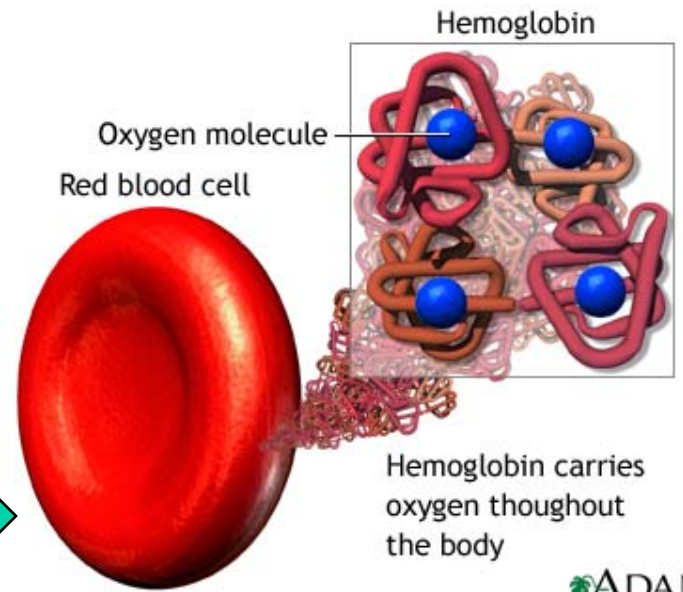
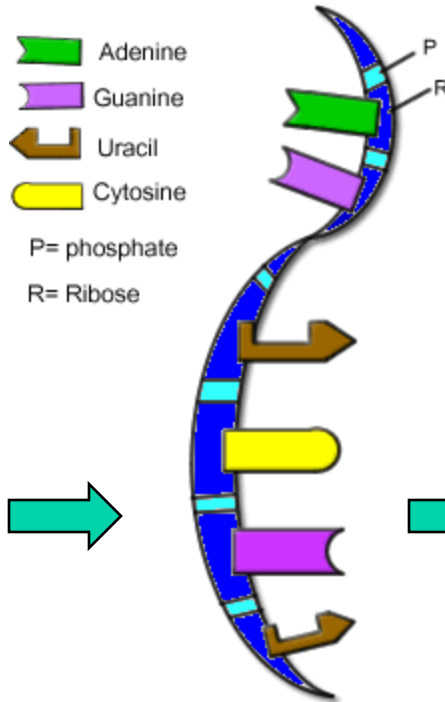


# Protein Synthesis

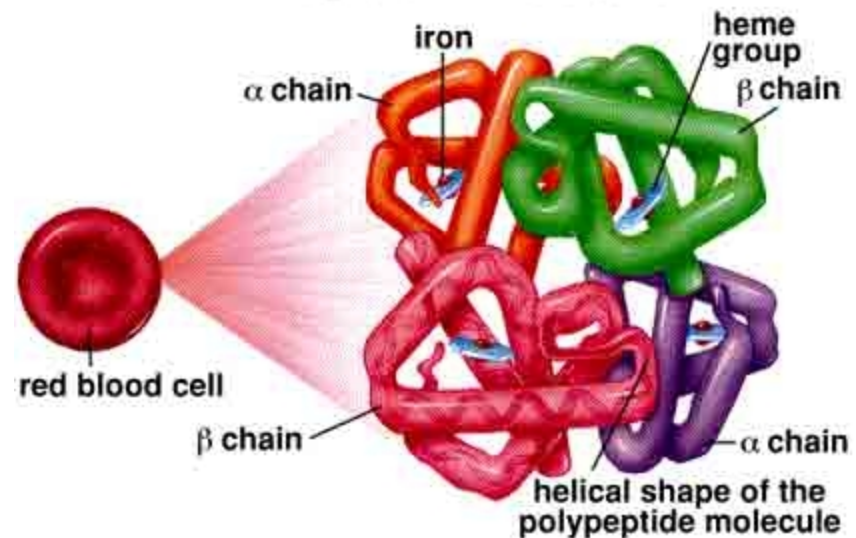


# Proteins in the Body

DNA is found in almost all living organisms and directs **protein synthesis**

Examples of protein are:

- Enzymes (ex. lactase)
- Hormones (ex. insulin)
- Antibodies
- Hemoglobin
- Cell membranes
- Receptor molecules



# Protein Synthesis

This is the complete genome of  $\phi$ X174 bacterial virus.

It has 9 genes=(9 proteins)

The highlighted section is 1 gene

The human genome is 1 million times larger than this

Start  
↓

```
CCGTCAGGCGCAGCCCTCCAAATGGATGCTTTCAGGCTCCAAATCCCTGGAGCTTTATATGTTTCGTTCTTATACCCCTCTGAATGTCACGGTC  
ACGAATACCTTCGGTTCGTAACCCCTAACCTCTTCTCATCTTTACGGTGTTCGGAGTTATCGTCCAAATTCGGGAGCTATGGGAGTTTCAGTTTTATTA  
GATGGATAACCGCATCAAGCTCTGGGAAGAGATTCTGTCTTTTCGTATGCGAGGCCCTTGAGTTCGATAAATGGTATATGATATGTTGACGGCCATAAGGCT  
ACAATAATTATAGTTCAACCCCTCGTGTAAACATCGTAACAACCGTTAAGTAGGTAATTGAAGAGTCAITGTCTATGTTTGGAGTAGTGCTTGGAGTCTTGG  
CTATAGACCACCCGCCGGAAGGGGACGAAAAATGGTTTTTACGAAACGAGAAGACGGTTACCGCAGTTTTGCCCGAACCTGGCTGGTGAACGCCCTCTTAA  
TTTCGGACATGGCCTATAGAATCAGGTCCGGACCTCGTTAGAACCTGTGAGTAGGAATATGGAAAGAAAAACCCATTAATATGAGTAGCGCTTATAGG  
GCTATTGAGCGTTTGGATGAATGCAATGGACAGGCTCATGCTGATGGTTGGTTTATCGTTTTGACAGTCTCACGTTGGCTGACGACCGGATTAGAGCGGT  
GTGAGGCGCACAGTTAGTAATCGGAACCGCTCGGAGCCGGTGGTCTTGGTATGCTGGTTATAGTGCTTTTATCAGTGGCTTTCGTAACCCCTAATAGTATTT  
GTATCAGTATTTTGTGTGGCTGAGTATCGTAGAGCTAATGGCCGCTTTCATTTCCATGCGGTGCACTTTATGGGACACTTCGTAGAGGTAGCGTTGAG  
CGCCATGGGTTGAGGCTACCCGTATGAGATGGTATTCGGGTGCATAAAAGGTTTCGATAAATTGAGCCCGGTAACCGATAGGCTGCTGGTTTTAATCG  
AGGACCGCTTTTTCAGCTTGTCTGGTGGTGGTGGCTGTGTATGCTAAAGGTTGAGGCGCTTAAAGGTAACAAGTTATATGGCTGTGGTTCATATGGCTAA  
GAAGGCTTCATGGGTTGCGAACCAAAAATCACTCAACAAGGTAAGAAATGGAAACAACCGAAATGGTTCGATCCAGGTATAGAGTGA AAAAGAAATTCGATA  
AAAGGTTTCAGAAATCAGAAATGAGCCGCAAGTTCCGGATGAAAATGGTCACAATGAGAAAATCTCCACGGAGTGGTAAATCGAAGTTAGCAAGGTGGGTT  
ACCGCGCGGTTTTTCAGCGCATGTCTATTGAAAAGGGTCCGAGTTAGAGTACAGAGAAAAAGGCAAGACGAAGTTATAGACCAACTTCCCGCAGCGCAGCA  
AGCTGTGACGAGAAATCTGGTCAAATTTATGGCCGCTTGGATAAAAATGATGGCGTATCCAACCTGGAGAGTTTTATCGGTTCCATGAGGCGAGAAGTTA  
AAAGGTTTCAGGTTGAAAGTAAAATTAAGCATTTTGTTCATCAATTAAGGACGAAATAGTTCTATAAAAAGGTGAGTAGTCTTTATAGGCTTTCACA  
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AATTAAGAGCTGTTTGTGTAGAGTGGTACTGTTTTCAGTACTA DGAATTTGGTTCAGGAGGCTTTCAGGTTCCGAGCTCCGAGTTCGTTGAGAGGAG  
AAGGCTGGATTAACCTCTGATTCGATCTGTTTCAGGAGTAAATGAGGAGAAATCAAGTCAAGTTGAGTCAAGTTGAGTCAAACTCCGAGCTTCCGAGCCCT  
GCAGCATGCTAGCTGCTTGAACAAATGAGAGGCTTTGAGCTTAGTAGAGGCTAAATGAGTTTTCGCGCTTCCGAGTACCGAGTATCTCCGCTGCT  
GCTCCGTTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCT  
GCTTTCGAGGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCT  
GTAAAGCCGAGTACGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCT  
TCCGAGAACGAGGACGAGAACCATGGGCT  
CTGCTTGGCAGTGTAGGTGCTCAGCACTTTA  
TAGACTTTCAGCGGTTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCT  
GGACCCGTTGCGCGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCT  
GTTCTTTCGCGGAGGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCT  
GCAGATGAGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCT  
GAGTCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCT  
ACTGAGCTTCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCT  
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TCTTGGCCAGGAGCTACTTGGCTTGGGAG  
GUTGATTCAGAGACGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCT  
GGCCTTTTAAATTCGAGAACGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCT  
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GATGGTGGTGGTATACGGTCAAGGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCTGCT  
TCGTTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGT  
ATTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGT  
TTTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGT  
TGTTCGCTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGT  
GTACCTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGTGGT
```

$\phi$ X174 bacterial virus

# What are proteins made of?

- Proteins are made up of **20 different amino acids**

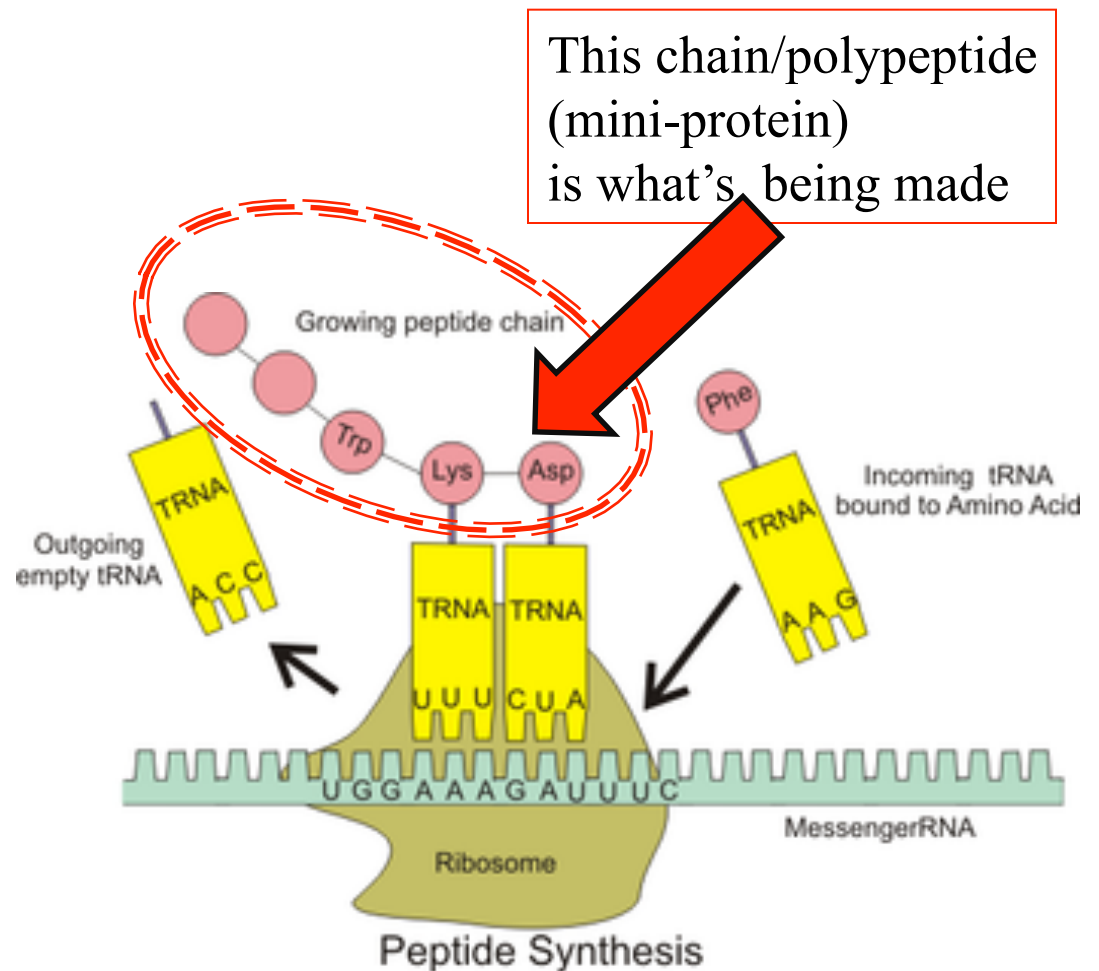
**Different combinations** of amino acids = **different protein produced**

- The amino acids formed are determined by the base sequence in our **DNA**

- One gene = one protein

- Protein Synthesis relies on 3 types of RNA

- **rRNA**
- **mRNA**
- **tRNA**



# DNA vs. mRNA

- Location: **nucleus** (and **cytoplasm** during cell division)

- Strand number:

**Double stranded**



- Sugar: **deoxyribose**

Nitrogen Bases: **4**

**C, G, A, Thymine**

- Location: **nucleus and cytoplasm**

- Strand number:

**Single stranded**



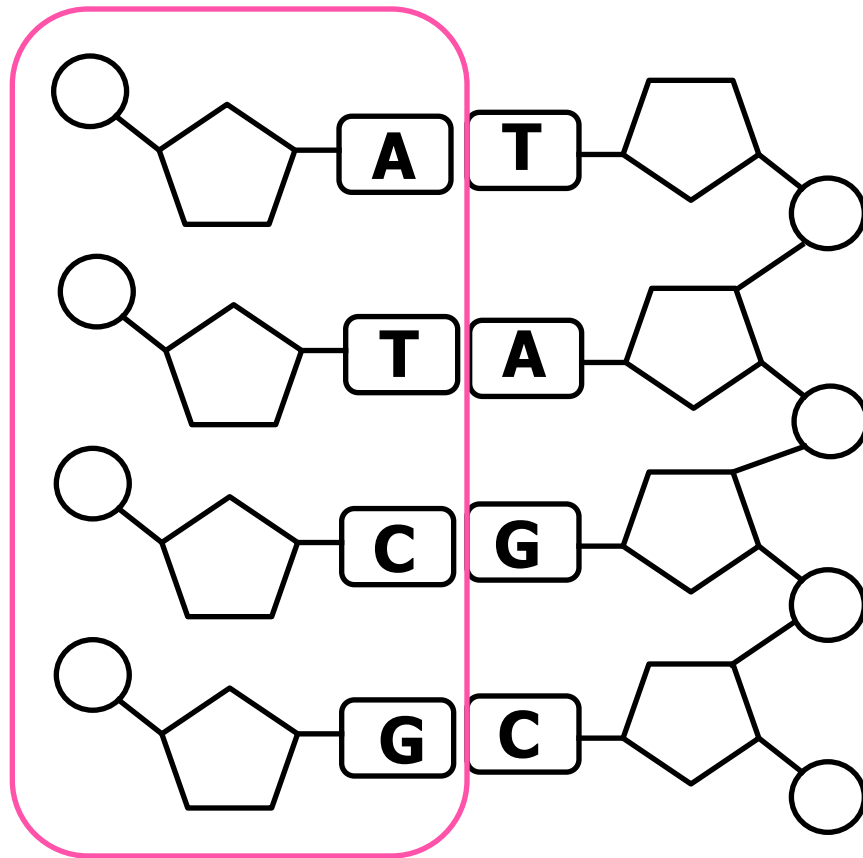
- Sugar: **ribose**

Nitrogen Bases: **4**

**– C, G, A, Uracil**

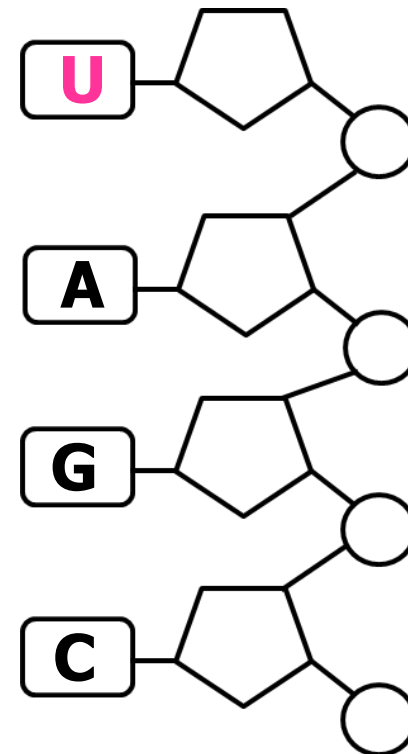
# Nucleic Acids

**DNA**



**Coding Strand**

**mRNA**





If I had to chose between DNA and RNA..

I'd chose  
RNA...

Because it has U in it

# Types of RNA

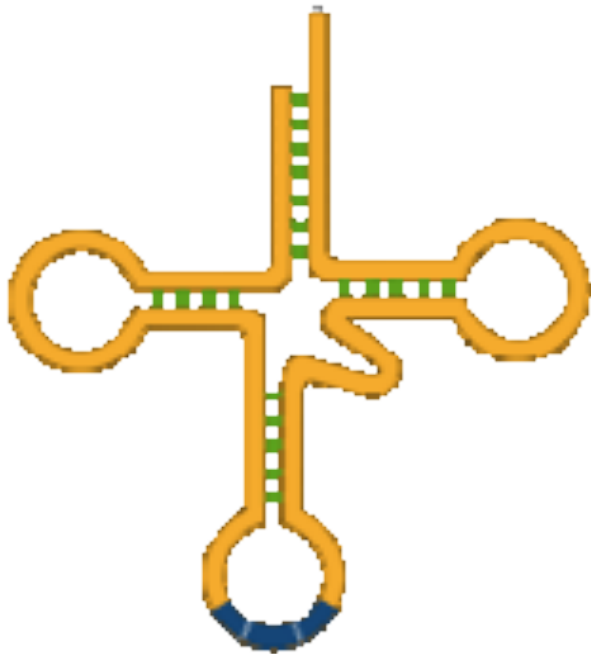
Type of RNA	Its Role	Where Located
Messenger RNA (mRNA)	-Involved in Transcription (first stage of protein synthesis) -“Photocopies” the DNA and carries message from <u>DNA in nucleus to ribosome in cytoplasm</u>	In cytoplasm & nucleus
Ribosomal RNA (rRNA)	Makes up the ribosomes which are the “factories” that make the proteins	In cytoplasm
Transfer RNA (tRNA)	Carries or transports the amino acids to mRNA to be turned into a protein	In cytoplasm



# Types of RNA



mRNA



tRNA



Ribosomes

# Protein Synthesis

- Occurs primarily in **ribosomes** “the protein factories”
- Instructions for protein contained in **DNA** (cookbook)
- Message must get from **nucleus** to **cytoplasm** (DNA to ribosome)
- Process occurs in 2 steps:

## 1. Transcription



transcription

translation



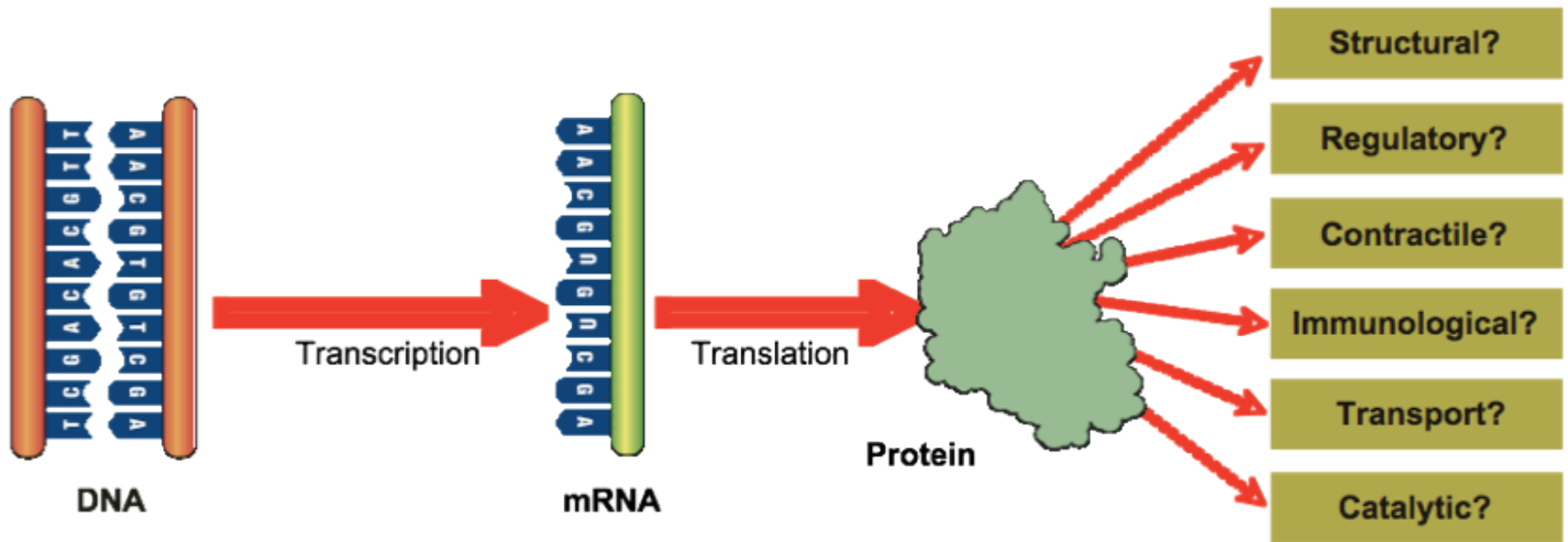
## 2. Translation



In nucleus

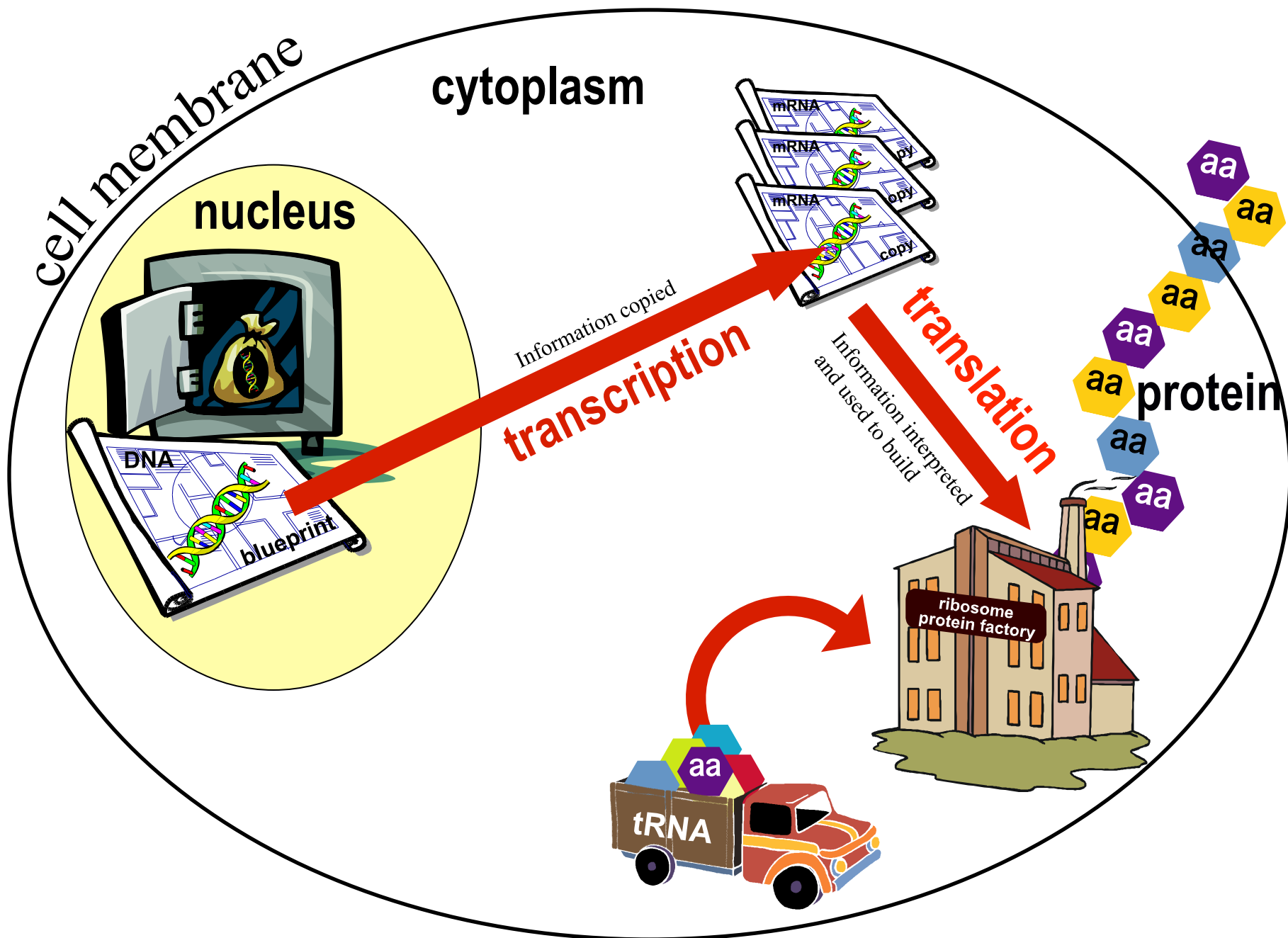
In cytoplasm

# Protein Synthesis...AN OVERVIEW



Occurs in  
nucleus

Occurs in  
Cytoplasm

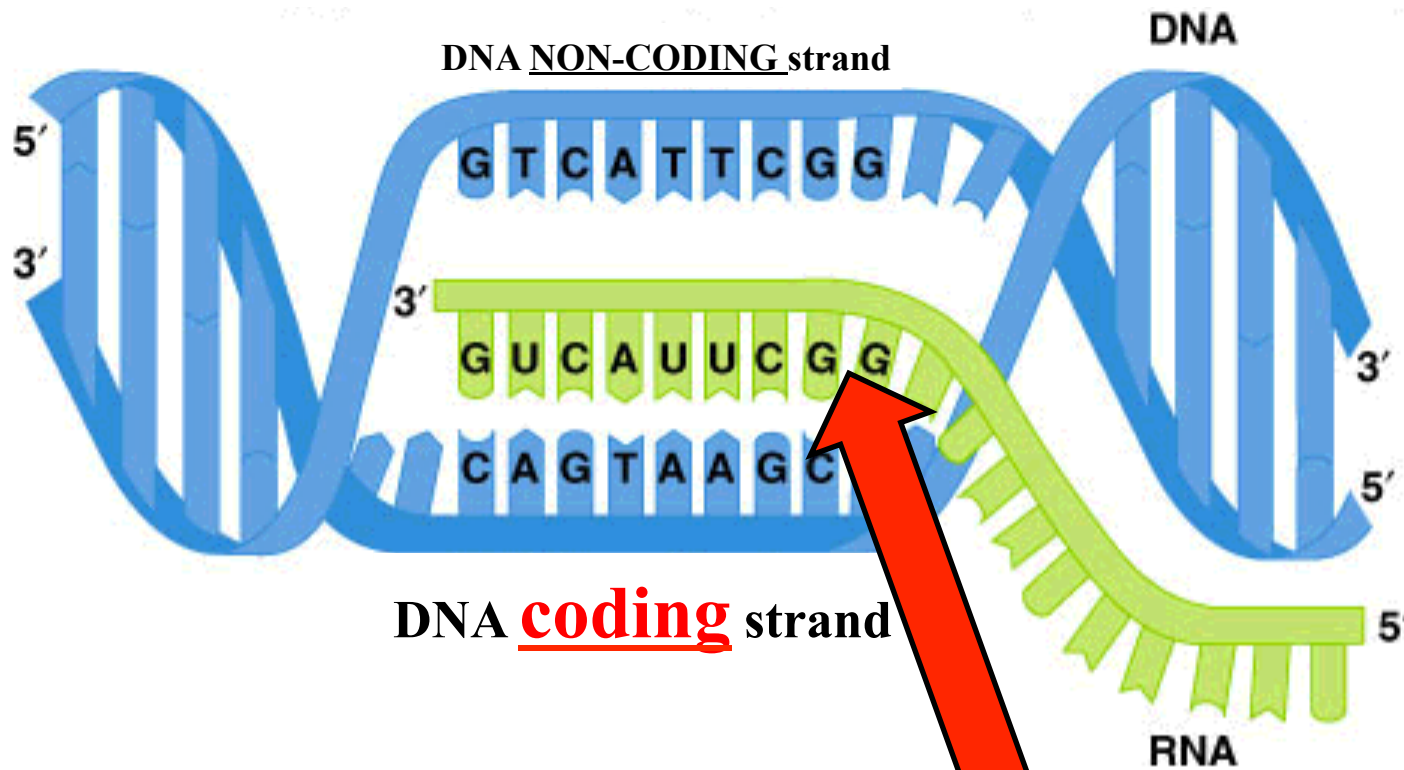


# Step1: Transcription

- Occurs in the nucleus
- **mRNA** makes a (photocopy) using **DNA as a template**
- If the **DNA** base sequence is  
**A A T T C C** (these are called **DNA triplets**)
- The **mRNA** molecule manufactured would be  
**U U A A G G** (these are called **codons** )
- Each **DNA triplet** has a complementary **codon** (on the mRNA)
- mRNA **exits nucleus**

Code must be  
transcribed  
then translated

[Transcription Animation](#)



## Transcription

DNA used as template  
to build mRNA

**Practice:**

DNA Strand:            A T G     G T C     T C G

mRNA Strand:            **U A C**    **C A G**    **A G C**

How many triplets or codons are there? **3**

# Codons

- Each codon codes for an amino acid(building block)  
(REMEMBER: codon = set of 3 nucleic acids...eg. ACG)

## ALSO...

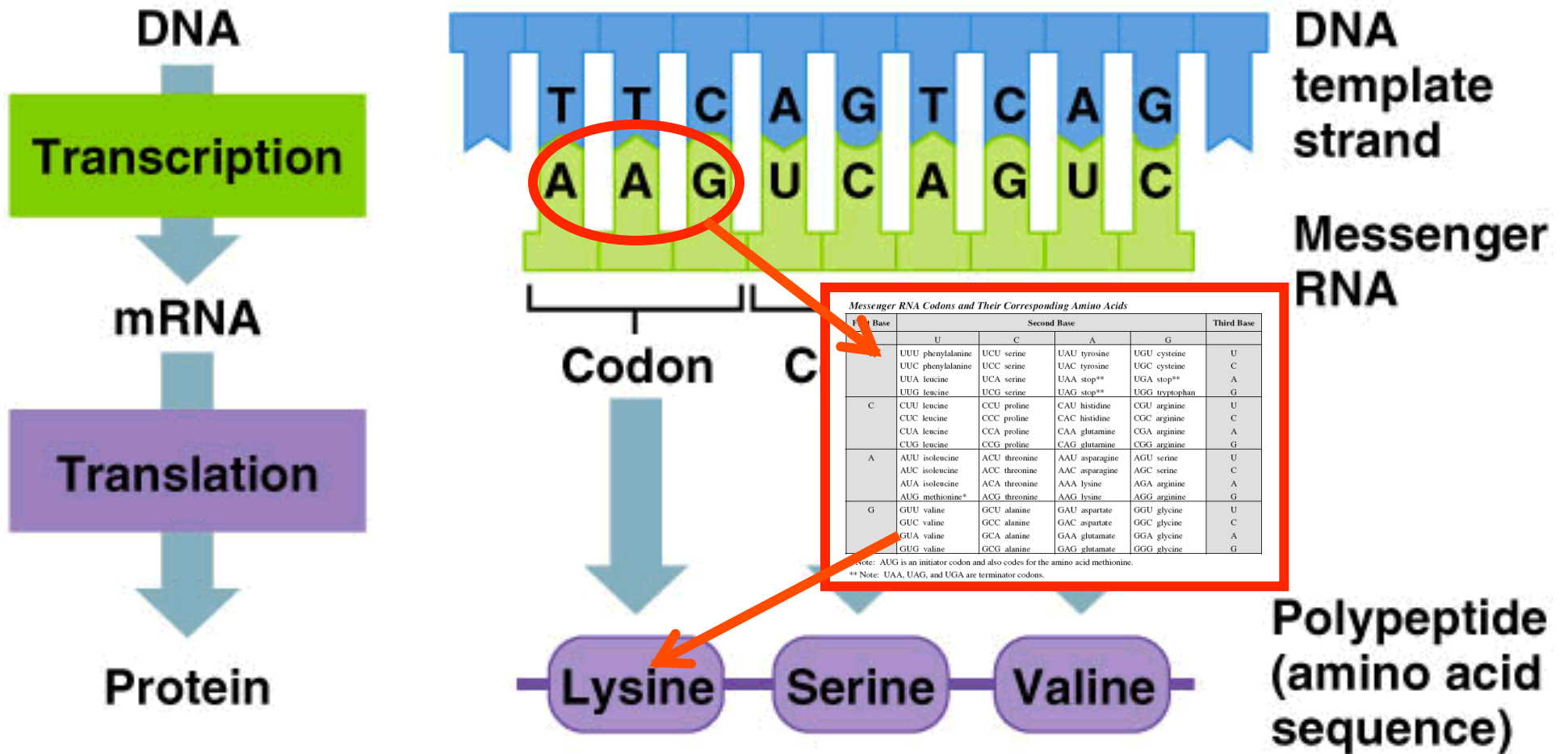
- May code for start = **initiator codon** (starts protein synthesis)  
(AUG)
- May code for stop = **terminator codon** (stops protein synthesis)  
(UAA UAG UGA)
- **AUG** is an **initiator codon** but also codes for the amino acid **methionine** if in the **MIDDLE** of the protein being made

Data table of mRNA codons is  
supplied in diploma!!



# Code must be transcribed then translated

## From DNA to RNA protein



**DON' T CONFUSE WITH DNA SEQUENCE!!**

**Messenger RNA Codons and Their Corresponding Amino Acids**

First Base	Second Base				Third Base
	U	C	A	G	
U	UUU phenylalanine	UCU serine	UAU tyrosine	UGU cysteine	U
	UUC phenylalanine	UCC serine	UAC tyrosine	UGC cysteine	C
	UUA leucine	UCA serine	UAA stop**	UGA stop**	A
	UUG leucine	UCG serine	UAG stop**	UGG tryptophan	G
C	CUU leucine	CCU proline	CAU histidine	CGU arginine	U
	CUC leucine	CCC proline	CAC histidine	CGC arginine	C
	CUA leucine	CCA proline	CAA glutamine	CGA arginine	A
	CUG leucine	CCG proline	CAG glutamine	CGG arginine	G
A	AUU isoleucine	ACU threonine	AAU asparagine	AGU serine	U
	AUC isoleucine	ACC threonine	AAC asparagine	AGC serine	C
	AUA isoleucine	ACA threonine	AAA lysine	AGA arginine	A
	AUG methionine*	ACG threonine	AAG lysine	AGG arginine	G
G	GUU valine	GCU alanine	GAU aspartate	GGU glycine	U
	GUC valine	GCC alanine	GAC aspartate	GGC glycine	C
	GUA valine	GCA alanine	GAA glutamate	GGA glycine	A
	GUG valine	GCG alanine	GAG glutamate	GGG glycine	G

\* Note: AUG is an initiator codon and also codes for the amino acid methionine.

\*\* Note: UAA, UAG, and UGA are terminator codons.

# An Example:

DNA  
non-coding

**ATG GGC CGT AGC TAT CGT TAG**

DNA coding  
strand

**TAC CCG GCA TCG ATA GCA ATC**

mRNA

**AUG GGC CGU AGC UAU CGU UAG**

Amino  
acids

**start gly arg ser tyr arg stop**

[Transcription animation- narrated](http://www.youtube.com/watch?v=D5vH4Q_tAkY&feature=related)

[http://www.youtube.com/watch?v=D5vH4Q\\_tAkY&feature=related](http://www.youtube.com/watch?v=D5vH4Q_tAkY&feature=related)

**I wish I was adenine**



**then I could pair  
with U**

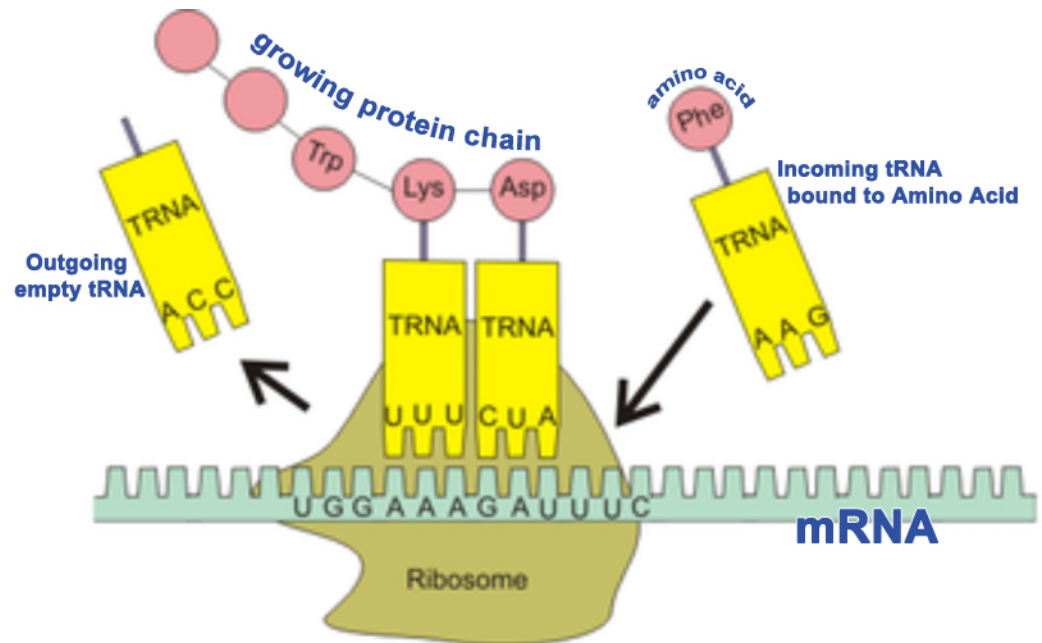
# Translation

- Occurs in the cytoplasm
- mRNA arrives at a **ribosome**
- This is where amino acids are assembled with the help of **tRNA** molecules
- **tRNA** brings the correct amino acid to the ribosome based on:

**Complimentary  
base pair rules**

Ex. A attracts U

- Since there are 20 amino acids , there are **20 different tRNAs**



[Translation Animation](#)

# Translation

- HOW DOES tRNA KNOW WHICH AMINO ACID TO BRING?

tRNA brings the correct amino acid to the ribosome when its **anticodon** matches the **mRNA codon**.

**IMPORTANT:** The amino acid required and brought in on the tRNA is determined by the codon on the mRNA(found on chart) and **NOT THE ANTI-CODON**

Original DNA

DNA AAT TCC GGA

3 codons

mRNA UUA AGG CCU

3 anticodons

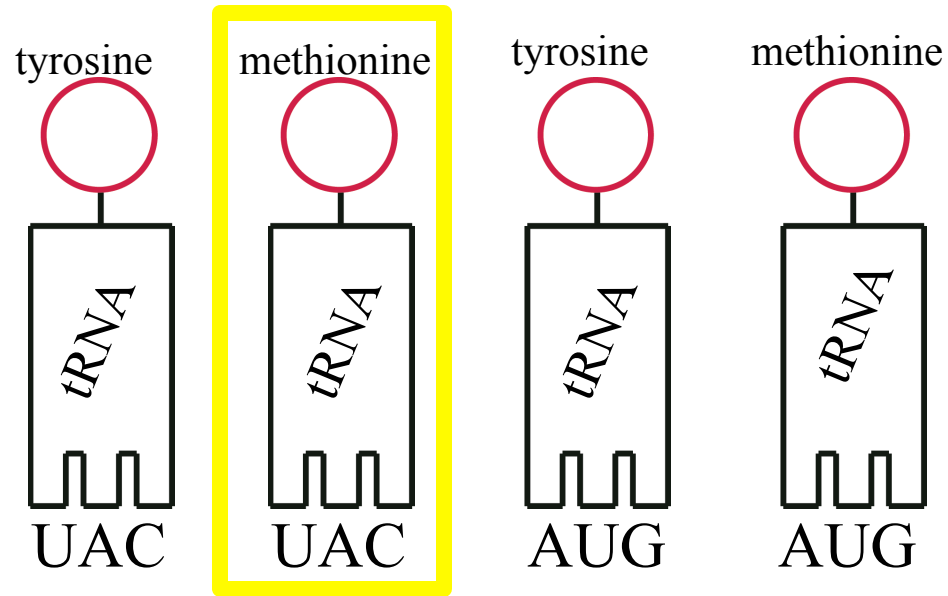
tRNA AAU UCC GGA

Amino acids

leucine - arginine - proline

Example question.

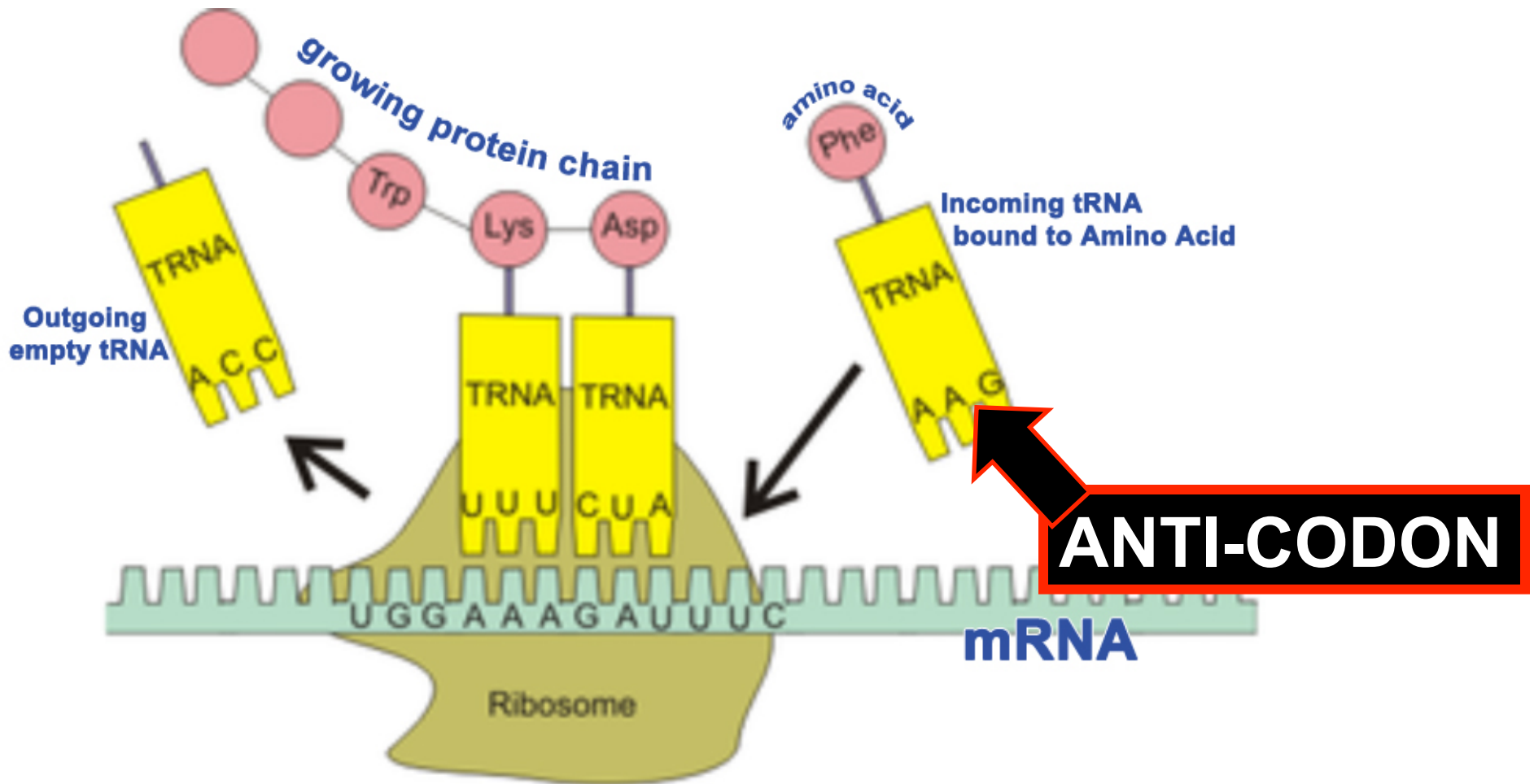
tRNA has an anti-codon that is UAC. Which amino acid will be used?



Because...

UAC is the anti-codon that is on the tRNA above but its complementary base pairing (on mRNA) is AUG which is used with the mRNA codon chart to determine that the amino acid used is methionine

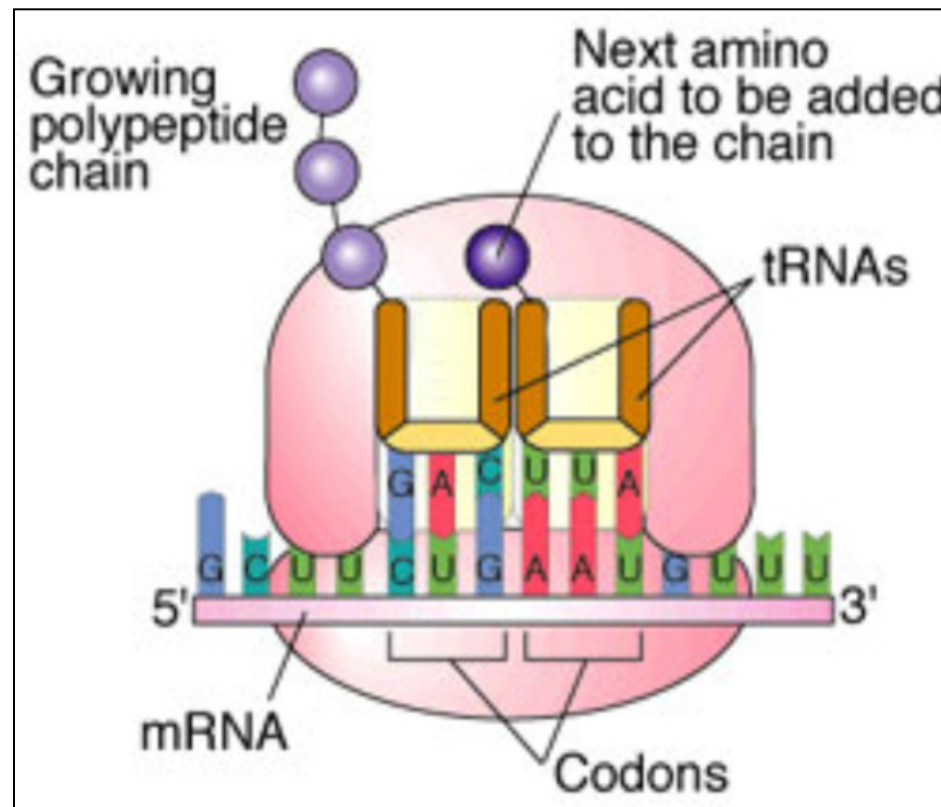
# Translation





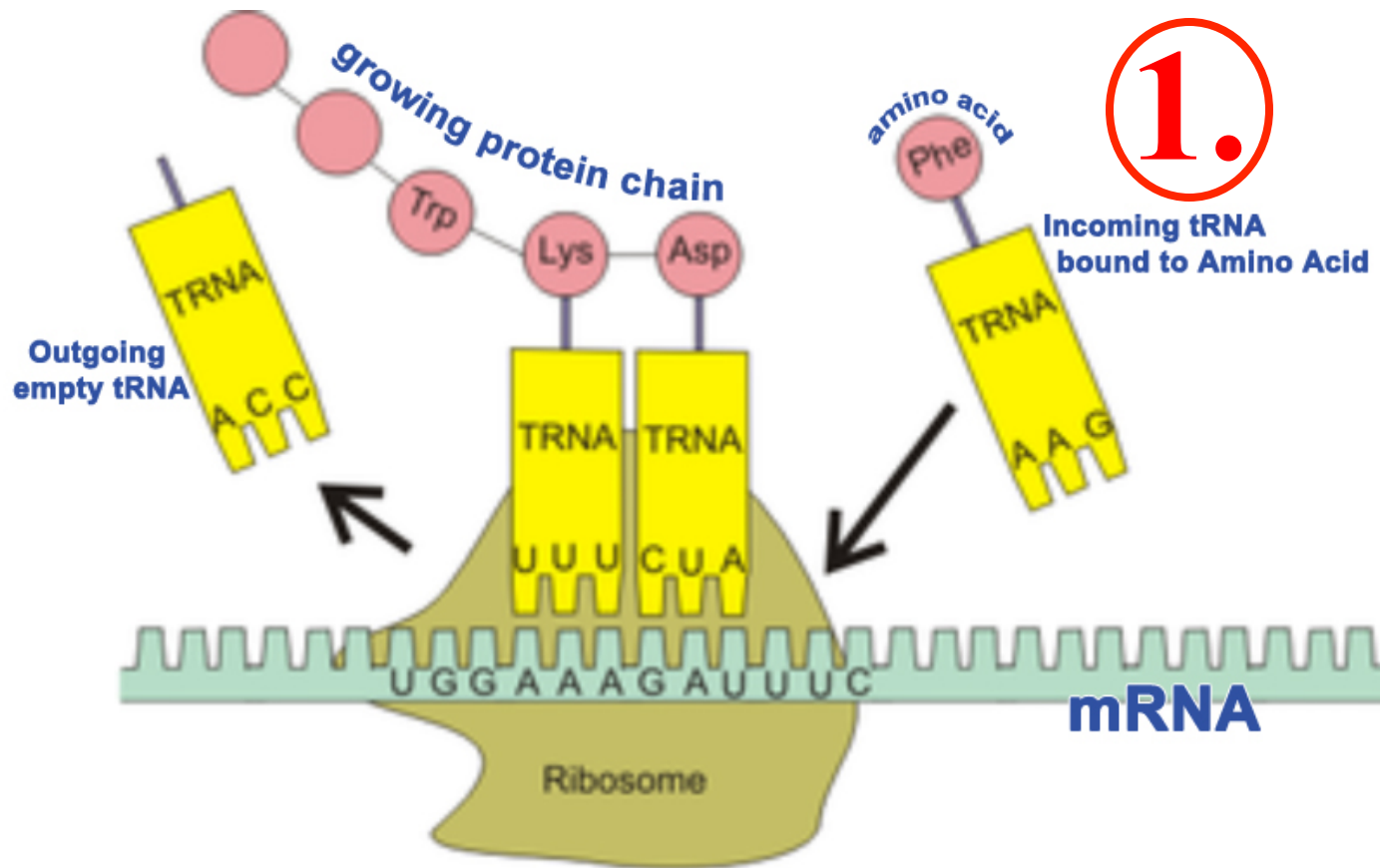
# Translation:

- **mRNA** from the nucleus associates with a ribosome.
- **Ribosomes** are made up of rRNA and other proteins
- The ribosome acts like a scaffold, holding the mRNA in position while the **protein** is being built



# Translation Step 1

1. tRNA, that has a matching anti-codon to the mRNA codon, picks up needed amino acid and joins with mRNA

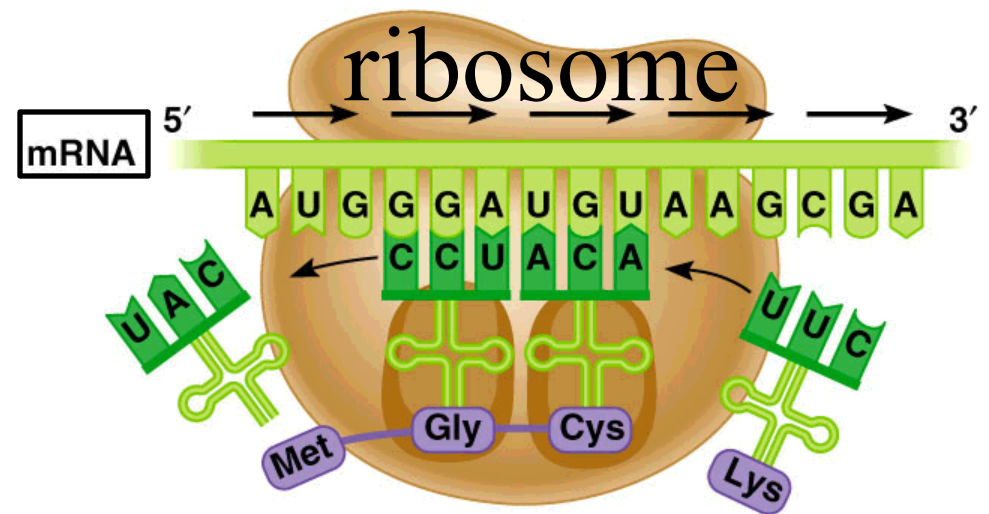


# Translation Step 2

2. The ribosome moves down the mRNA and another tRNA brings the next amino acid.

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## Translating a polypeptide



B

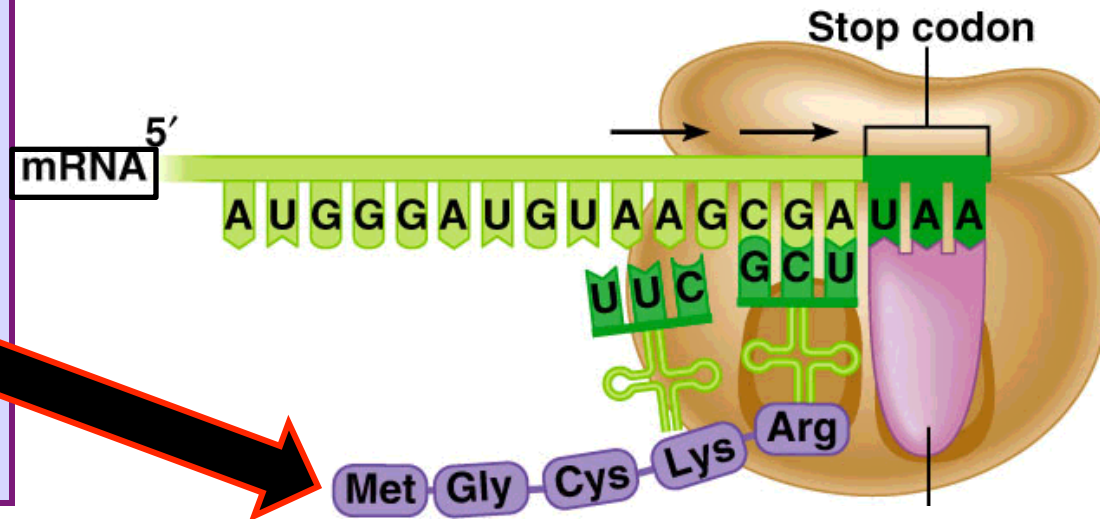
Adjacent amino acids are held together by peptide bonds.

# Translation Step 3

## Translating a polypeptide

3. When mRNA codon reads “stop” (either UAG, UAA, or UGA), the **polypeptide** (amino acid chain) is released.

### TRANSLATION TERMINATION



# Protein Synthesis-THE FINAL RESULT

Depending on how the amino acids are assembled, they fold and take on different 3-D shapes

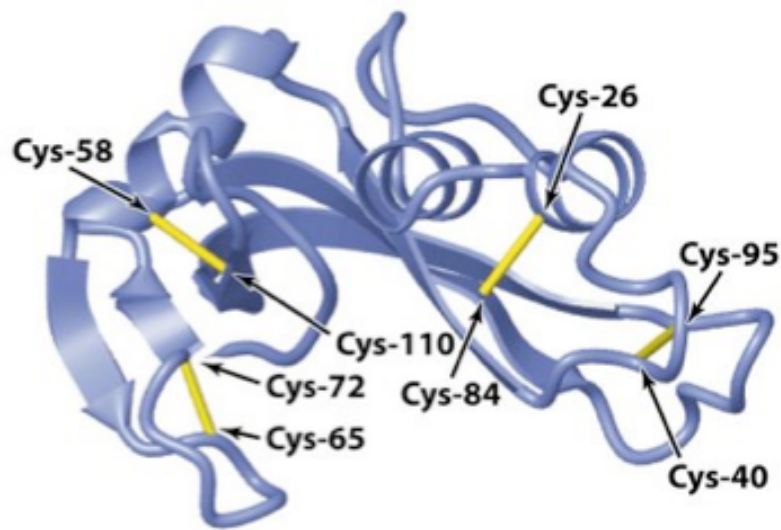
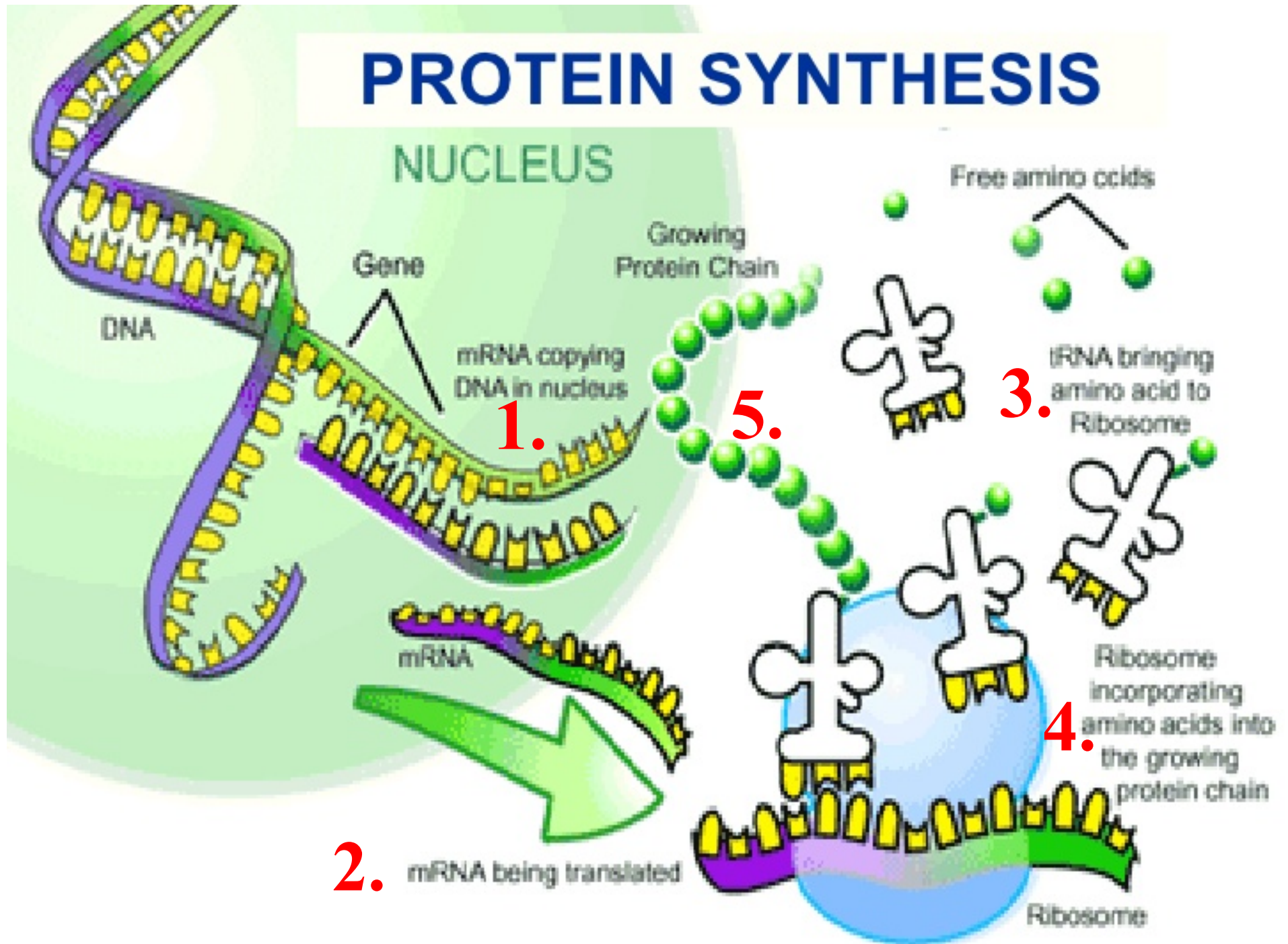


Figure 4-28a Principles of Biochemistry, 4th  
© 2004 Pearson Prentice Hall, Inc.

The shape of a protein is essential to its function



# PROTEIN SYNTHESIS



# Protein Synthesis

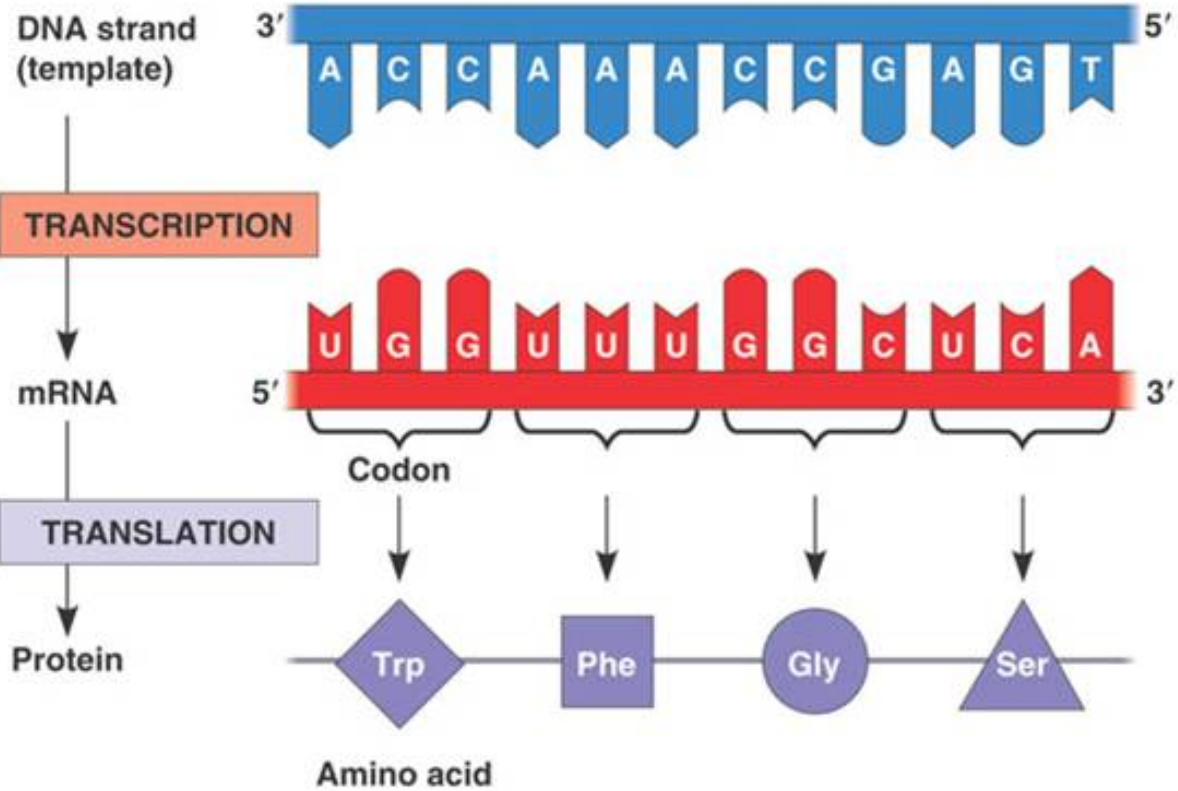
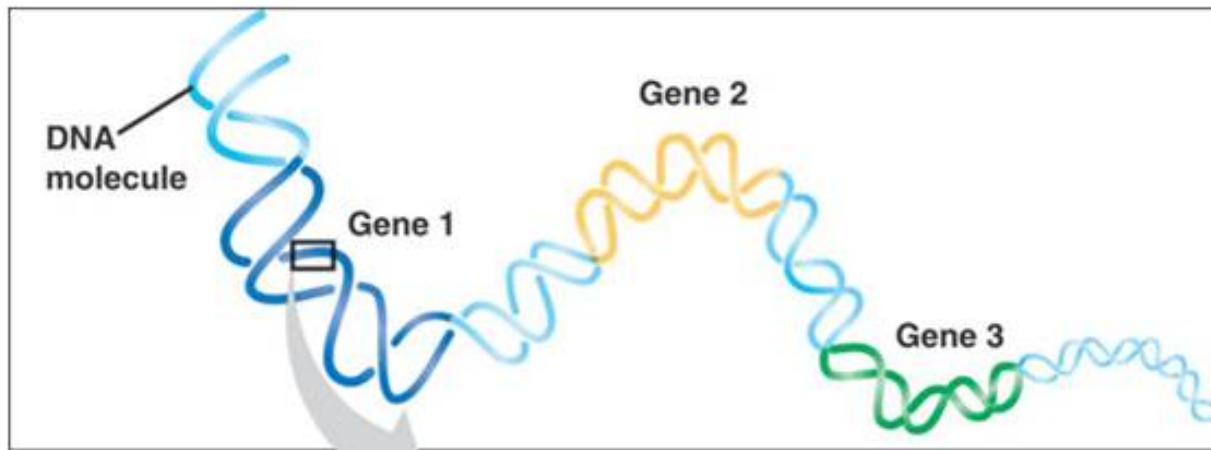
## Transcription

- Location: **nucleus**
- DNA (a gene) is used to code for mRNA
- One gene = one protein
- “T” is replaced with “**U**”

## Translation

- Location: **cytoplasm and ribosomes**
- mRNA is read
- tRNA transfers amino acids
- amino acids are linked by **peptide bonds**

[WATCH - Bozeman-Transcription and Translation](#)





DNA song

Build Your Own Protein

[http://learn.genetics.utah.edu/  
content/molecules/transcribe/](http://learn.genetics.utah.edu/content/molecules/transcribe/)

Extra:

Crash Course: Transcription & Translation

skip 5:13-7:28 - watch till 11:00

Extra:

Bozeman DNA, RNA and Protein Synthesis

<b>1</b>	<b>C</b>									<b>DNA strand 1</b> <i>(non-coding)</i>
<b>2</b>							<b>A</b>	<b>G</b>	<b>G</b>	<b>DNA strand 2</b> <i>(coding)</i>
<b>3</b>		<b>C</b>	<b>A</b>				<b>U</b>			<b>mRNA codons</b>
<b>4</b>				<b>U</b>	<b>G</b>	<b>G</b>				<b>tRNA anticodons</b>
<b>5</b>										<b>amino acids</b>

**Can you go back and forth? Given an mRNA codon, you should be able to determine the nucleotide sequence on the DNA coding strand, tRNA anticodons and the amino acids!**

1	C	C	A	A	C	C	T	C	C	DNA strand 1 (anti-sense)
2	G	G	T	T	G	G	A	G	G	DNA strand 2 (sense)
3	C	C	A	A	C	C	U	C	C	mRNA codons
4	G	G	U	U	G	G	A	G	G	tRNA anticodons
5	PROLINE		THREONINE			SERINE		amino acids		

Can you go back and forth? Given an mRNA codon, you should be able to determine the nucleotide sequence on the DNA coding strand, tRNA anticodons and the amino acids!

# Review Questions

- What is the mRNA codon for the DNA triplet **AAT** = **UUA**
- What is the DNA triplet for the mRNA codon **CCG** = **GGC**  
mRNA tRNA
- What is the tRNA anticodon for the DNA triplet **GCA** = **CGU** = **GCA**
- What is the mRNA codon for the tRNA **GAU** = **CUA**
- What is the tRNA anticodon for the mRNA codon **UUA** = **AAU**  
mRNA DNA
- What is the DNA triplet for the anticodon **CUA** = **GAU** = **CTA**
- What is the codon for the anticodon **UAG** = **AUC**  
mRNA tRNA
- What is the anticodon for the DNA triplet **CTA** = **GAU** = **CUA**

Make your own protein!

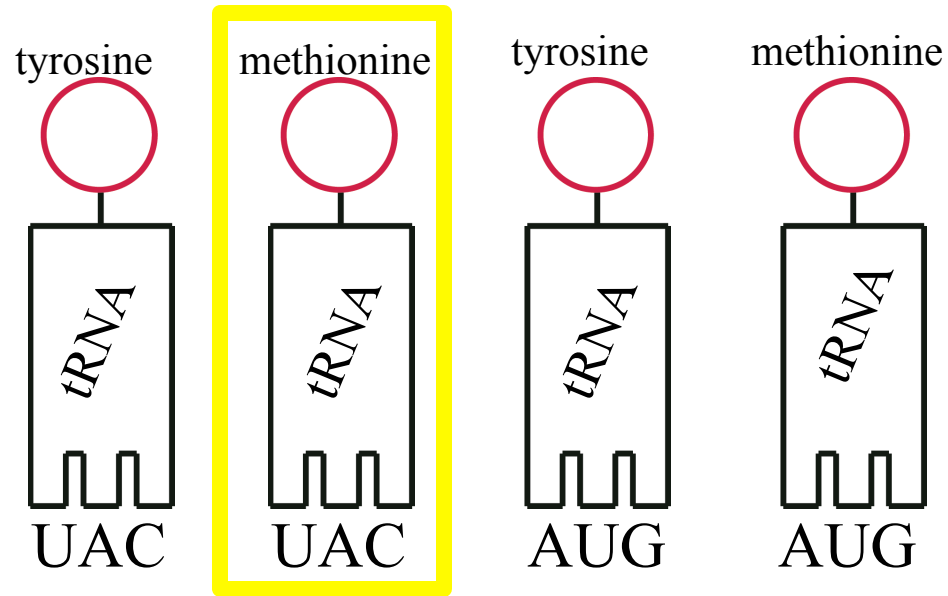
# Great Review Videos

## Transcription

- [http://www.youtube.com/watch?v=D5vH4Q\\_tAkY&feature=related](http://www.youtube.com/watch?v=D5vH4Q_tAkY&feature=related)

Example question.

tRNA has an anti-codon that is UAC. Which amino acid will be used?



Because...

UAC is the anti-codon that is on the tRNA above but its complementary base pairing (on mRNA) is AUG which is used with the mRNA codon chart to determine that the amino acid used is methionine

The hemoglobin molecule contains iron. A portion of the DNA template that codes for the hemoglobin molecule is shown below.

**CAT GCC ATA GAG**

The anticodon of the tRNA molecule that transports the first amino acid coded by this portion of the DNA molecule is

- A.** CAU
- B.** CUA
- C.** GAU
- D.** GUA

DNA: CAT  
mRNA: GUA  
tRNA: CAU

A DNA nucleotide triplet that codes for the amino acid glutamine is

- A.** GAC
- B.** GTC
- C.** CTT
- D.** CTC

On mRNA codon chart glutamine = CAA or CAG

mRNA: CAA                      CAG  
DNA:    GTT                      GTC

The mRNA nucleotides that are transcribed from the DNA trinucleotide CTG contain phosphate,

- A.** ribose, and the bases guanine, adenine, and cytosine
- B.** ribose, and the bases cytosine, thymine, and guanine
- C.** deoxyribose, and the bases guanine, adenine, and cytosine
- D.** deoxyribose, and the bases cytosine, thymine, and guanine

DNA:	CTG
mRNA:	GAC

*ribose*