30.1 Protein synthesis

Name: _____ Class: _____ Date: _____ **Total: 26 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
- explain intron removal, alternative splicing, polysomes and the modification of proteins after translation

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).

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

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).

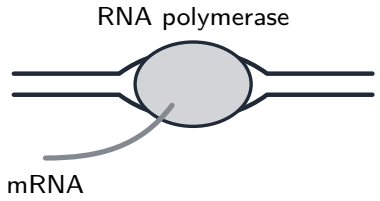
HL: eukaryotic genes have **introns** (non-coding) and **exons**. The first RNA is processed: introns are cut out, and **alternative splicing** joins exons in different combinations, so one gene can code for several proteins. Many ribosomes can translate one mRNA at once (**polysome**). Some polypeptides are modified after translation, e.g. **insulin** is cut from proinsulin. Unwanted proteins are broken down by **proteasomes**.

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]



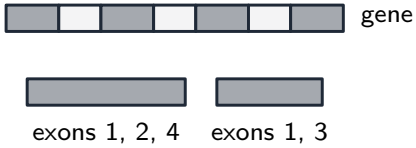
2.2 A template strand of DNA has the sequence TAC CCG ATT. Write the mRNA sequence and use the table in the key-knowledge panel to give the amino acids. Explain what happens at the last codon. [3]



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

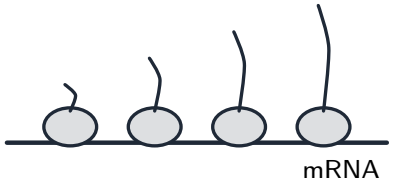


2.4 Explain how one gene can code for more than one protein. [3]



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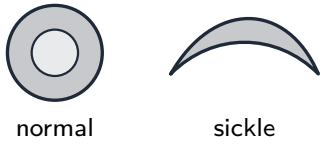
2.5 State what a polysome is, and explain its advantage. [3]



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

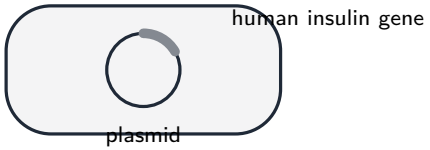


(a) Give the mRNA codon for the sickle allele. [1]

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

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

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

2.4

the gene has exons and introns; introns are removed from the RNA; alternative splicing joins different combinations of exons, giving different mRNAs and proteins

2.5

several ribosomes translating the same mRNA at the same time; many copies of the protein are made quickly

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

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