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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.

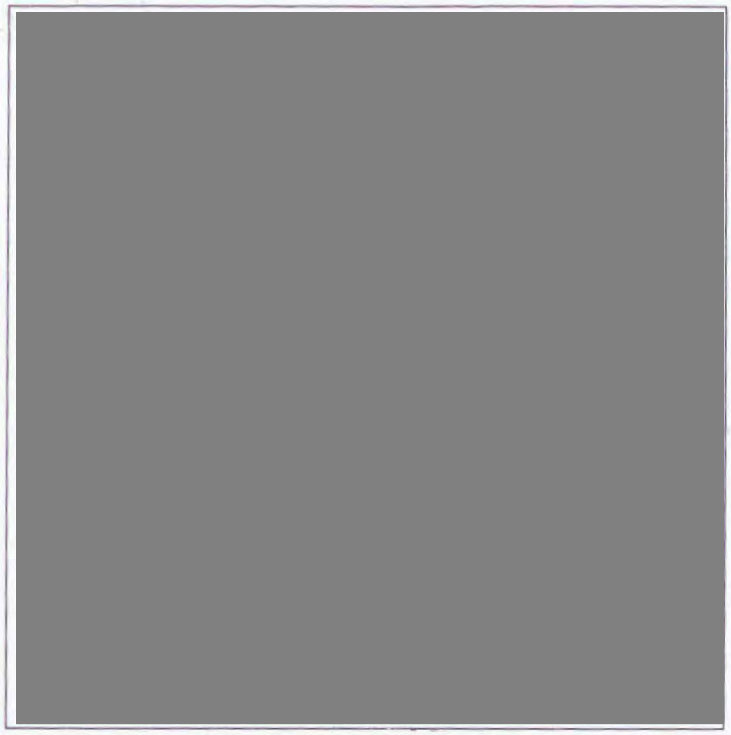
Excellence

TOTAL 21

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	Double Stranded	Single Stranel
2	Has thymine bonding with adenine	Has uracil bonding with adenine
3	Contains the whole genetic code	Contains part of the genetic code



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.

The messenger RNA's (mRNA) function is to copy down the coding strand of DNA during transcription, and go to the cytoplasm to have the ribosome read it during translation. The tRNA's function is on the other hand, is to bring the amino acids to build the polypeptide chain during transcription.

The first stage of protein synthesis is transcription. During transcription, the RNA polymerase unwinds the DNA strand into two seperate strands - the coding and template strands.

The mRNA strand then attaches to the template strand and starts to get built complementary to the template strand using the base-pair rule (adenine with thymine (uracil for mRNA), and cytosine with guanine). Being built in this fashion allows the mRNA to be an exact copy of the coding strand (but with uracil instead of thymine). Once the mRNA strand has been built, RNA polymerase zips up the DNA and the mRNA leaves the nucleus and goes to the cytoplasm.

In the cytoplasm, stage 2 of protein synthesis takes place - translation. When the mRNA strand enters the cytoplasm, the ribosome starts to read the mRNA in consecutive sets of three called codons. The ribosome first scans along the mRNA looking for a start codon, and from there, it starts to read the mRNA codons until it reaches a stop codon. As each codon is read, a tRNA with a complementary set of anticodons attached to the bottom (complementary in terms of the base-pair rule) goes to get the amino acid which it codes for and drops it off by the mRNA strand. As it drops it off the mRNA and tRNA temporarily connect, until the tRNA unbinds and leaves. As more codons are read, more tRNA organelles get the amino acids until a stop codon is reached by the ribosome, where the amino acids have formed a polypeptide chain and fold to make the protein.

Since the mRNA is no longer needed, it breaks down within a few hours, which is why the mRNA isn't stable.

The tRNA being stable, on the other hand, allows the same tRNA to be used many times ~~before breaking down~~ for many different mRNA strands before breaking down, which saves the body and the cells some resources as it doesn't have to constantly make more tRNA.

QUESTION TWO: Mutations

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

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	Glu	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	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 permanent change in the base sequence of DNA. ~~[illegible]~~ One way a mutation can happen is via a mutagen, which is when something in your enviroment (eg. radiation) changes the base sequence of DNA. These mutations cannot be passed down to your offspring. Another way to get a mutation is if there was an error during DNA replication, resulting in you being born with a mutation. These mutations can be passed down to your offspring as they are gametic mutations.

In this example, this is a gametic mutation that occured due to an error during DNA replication. It is also a missense mutation, where one base is changed, resulting in the new triplet coding for a different amino acid. There are less severe mutations such as a silent mutation, which is where a single base is changed, but the resulting triplet codes for the same amino acid. Since the amino acid stays the same, so does the polypeptide chain, so it folds perfectly, resulting in a protein that can function properly. for a missense mutation, since one amino acid is changed, the polypeptide chain is going to be slightly different, so it likely won't fold propely, resulting in a protein that can't function propely.

Another type of mutation is a nonsense/stopsense mutation, which is when a base on the DNA is changed, and the resulting triplet codes for a premature stop codon. This type of mutation is more severe than the given missense mutation. Since there is an earlier stop codon, every amino acid that comes after it isn't produced, resulting in a shortened polypeptide chain, which means that the protein isn't folded properly, so the protein will likely not function at all.

For this example, the new mutation slightly alters the polypeptide chain, and therefore the protein, so instead of regular β-globin polypeptide forming, a mutated version is produced. This mutation results in sickle cell disease, an inherited inheritable disorder where some blood cells produced can't carry enough oxygen, and are also sickle-shaped and quite sticky, so they can block veins and other blood channels. The lack of oxygen that these blood cells can carry also limits the ability for respiration, resulting in less energy being made.

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 biochemical reactions that take place in the body, where the products of one reaction are the reactants for the next.

In this example, gene 1 codes for enzyme 1 which converts the precursor substate into the intermediate substrate. Gene 2 codes for enzyme 2 which converts the intermediate substrate into haem, the final product, with iron acting as a co-factor for enzyme 2.

If a severe-enough mutation were to occur to gene 1, then enzyme 1 won't be coded for and produced properly, so it won't be able to properly convert the precursor substrate into the intermediate substrate. This will result in a build-up of the precursor substrate, and very little to no intermediate substrate being produced, so very little to no haem will be produced, so there will be a lower-than-normal amount of healthy red blood cells, resulting in the individual developing anaemia.

If a severe-enough mutation were to occur to gene 2, then enzyme 2 won't be coded for and produced properly, so it won't be able to properly convert the intermediate substrate into haem, the final product. This will result in a build-up of the intermediate substrate. Very little to no haem will be produced, so there will be a lower-than-normal amount of healthy red blood cells, resulting in the individual developing anaemia.

If there was low iron, enzyme 2 won't be able to convert as much of the intermediate substrate into haem due to the lack of a co-factor. This will result in a build-up of the intermediate substrate. There will also be only a small amount of haem being produced, so there will be a lower-than-normal amount of healthy red blood cells being produced, resulting in the individual developing anaemia.

If there are high levels of lead, alot of the enzyme 2 enzymes will have their active site blocked (due to

lead being an enzyme inhibitor). This will result in a ~~build~~ build up of the intermediate substrate, ~~which~~ as well as not enough anaemia ~~is~~ being produced as the enzymes can't carry out their reactions between the intermediate substrate and ~~the~~ haem. This lack of haem will result in a lower-than-normal amount of healthy red blood cells, resulting in the individual developing anaemia

Excellence

Subject: Biology

Standard: 91159

Total score: 21

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 describes the complementary nature of codons and anticodons and acknowledges the importance of tRNA's stability.
Two	E7	This response discusses the effect of the substitution mutation on the amino acid sequence and links this to the shape and functioning of haemoglobin.
Three	E8	This response discusses the specific metabolic pathway provided and explains how mutations in gene 1, gene 2, or both can lead to anaemia. It also discusses how lead can cause anaemia by blocking enzyme 2, noting that iron is necessary for enzyme 2 to function, and links this to changes in the rate of haem formation.