UNIT 6: DNA/RNA/PROTEIN SYNTHESIS

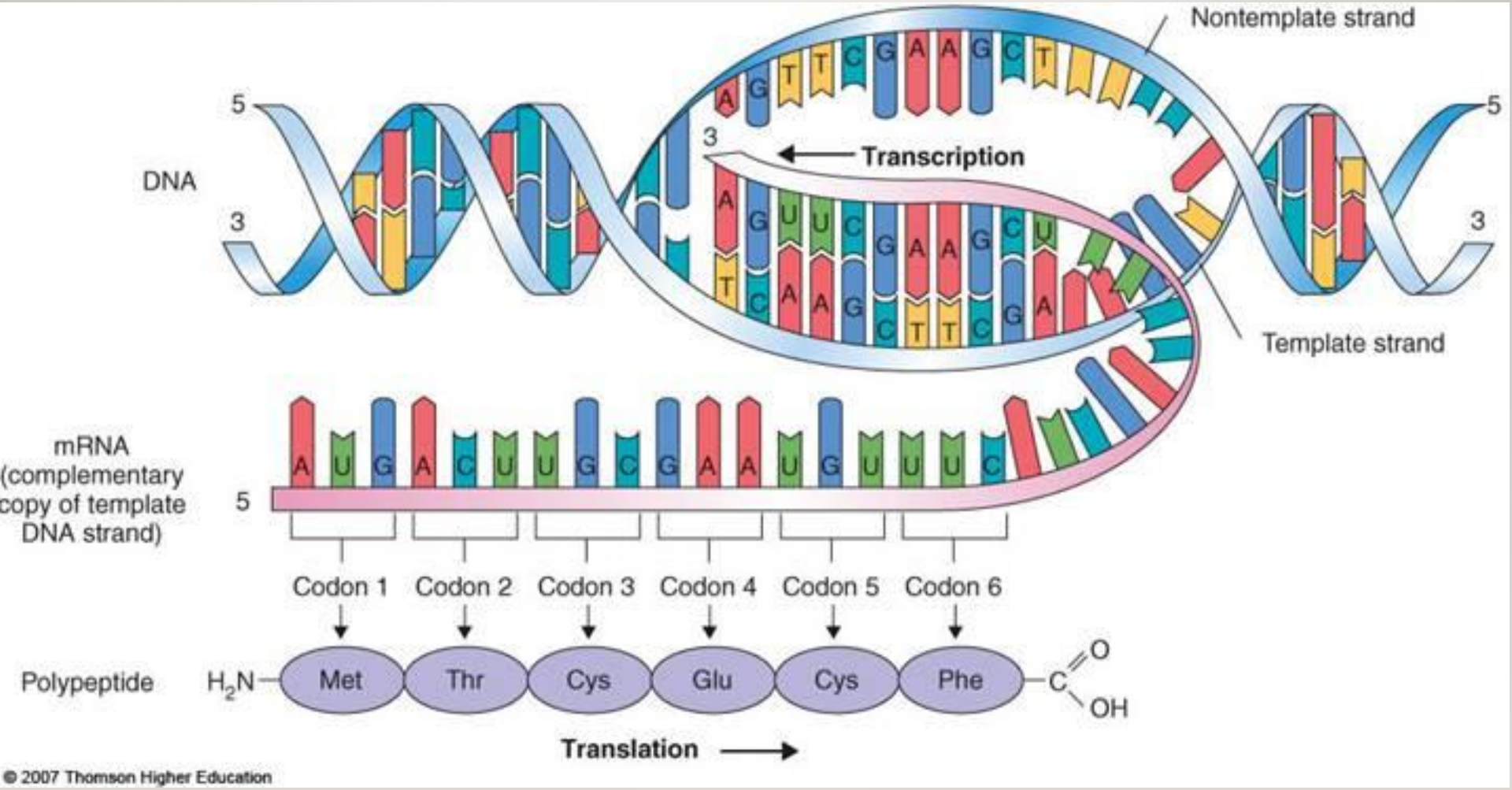
TOPIC 3: PROTEIN SYNTHESIS

By the end of this topic, you should be able to…

- *Describe the differences between DNA and RNA*
- *Identify and order the steps in protein synthesis (transcription and translation)*
- *Explain the purpose of the molecules used in both transcription and translation*
- *Use a codon chart to determine a protein sequence based on an mRNA code*
- *Compare and contrast gene and chromosomal mutations*
- *Predict the effect of DNA mutations on the resulting protein*

WHAT CARRIES THE GENETIC MATERIAL OF THE CELL?

- DNA. However, why did early scientists think that protein carried this material?
  - Compare the number of different monomers protein has with the number of monomers DNA (nucleic acids) have.

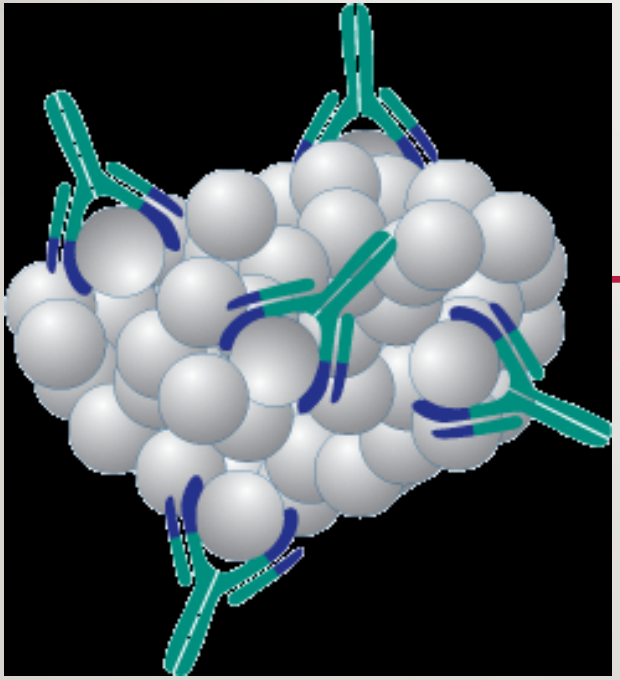


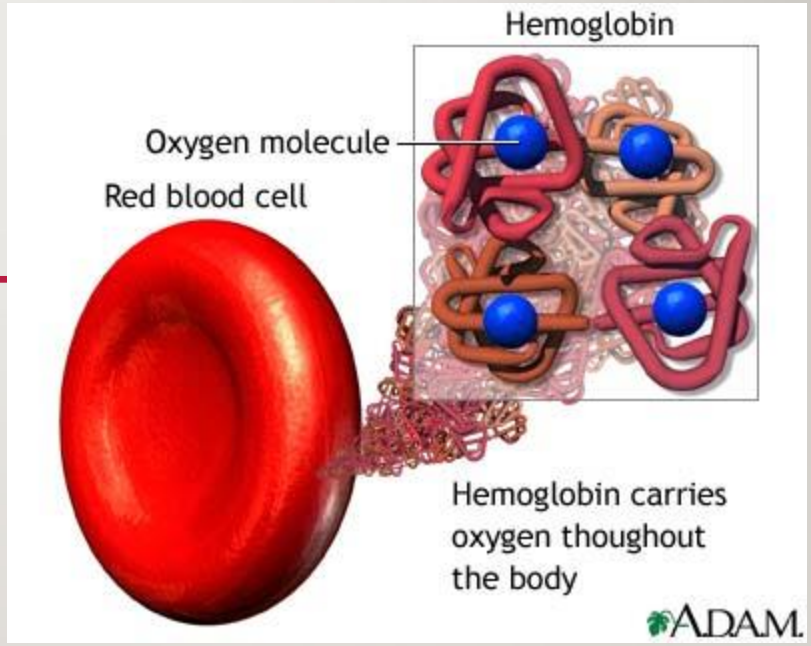
SO WHAT ARE PROTEINS?

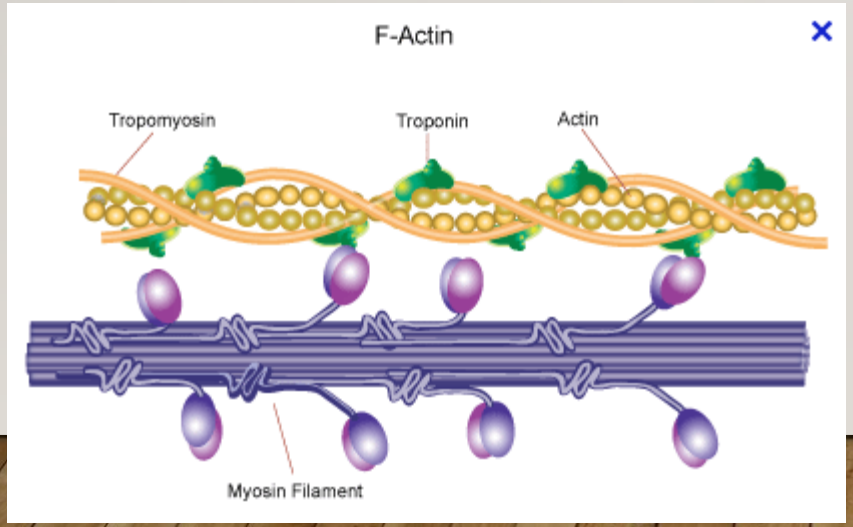
- Proteins are the "work-horses" of the cell…they do a lot of different jobs!

A) Antibodies – immune system (defense)
B) Structure – hair and nails
C) Speeding Up Reactions – enzymes
D) Transport – hemoglobin (in blood)
E) Movement – muscle

And the list goes on!

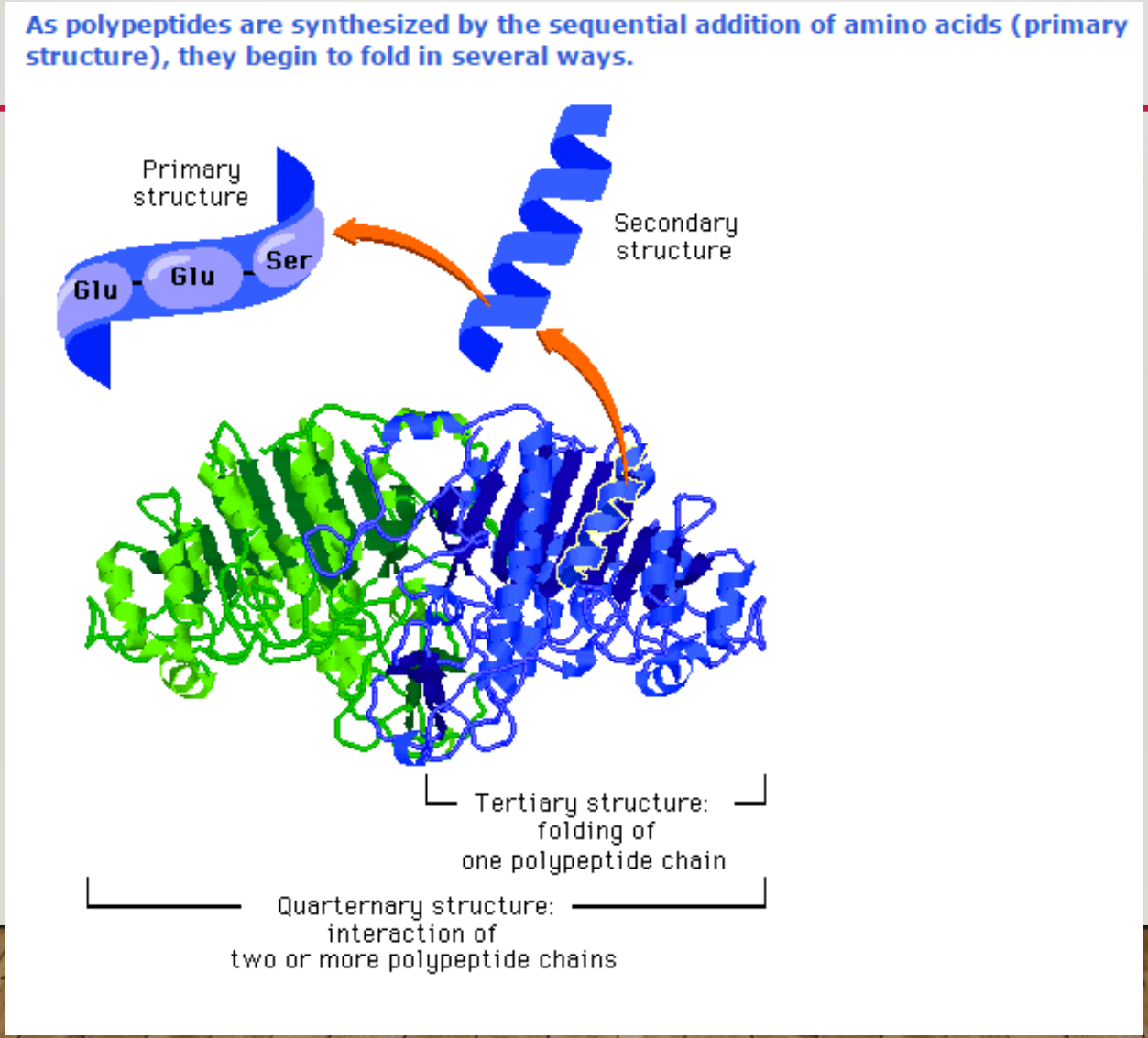




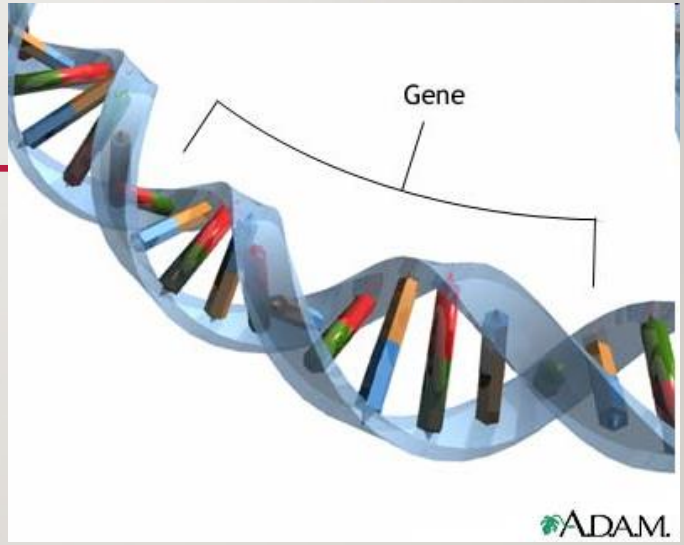


Question: Why do these proteins all have different shapes?

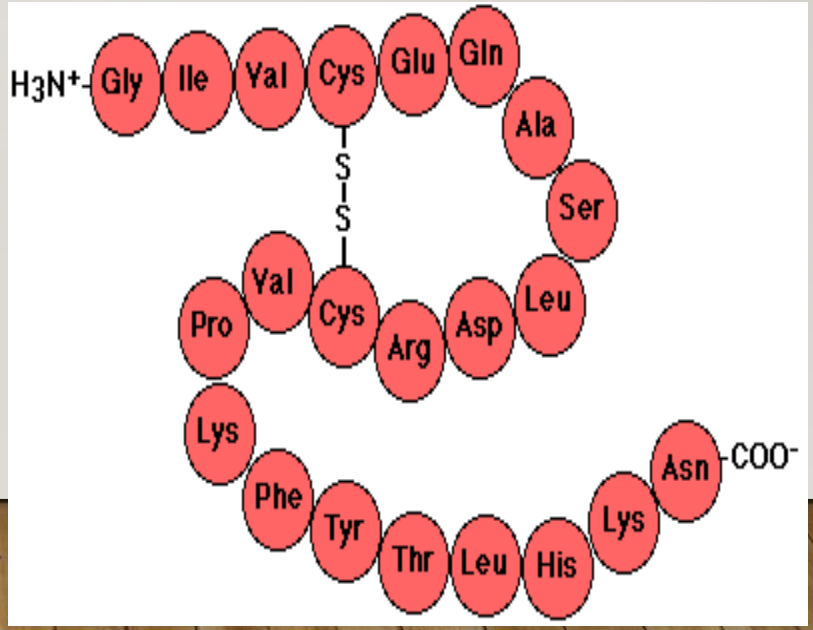
PROTEIN STRUCTURE



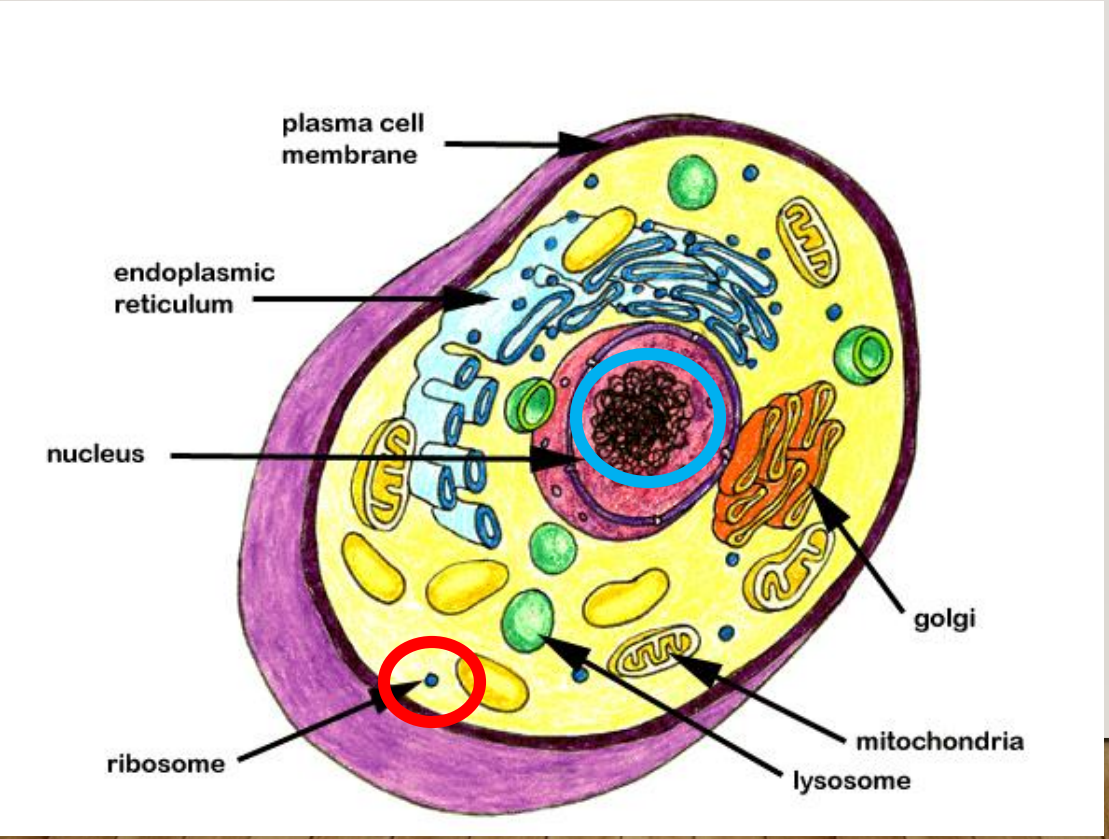
HOW DO OUR CELLS MAKE PROTEINS?



- DNA contains genes, sections of nucleotide chains
- Genes code for polypeptides (proteins)
- Polypeptides are amino acid chains

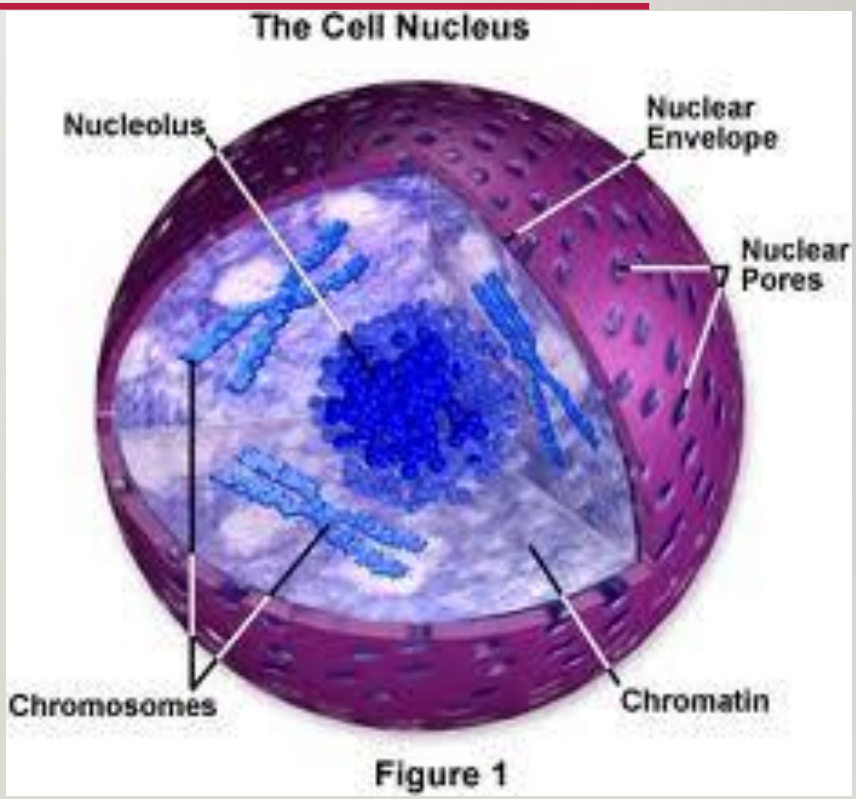


- DNA is found inside the nucleus. but proteins are made in ribosomes
- **Predictions:** So how do we get the message from DNA in the nucleus to the ribosomes?



THE SOLUTION?

- A molecule called RNA carries the message from the nucleus to the cytoplasm!
- Unlike DNA, RNA is small enough to fit through the pores in the nuclear membrane



PUTTING IT TOGETHER

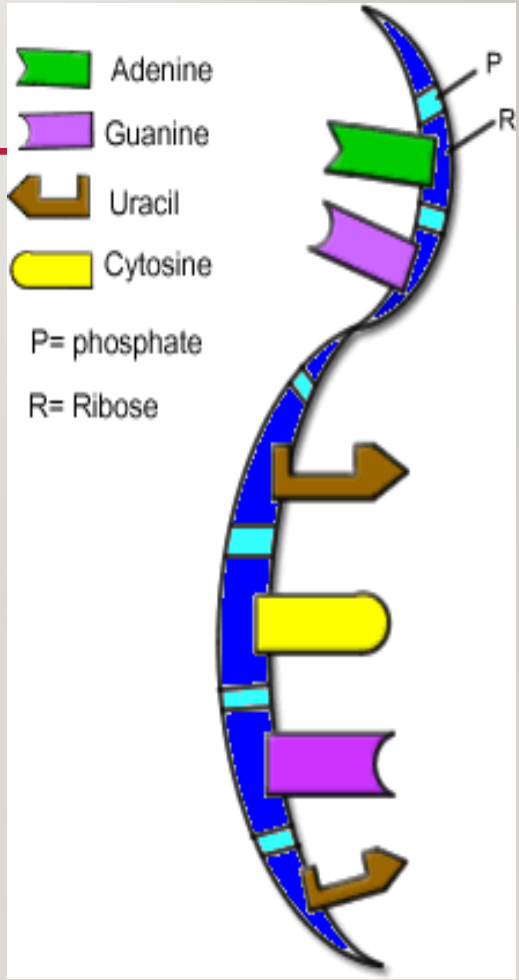
- **DNA** is responsible for controlling the production of **proteins** in the cell, which is essential to life
  - DNA→RNA→Proteins
- **Chromosomes** contain several thousand **genes**, each with the directions to make one **protein**
  - Do you remember the organelle where proteins are produced?

WHERE ARE PROTEINS PRODUCED?

- **Ribosomes**!
  - Ribosomes are where proteins are made
- Ribosomes are found in two places:
  - – Free floating in the **cytoplasm**
  - – Attached to **Endoplasmic Reticulum (Rough ER)**
- So…how does information needed to build the protein get delivered from the DNA to the ribosomes???
  - -With the help of **RNA** in a process called **protein synthesis**!

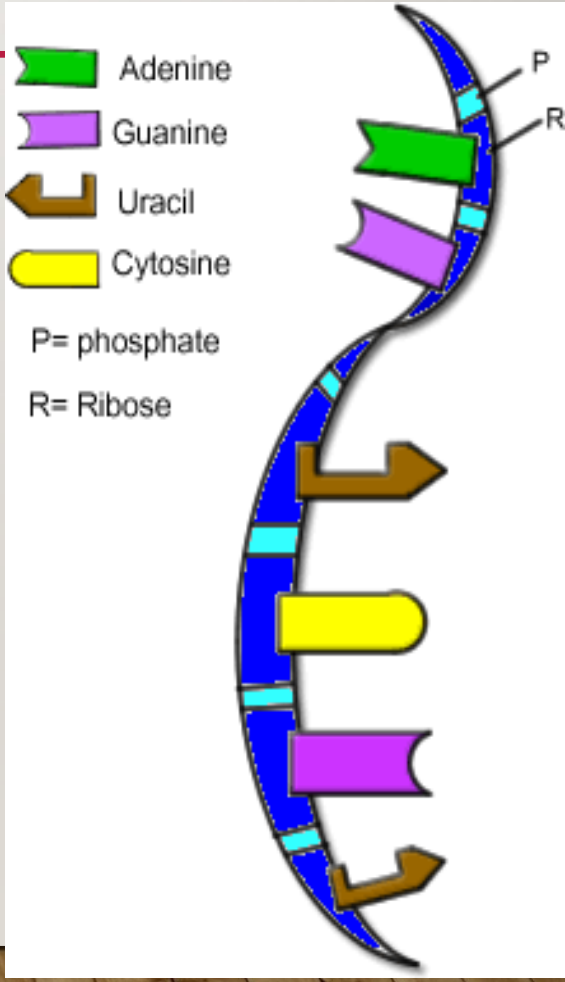
WHAT IS RNA?

- RNA stands for **ribonucleic acid**
- One subunit of RNA is a **nucleotide** (just like DNA!)
  - 1 - 5 carbon **sugar** (it's ribose in RNA)
  - 1 - **phosphate** group
  - 1 – nitrogenous (N) **base**
- Three types of RNA
  - **mRNA, rRNA, tRNA**
  - First, we will look at mRNA!



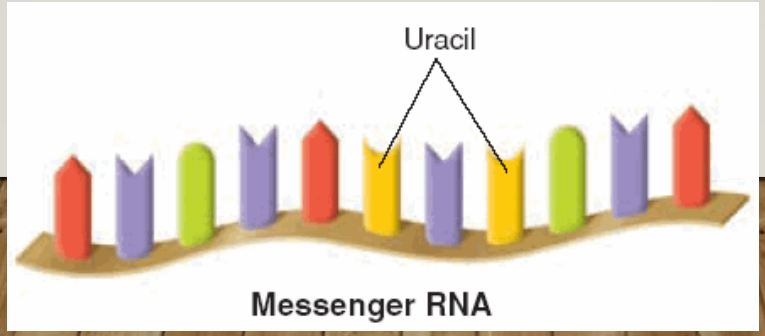
A CLOSER LOOK AT RNA

- Looking at the mRNA to the right, how is it different visually from DNA?
  - It is **single** stranded
  - It is **shorter** and able to leave the **nucleus**
  - The sugar is **ribose**
  - There is a different base
    - **Uracil** (U) takes the place of **Thymine** (T)



ABOUT mRNA

- The job of mRNA is to take the directions for one gene and transport it to a **ribosome** in the **cytoplasm** where it is translated.
  - This is so the cell can begin assembling **amino acids**, the building blocks of **proteins**
  - Like it's name, it is sending a **message** on how to do the job
  - This is part of a process called protein synthesis

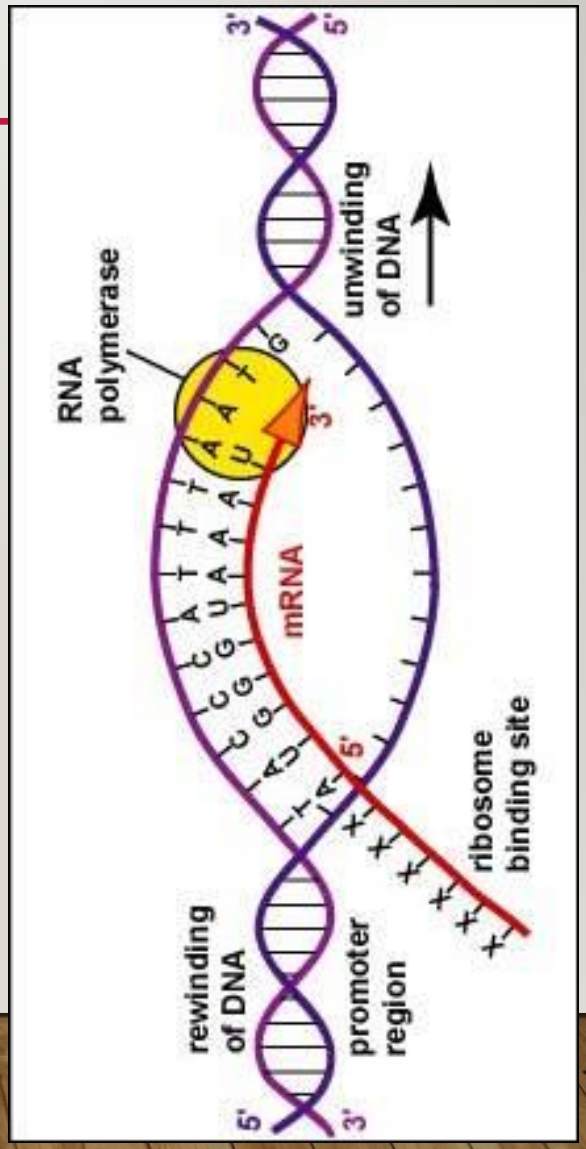


PROTEIN SYNTHESIS

- Protein synthesis is a two stage process
  - **Transcription and Translation**
- In this process, a **messenger** molecule (mRNA) carries instructions from DNA to ribosomes
  - DNA **cannot** leave the nucleus; **mRNA** can!
  - **mRNA** makes it possible for **proteins** to be assembled by **ribosomes** outside of the nucleus

TRANSCRIPTION

- Transcription happens when **DNA** is turned into **mRNA**
- This happens when **proteins** need to be made in the **cytoplasm**!
- Since DNA cannot leave the **nucleus**, it is **transcribed** into RNA (DNA→RNA)
  - Transcribe: **to copy** (copy in the same nucleic acid language, but only copy what is needed)

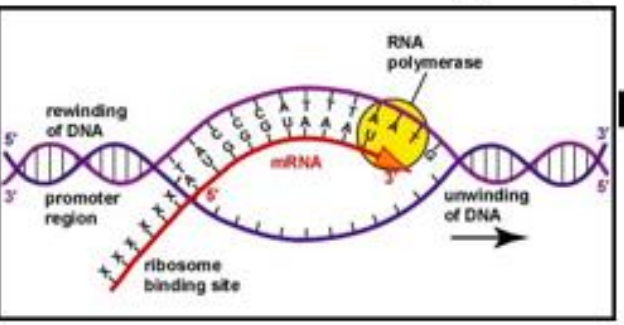


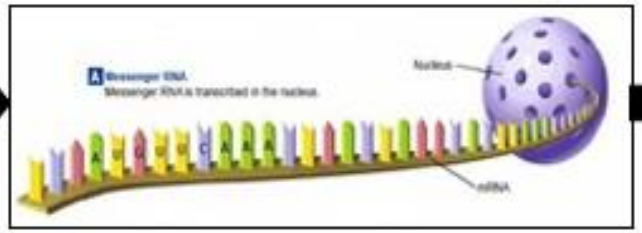
HOW DOES IT HAPPEN?

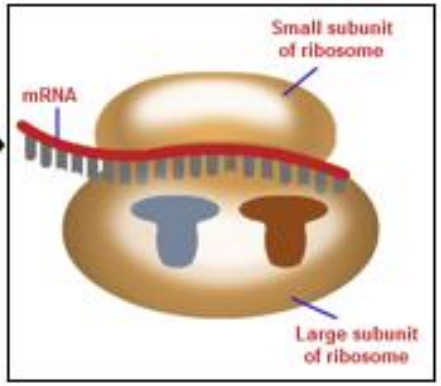
- After an **enzyme** targets the portion of the DNA that should be copied (**initiation**), the sections of DNA (**genes**) will temporarily **unwind** to allow mRNA to **transcribe** (copy). This will continue until an enzyme signals “the end”
- mRNA leaves the **nucleus**, travels into the **cytoplasm** and attaches to a **ribosome**
- The “message” from DNA can now be translated to make a **protein**

PROTEIN SYNTHESIS

Think about it: What is happening in each photo below during transcription?







BASE PAIRS

- Transcribing DNA to mRNA is very easy if you remember these complementary pairs!
  - **C** (in RNA) will attach to a **G** (in DNA)
  - **G** (in RNA) will attach to a **C** (in DNA)
  - **A** (in RNA) will attach to a **T** (in DNA)
  - **U** (in RNA) will attach to a **A** (in DNA)

Try it!

- A piece of DNA reads: T A G C A T T C C G A U
  - transcribe to mRNA:_____
- 1 side of DNA reads: A A G C G T A T C C C G
  - Transcribe to mRNA: _____

TRANSLATION

- *Translation*: the process in which **mRNA** is used as a **blueprint** to form chains of **amino acids** (RNA→Protein)
  - Amino acids linked together form a **protein**
  - Translate: To change a sentence from one language (**nucleic acid**) to another (**amino acid**)
- Every 3 letters on an mRNA chain = **codon**
- Each codon (3 DNA letters) = 1 **amino acid**

READING A CODON CHART

- Given the **mRNA**, we can read a **codon** chart to translated into the amino acid it codes for
- Remember, 1 word in nucleic acid language is a **codon** (three nucleotides)

First Letter	Second Letter				Third Letter
	U	C	A	G	
U	phenylalanine	serine	tyrosine	cysteine	U
	phenylalanine	serine	tyrosine	cysteine	C
	leucine	serine	stop	stop	A
	leucine	serine	stop	tryptophan	G
C	leucine	proline	histidine	arginine	U
	leucine	proline	histidine	arginine	C
	leucine	proline	glutamine	arginine	A
	leucine	proline	glutamine	arginine	G
A	isoleucine	threonine	asparagine	serine	U
	isoleucine	threonine	asparagine	serine	C
	isoleucine	threonine	lysine	arginine	A
	(start) methionine	threonine	lysine	arginine	G
G	valine	alanine	aspartate	glycine	U
	valine	alanine	aspartate	glycine	C
	valine	alanine	glutamate	glycine	A
	valine	alanine	glutamate	glycine	G

Think about it: What amino acid is coded for?

AUG _____

GUC _____

GCC _____

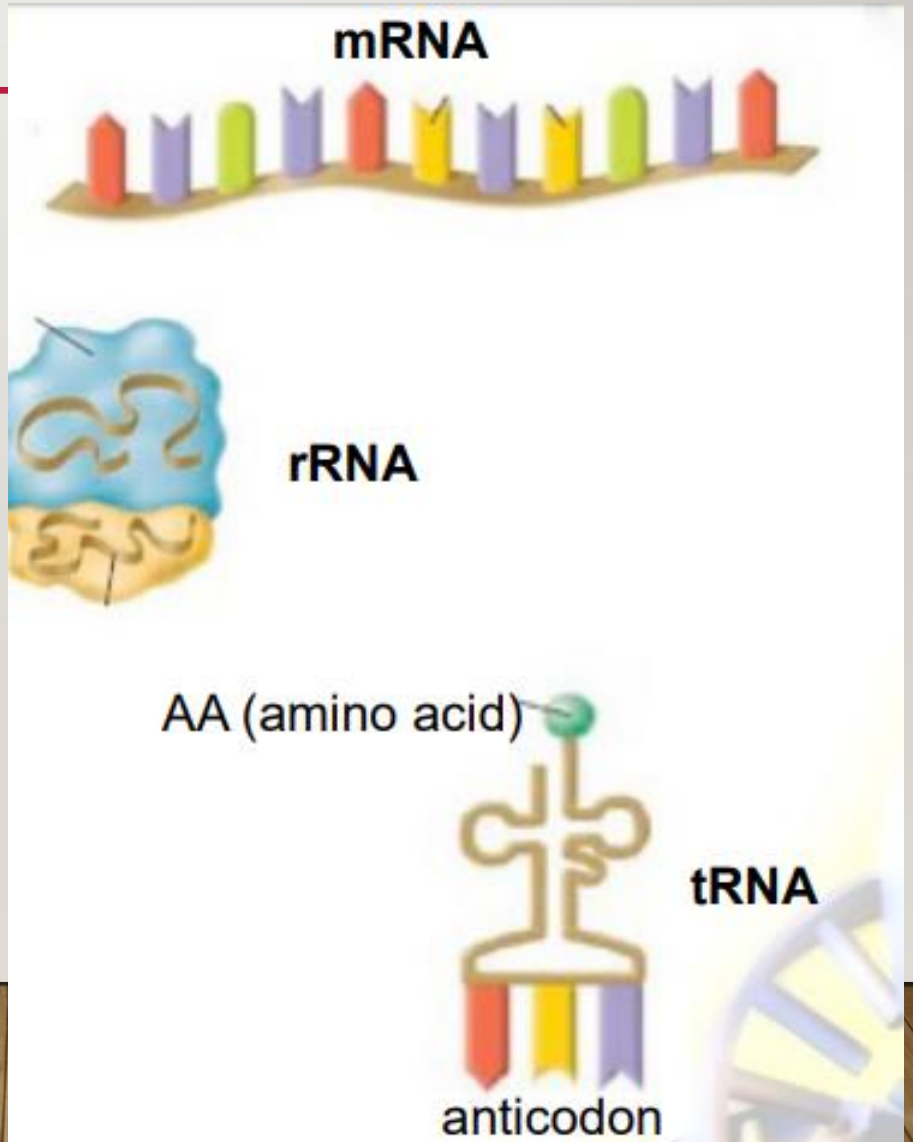
CGA _____

UAA _____

First Letter	Second Letter				Third Letter
	U	C	A	G	
U	phenylalanine	serine	tyrosine	cysteine	U
	phenylalanine	serine	tyrosine	cysteine	C
	leucine	serine	stop	stop	A
	leucine	serine	stop	tryptophan	G
C	leucine	proline	histidine	arginine	U
	leucine	proline	histidine	arginine	C
	leucine	proline	glutamine	arginine	A
	leucine	proline	glutamine	arginine	G
A	isoleucine	threonine	asparagine	serine	U
	isoleucine	threonine	asparagine	serine	C
	isoleucine	threonine	lysine	arginine	A
	(start) methionine	threonine	lysine	arginine	G
G	valine	alanine	aspartate	glycine	U
	valine	alanine	aspartate	glycine	C
	valine	alanine	glutamate	glycine	A
	valine	alanine	glutamate	glycine	G

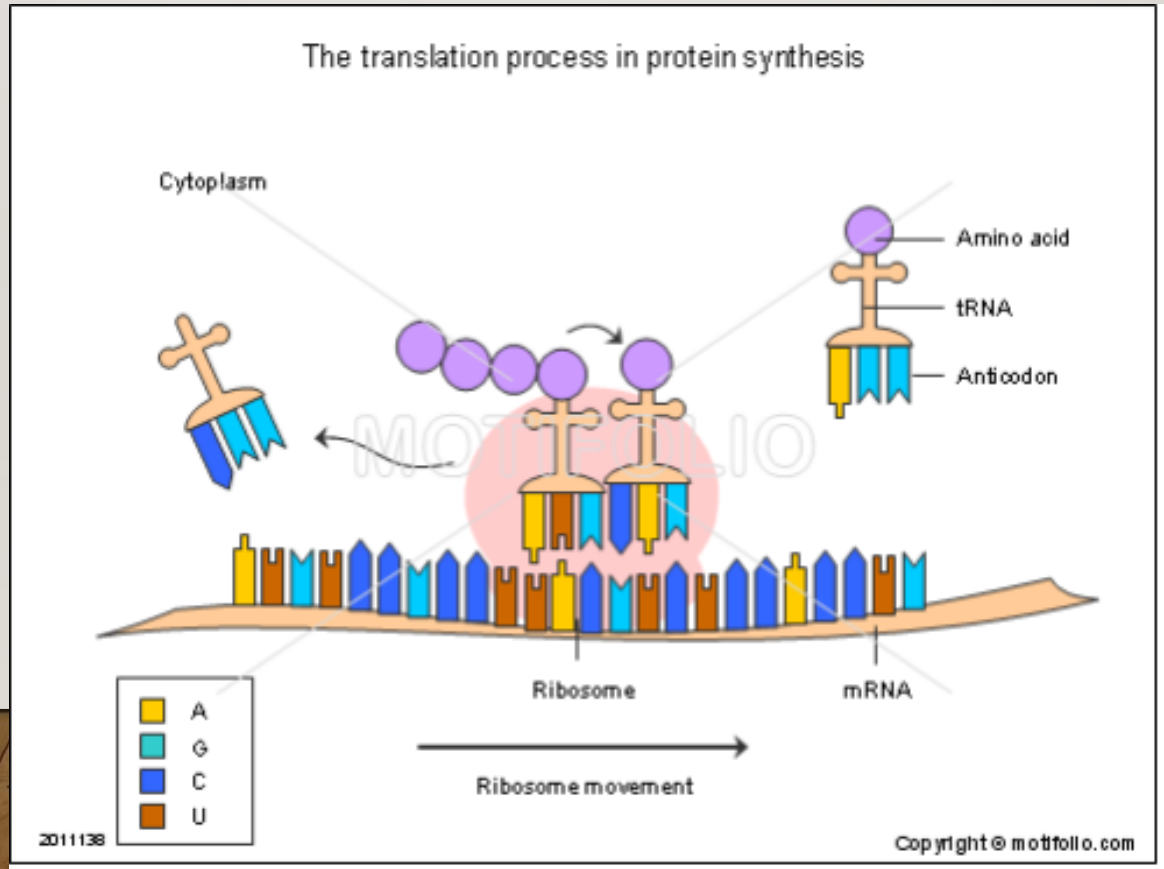
TRANSLATION

- Occurs in a **ribosome** in ALL cells
- This process uses all three forms of RNA **(mRNA, rRNA, and tRNA)**
- DNA is not directly used!



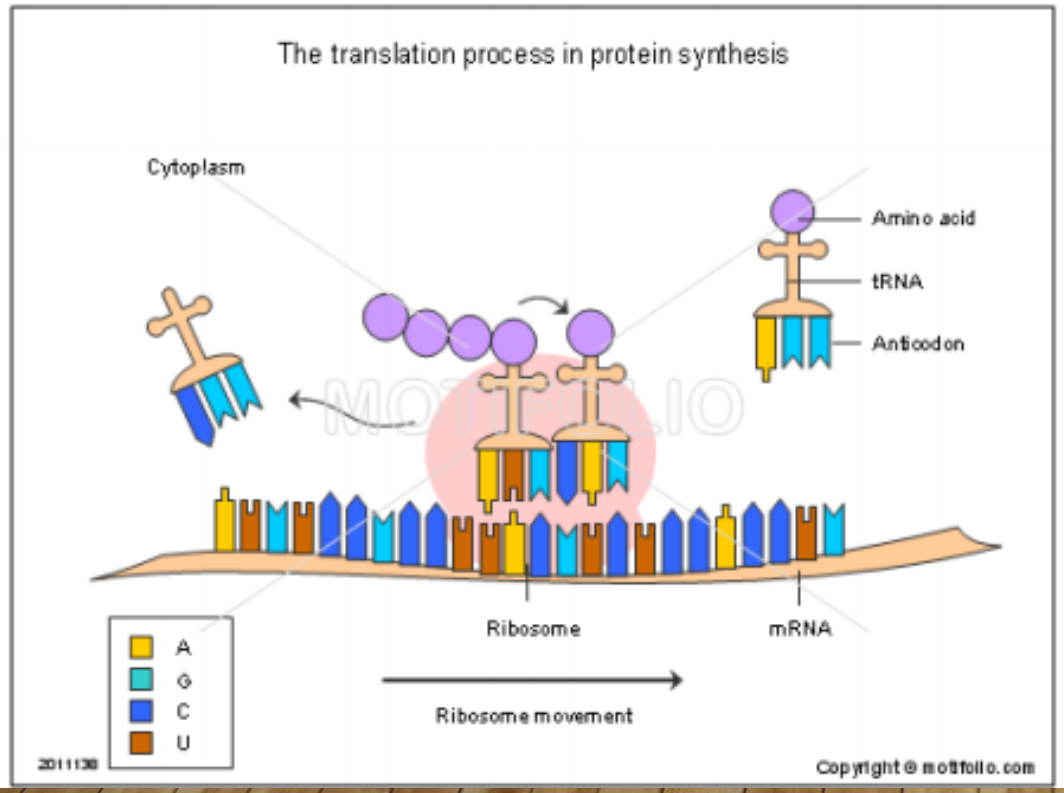
STEPS OF TRANSLATION

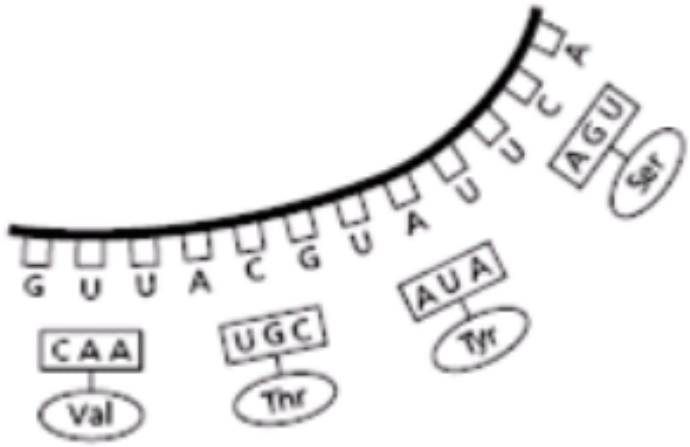
1.The mRNA leaves the **nucleus** and lands on a **ribosome** (rRNA)

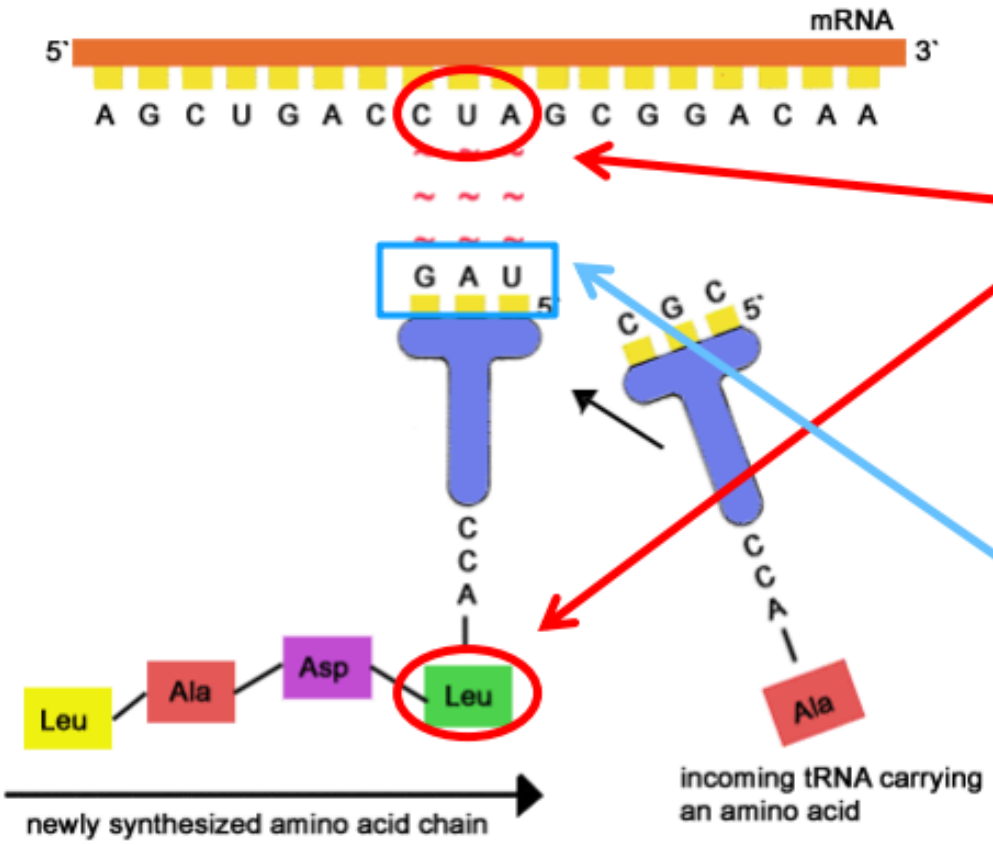


STEPS, CONT

2. **tRNA** (with the correct anticodon) lands on the ribosome opposite a **codon** on the mRNA

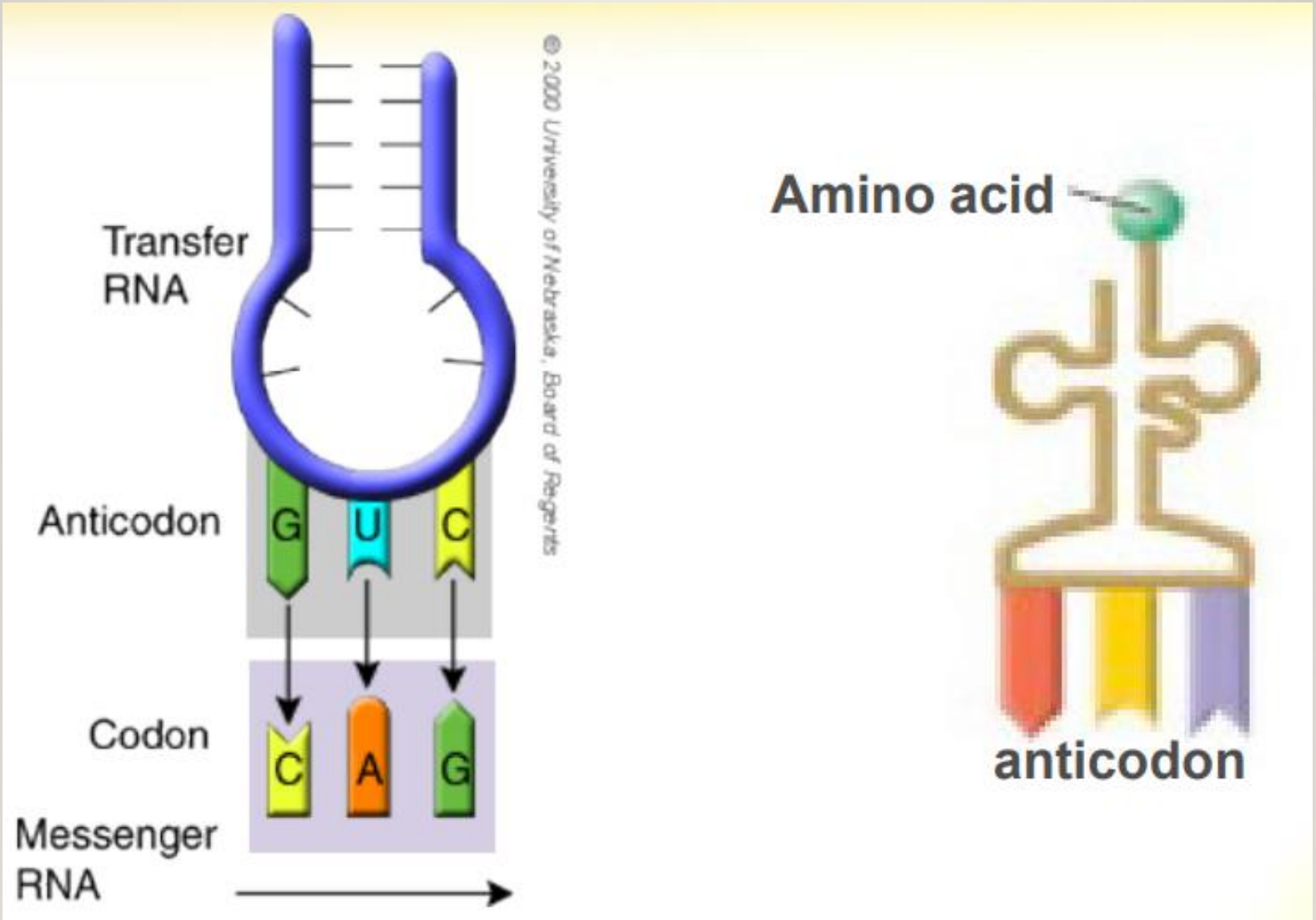






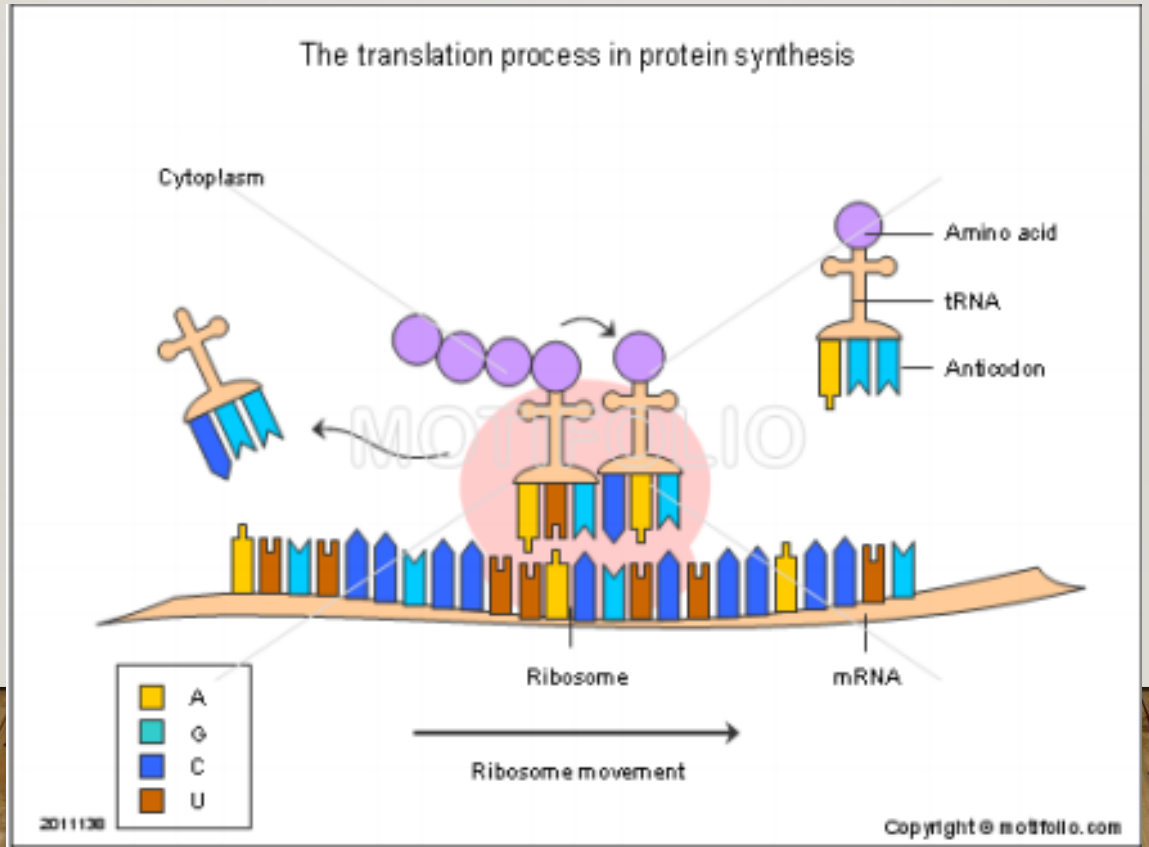
Notice the tRNA is carrying the amino acid leucine, coded for by the sequence "CUA" (check your codon chart")

The tRNA knows how to match using bases! In RNA, G→C and A→U: So…mRNA codon reads "CUA," so the tRNA anticodon will be "GAU"


Transfer RNA
Anticodon
G
U
C
Codon
C
A
G
Messenger RNA
© 2000 University of Nebraska, Board of Regents
Amino acid
anticodon

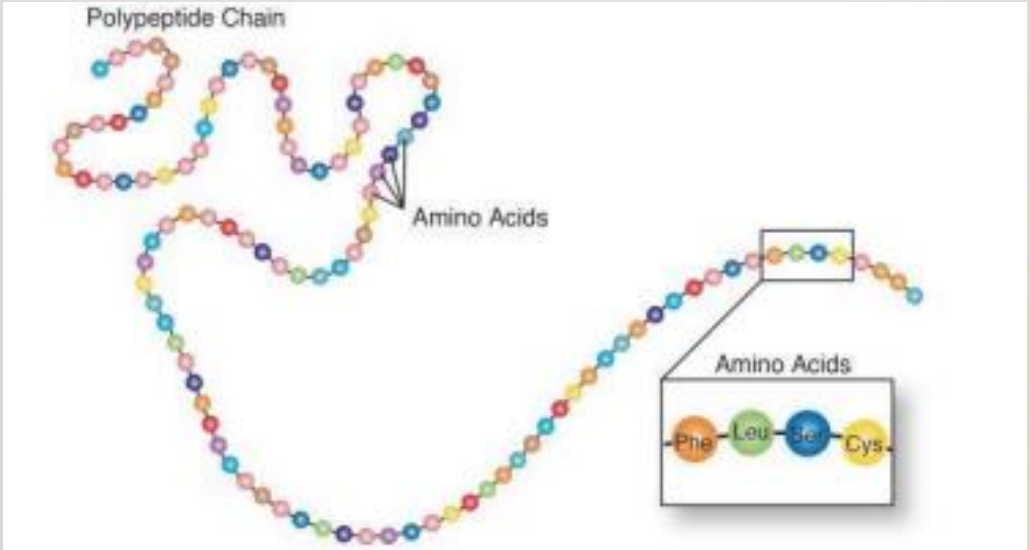
STEPS, CONT

3. The tRNA leaves the ribosome, but the **amino acid** that it coded for stays on the ribosome to wait for next codon to be read



STEPS, CONT

4. The **ribosome** moves to the next **codon** bringing in another **amino acid** to the growing protein chain.

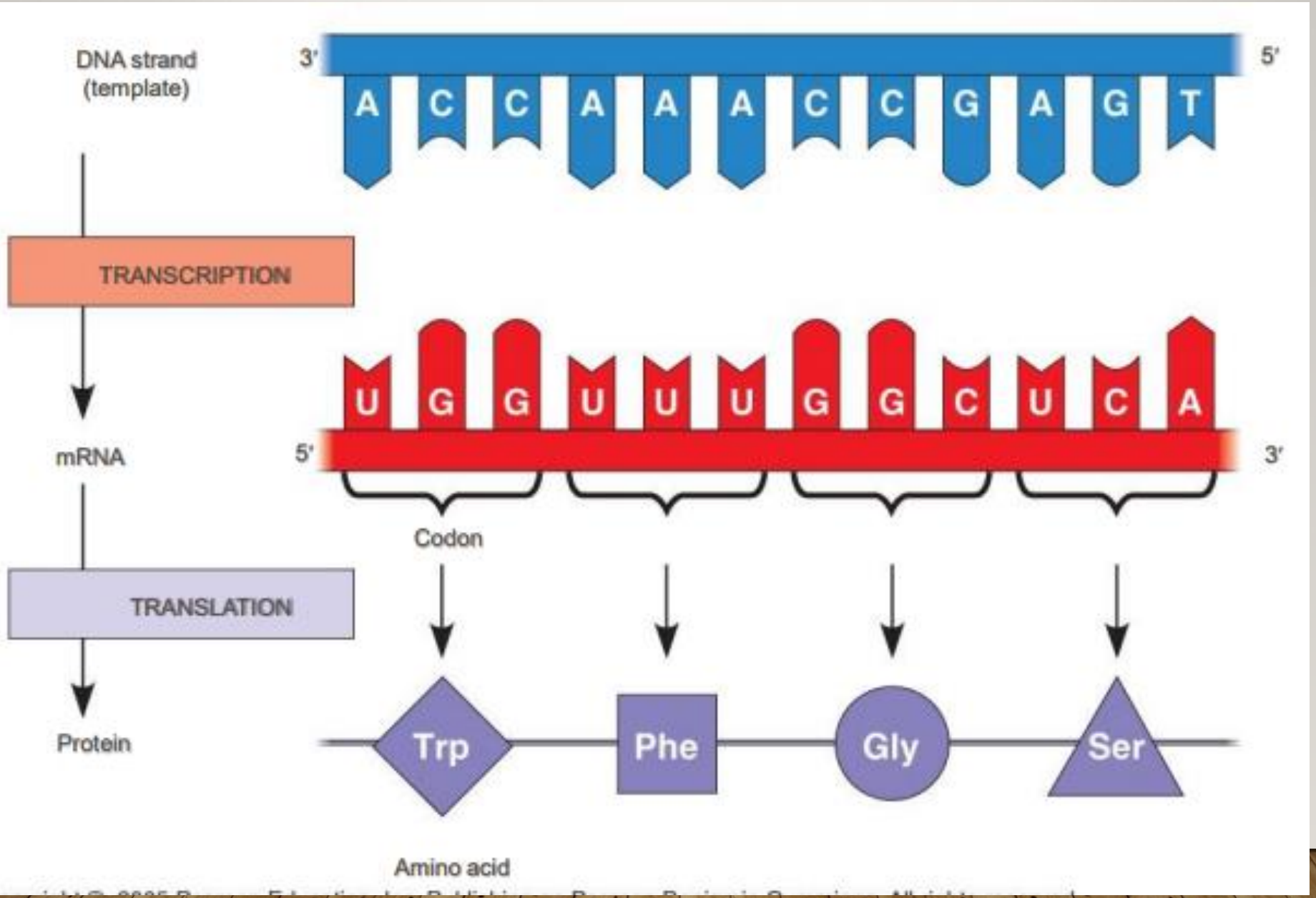


Amino Acids

Ala: Alanine	Gln: Glutamine	Leu: Leucine	Ser: Serine
Arg: Arginine	Glu: Glutamic acid	Lys: Lysine	Thr: Threonine
Asn: Asparagine	Gly: Glycine	Met: Methionine	Trp: Tryptophane
Asp:Aspartic acid	His: Histidine	Phe: Phenylalanine	Tyr: Tyrosisne
Cys:Cysteine	Ile: Isoleucine	Pro: Proline	Val: Valine

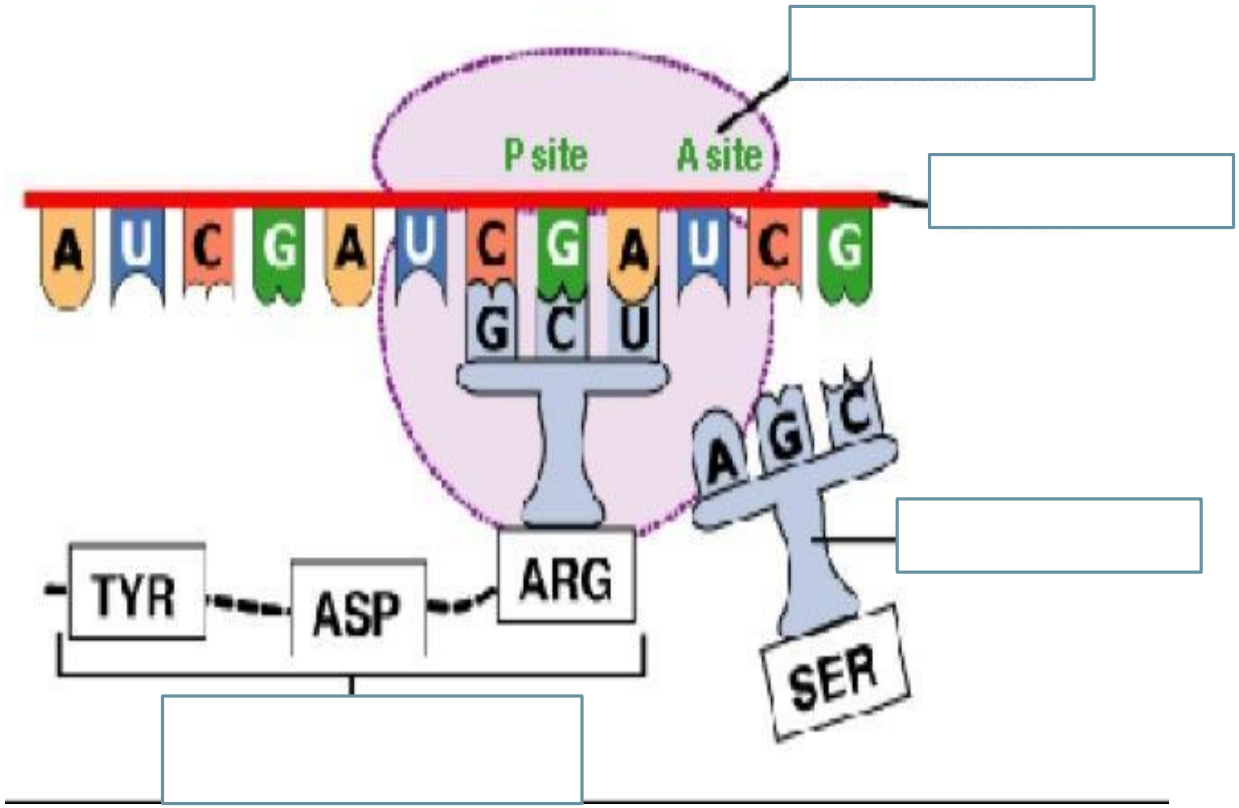
AN AMINO ACID CHAIN

- The amino acid chain will ALWAYS begin with the "**START codon**"
  - AUG
- The tRNA will continue to add amino acids until it reaches a "**STOP codon**" (UAA, UAG, UGA)
- When it reaches a stop codon, then a complete **protein** has been built! The protein **unattaches** itself from the ribosome.


DNA strand
(template)
3'
5'
A C C A A A C C G A G T
TRANSCRIPTION
mRNA
5'
3'
U G G U U U G G C U C A
Codon
TRANSLATION
Protein
Trp
Phe
Gly
Ser
Amino acid

Think about it: Label the diagram of translation to the right with the following terms!

- ribosome
- mRNA
- tRNA
- codon
- anticodon
- amino acid chain



PRACTICE

- Given the strand of DNA below, what would it's complementary DNA strand read?

ATC

- Now, transcribe the DNA to mRNA _____
- What amino acid does the codon code for? (use codon chart)

  _____
- What would the anticodon on the tRNA read? _____

PRACTICE

- Given the strand of DNA below, what would it's complementary DNA strand read?

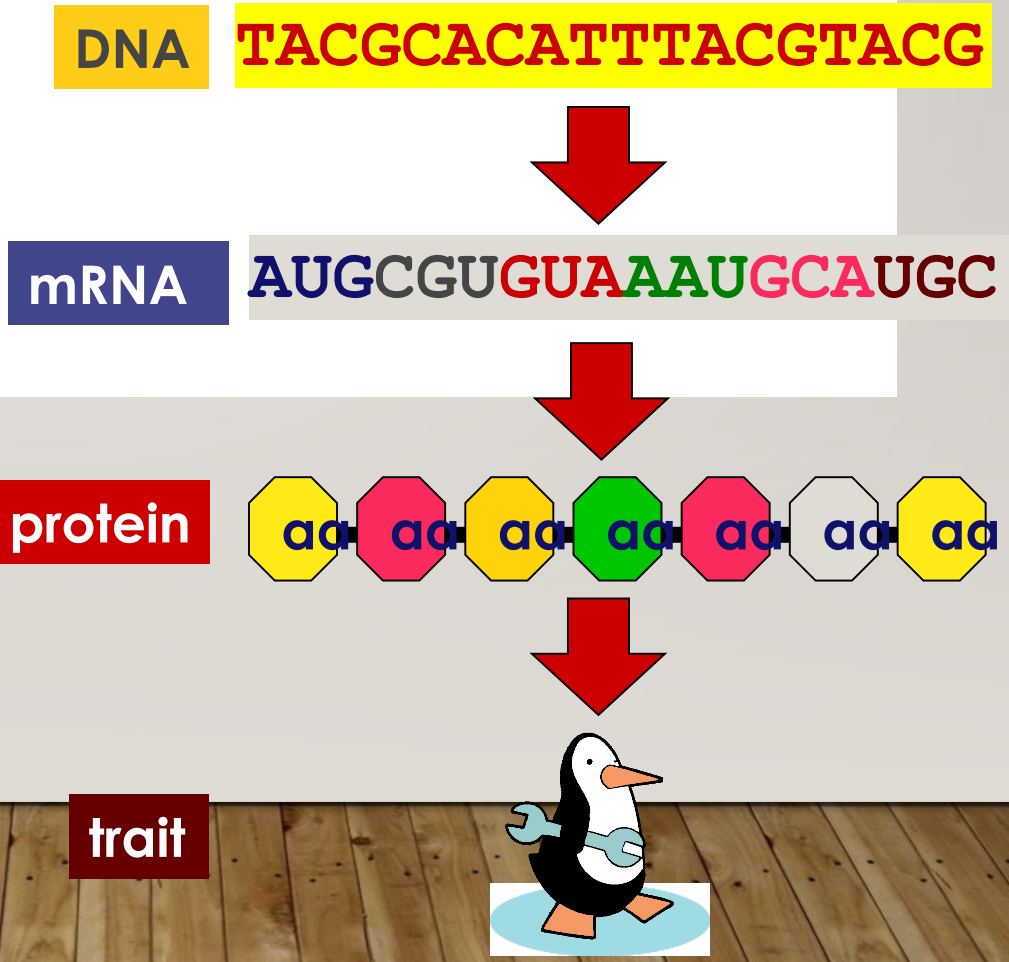
TGA

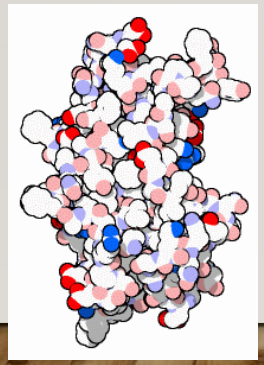
- Now, transcribe the DNA to mRNA _____
- What amino acid does the codon code for? (use codon chart)

  _____
- What would the anticodon on the tRNA read? _____

MUTATIONS

- Changes to DNA are called mutations
  - change the **DNA**
  - changes the **mRNA**
  - may change **protein**
  - may change **trait**





2 MAIN TYPES OF MUTATIONS

1.) Chromosomal Mutations

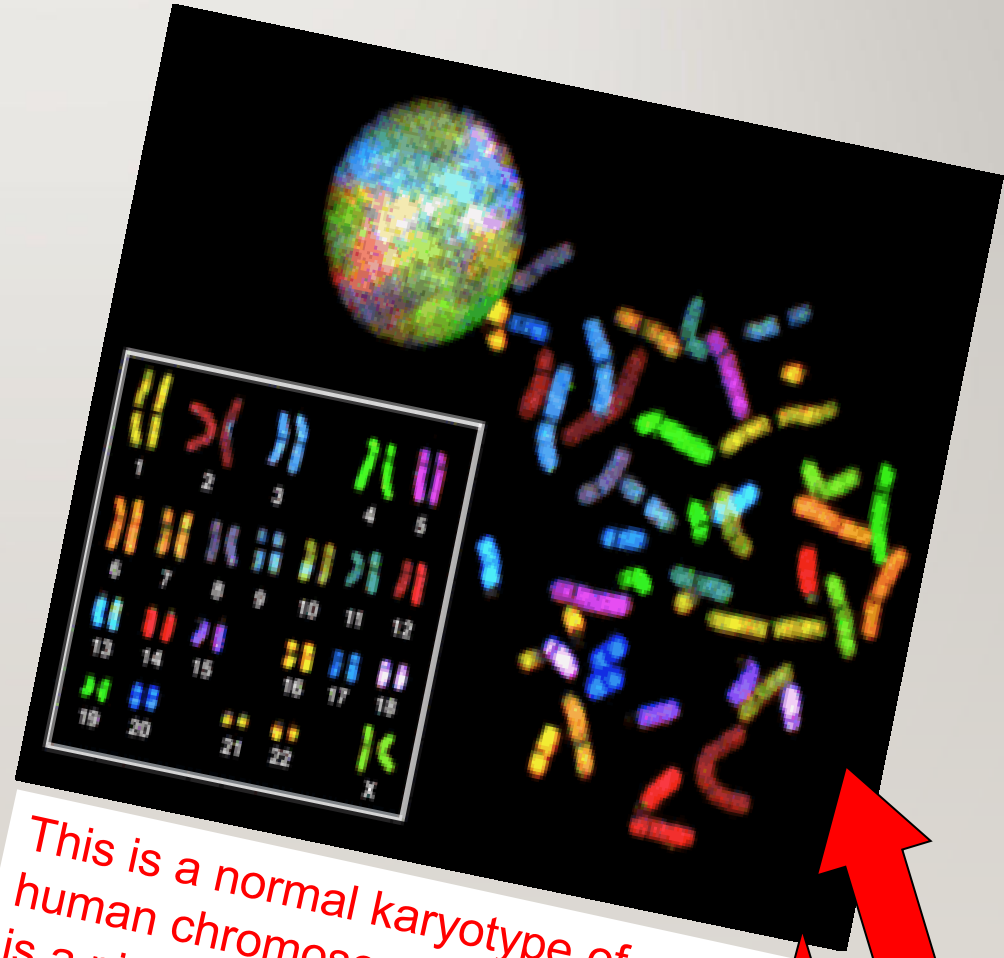
- a mutation involving **many genes**

2.) Gene Mutations

- a mutation that involves a few **nucleotides**

WHAT ARE CHROMOSOMES?

- Humans have 23 pairs of chromosomes, with one chromosome from each parent.
- The chromosomes are coiled up DNA.
- Under normal conditions all of the chromosomes are inherited in tact.
- When will a mutation be passed onto offspring?
  - When it is in an **egg or sperm cell**



This is a normal karyotype of human chromosomes. A karyotype is a picture of chromosomes lined up to look at and compare.

CHROMOSOMAL MUTATIONS

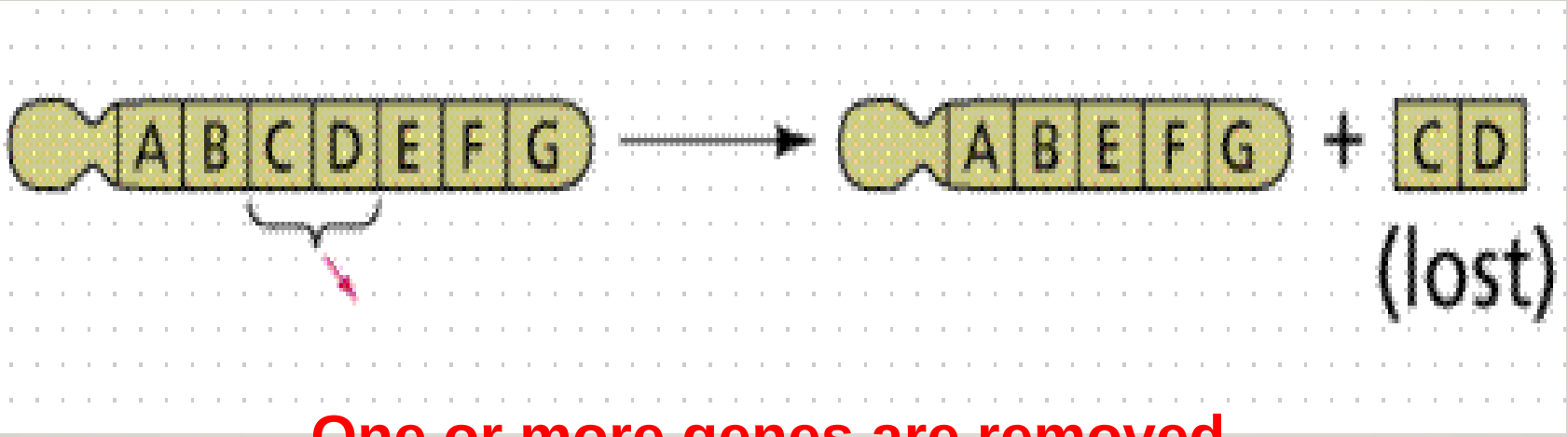
- Any change in the **structure** or **number** of chromosomes

- Large scale: Affect *many* genes

5 TYPES:

1. Deletion
2. Duplication
3. Inversion
4. Translocation
5. NonDisjunction

CHROMOSOMAL DELETION



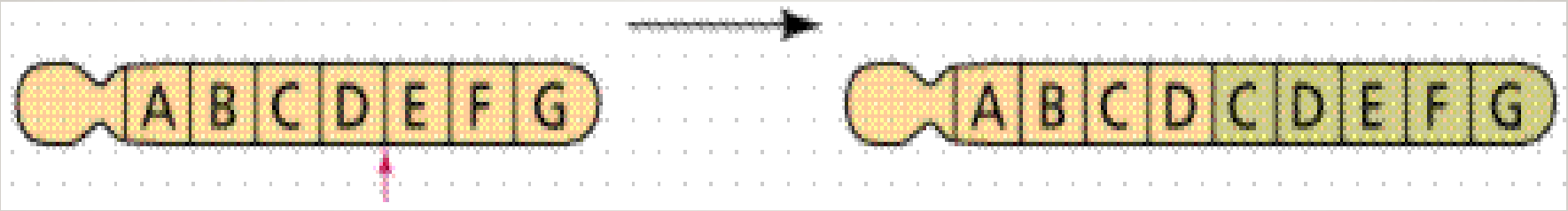
One or more genes are removed

Causes:

Wolf-Hirschhorn syndrome (severe mental retardation)

cri du chat syndrome (mewing sounds, mental retardation)

CHROMOSOMAL DUPLICATION



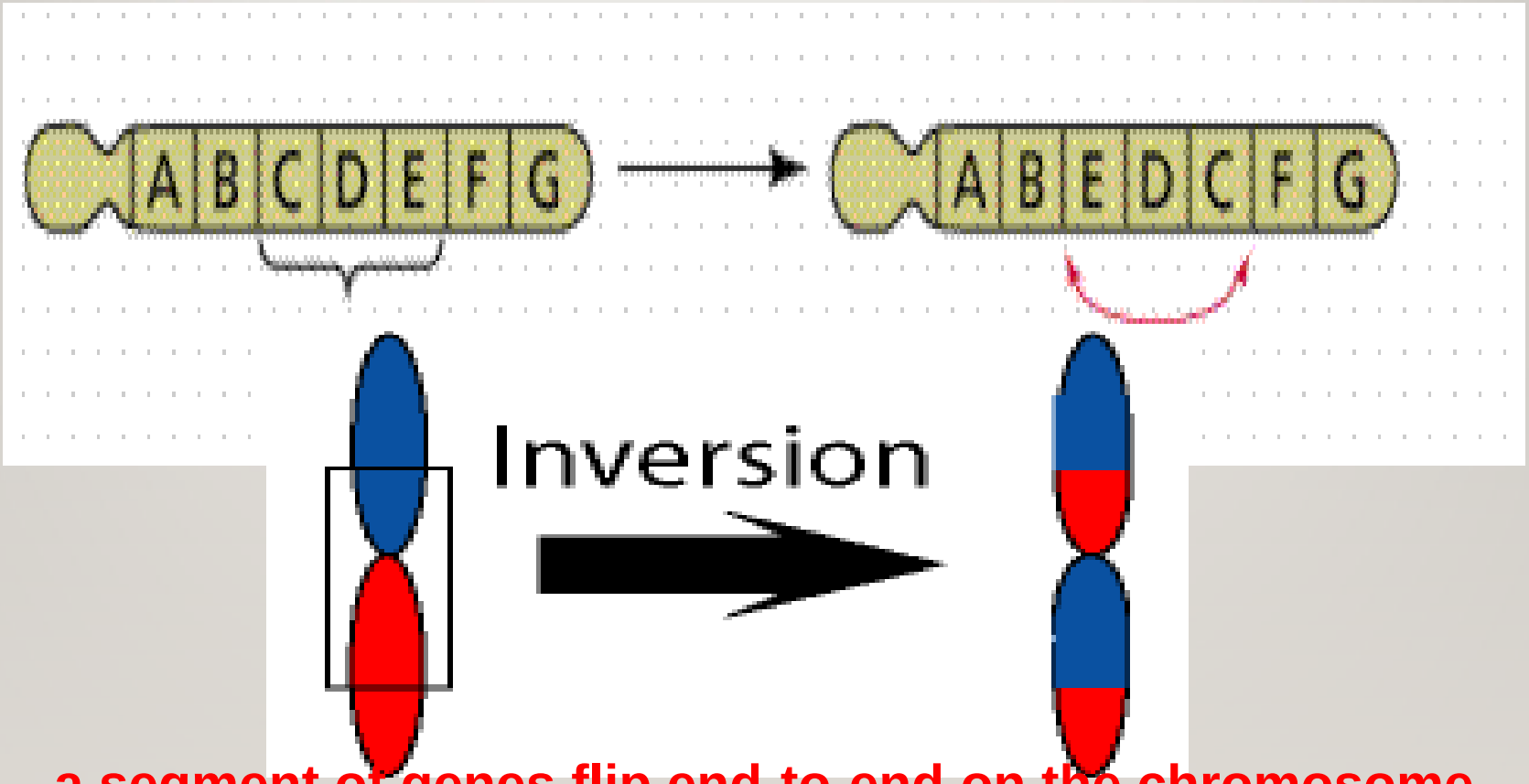
A segment of genes is copied twice and added to the chromosome

Causes:

Charcot–Marie–Tooth disease

(high arched foot, claw feet, confined to a wheelchair)

CHROMOSOMAL INVERSION



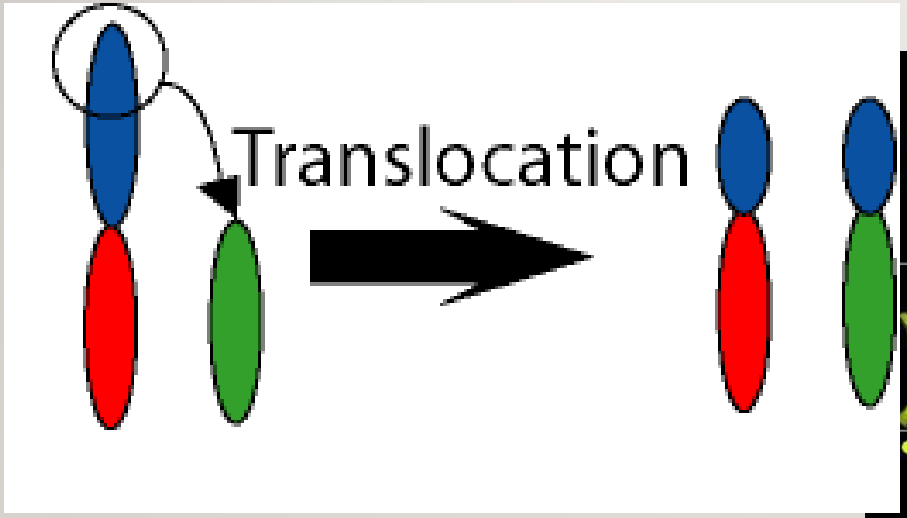
a segment of genes flip end-to-end on the chromosome

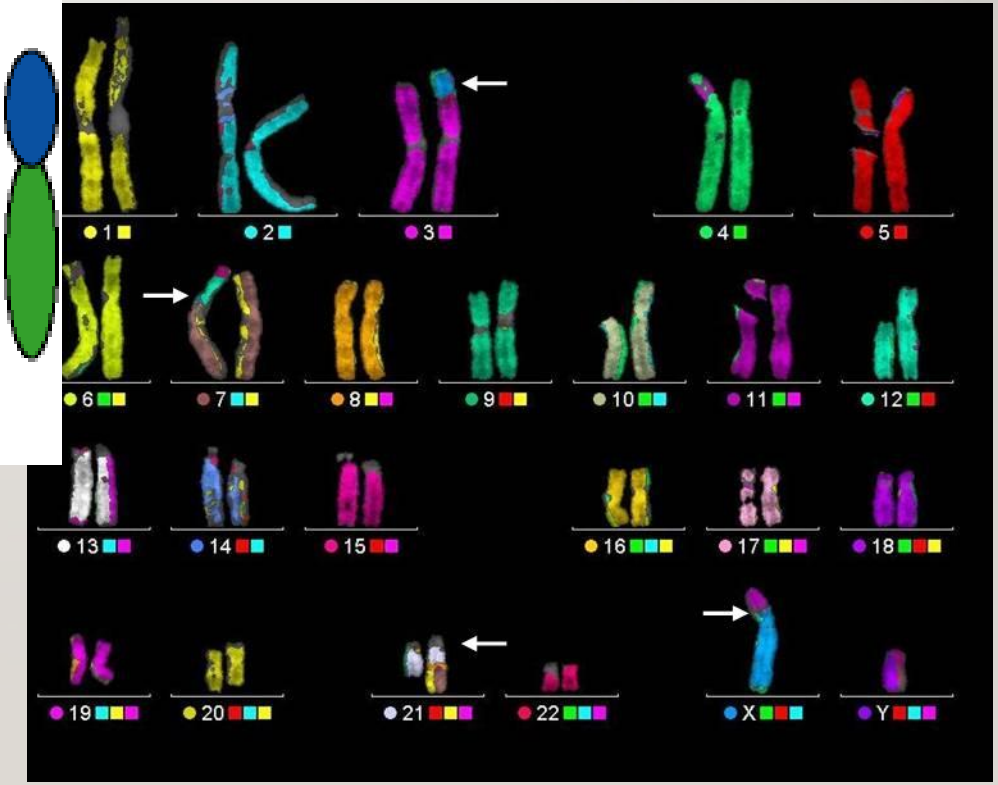
Causes:

Four-Ring Syndrome

(cleft pallate, club feet, testes don't descend)

CHROMOSOMAL TRANSLOCATION





Material is swapped with another chromosome

Causes:

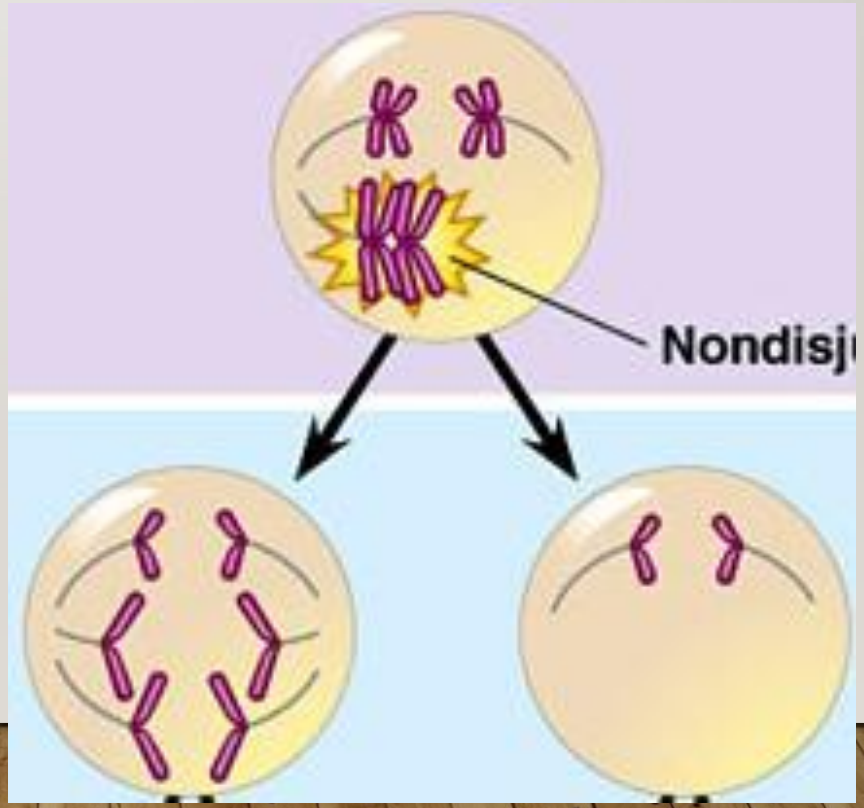
Burkitt's Lymphoma

(cancer of the lymph nodes, in children)

NONDISJUNCTION

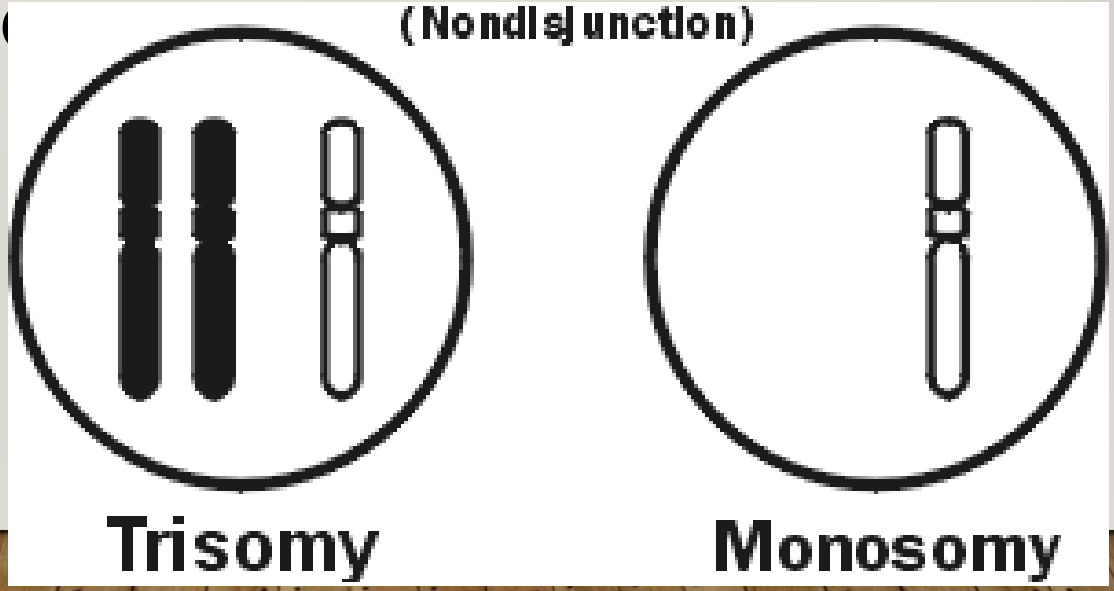
- Chromosomes **FAIL TO SEPARATE** during **meiosis**

- Meiosis I Nondisjunction
- Meiosis II Nondisjunction



NONDISJUNCTION

- Produces gametes (and therefore a baby) with one missing chromosome **or** one extra chromosome



CHROMOSOMAL MUTATIONS

- Most chromosomal mutations are *lethal*
- *If* the fetus survives: Tend to cause wide-spread abnormalities
- *Example:* Down Syndrome

ONTO GENE MUTATIONS!

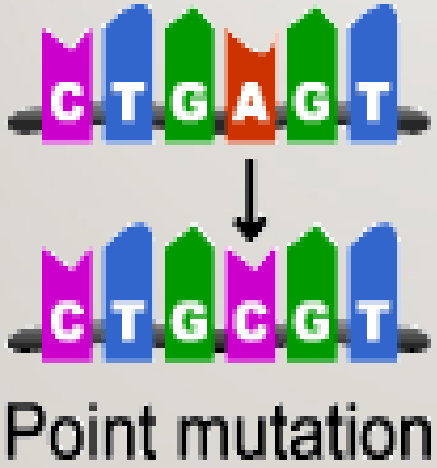
GENE MUTATIONS

- ***Small scale:*** one gene is affected
- Any change to the DNA sequence of a gene:

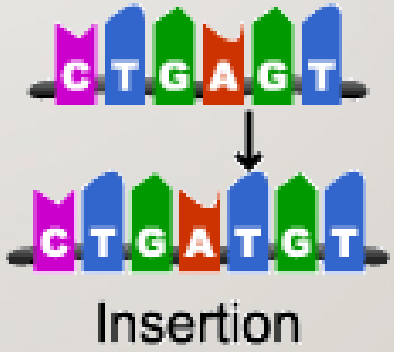
Nucleotides/Bases may be **added**, **missing**, or **changed**

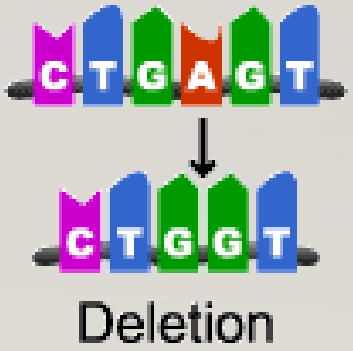
GENE MUTATIONS: 2 TYPES:

POINT MUTATION (SUBSTITUTION)



FRAMESHIFT MUTATION





TYPES OF MUTATIONS

- Changes to the letters (A,C,T,G bases) in the DNA
  - point mutation
    - change to ONE letter (base) in the DNA
    - may (or may not) cause change to protein
  - frameshift mutation
    - addition of a new letter (base) in the DNA sequence
    - deletion of a letter (base) in the DNA
    - both of these shift the DNA so it changes how the codons are read
    - big changes to protein*!*

POINT MUTATION

- One base (A, T, C, or G) is substituted for another
- Causes: *Sickle-cell anemia*
- 3 Possible Consequences:
  - nonsense mutations: code for a stop, which can translate the protein
  - missense mutations: code for a different amino acid
  - silent mutations: code for the same amino acid

POINT MUTATIONS

- Missense mutation = *changes* amino acid

AUG CGU GUA UAC GCA UGC GAG UGA

Met Arg Val Tyr Ala Cys Glu Stop

AUG CGU GUA UAC GUA UGC GAG UGA

Met Arg Val Tyr Val Cys Glu Stop

POINT MUTATIONS

- Silent mutation = no change to protein

AUG CGU GUA UAC GCA UGC GAG UGA

Met Arg Val Tyr Ala Cys Glu Stop

AUG CGU GUA UAC GCU UGC GAG UGA

Met Arg Val Tyr Ala Cys Glu Stop

POINT MUTATIONS

- Nonsense mutation = change to STOP

AUG CGU GUA UAC GCA UGC GAG UGA

Met Arg Val Tyr Ala Cys Glu Stop

AUG CGU GUA UAA GCA UGC GAG UGA

Met Arg Val Stop

FRAMESHIFT MUTATION

- Addition or deletion of one or more bases (A, T, C, or G)
- Causes: *Cystic Fibrosis*
- Caused by:
  - Insertion: adding a base
  - Deletion: removing a base

FRAMESHIFT MUTATIONS

- Addition/Insertion = add one or more bases

AUG CGU GUA UAC GCA UGC GAG UGA

Met Arg Val Tyr Ala Cys Glu Stop

AUG CGU GUA UAC GUC AUG CGA GUG A

Met Arg Val Tyr Val Met Arg Val

FRAMESHIFT MUTATIONS

- Deletion = lose one or more bases

AUG CGU GUA UAC GCA UGC GAG UGA

Met Arg Val Tyr Ala Cys Glu Stop

AUG CGU GUA UAC GAU GCG AGU GA

Met Arg Val Tyr Asp Ala Ser

CAUSES OF MUTATIONS

- spontaneous
- occur during DNA replication
- **Caused by MUTAGENS**
    - physical, ex: radiation from UV rays, X-rays or extreme heat
    - or chemical (molecules that misplace base pairs or disrupt the helical shape of DNA).

GENE MUTATIONS

- **KEY IDEA:** A mutated ***gene*** will make a mutated ***protein***

- **Mutant proteins are trouble!**
  - They do not **go** where they are supposed to go
  - They do not ***do*** what they are supposed to do

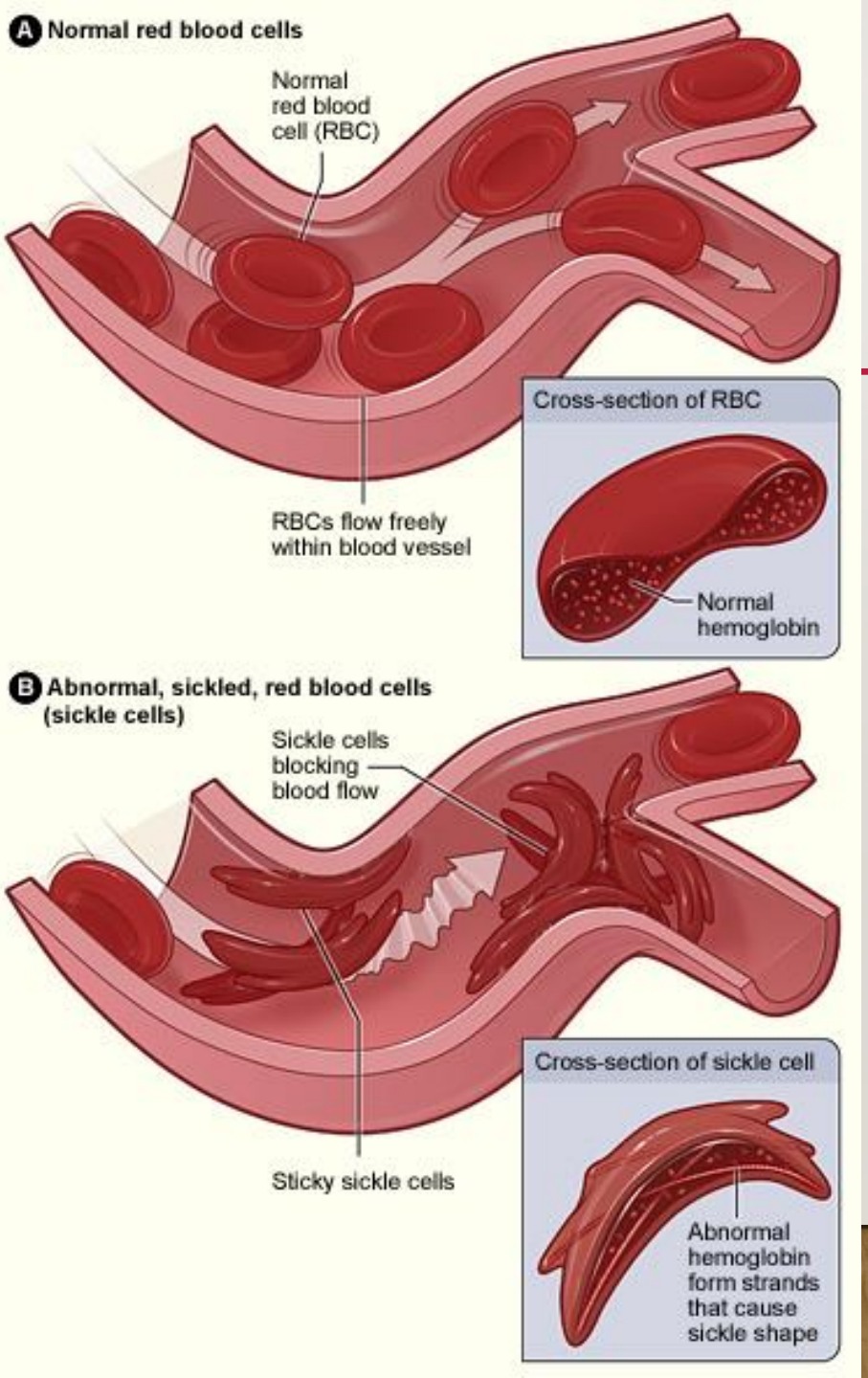
EXAMPLE: SICKLE CELL ANEMIA

NORMAL RED BLOOD CELL

- Red blood cells shaped like a disc
- Hemoglobin (protien) carries oxygen to all parts of the body

SICKLE RED BLOOD CELL

- Red blood cells form an abnormal crescent shape
- Hemoglobin (protein) is abnormally shaped
- don't move easily through your blood vessels
- form clumps and get stuck in the blood vessels


A Normal red blood cells
Normal red blood cell (RBC)
RBCs flow freely within blood vessel
Cross-section of RBC
Normal hemoglobin
B Abnormal, sickled, red blood cells (sickle cells)
Sickle cells blocking blood flow
Sticky sickle cells
Cross-section of sickle cell
Abnormal hemoglobin form strands that cause sickle shape