzymes from working. It identifies that a change in a gene can cause anaemia or prevent haem from being produced.