Translation Overview

A Level

Part A Initiation

Translation is initiated when a [ ] binds to the [ ] end of the mature messenger RNA (mRNA), and moves along the mRNA. When it reaches the [ ] (AUG), it facilitates the binding of the [ ] with the complementary [ ].

Items:

start codon **anticodon** **ribosome** **stop codon** **codon** **transfer RNA (tRNA)** $3'$ $5'$

Part B Elongation

After the binding of the first tRNA to the first (start) codon, a second tRNA binds to the second codon. The [ ] of one tRNA binds to that of the next tRNA via [ ]. The ribosome then moves to the third codon, and a third tRNA binds (bringing with it the third amino acid). As this happens, the first tRNA (but not the first amino acid) detaches. This process repeats along the length of the mRNA: tRNAs bind to the mRNA, amino acids bind to each other, and then tRNAs detach. The string of amino acids is called [ ].

Items:

a polypeptide chain **a peptide bond** **hydrogen bonds** **anticodon** **a polysaccharide** **amino acid**

Part C Termination

When the ribosome reaches the [ ], it detaches from the mRNA. The [ ] is then released from the final tRNA, and undergoes folding and post-translational modifications to become a functional [ ].

Items:

$5'$ cap	anticodon	poly(A) tail	protein	polypeptide chain	stop codon

Part D From gene to protein

Drag the steps below (left) into the correct chronological order (right).

Available items

- The ribosome moves along the mRNA strand, and transfer RNA (tRNA) molecules bind to the mRNA strand, beginning at the "start" codon (AUG). Each tRNA molecule is bound at one end to a specific amino acid, and at the other end contains a specific triplet of unbound RNA bases called an "anticodon", which binds to complementary codons.
- The polypeptide chain undergoes folding and post-translational modifications to become a functional, three-dimensional protein.
- RNA polymerase reaches the end of the gene and transcription ends. The newly-synthesised RNA strand is called messenger RNA (mRNA).
- Transcription factors and RNA polymerase bind to the promoter region of a gene.
- A ribosome binds to the $5'$ end of the mature mRNA strand.
- Adjacent amino acids bind to each other via peptide bonds, forming a polypeptide chain. Once the ribosome reaches the stop codon the polypeptide chain detaches from the last tRNA molecule.
- The mRNA strand undergoes post-transcriptional modifications and is exported out of the nucleus.
- RNA polymerase moves along the DNA, allowing complementary RNA nucleotides to sequentially bind to each other (through phosphodiester bonds).
- RNA polymerase causes the two DNA strands to unwind and separate.

Translation vs Transcription

A Level

In the table below, identify which statements about translation and transcription are correct, and which are incorrect. Fill in every box with either a tick (correct) or a cross (incorrect).

	Translation	Transcription
occurs within ribosomes		
occurs within the nucleus		
free nucleotides bind as individual nucleotides		
nucleotide binding occurs in triplets		
mRNA is involved		

Items:

✔ ✖

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Transfer RNA (tRNA)

A Level

Part A tRNA structure

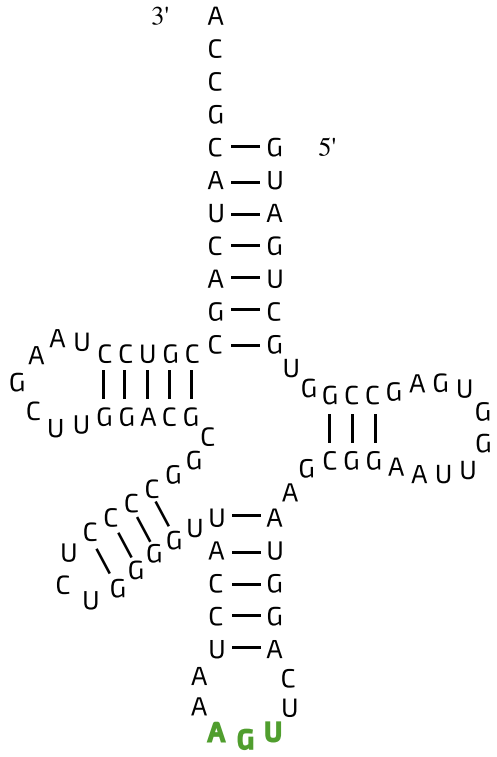
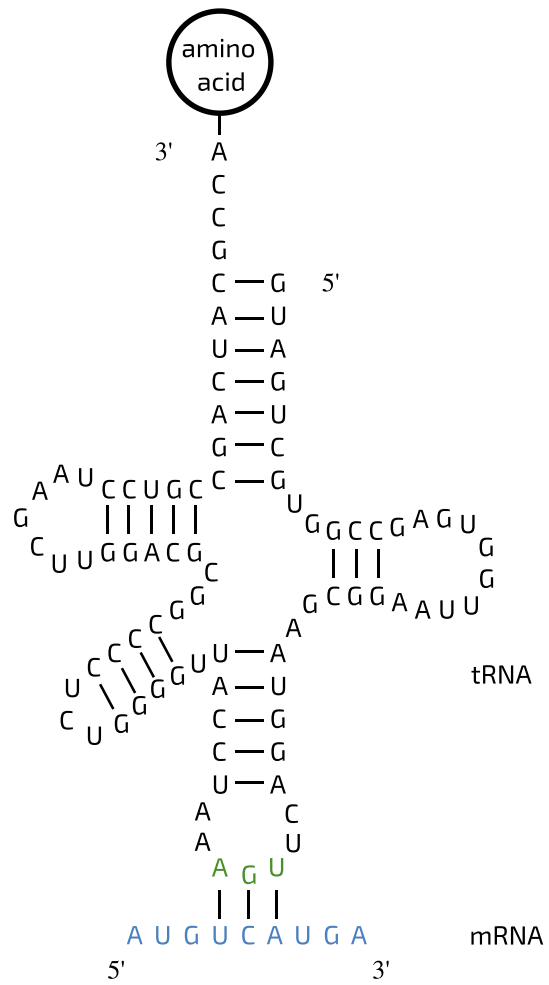


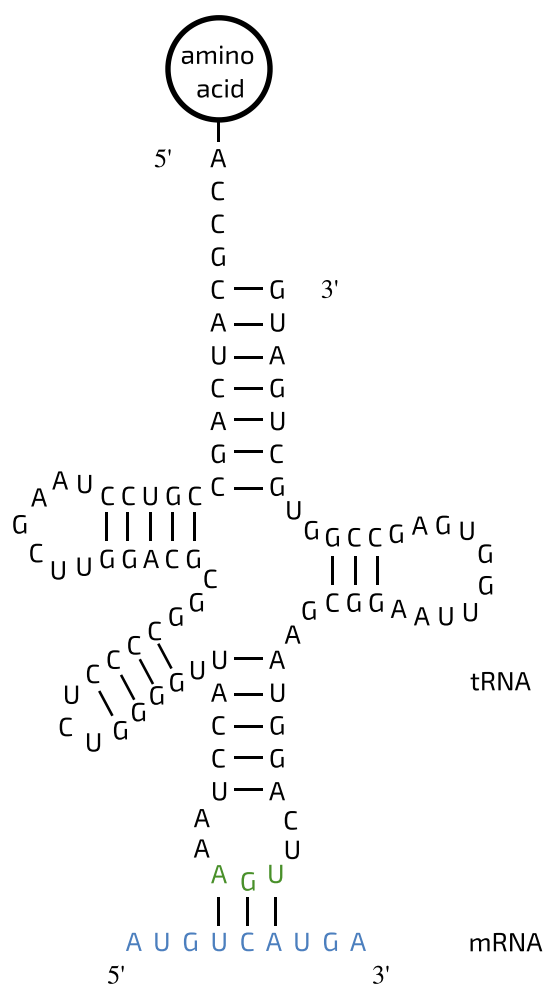
Figure 1: The secondary structure of a human tRNA molecule which binds to the amino acid serine.

What is the name given to the highlighted region (green) of the tRNA molecule in Figure 1?

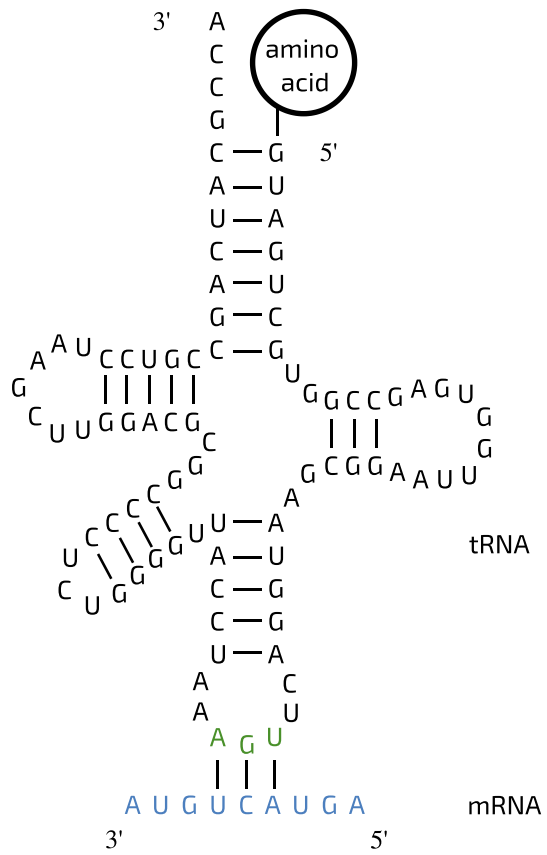
Part B tRNA binding



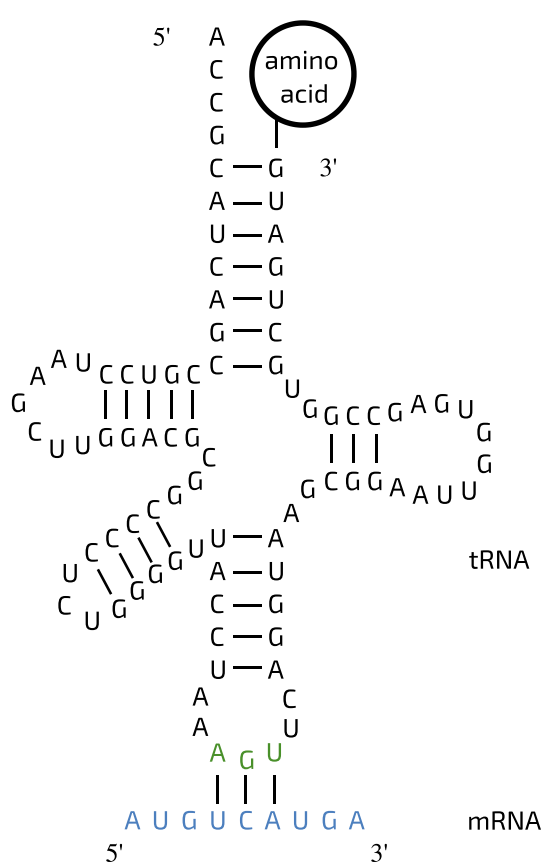
A



B



C



D

Which image above correctly shows how a tRNA molecule binds to an amino acid and an mRNA strand?

- A
- B
- C
- D

Part C Nucleic acid types

Match the nucleic acid to the description.

- [ ]: single-stranded nucleic acid that combines with specific proteins to form the organelles responsible for translation
- [ ]: double-stranded nucleic acid
- [ ]: single-stranded nucleic acid that folds into secondary and tertiary structures. Each different type binds to a different amino acid.
- [ ]: single-stranded nucleic acid that is "read" by ribosomes during translation

Items:

transfer RNA (tRNA) **ribosomal RNA (rRNA)** **DNA** **messenger RNA (mRNA)**

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Translate the Sequences

A Level

C C C

The table below shows the corresponding tRNA anticodon(s) for a selection of amino acids.

Amino acid	tRNA(s) ($3'$ to $5'$)
glutamine	GUU, GUC
glycine	CCA, CCG, CCU, CCC
lysine	UUU, UUC
methionine	UAC
phenylalanine	AAA, AAG
proline	GGA, GGG, GGU, GGC
tyrosine	AUA, AUG
valine	CAA, CAG, CAU, CAC

Part A mRNA to amino acid

Using the anticodon table above, work out the amino acid sequence that would be produced from the mRNA sequence ($5'$ to $3'$):

AUGGGGAAGUUC

Assume that the first three nucleotides correspond to the first codon.

- Amino acid 1:
- Amino acid 2:
- Amino acid 3:
- Amino acid 4:

Items:

glutamine **glycine** **lysine** **methionine** **phenylalanine** **proline** **tyrosine** **valine**

Part B Sense to amino acid

Using the anticodon table above, work out the amino acid sequence that would be produced from the following sense strand DNA sequence ($5'$ to $3'$):

ATGCAGTATCAA

Assume that the first three nucleotides correspond to the first codon.

- Amino acid 1:
- Amino acid 2:
- Amino acid 3:
- Amino acid 4:

Items:

glutamine **glycine** **lysine** **methionine** **phenylalanine** **proline** **tyrosine** **valine**

Part C Antisense to amino acid

Using the anticodon table above, work out the amino acid sequence that would be produced from the following antisense strand DNA sequence ($3'$ to $5'$):

TACATGCACGTC

Assume that the first three nucleotides correspond to the first codon.

- Amino acid 1: [ ]
- Amino acid 2: [ ]
- Amino acid 3: [ ]
- Amino acid 4: [ ]

Items:

glutamine **glycine** **lysine** **methionine** **phenylalanine** **proline** **tyrosine** **valine**

Part D What kind of sequence is it?

The four sequences below represent four complementary sequences of different types (DNA sense strand, DNA antisense strand, mRNA, and tRNA). Match the sequence type to the sequence.

- TGTGAAACTGCT: DNA sense strand ($5'$ to $3'$)
- ACACUUUGACGA: [ ]
- UGUGAAACUGCU: [ ]
- ACACTTTGACGA: [ ]

Items:

DNA antisense strand ($3'$ to $5'$) **mRNA ($5'$ to $3'$)** **tRNA ($3'$ to $5'$)**

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Translation Calculations

A Level

C C C

Part A Polypeptide length

If a section of a gene is 420 base pairs long, how many amino acids long will the encoded polypeptide be?

Assume that the first three nucleotides correspond to one codon, and that the section does not contain a stop codon (i.e. every codon is translated into an amino acid).

Part B Translation rate

A ribosome can translate 18 bases per second. How long would it take to produce a protein that was 300 amino acids long?

Part C Alien translation

Imagine that an alien organism is found that translates its RNA using pairs of nucleotides instead of triplets.

During translation, the alien organism can use 50 possible amino acids (rather than the 20 used in life on Earth).

What is the minimum number of different types of nucleotides that would be needed to code for all of the possible amino acids?

Adapted with permission from NSAA 2022 Specimen Paper Section 1 Q75 & NSAA 2018 Section 2 Question B1

Post-translational Modifications

A Level

Part A Types of modifications

After translation, a polypeptide chain undergoes folding to become a functional protein. Some proteins undergo further post-translational modifications. These include:

- [ ] (the addition of a phosphate group),
- [ ] (the addition of a carbohydrate to form a [ ]), and
- [ ] (the addition of a lipid to form a [ ]).

Items:

glycosylation **proteolipid** **glycoprotein** **phosphorylation** **lipidation**

Part B Modification locations

- Proteins that will be secreted from the cell are translated in [ ] ribosomes. They then undergo post-translational modifications in the endoplasmic reticulum and [ ].
- Proteins that will remain in the cell (i.e. will not be secreted) are translated in [ ] ribosomes. They then undergo post-translational modifications in the [ ].

Items:

free **Golgi apparatus** **bound** **cytoplasm**

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