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VCE Biology ¾

Gene Expression & The trp Operon [1.3]

Test Solutions

40 Marks. 1 Minute Reading. 32 Minutes Writing.

Results:

Test Questions	_____ / 35
Extension	_____ / 5

Section A: Test Questions (35 Marks)

INSTRUCTION: 35 Marks. 1 Minute Reading. 28 Minutes Writing.

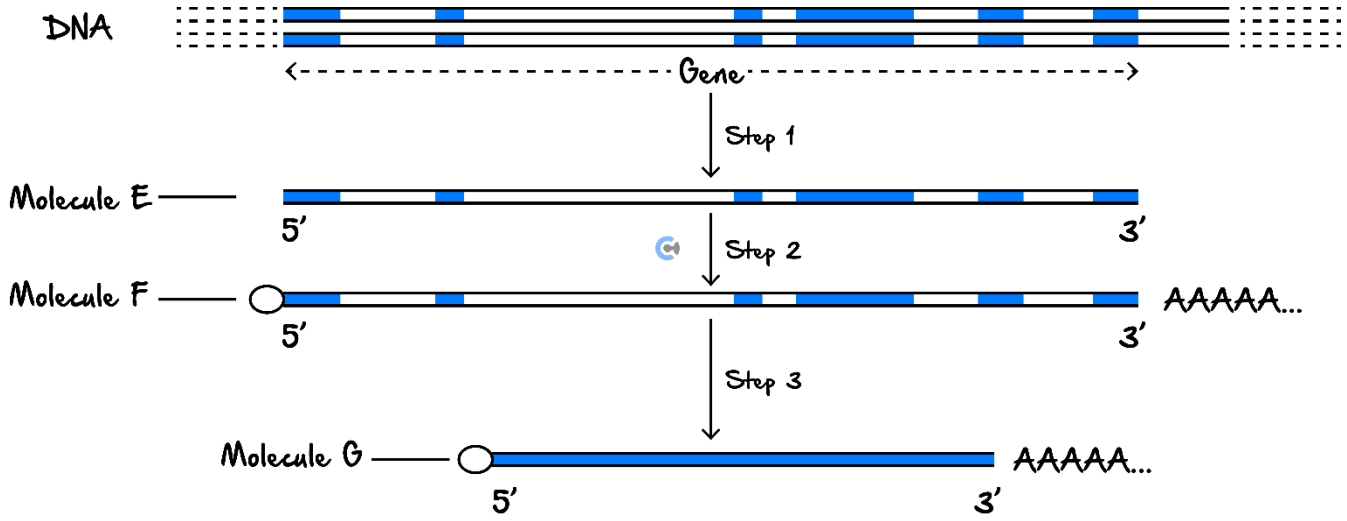
Question 1 (4 marks)

Tick whether the following statements are **true** or **false**.

	True	False
a. Transcription is the process by which DNA is copied into mRNA.	✓	
b. RNA polymerase catalyses the binding of DNA nucleotides during transcription.		✓
c. The mRNA strand produced during transcription is complementary to the DNA template strand.	✓	
d. The addition of a methyl cap to the 5′ end of mRNA prevents degradation and facilitates translation.	✓	
e. Translation involves the synthesis of polypeptides from mRNA templates.	✓	
f. Ribosomes read mRNA in the 5′ to 3′ direction during translation.	✓	
g. A tRNA molecule with the anticodon complementary to the mRNA start codon binds to the ribosome during initiation.	✓	
h. The attenuator loop in the trp operon forms when tryptophan is scarce.		✓
i. Regulatory genes code for proteins that influence the expression of structural genes.	✓	
j. The small subunit of the ribosome is responsible for catalysing peptide bond formation.		✓
k. Transcription and translation occur simultaneously in eukaryotic cells.		✓

Question 2 (1 mark)

The following diagram shows some of the steps in the production of a protein within a cell.



Which one of the following is a correct statement?

A. Step 1 represents the process of transcription.

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B. Molecule F undergoes alternative splicing during processing.

C. RNA polymerase is involved in the addition of the poly-A tail.

D. Step 3 represents the export of mature mRNA from the nucleus.

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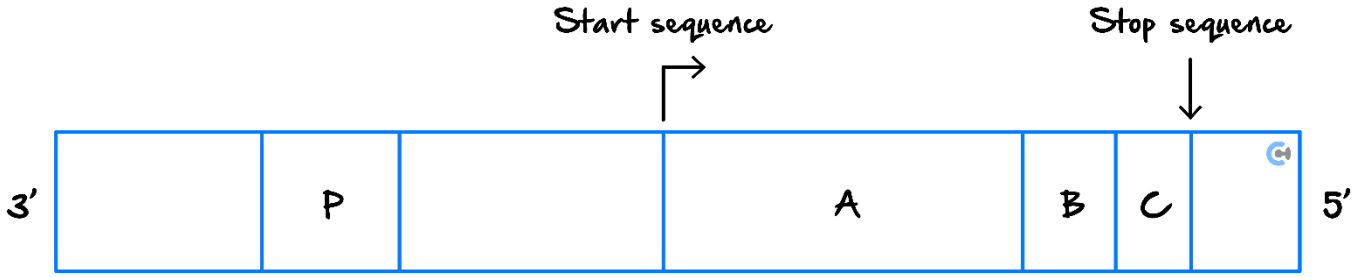
Question 3 (1 mark)

The diagram below shows the processes of gene expression.



Which of the following modifications ensures the stability of mRNA after transcription?

A. Removal of introns by splicing.

B. Addition of a methyl cap at the 5′ end.

C. Binding of RNA polymerase to the promoter.

D. Formation of peptide bonds between amino acids.

Question 4 (1 mark)

A mutation occurs in the spliceosome that prevents introns from being removed. Which of the following is the most likely consequence?

A. Translation of a functional protein occurs normally.

B. Transcription stops before pre-mRNA is produced.

C. mRNA is exported to the ribosome but contains incorrect sequences.

D. A poly-A tail cannot be added to the pre-mRNA molecule.

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Question 5 (1 mark)

In the trp operon of *E. coli*, what would happen if a mutation occurred in the regulatory gene preventing the repressor protein from binding to tryptophan?

A. The operon would be permanently repressed, regardless of tryptophan levels.

B. The operon would be permanently active, regardless of tryptophan levels.

C. Transcription of the operon would occur only when tryptophan is present.

D. The attenuator loop would fail to form, causing continuous transcription.

Question 6 (1 mark)

Which of the following correctly describes the role of attenuation in regulating the trp operon?

A. It prevents transcription from starting when tryptophan levels are high.

B. It halts the translation of the structural genes when tryptophan levels are low.

C. It allows transcription to terminate prematurely when tryptophan levels are high.

D. It enables the repressor protein to bind more tightly to the operator.

Question 7 (8 marks)

Gene expression is the process by which proteins are able to be produced from DNA.

a. Describe the role of complementary base pairing in transcription. (2 marks)

Complementary bases come and bind to the exposed template, ensuring that the new mRNA strand is complementary and thus carries a correct copy of the genetic instructions of that gene.

b. After transcription, the DNA template sequence is modified and then leaves the nucleus of a eukaryotic cell.

Identify **two** events that occur during the modification of the DNA template sequence. (2 marks)

Any two of:

- The introns are removed from the pre-mRNA.
- The remaining exons are joined together.
- A methylated cap is added to stabilise the mRNA.
- A poly A tail is added to stabilise the mRNA.

2 marks

1 mark for each event identified.

c. Nucleotides 9-15 are removed from the DNA template sequence prior to translation.

i. Determine the nucleotide sequence after this modification. (1 mark)

UCA – GGC – AUG – GCC – AAC

ii. The table below lists codons and their corresponding amino acids.

First base	Second base: U	Second base: C	Second base: A	Second base: G	Third base
U	Phe	Ser	Tyr	Cys	U
	Phe	Ser	Tyr	Cys	C
	Leu	Ser	Stop	Stop	A
	Leu	Ser	Stop	Trp	G
C	Leu	Pro	His	Arg	U
	Leu	Pro	His	Arg	C
	Leu	Pro	Gln	Arg	A
	Leu	Pro	Gln	Arg	G
A	Ile	Thr	Asn	Ser	U
	Ile	Thr	Asn	Ser	C
	Ile	Thr	Lys	Arg	A
	Met	Thr	Lys	Arg	G
G	Val	Ala	Asp	Gly	U
	Val	Ala	Asp	Gly	C
	Val	Ala	Glu	Gly	A
	Val	Ala	Glu	Gly	G

Using the information in the table, determine the polypeptide sequence after translation. (1 mark)

Ser-Gly-Met-Ala-Asn 1 mark

*Note: Consequential on answer to **Question 1c.i.***

d. The polypeptide formed from the DNA template sequence is coded by a single gene; however, there are multiple different polypeptides that can be coded for by this gene.

Identify and explain the process that allows this to occur. (2 marks)

alternative splicing 1 mark

This process may include or exclude particular exons from the mRNA produced by the gene. As a result, the gene's exons can be combined into different arrangements, which leads to a variety of mRNA strands and thus a variety of polypeptides. 1 mark

Question 8 (6 marks)

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

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

C	d product
F	
protein	

Acceptable responses were as follows.

Cellular activity	Immediate end product
transcription	pre-mRNA
RNA processing	mRNA
translation	polypeptide
breakdown of protein	amino acids

b. Four genes from *D. melanogaster* and the functions of their gene products are outlined in the table below.

Gene	Function of Gene Product
HSP70	Assists in protein folding under stress conditions.
TEIID	Binds to the promoter region and assists in transcription initiation.
DSP542	Prevents transcription of neural genes via factors.
AquaPl	Forms water channels in cell membranes.

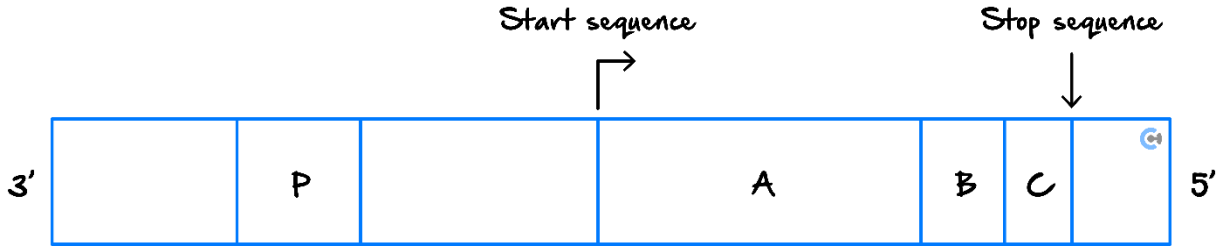
Identify the regulatory genes in the table and justify your response. (2 marks)

The correct response was TFIID and DSP542.

Both of their gene products regulate, for example, transcription.

Many students were able to identify the regulatory genes. However, it was common for students to repeat the function of the gene product information given in the table, which was not an acceptable justification.

c. One particular *D. melanogaster* protein, Actin-A1, plays a role in cytoskeleton formation. Below is a diagram of the gene for Actin-A1, showing a promoter region (labelled *P*), start and stop sequences, and one intron (labelled *B*).



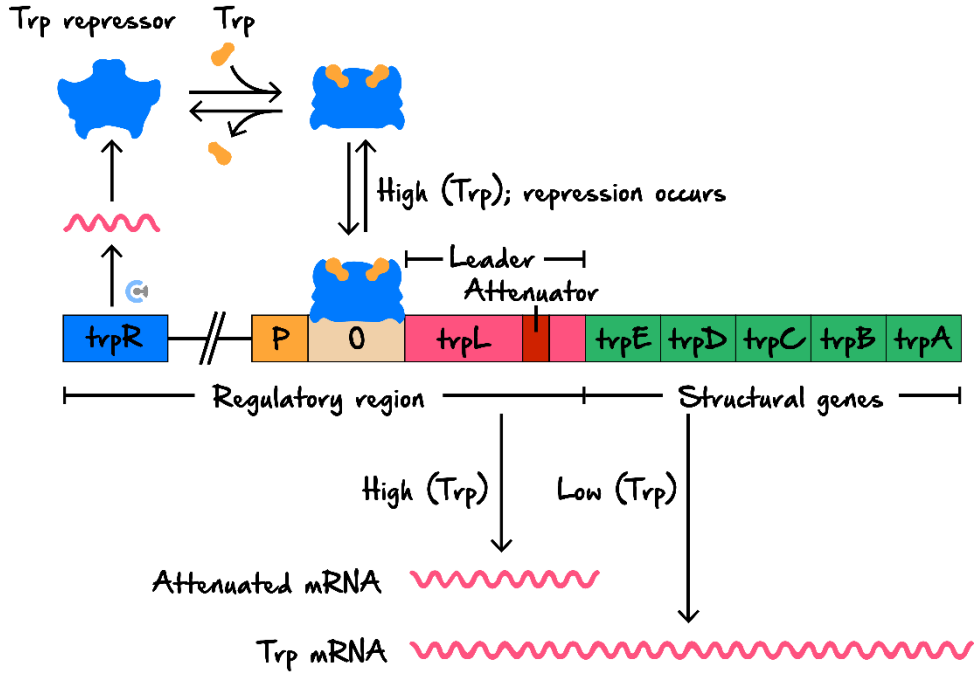
Give the general name of the sections labelled *A* and *C* and outline the function of these sections. (2 marks)

The correct answer was exons, with a suitable function such as:

- code for a protein
- be translated into a protein
- code for mRNA
- be transcribed into mRNA.

Question 9 (6 marks)

The diagram below shows the trp operon.



Source: <https://en.wikipedia.org/wiki/File:Trpopcron.svg

In $E.coli$ there are two mechanisms that repress the genes E, D, C, B and A in the trp operon.

a. Explain how one of these mechanisms prevents the formation of tryptophan in a high tryptophan environment. (3 marks)

One of the following for 3 marks:
Tryptophan molecules present binds to repressor protein (1). Activated repressor protein / tryptophan complex binds to the operator region of gene (1) preventing the RNA polymerase from binding, preventing transcription (1).
OR
Attenuation: High tryptophan allows leader sequence to be transcribed / not paused at trp codons (1). A hairpin loop forms between segments 3 and 4 (1). Ribosome detaches from short mRNA sequence (1), stopping transcription from being completed. *3 marks*

If the level of tryptophan is low, the *E.coli* will transcribe and translate the operon. Three forms of RNA are involved in these processes.

b. Describe the role of each type of RNA. (3 marks)

mRNA: messenger RNA provides the template for protein production (1) (not carries the information out of the nucleus).
tRNA: transport RNA carries a specific amino acid to the mRNA codon (1).
rRNA: ribosomal RNA reads the codon on the mRNA and bonds the specific amino acids together in the correct order (1). *3 marks*

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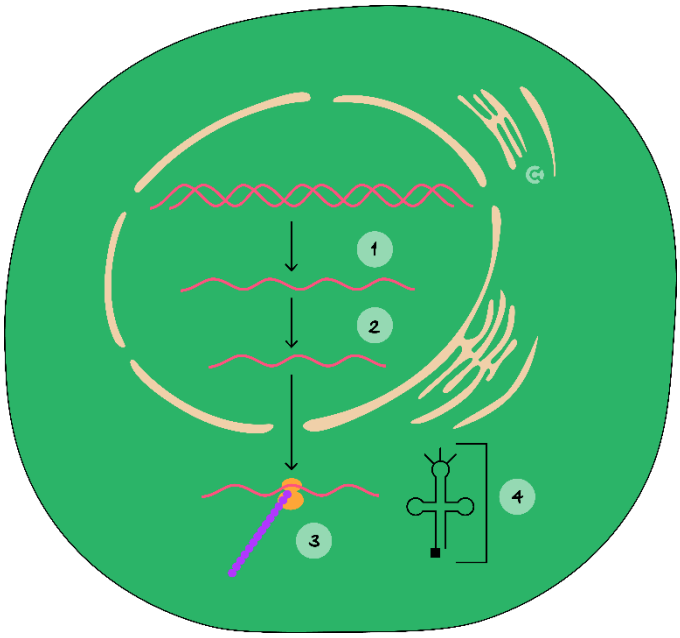
Question 10 (6 marks)

The following diagram outlines events associated with the production of a polypeptide chain in a eukaryotic cell.



a. What is the name of the process at step 1? (1 mark)

Questions 2a–c.						
Marks	**0**	**1**	**2**	**3**	**4**	**Average**
%	24	13	23	19	21	**2.0**

Question 2a.
Transcription

b.

i. Name the product of step 1. (1 mark)

Either of:
- Pre-mRNA
- primary RNA.

mRNA was not an acceptable answer.

ii. Outline what occurs at step 2. (1 mark)

Either of:
- introns are removed
- any other post transcriptional modification.

c. Name the event that occurs at structure 3. (1 mark)

One of:
- translation
- polypeptide synthesis
- protein synthesis.

d.

i. Name the structure at 4. (1 mark)

Marks	0	1	2	Average
%	47	15	38	0.9

2di.
Transfer RNA (tRNA)

ii. Outline the function of the structure you named in **part d.i.** (1 mark)

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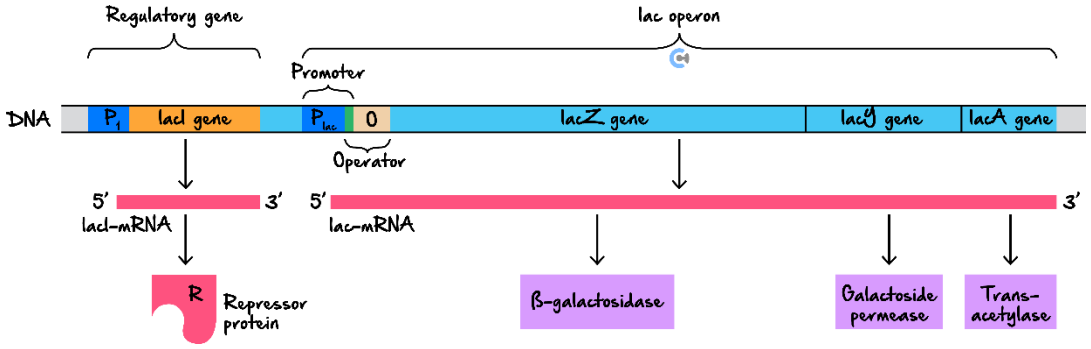
Section B: Extension (5 Marks)

INSTRUCTION: 5 Marks. 4 Minutes Writing.

Question 11 (5 marks)

The diagram below shows gene regulation in the lac operon.



a. State one benefit of gene regulation to the cells of an organism. (1 mark)

Any one of:

Saves energy OR saves resources OR prevents accumulation of products 1 mark

b. Explain the function of the repressor protein in gene regulation in the lac operon. (2 marks)

The repressor protein determines whether the genes of the *lac* operon will be expressed or not by controlling whether transcription will or will not occur. (1)

Then a brief explanation:

When the repressor protein attaches to the operator region of the operon, mRNA is prevented from attaching to the promoter region, therefore transcription of the genes of the operon is prevented (genes are repressed/turned off)

OR

When the repressor protein is changed in shape, it cannot bind to the operator and so the mRNA can bind to the promoter region allowing transcription to begin (genes are expressed/turned on) (1)

2 marks

c. Explain why there is a low basal rate of production of the repressor protein. (2 marks)

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