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VCE Biology ¾

Gene Expression & The trp Operon I [0.3]

Workshop

Section A: Multiple Choice Questions (20 Marks)

Question 1 (1 mark)

The outcome of transcription in prokaryotes is the production of:

A. mRNA.

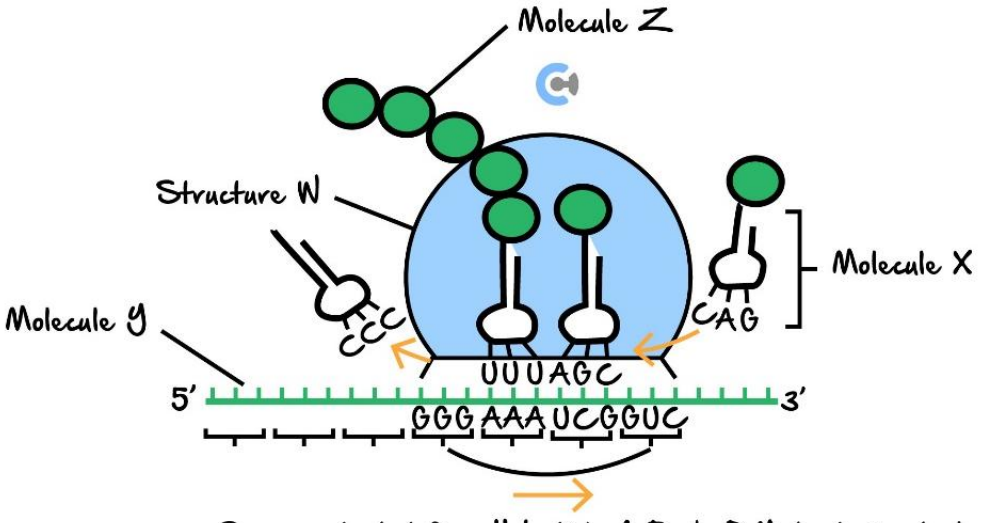
B. A protein.

C. Pre-mRNA.

D. An amino acid chain.

Question 2 (1 mark)

Consider the diagram shown below, with molecules *X*, *Y* and *Z*, and Structure *W* labelled. All arrows depict the movement of molecules or structures.



Source: adapted from H Lodish, A Berk, P Matsudaria et al., Molecular Cell Biology, 5th edition, WH Freeman and Company, New York, 2003, p.119

Which one of the following is a correct statement about the diagram above?

A. Structure *W* is a copy of template DNA found in the nucleus.

B. Molecule *X* carries an amino acid that will be added to the growing polypeptide.

C. Molecule *Y* is being read in the 3′ to 5′ direction.

D. Molecule *Z* contains a codon.

Question 3 (1 mark)

The table below shows all of the mRNA codons for the amino acid leucine and the corresponding tRNA anticodons.

mRNA codons	tRNA anticodons
UUA	AAU
UUG	AAC
CUU	GAA
CUC	GAG
CUA	GAU
CUG	GAC

Based on the information given, it is reasonable to state that:

A. Leucine is a polypeptide.

B. The genetic code is degenerate.

C. The genetic code is universal in nature.

D. Transcription of the mRNA codons gives rise to a functional protein.

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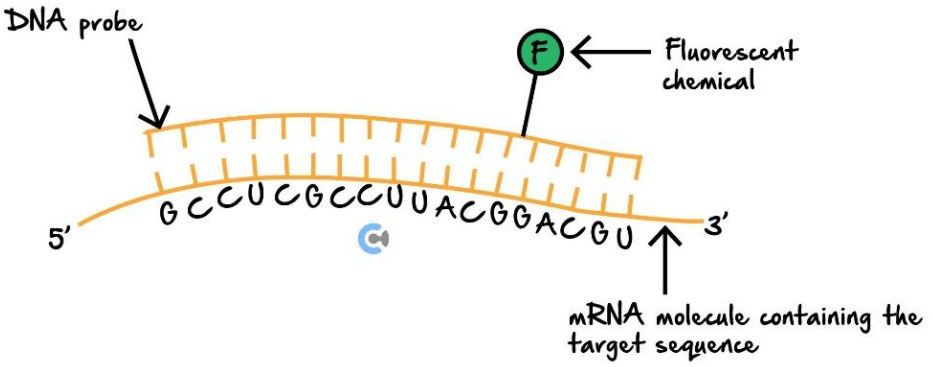
Question 4 (1 mark)

One method that is used to identify and measure quantities of mRNA molecules is called fluorescence in situ hybridisation (FISH).

The fluorescent chemical is attached to the DNA probe. When the DNA probe binds to the target mRNA sequence, as shown in the diagram the fluorescent chemical allows the mRNA molecule to be visualised.



Source: adapted from LVJC Mannack, S Eising and A Rentmeister, 'Current techniques for visualizing RNA in cells', F1000 Research, 5:F1000 Faculty Rev-775, 28 April 2016, <https://doi.org/10.12688/f1000research.8151.1>

To make the mRNA molecule containing the target sequence, a cell must:

A. Synthesise DNA polymerase.

B. Attach a poly-A tail to the 3′ end of the gene.

C. Create a nucleotide chain with a ribose-phosphate backbone.

D. Have a ready supply of the N-containing bases adenine, thymine, guanine and cytosine.

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Question 5 (1 mark)

The mRNA molecule identified by FISH is used by the cell to produce a new type of molecule.

Which one of the following statements correctly describes one aspect of the production of this new molecule?

A. The rRNA and its associated proteins create a binding site for the mRNA.

B. The tRNA delivers and attaches a nucleotide to the new growing molecule.

C. The mRNA anticodons are complementarily matched with the tRNA codons.

D. The mRNA attaches to the smaller sub-unit of the ribosome to initiate transcription.

Question 6 (1 mark)

Using the information provided in the diagram and your own knowledge of genetic coding, which of the following is correct? Assume that there are no STOP codons in the target mRNA sequence.

	Probe sequence	Number of amino acids coded by the mRNA target sequence
A.	3′ GCAGGCAUUCCGAUCCGA 5′	5
B.	3′ CGGAGCGGAATGCCTGCA 5′	5
C.	3′ CGGAGCGGAAUGCCUGCA 5′	6
D.	3′ CGGAGCGGAATGCCTGCA 5′	6

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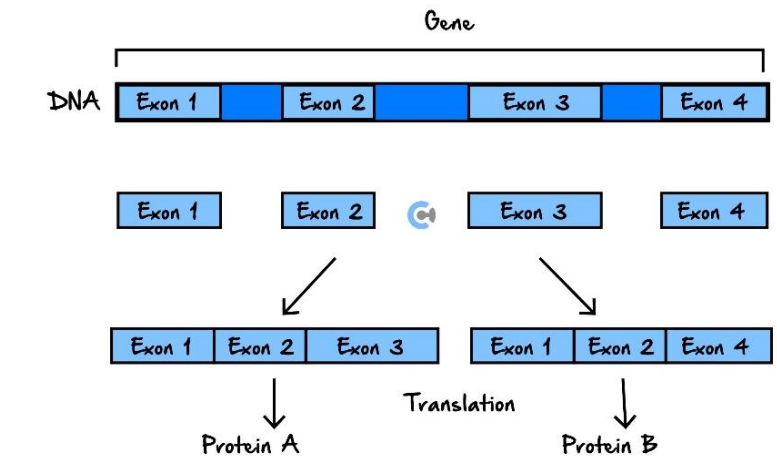
Question 7 (1 mark)



Source: https://study.com/academy/lesson/

What process does the above diagram depict?

A. Alternative splicing.

B. Translation.

C. Transcription.

D. Condensation polymerisation.

Question 8 (1 mark)

This process can explain:

A. How enzyme inhibition occurs.

B. The concept of rational drug design.

C. How the expression of a single gene can lead to the production of different proteins.

D. Why do antigens and antibodies agglutinate and are removed from the body.

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Question 9 (1 mark)

In order for a gene to be transcribed, RNA polymerase must be able to bind to the gene's:

A. Regulator region.

B. Promotor region.

C. Operator region.

D. Repressor region.

Question 10 (1 mark)

Proteins that block the movement of RNA polymerase along a gene are called:

A. Operons.

B. Activators.

C. Promotors.

D. Repressors.

Question 11 (1 mark)

Within eukaryotic cells, DNA provides a set of instructions for the manufacture of proteins.

The processes that are involved in the expression of a protein listed in the correct order are:

A. Transcription, translation and RNA processing.

B. Transcription. RNA processing and translation.

C. Translation, transcription and RNA processing.

D. Translation, RNA processing and transcription.

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Question 12 (1 mark)

The main difference between gene expression in eukaryotes compared to prokaryotes is that:

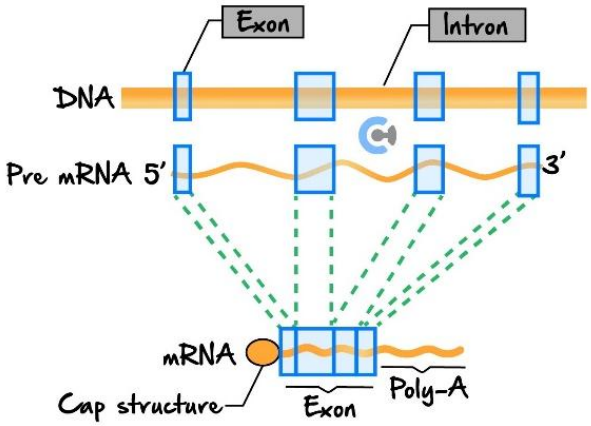
A. Prokaryotes are comprised of single-stranded DNA, whereas eukaryotes are comprised of double-stranded DNA.

B. Eukaryotes splice out introns, whereas prokaryotes do not.

C. Eukaryotes involve RNA polymerase, whereas prokaryotes do not involve RNA polymerase.

D. Prokaryotes have a repressor to deactivate genes, whereas eukaryotic genes are always active.

Question 13 (1 mark)



Source: https://cals-best.c.u-tokyo.ac.jp/images/fig/fig03_8.gif

The image above depicts:

A. Translation.

B. RNA processing.

C. Reverse transcription.

D. The polymerase chain reaction.

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Question 14 (1 mark)

The similarity between DNA and RNA polymerase is that:

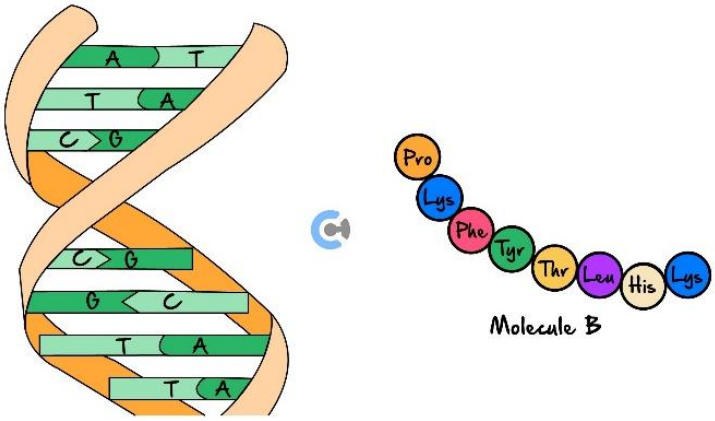
A. They both lead to the production of semi-conservative molecules.

B. They both act outside the nucleus.

C. They both create a nucleic acid strand consisting of complementary nucleotides in a 3′- 5′ direction.

D. They both read DNA in a 3′-5′ direction.

Question 15 (1 mark)



Which of the following correctly shows the functional link between molecule *A* and molecule *B* in the diagrams above?

A. Transcription then replication.

B. Translation then transcription.

C. Replication then translation.

D. Transcription then translation.

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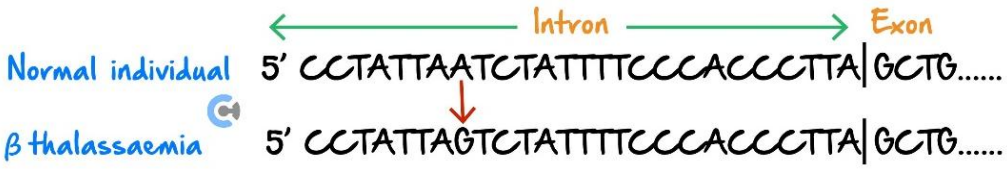
Question 16 (1 mark)

The diagram below shows a section of the DNA sequence of a normal individual and a person suffering from β thalassaemia.



The best explanation for this mutation causing β thalassaemia would be that this mutation:

A. Changes the amino acid for the codon containing the changed base.

B. Causes a frameshift in the reading of the bases.

C. Interferes with the splicing out of the intron.

D. Results in many copies of the gene being made.

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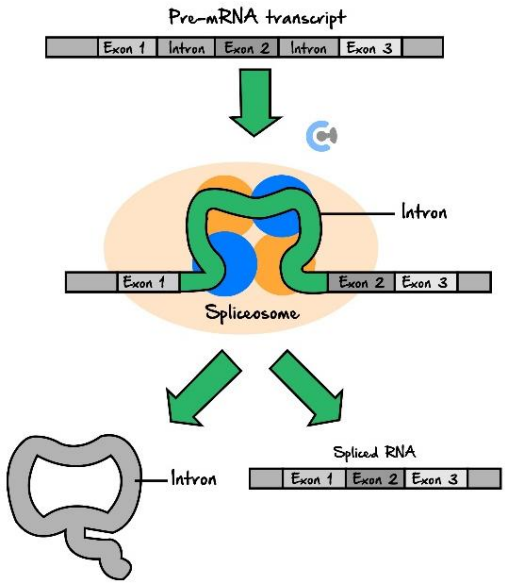
Question 17 (1 mark)

The diagram below shows a process that occurs during the post-transcriptional modification of the pre-mRNA transcript.



Which of the following statements is correct?

A. The spliced RNA will now leave the nucleus and be read by a ribosome.

B. The spliceosome is made up of DNA that will be broken down and reused.

C. A methylated cap needs to be added to the spliced RNA in front of the first exon.

D. All post-transcriptional modification processes protect mRNA from degradation by the actions of nucleases.

Question 18 (1 mark)

A small segment of DNA has the sequence:

5′ CTTAGCTAACGTAC 3′

The complementary strand will be:

A. 5′ GTACGTTAGCTAAG 3′

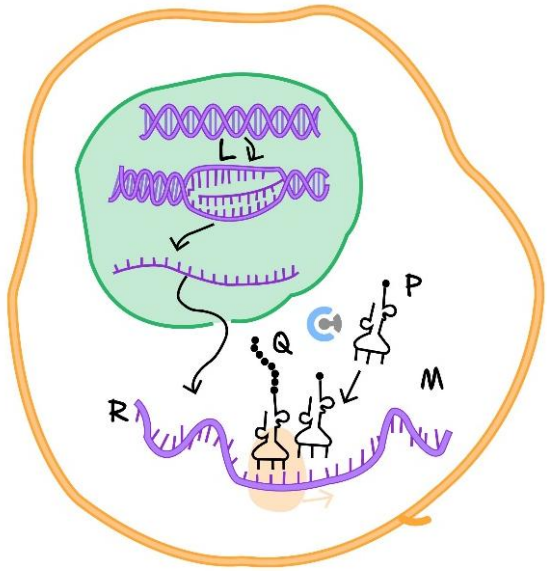
B. 5′ GAATCGATTGCATG 3′

C. 5′ GAAUCGAUUGCAUG 3′

D. 5′ GUACGUUAGCUAAG 3′

Question 19 (1 mark)

The diagram below shows a process that occurs in all nucleated cells.



Modified from http://en.wikipedia.org/wiki/Protein_biosynthesis

The correct labelling for this diagram is:

	L	***M***	***P***	***Q***	***R***
A.	Translation	Transcription	mRNA	Protein	DNA
B.	Translation	Transcription	tRNA	Polypeptide	DNA
C.	Transcription	Translation	mRNA	Protein	tRNA
D.	Transcription	Translation	tRNA	Polypeptide	mRNA

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Question 20 (1 mark)

When pre-mRNA is processed to mRNA:

A. Exons are removed, and the remaining introns have a methylated cap at the 5′ end and a poly-A-tail at the 3′ end.

B. Introns are removed, and the remaining exons have a methylated cap at the 3′ end and a poly-A-tail at the 5′ end.

C. Exons are removed, and the remaining introns have a methylated cap at the 3′ end and a at the 5′ end.

D. Introns are removed, and the remaining exons have a methylated cap at the 5′ end and a poly-A-tail at the 3′ end.

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Section B: Short Answer Questions (60 Marks)

Question 21 (2 marks)

Why might it be beneficial for a cell to have mRNA as an intermediate between DNA and protein?

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_____

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Question 22 (1 mark)

What principle ensures that the mRNA strand will be complementary to the DNA during transcription?

_____

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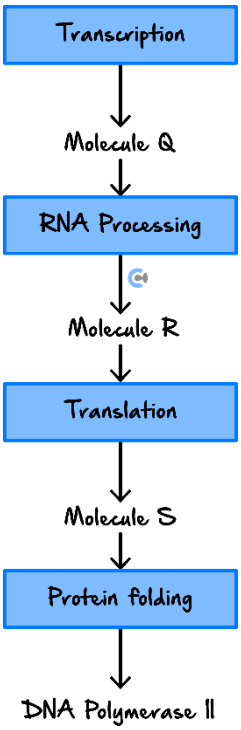
Question 23 (2 marks)

Lysozyme is an enzyme comprising a single polypeptide chain. Lysozyme is found naturally in human secretions such as tears and milk. It plays an important part in the body's defence against disease because it digests peptidoglycan which is the major component of gram-positive bacterial cell walls.

The flowchart below shows the steps involved in the synthesis of lysozyme.



a. What is the name of molecule "Q"? (1 mark)

_____

_____

b. Name a difference between molecule "Q" and molecule "R". (1 mark)

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Question 24 (5 marks)

Scientists studying the nucleus of the fruit fly *Drosophila melanogaster* observed distinct types of nucleic acid chains.

These scientists noticed that one type of nucleic acid chain was able to pass through the nuclear membrane and move to a ribosome. After the nucleic acid chain attaches to the ribosome, a polymer is produced.

a. Describe the steps occurring at the ribosome that resulted in the production of the polymer. (3 marks)

_____

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b. One particular length of nucleic acid chain passed through the nuclear membrane and coded for the production of a polymer that was 90 monomers long.

How many nucleotide bases on the nucleic acid chain were involved in the coding for this polymer?

Explain your response. (2 marks)

_____

_____

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Question 25 (4 marks)

Consider the template strand of a hypothetical gene, shown below. The exons are in bold type.

3′**TAC AAA** CCG GCC **TTT GCC AAA** CCC AAC CTA **AAT ATG AAA ATT** 5′

Note:

1. The DNA triplet **TAC** indicates START and codes for the amino acid methionine that remains in the polypeptide.
2. The DNA triplets **ATC**, **ATT** and **ACT** code for a STOP instruction.

a.

i. How many amino acids would be present in the polypeptide expressed by this gene? (1 mark)

_____

_____

ii. An allele for this gene codes for a polypeptide with only five amino acids. This is caused by a mutation in one of the exons. This mutation is a result of one nucleotide change.

By referring to the original sequence above, identify the nucleotide change that must have occurred to bring about this shorter polypeptide. (1 mark)

_____

_____

b. Write the mRNA sequence transcribed from this DNA template. (2 marks)

_____

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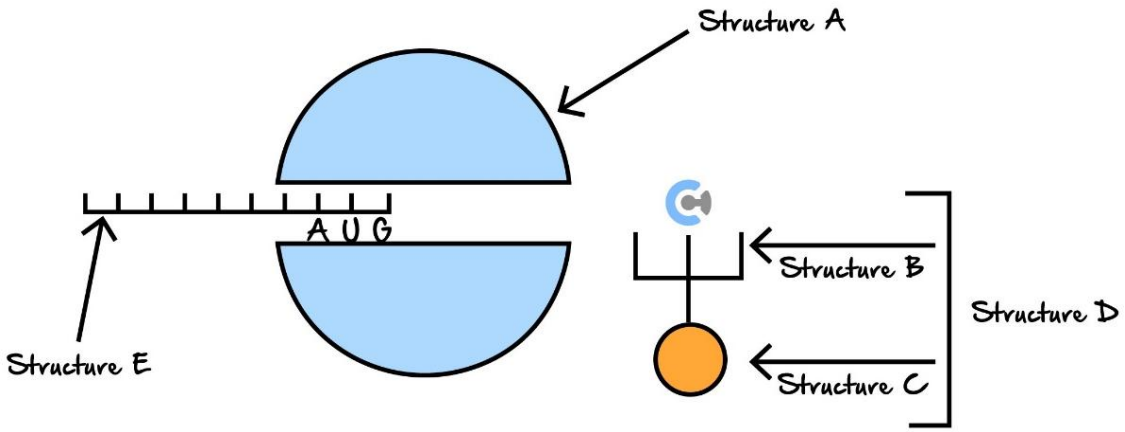
Question 26 (4 marks)

The following diagram shows part of a cellular process involved in the production of the trypsin enzyme within a pancreatic cell.



a. Identify structure D. (1 mark)

b. Outline the function of structure B and structure C. (2 marks)

c. Name the location where structure E is originally produced. (1 mark)

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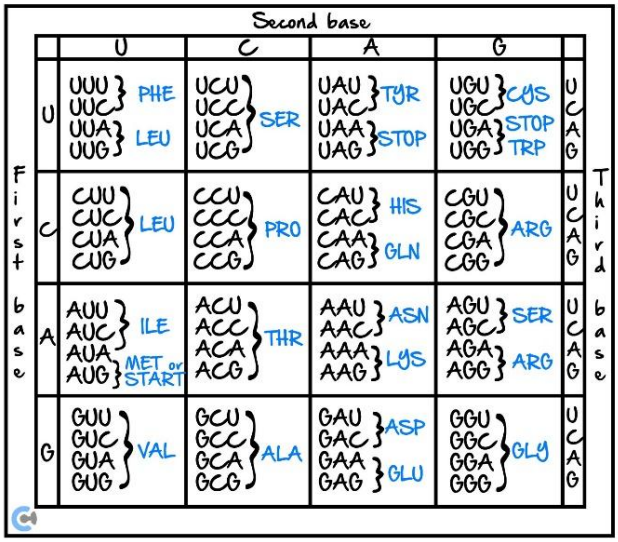
Question 27 (7 marks)

Messenger RNA Codons and Amino Acids for Which They Code



Source: http://iamqs.blogspot.com.au/2010/05/programming-fundamentals-in-biomedical.html

The following DNA sequence comes from a gene found on chromosome 4.

TTACTGGAACTGCGA

This DNA sequence contributes to producing a polypeptide which forms part of an enzyme involved in the breakdown of a specific carbohydrate.

a. Name the enzyme that is involved in converting this sequence of DNA to RNA via the process of transcription. (1 mark)

_____

_____

b. List the anticodon sequence that corresponds with this DNA sequence. (1 mark)

_____

_____

c. List the amino acid sequence that corresponds with this DNA sequence. (1 mark)

_____

_____

A mutation occurred to the original DNA sequence and the following is the new DNA sequence following the mutation:

TTACTGGCAACTGCGA

d. Name the type of mutation that occurred. (1 mark)

_____

_____

e. Describe the impact that this mutation would have on the polypeptide produced. How may this then impact on an individual? (3 marks)

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Question 28 (6 marks)

a. There are several cellular activities that directly alter the number of proteins within a yeast cell. These include transcription, RNA processing, translation, and breakdown of protein.

For each cellular activity listed in the table below, state the immediate end product of the activity. (2 marks)

Cellular activity	Immediate end product
Transcription	
RNA Processing	
Translation	
Breakdown of Protein	

b. Four *S. cerevisiae* genes and the functions of their gene products are outlined in the table below.

***S. cerevisiae* genes and the functions of their gene products**

Gene	Function of the gene product
HSP82	Active on the plasma membrane to pump protons out of the cell.
ADR1	Binds to DNA and acts as a transcriptional factor.
GCN4	Controls the activity of RNA polymerase.
AQY1	A water channel in the plasma membrane.

Identify the regulatory genes in the table above and justify your response. (2 marks)

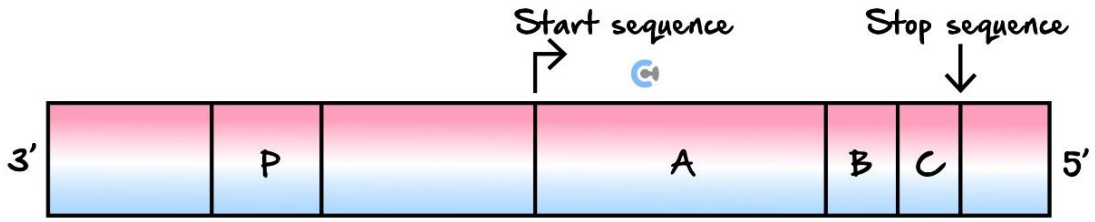
_____

_____

_____

_____

c. One particular *S. cerevisiae* protein, PFY1, assists with the organisation of a cell's cytoskeleton. In the diagram below, the gene for the PFY1 protein is shown with a promoter region (labelled *P*), start and stop transcription sequences, and a single intron (labelled *B*).



Give the general name of the sections labelled *A* and *C*, and outline the function of these sections. (2 marks)

_____

_____

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Question 29 (10 marks)

Klotho is a fascinating protein that has garnered significant attention in ageing research due to its potential anti-ageing properties. It was originally identified in mice, where a mutation in the Klotho gene resulted in a syndrome that mimicked accelerated human ageing, including shortened lifespan, infertility, osteoporosis, and skin atrophy.

In humans, Klotho is primarily expressed in the kidney, brain, and reproductive organs. It functions as a co-receptor for fibroblast growth factors (FGFs) and is crucial in regulating phosphate and calcium homeostasis in the body. This regulation is essential for maintaining healthy bone density and preventing vascular calcification.

Beyond its role in mineral metabolism, Klotho has been shown to exert protective effects against oxidative stress and inflammation, which are key contributors to ageing and age-related diseases. Interestingly, higher levels of Klotho in the body have been associated with increased longevity and improved cognitive function.

However, one of the detriments of Klotho is that any regulation of it would be difficult to manage given that shares a gene in the code with Glucagon, a blood sugar-controlling hormone. Any increase in glucagon may cause dangerous increases in blood sugar.

a. Explain how a single gene can code for multiple different proteins. (3 marks)

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The first step in producing Klotho in the body is transcription.

b. Why must the DNA be unwound before it can be read during transcription? (1 mark)

_____

_____

c. What direction is the template strand read in during transcription? Explain why this is the case. (3 marks)

d. What happens to the primary transcript after transcription before it is converted into a polypeptide? (3 marks)

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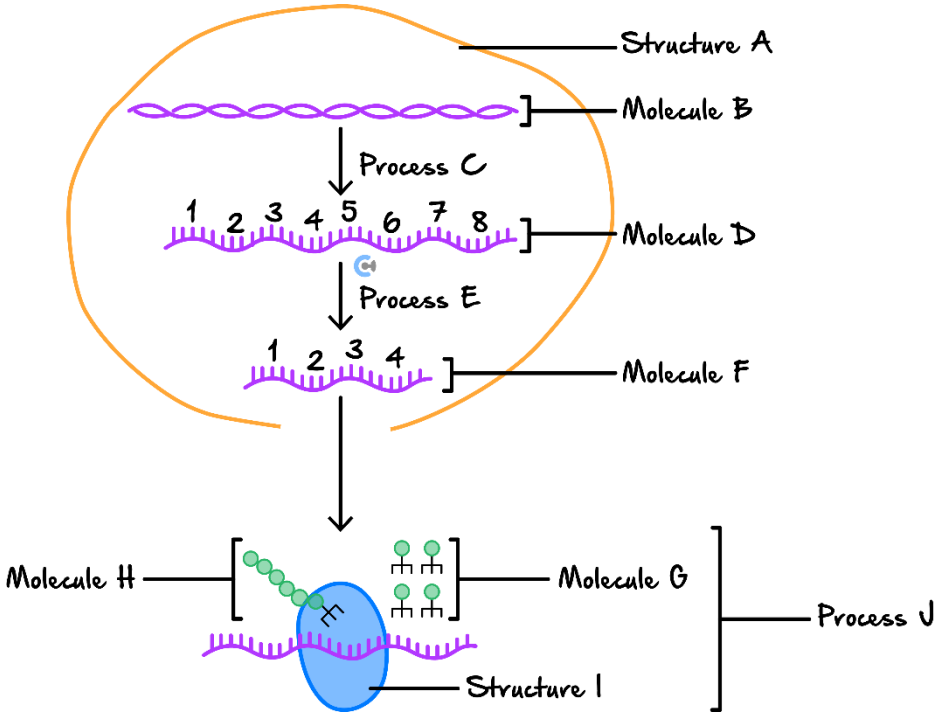
Question 30 (9 marks)

A simplified diagram of gene expression is shown below. Labels *A*-*G* represent various structures, molecules, and processes involved in gene expression.



a.

i. Identify structure *A*. (1 mark)

_____

ii. Identify structure *E*. (1 mark)

_____

iii. RNA polymerase is involved in the production of molecule *D*.

Identify molecule *D*. (1 mark)

_____

b.

i. Molecule *G* translates a message.

Identify the **two** parts of molecule *G* that enable it to do this. (2 marks)

_____

_____

ii. Molecule *D* has eight sections. Each section comprises 30 nucleotides.

Based on this information, determine and justify the length and composition of molecule *H*, which is formed at the end of process *J*. In your response, identify any relevant structures, molecules and processes. (4 marks)

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Question 31 (4 marks)

Many structures have important functions in gene expression.

a. Explain the function of RNA polymerase in transcription. (2 marks)

_____

_____

_____

_____

b. The next stage in the production of pepsin is translation which happens at the ribosomes. Describe the relationship between mRNA and tRNA in this process. (2 marks)

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Question 32 (2 marks)

Identify **TWO** differences in gene expression between eukaryotes and prokaryotes.

Question 33 (4 marks)

Outline two events that happen during RNA processing and the significance of both to gene expression.

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