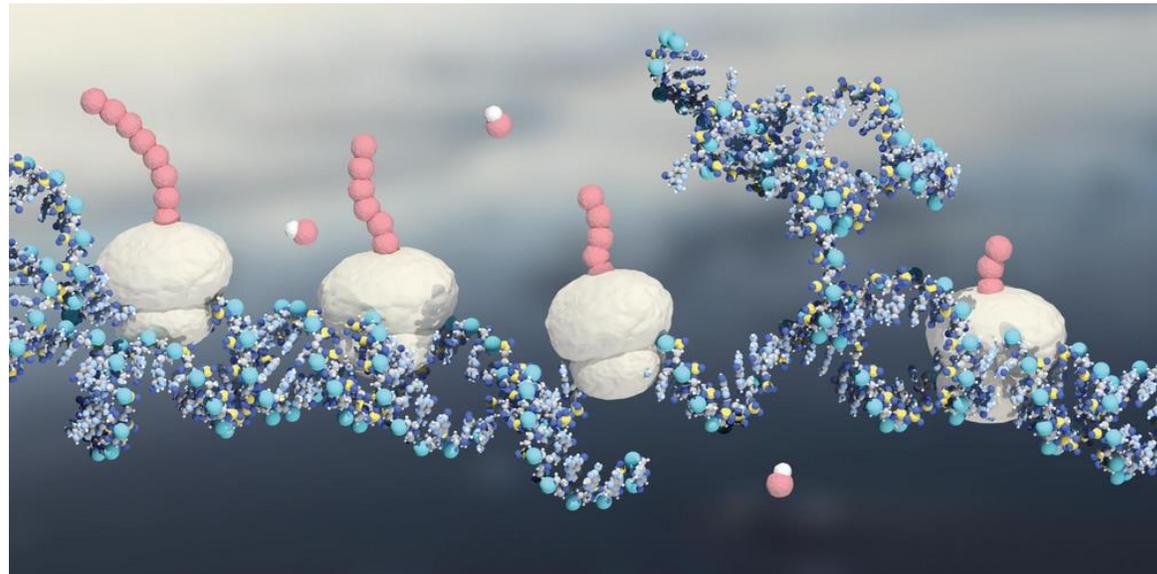


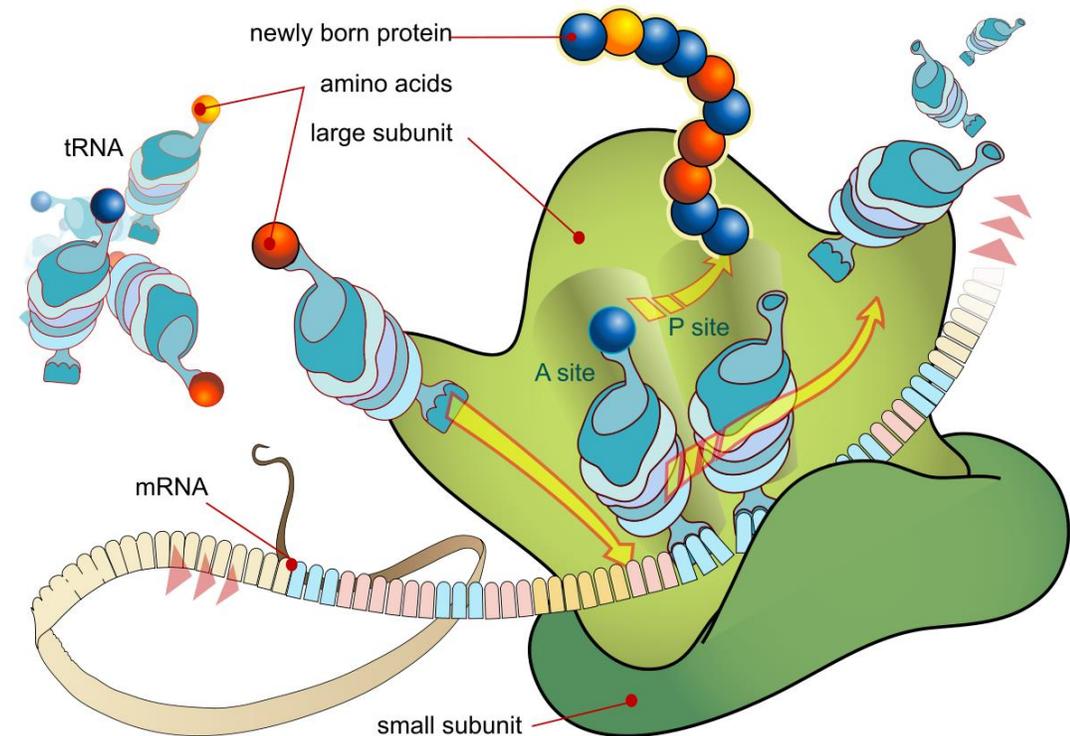
Lesson 12

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**



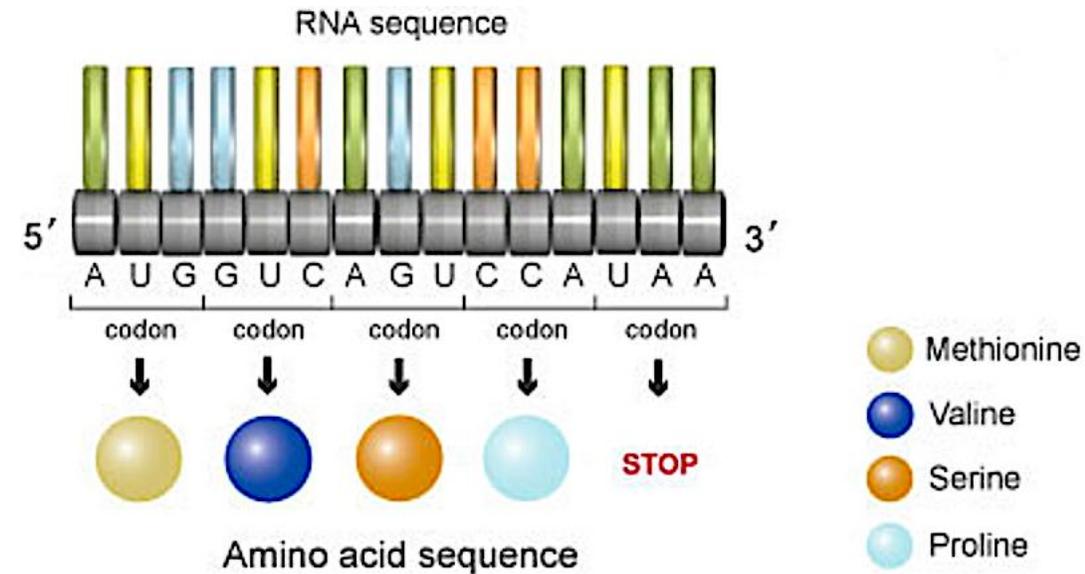
The genetic code

- 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**

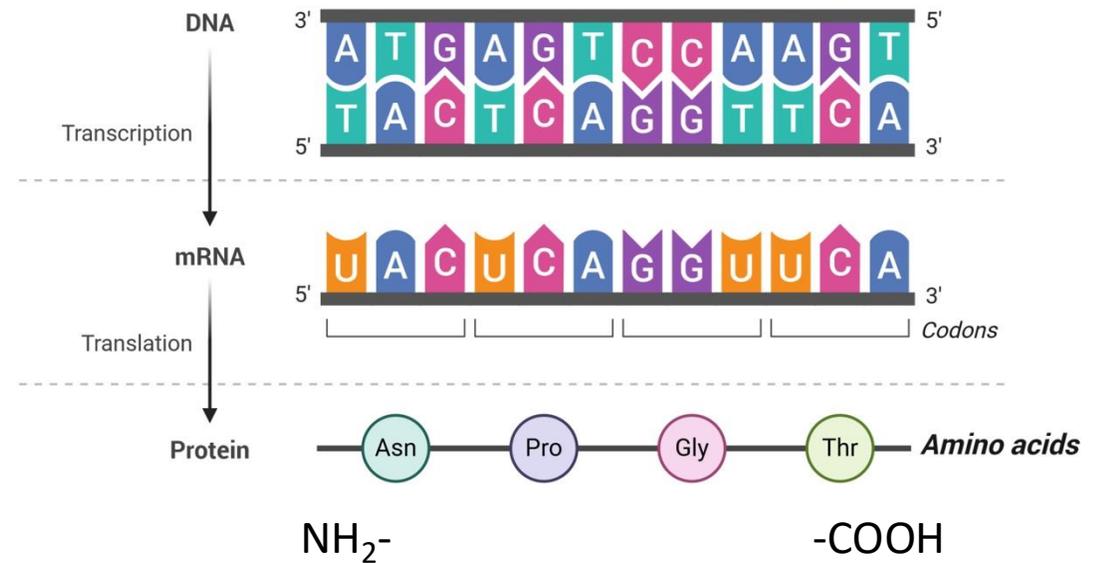


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- **mRNA is read from 5' to 3'**

The genetic code

- 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_2 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	UUU } Phenyl- UUC } alanine F UUA } Leucine L UUG }	UCU } UCC } Serine UCA } S UCG }	UAU } Tyrosine Y UAC } UAA } Stop codon UAG } Stop codon	UGU } Cysteine C UGC } UGA } Stop codon UGG } Tryptophan W	Third base	U
	C	CUU } CUC } Leucine L CUA } CUG }	CCU } CCC } Proline CCA } P CCG }	CAU } Histidine H CAC } CAA } Glutamine Q CAG }	CGU } CGC } Arginine CGA } R CGG }		C
	A	AUU } Isoleucine I AUC } AUA } AUG } Methionine start codon M	ACU } ACC } Threonine ACA } T ACG }	AAU } Asparagine N AAC } AAA } Lysine K AAG }	AGU } Serine S AGC } AGA } Arginine AGG } R		A
	G	GUU } GUC } Valine V GUA } GUG }	GCU } GCC } Alanine GCA } A GCG }	GAU } Aspartic GAC } acid D GAA } Glutamic GAG } acid E	GGU } GGC } Glycine GGA } G GGG }		G

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		U	C	A	G		
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	C	CUU } CUC } Leucine L CUA } CUG }	CCU } CCC } Proline P CCA } CCG }	CAU } Histidine H CAC } CAA } Glutamine Q CAG }	CGU } CGC } Arginine R CGA } CGG }		C
	A	AUU } Isoleucine I AUC } AUA } AUG } Methionine M start codon	ACU } ACC } Threonine T ACA } ACG }	AAU } Asparagine N AAC } AAA } Lysine K AAG }	AGU } Serine S AGC } AGA } Arginine R AGG }		A
	G	GUU } GUC } Valine V GUA } GUG }	GCU } GCC } Alanine A GCA } GCG }	GAU } Aspartic acid D GAC } GAA } Glutamic acid E GAG }	GGU } GGC } Glycine G GGA } GGG }		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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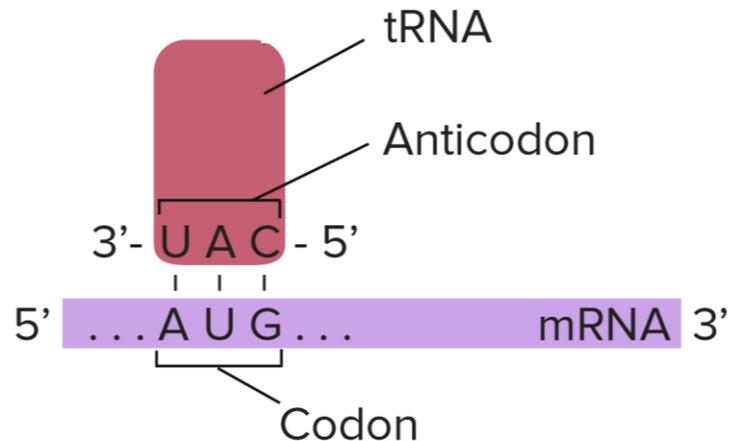
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- After codon-anticodon matching, the **tRNAs covalently binds the correct amino acid** and carries it to the ribosome for the protein synthesis

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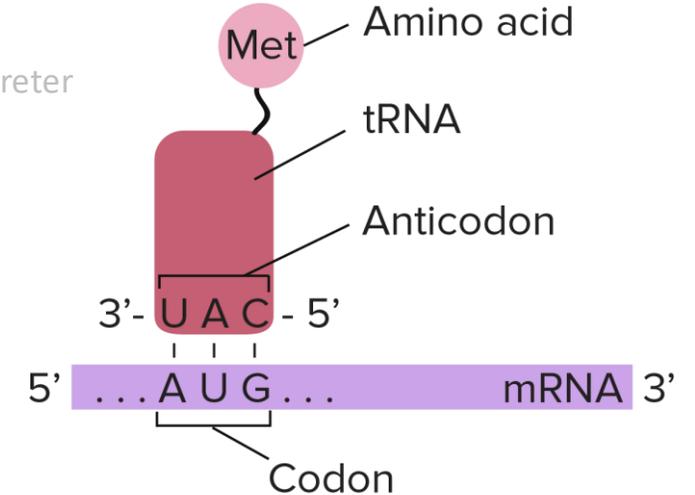


- After codon-anticodon matching, the tRNA covalently binds the correct amino acid and carries it to the ribosome for the protein synthesis
- **For example: the mRNA codon 5'AUG3' encodes for the amino acid methionine, then:**
 1. the particular tRNA that has the anticodon 3'UAC5' base-pairs with this codon

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- 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^{MET})
 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^{MET})
 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 } UAA Stop UAG Stop	UGU } Cys UGC } UGA Stop 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 } AUG Met	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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		U	C	A	G	
First letter	U	UUU } Phe UUC } UUA } Leu UUG }	UCU } UCC } Ser UCA } UCG }	UAU } Tyr UAC } UAA Stop UAG Stop	UGU } Cys UGC } UGA Stop UGG Trp	U C A G
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“Cracking” the genetic code



DNA template strand

3' TACAAACCGAGT 5'

transcription

mRNA

5' AUGUUUGGCUCA 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

