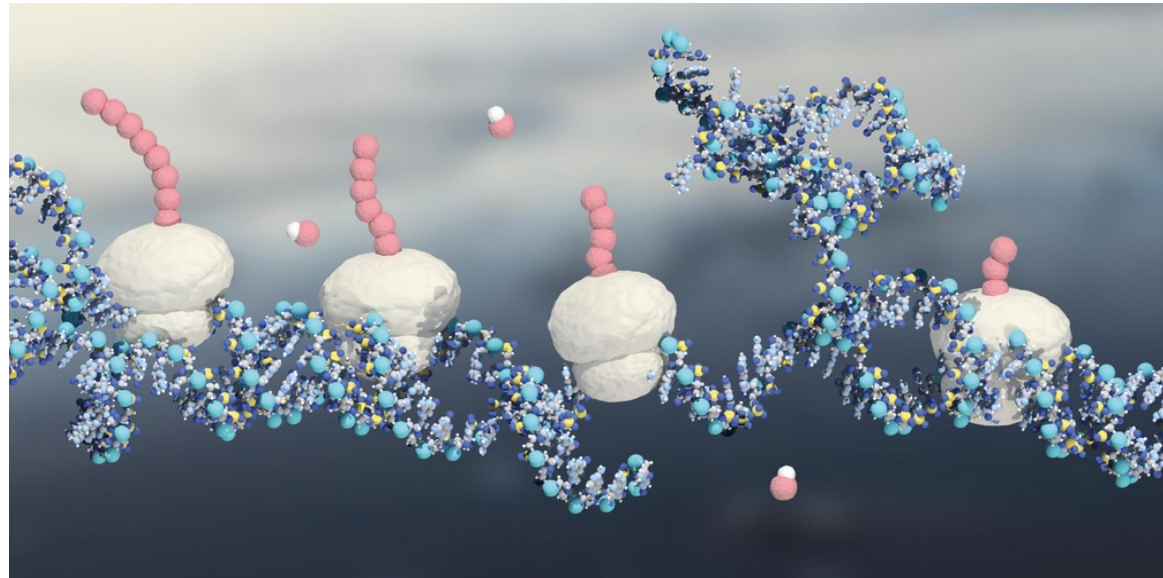


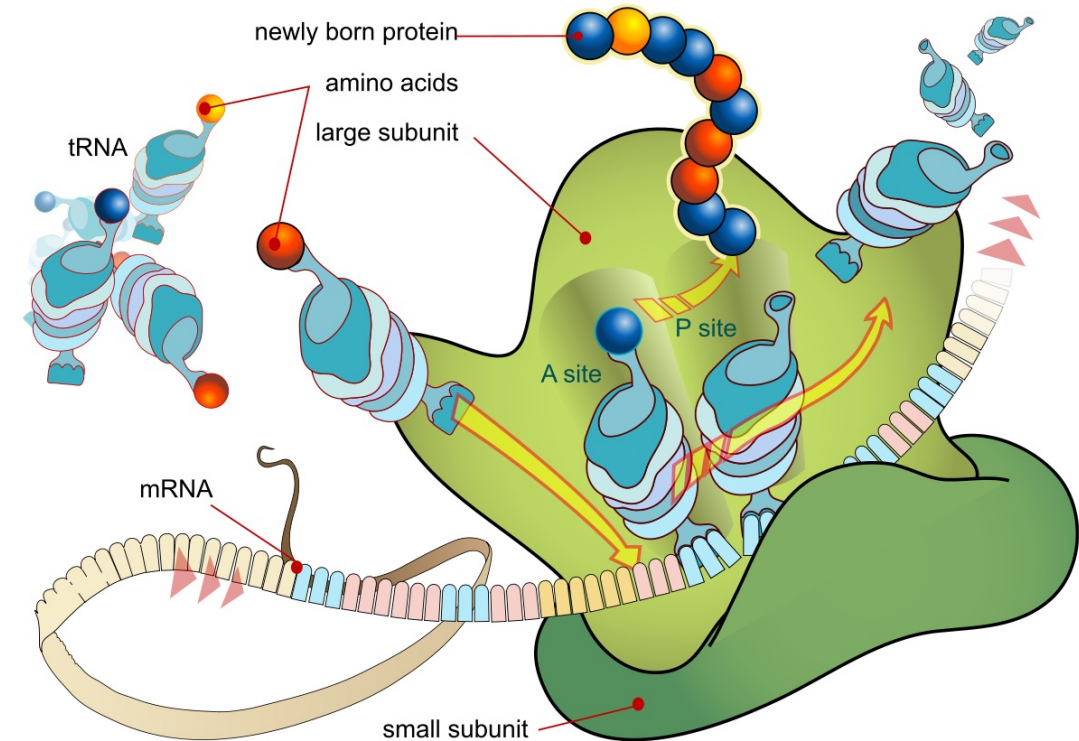
# Lesson 12

## RNA translation (protein synthesis)



# RNA translation

- **RNA translation** is a process that produces a **protein** from an mRNA template via the **genetic code**
- There is a change of language
  - From the language of nucleic acids (nucleotides) to the language of proteins (amino acids)
- The process takes place in the cytoplasm
- Requires another RNA, called **tRNA**
- Protein synthesis is operated by cell organelle called **ribosome**



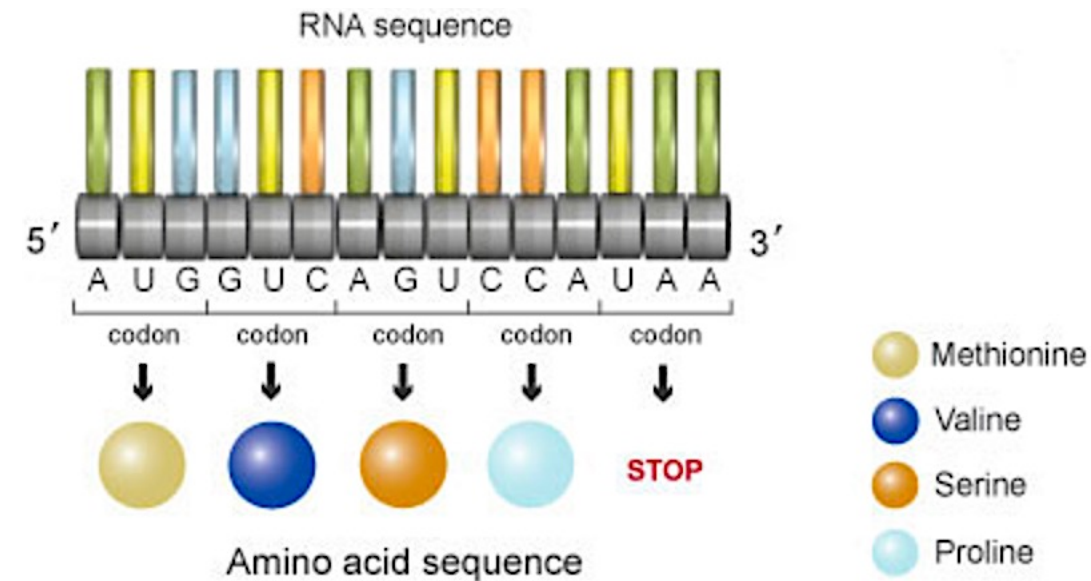
# The genetic code

- The **genetic code** = **triplets of RNA bases** (called **codons**)

AGC UAG CAG UUA  
└─┘ └─┘ └─┘ └─┘  
codon codon codon codon

# The genetic code

- The genetic code = triplets of RNA bases (called **codons**)
- **Each codon** encodes **1 amino acid**

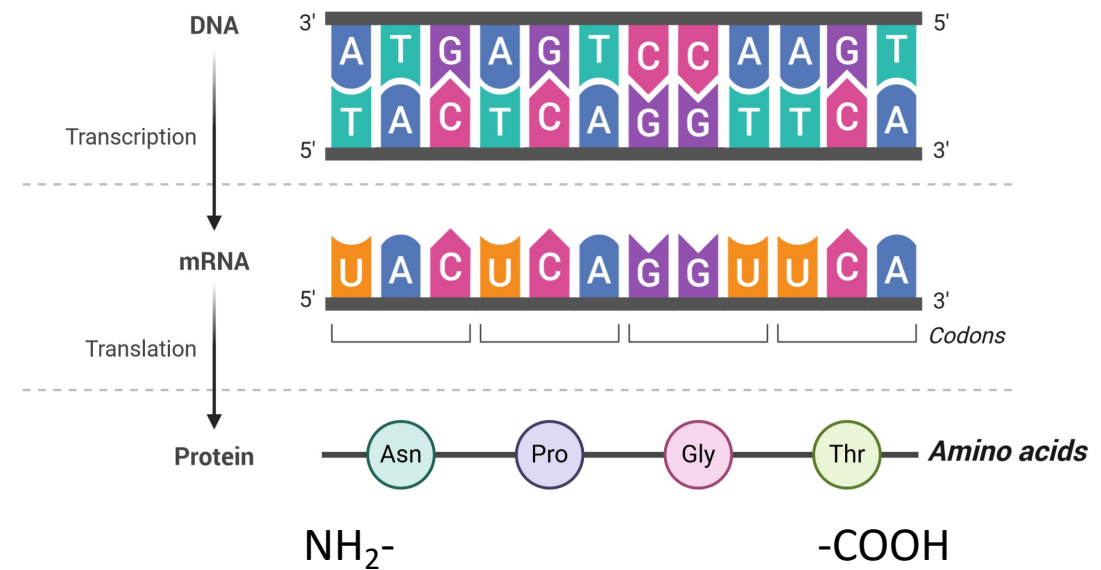


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- The **genetic code** = triplets of RNA bases (called **codons**)
- **Each codon** encodes **1 amino acid**
- mRNA is read from 5' to 3'
- The protein is made from the -NH<sub>2</sub> end to the COOH end
  - Each new amino acid is added to the C end of the preceding one (discussed in Lesson 3)



# The genetic code

		Second base				
		U	C	A	G	
First base	U	<b>UUU</b> } Phenyl- <b>UUC</b> } alanine <b>F</b> <b>UUA</b> } Leucine <b>L</b> <b>UUG</b> }	<b>UCU</b> } <b>UCC</b> } Serine <b>S</b> <b>UCA</b> } <b>UCG</b> }	<b>UAU</b> } Tyrosine <b>Y</b> <b>UAC</b> } <b>UAA</b> } Stop codon <b>UAG</b> } Stop codon	<b>UGU</b> } Cysteine <b>C</b> <b>UGC</b> } <b>UGA</b> } Stop codon <b>UGG</b> } Tryptophan <b>W</b>	U C A G
	C	<b>CUU</b> } <b>CUC</b> } Leucine <b>L</b> <b>CUA</b> } <b>CUG</b> }	<b>CCU</b> } <b>CCC</b> } Proline <b>P</b> <b>CCA</b> } <b>CCG</b> }	<b>CAU</b> } Histidine <b>H</b> <b>CAC</b> } <b>CAA</b> } Glutamine <b>Q</b> <b>CAG</b> }	<b>CGU</b> } <b>CGC</b> } Arginine <b>R</b> <b>CGA</b> } <b>CGG</b> }	U C A G
	A	<b>AUU</b> } Isoleucine <b>I</b> <b>AUC</b> } <b>AUA</b> } <b>AUG</b> } Methionine <b>M</b> start codon	<b>ACU</b> } <b>ACC</b> } Threonine <b>T</b> <b>ACA</b> } <b>ACG</b> }	<b>AAU</b> } Asparagine <b>N</b> <b>AAC</b> } <b>AAA</b> } Lysine <b>K</b> <b>AAG</b> }	<b>AGU</b> } Serine <b>S</b> <b>AGC</b> } <b>AGA</b> } Arginine <b>R</b> <b>AGG</b> }	U C A G
	G	<b>GUU</b> } <b>GUC</b> } Valine <b>V</b> <b>GUA</b> } <b>GUG</b> }	<b>GCU</b> } <b>GCC</b> } Alanine <b>A</b> <b>GCA</b> } <b>GCG</b> }	<b>GAU</b> } Aspartic <b>GAC</b> } acid <b>D</b> <b>GAA</b> } Glutamic <b>GAG</b> } acid <b>E</b>	<b>GGU</b> } <b>GGC</b> } Glycine <b>G</b> <b>GGA</b> } <b>GGG</b> }	U C A G



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	C	CUU } CUC } Leucine <b>L</b> CUA } CUG }	CCU } CCC } Proline <b>P</b> CCA } CCG }	CAU } Histidine <b>H</b> CAC } CAA } Glutamine <b>Q</b> CAG }	CGU } CGC } Arginine <b>R</b> CGA } CGG }	U C A G
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	G	GUU } GUC } Valine <b>V</b> GUA } GUG }	GCU } GCC } Alanine <b>A</b> GCA } GCG }	GAU } Aspartic acid <b>D</b> GAC } GAA } Glutamic acid <b>E</b> GAG }	GGU } GGC } Glycine <b>G</b> GGA } GGG }	U C A G



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# t-RNA

- In any case of unknown language change you need someone who understand both languages → interpreter
- In RNA translation you need an interpreter to translate **CODONS** into **AMINOACIDS**
- These interpreters are the **tRNAs** (small RNAs present throughout living cells)
- Each tRNA has a sequence called **ANTICODON** that base-pairs with a **specific codon** on a mRNA
- Each tRNA base-pairs with 1 mRNA codon a time

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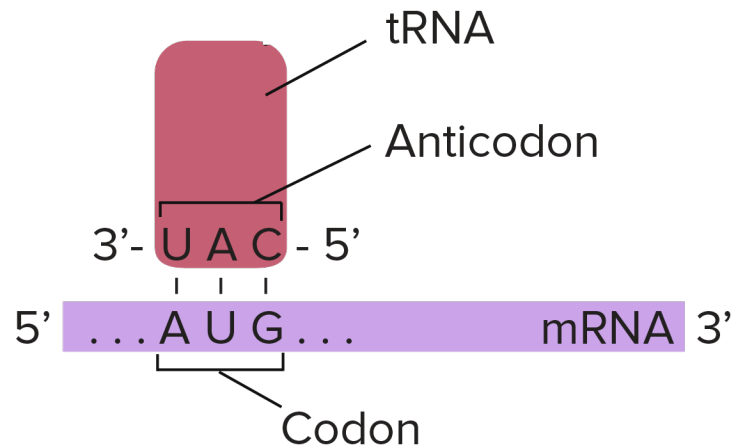
- After codon-anticodon matching, the **tRNAs covalently binds the correct amino acid** and carries it to the ribosome for the protein synthesis

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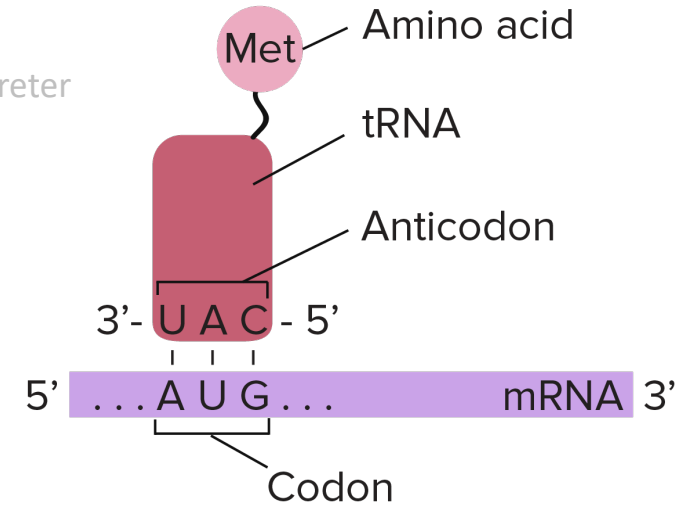
- After codon-anticodon matching, the tRNA covalently binds the correct amino acid and carries it to the ribosome for the protein synthesis
- For example: the mRNA codon 5'AUG3' encodes for the amino acid methionine, then:
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  2. It then covalently binds the amino acid Methionine (tRNA<sup>MET</sup>)
  3. It finally shuttles to the ribosome where the amino acid will be released and added to the growing protein





# t-RNA

- In any case of language change you need someone who understand both languages → interpreter
- In RNA translation you need an interpreter to translate CODONS into AMINOACIDS
- This interpreter is the tRNA (a small RNA present throughout living cells)
- A tRNA has a sequence called ANTICODON that base-pairs with a specific codon on a mRNA
- For example:

mRNA codon 5'AUG3'

tRNA anticodon 3'UAC5'

- Each tRNAs carries the correct amino acid at the right moment to the ribosome for the protein synthesis
- For example: the mRNA codon 5'AUG3' encodes for the amino acid methionine, then:
  1. the particular tRNA that has the anticodon 3'UAC5' base-pairs with this codon
  2. It then covalently binds the amino acid Metionine (tRNA<sup>MET</sup>)
  3. It finally shuttles to the ribosome where the amino acid will be released and added to the growing protein
- **First codon = START codon**
- **Always 5'AUG3' codon = start codon for N-terminus Met**

# From mRNA to protein

1. Read mRNA sequence: 5'AUGAAAACU.....3'
2. Identify codons: 5'AUG/AAA/ACU/.....3'
3. Match codons with amino acids
  - AUG → Met (M)
  - AAA → Lys (K)
  - ACU → Thr (T)
  - .....

		Second letter				
		U	C	A	G	
First letter	U	UUU } Phe UUC } UUA } Leu UUG }	UCU } UCC } Ser UCA } UCG }	UAU } Tyr UAC } <b>UAA Stop</b> <b>UAG Stop</b>	UGU } Cys UGC } <b>UGA Stop</b> UGG } Trp	U C A G
	C	CUU } CUC } Leu CUA } CUG }	CCU } CCC } Pro CCA } CCG }	CAU } His CAC } CAA } Gln CAG }	CGU } CGC } Arg CGA } CGG }	U C A G
	A	AUU } AUC } Ile AUA } <b>AUG Met</b>	ACU } ACC } Thr ACA } ACG }	AAU } Asn AAC } AAA } Lys AAG }	AGU } Ser AGC } AGA } Arg AGG }	U C A G
	G	GUU } GUC } Val GUA } GUG }	GCU } GCC } Ala GCA } GCG }	GAU } Asp GAC } GAA } Glu GAG }	GGU } GGC } Gly GGA } GGG }	U C A G
						Third letter

4. Continue until you find the stop codon (UAA or UAG or UGA)

Note: stop codons do not code for any amino acid; they just stop translation

# The genetic code again

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First letter	U	UUU } Phe UUC } UUA } Leu UUG }	UCU } UCC } Ser UCA } UCG }	UAU } Tyr UAC } <b>UAA Stop</b> <b>UAG Stop</b>	UGU } Cys UGC } <b>UGA Stop</b> UGG Trp	U	C
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	A	AUU } Ile AUC } AUA } <b>AUG Met</b>	<b>ACU } Thr</b> ACC } ACA } ACG }	AAU } Asn AAC } AAA } Lys AAG }	AGU } Ser AGC } AGA } Arg AGG }	U	C
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						A	G



# “Cracking” the genetic code



DNA template strand

3' TACAAACCGAGT 5'

transcription

mRNA

5' AUGUUUUGGCUCA 3'

translation (via tRNA)

protein

NH2 Met Phe Gly Ser COOH

direction of translation



# tRNA - recap

- Each tRNA anticodon base-pairs with the corresponding mRNA codon
- Each tRNA binds the corresponding amino acid and delivers it to the ribosome
- The ribosome brings all amino acid together and join them covalently in the correct ordered sequence
- The tRNA is then released and can re-enter the translation loop when needed

