

Protein Synthesis

Key ideas

Transcription (nucleus): RNA polymerase reads the DNA **template** strand 3' → 5' and builds mRNA 5' → 3'. In RNA, **U** replaces T (A–U, T–A, G–C, C–G).

Translation (ribosome): the mRNA is read in **codons** of three bases, starting at AUG. tRNAs with matching **anticodons** bring amino acids. Translation stops at UAA, UAG or UGA.

Mutations: silent (same amino acid), missense (different amino acid), nonsense (early stop), frameshift (base added or deleted).

A DNA vs RNA

2 marks

½ mark per row.

	Feature	DNA	RNA
1.	Sugar		
2.	Bases		
3.	Number of strands		
4.	Where it works		

B Transcription

3 marks

5. Transcribe this DNA template strand into mRNA: 3' - T A C G G A T T C A C T - 5'

6. Transcribe: 3' - T A C C G T T G G A T C - 5'

7. Where in the cell does transcription happen, and which enzyme carries it out?

C Translation

4 marks

Codon chart (mRNA): first base on the left, second base on top, third base on the right					
	U	C	A	G	
U	UUU Phe UUC Phe UUA Leu UUG Leu	UCU Ser UCC Ser UCA Ser UCG Ser	UAU Tyr UAC Tyr UAA Stop UAG Stop	UGU Cys UGC Cys UGA Stop UGG Trp	U C A G
C	CUU Leu CUC Leu CUA Leu CUG Leu	CCU Pro CCC Pro CCA Pro CCG Pro	CAU His CAC His CAA Gln CAG Gln	CGU Arg CGC Arg CGA Arg CGG Arg	U C A G
A	AUU Ile AUC Ile AUA Ile AUG Met	ACU Thr ACC Thr ACA Thr ACG Thr	AAU Asn AAC Asn AAA Lys AAG Lys	AGU Ser AGC Ser AGA Arg AGG Arg	U C A G
G	GUU Val GUC Val GUA Val GUG Val	GCU Ala GCC Ala GCA Ala GCG Ala	GAU Asp GAC Asp GAA Glu GAG Glu	GGU Gly GGC Gly GGA Gly GGG Gly	U C A G

8. Translate this mRNA into amino acids: 5' - A U G C C U A A G U G A - 3'

9. Translate: 5' - A U G G C A U G G C A U U A A - 3'

10. A codon on the mRNA is 5'-CCU-3'. What is the anticodon on the tRNA that reads it?

11. Why is AUG called the start codon?

D From DNA to protein

2 marks

12. A DNA template strand reads 3' - T A C A A A C C G A T T - 5'. Write the mRNA and the amino acid sequence. (2 marks)

E Mutations

5 marks

The normal mRNA is 5' - AUG GAG CCU UGG AAA UAA - 3' (Met-Glu-Pro-Trp-Lys). For each mutated mRNA, translate it and name the type of mutation: silent, missense, nonsense or frameshift.

13. 5' - AUG GAA CCU UGG AAA UAA - 3'

14. 5' - AUG GUG CCU UGG AAA UAA - 3'

15. 5' - AUG GAG CCU UGA AAA UAA - 3'

16. 5' - AUG AGC CUU GGA AAU AA - 3' (one G deleted)

17. Why is a frameshift mutation usually more harmful than a single-base substitution?

F The steps of protein synthesis

3 marks

18. Put the steps in order. (2 marks)

- P mRNA leaves the nucleus through a nuclear pore
- Q RNA polymerase transcribes the DNA template into mRNA
- R tRNAs bring amino acids that match each codon
- S The ribosome reaches a stop codon and releases the polypeptide
- T A ribosome attaches to the mRNA at the start codon AUG

____ → ____ → ____ → ____ → ____

19. What is the job of tRNA in translation?

G Spot the mistake

2 marks

20. A student writes: "During transcription, adenine on the DNA pairs with thymine on the mRNA." Explain the error and correct it.

21. A student writes: "Each amino acid is coded for by one base on the mRNA." Explain the error and correct it.

Protein Synthesis

ANSWER KEY

Key ideas

Transcription (nucleus): RNA polymerase reads the DNA **template** strand 3' → 5' and builds mRNA 5' → 3'. In RNA, **U** replaces T (A–U, T–A, G–C, C–G).

Translation (ribosome): the mRNA is read in **codons** of three bases, starting at AUG. tRNAs with matching **anticodons** bring amino acids. Translation stops at UAA, UAG or UGA.

Mutations: silent (same amino acid), missense (different amino acid), nonsense (early stop), frameshift (base added or deleted).

A DNA vs RNA

2 marks

½ mark per row.

	Feature	DNA	RNA
1.	Sugar	Deoxyribose	Ribose
2.	Bases	A, T, G, C	A, U, G, C
3.	Number of strands	Two (double helix)	One
4.	Where it works	Stays in the nucleus	Leaves the nucleus (mRNA)

B Transcription

3 marks

5. Transcribe this DNA template strand into mRNA: 3' - T A C G G A T T C A C T - 5'

5' - A U G C C U A A G U G A - 3'

6. Transcribe: 3' - T A C C G T T G G A T C - 5'

5' - A U G G C A A C C U A G - 3'

7. Where in the cell does transcription happen, and which enzyme carries it out?

In the nucleus, by RNA polymerase

C Translation

4 marks

Codon chart (mRNA): first base on the left, second base on top, third base on the right					
	U	C	A	G	
U	UUU Phe UUC Phe UUA Leu UUG Leu	UCU Ser UCC Ser UCA Ser UCG Ser	UAU Tyr UAC Tyr UAA Stop UAG Stop	UGU Cys UGC Cys UGA Stop UGG Trp	U C A G
C	CUU Leu CUC Leu CUA Leu CUG Leu	CCU Pro CCC Pro CCA Pro CCG Pro	CAU His CAC His CAA Gln CAG Gln	CGU Arg CGC Arg CGA Arg CGG Arg	U C A G
A	AUU Ile AUC Ile AUA Ile AUG Met	ACU Thr ACC Thr ACA Thr ACG Thr	AAU Asn AAC Asn AAA Lys AAG Lys	AGU Ser AGC Ser AGA Arg AGG Arg	U C A G
G	GUU Val GUC Val GUA Val GUG Val	GCU Ala GCC Ala GCA Ala GCG Ala	GAU Asp GAC Asp GAA Glu GAG Glu	GGU Gly GGC Gly GGA Gly GGG Gly	U C A G

8. Translate this mRNA into amino acids: 5' - A U G C C U A A G U G A - 3'

Met-Pro-Lys (UGA = stop)

9. Translate: 5' - A U G G C A U G G C A U U A A - 3'

Met-Ala-Trp-His (UAA = stop)

10. A codon on the mRNA is 5'-CCU-3'. What is the anticodon on the tRNA that reads it?

3'-GGA-5' (complementary and antiparallel)

11. Why is AUG called the start codon?

It signals the ribosome where to begin translation, and codes for methionine (Met).

D From DNA to protein

2 marks

12. A DNA template strand reads 3' - T A C A A A C C G A T T - 5'. Write the mRNA and the amino acid sequence. (2 marks)

mRNA 5'-AUG UUU GGC UAA-3' → Met-Phe-Gly, then stop

E Mutations

5 marks

The normal mRNA is 5' - AUG GAG CCU UGG AAA UAA - 3' (Met-Glu-Pro-Trp-Lys). For each mutated mRNA, translate it and name the type of mutation: silent, missense, nonsense or frameshift.

13. 5' - AUG GAA CCU UGG AAA UAA - 3'

Silent: Met-Glu-Pro-Trp-Lys. GAG → GAA still codes for Glu, so the protein is unchanged.

14. 5' - AUG GUG CCU UGG AAA UAA - 3'

Missense: Met-Val-Pro-Trp-Lys. GAG → GUG changes Glu to Val; this is the sickle-cell mutation.

15. 5' - AUG GAG CCU UGA AAA UAA - 3'

Nonsense: Met-Glu-Pro. UGG (Trp) → UGA, a stop codon, so the protein is cut short.

16. 5' - AUG AGC CUU GGA AAU AA - 3' (one G deleted)

Frameshift: Met-Ser-Leu-Gly-Asn. One base deleted, so every codon after it is read differently.

17. Why is a frameshift mutation usually more harmful than a single-base substitution?

It shifts the reading frame, so every codon after the mutation changes, often adding an early stop codon.

F The steps of protein synthesis

3 marks

18. Put the steps in order. (2 marks)

- P mRNA leaves the nucleus through a nuclear pore
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Q → P → T → R → S

19. What is the job of tRNA in translation?

tRNA carries a specific amino acid to the ribosome and matches it to the mRNA codon using its anticodon.

G Spot the mistake

2 marks

20. A student writes: "During transcription, adenine on the DNA pairs with thymine on the mRNA." Explain the error and correct it.

RNA has no thymine. Adenine on the DNA pairs with uracil on the mRNA.

21. A student writes: "Each amino acid is coded for by one base on the mRNA." Explain the error and correct it.

Each amino acid is coded for by a codon of three bases. That gives 64 codons for 20 amino acids.