25.1 Protein synthesis

Name: _____ Class: _____ Date: _____ **Total: 20 marks**

KEY WORDS transcription • translation • codon • anticodon • RNA polymerase RNA • degenerate

Objective

Build the skills to answer exam questions on **protein synthesis** : transcription, translation, the genetic code, and the roles of mRNA, tRNA and ribosomes.

You must be able to:

- describe transcription by RNA polymerase, using the template strand
- describe translation: mRNA codons, tRNA anticodons and ribosomes
- use the genetic code to work out an amino acid sequence, and explain why the code is degenerate and universal
- explain how a change in the base sequence can change a protein

1 Key knowledge and worked examples

■ Protein synthesis

Transcription (in the nucleus): **RNA polymerase** separates the DNA strands and joins RNA nucleotides that pair with the **template strand** (A–U, T–A, C–G, G–C). The **mRNA** has the same sequence as the **coding strand**, with **U** instead of T.

Translation (at ribosomes): the mRNA binds to a **ribosome**; each **codon** (three bases) pairs with the **anticodon** of a **tRNA** carrying a specific amino acid; the ribosome joins amino acids by **peptide bonds**; translation starts at **AUG** (start) and ends at a **stop codon**.

The genetic code: $4^3 = 64$ codons for 20 amino acids, so the code is **degenerate** (several codons per amino acid). It is nearly **universal**: the same codons mean the same amino acids in almost all organisms, which lets genes be transferred between species (e.g. human insulin made by bacteria).

codon	amino acid	codon	amino acid
AUG	Met (start)	GCU	Ala
UUU	Phe	GGC	Gly
CAU	His	UAA	stop

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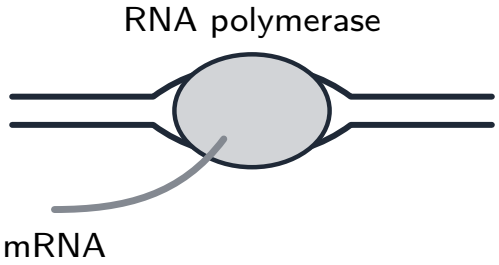
Mutation link: changing one base can change one codon, so a different amino acid may be placed, changing the protein's shape (e.g. sickle cell: GAG → GTG gives valine instead of glutamic acid).

Worked example. Template DNA TAC AAA GTA → mRNA AUG UUU CAU → Met–Phe–His.

Answer shapes: codon (mRNA) and anticodon (tRNA) pair; three bases code for one amino acid.

2 Practice

2.1 State the role of RNA polymerase. [2]

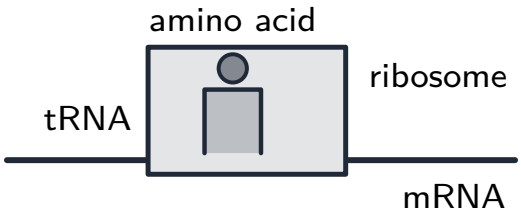


2.2 A template strand of DNA has the sequence TAC CCG ATT. Write the mRNA sequence and use the table in the key-knowledge panel to give the amino acids. Explain what happens at the last codon. [3]



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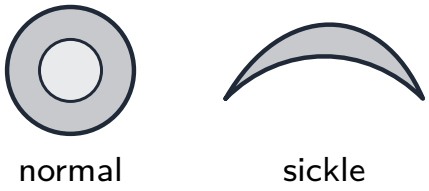
2.3 Explain the roles of tRNA and ribosomes in translation. [3]



3 Exam-style questions

3.1 Sickle cell anaemia is caused by a change in the gene for the β-chain of haemoglobin.

	DNA coding strand	**mRNA codon**	**amino acid**
normal	GAG	GAG	glutamic acid
sickle	GTG		valine



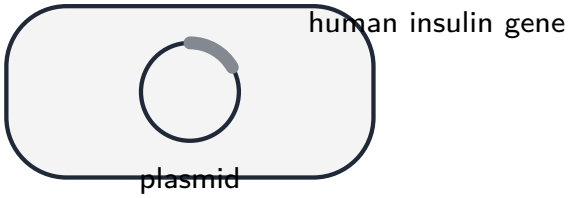
(a) Give the mRNA codon for the sickle allele. [1]

(b) Explain how this change produces a different protein. [3]

(c) Explain why some base changes do not change the protein. [2]

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3.2 Human insulin is now made by bacteria that contain the human insulin gene.



(a) Explain why bacteria can make a human protein from a human gene. [2]

(b) State where transcription and translation happen in a human cell. [2]

(c) Explain why there are 64 codons but only 20 amino acids. [2]

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Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

2.1

unwinds / separates the DNA strands; joins RNA nucleotides complementary to the template strand to make mRNA

2.2

mRNA: AUG GGC UAA; Met–Gly; UAA is a stop codon, so translation ends and the polypeptide is released

2.3

each tRNA carries a specific amino acid and has an anticodon; the anticodon pairs with a complementary mRNA codon in the ribosome; the ribosome joins the amino acids with peptide bonds and moves along the mRNA

3.1

(a) GUG

(b) the base substitution changes one codon in the mRNA; a tRNA brings valine instead of glutamic acid; the haemoglobin has a different shape / sticks together, making cells sickle-shaped

(c) the code is degenerate: several codons code for the same amino acid; so the new codon may still code for the same amino acid

3.2

(a) the genetic code is universal; so the bacterial ribosomes and tRNAs read the codons as the same amino acids

(b) transcription: nucleus; translation: ribosomes in the cytoplasm / on the rough ER

(c) $4^3 = 64$ combinations of three bases; most amino acids have more than one codon / some codons are stop signals