Unit 7: Biotech, Protein Synthesis, Mutations

DNA/ RNA Review

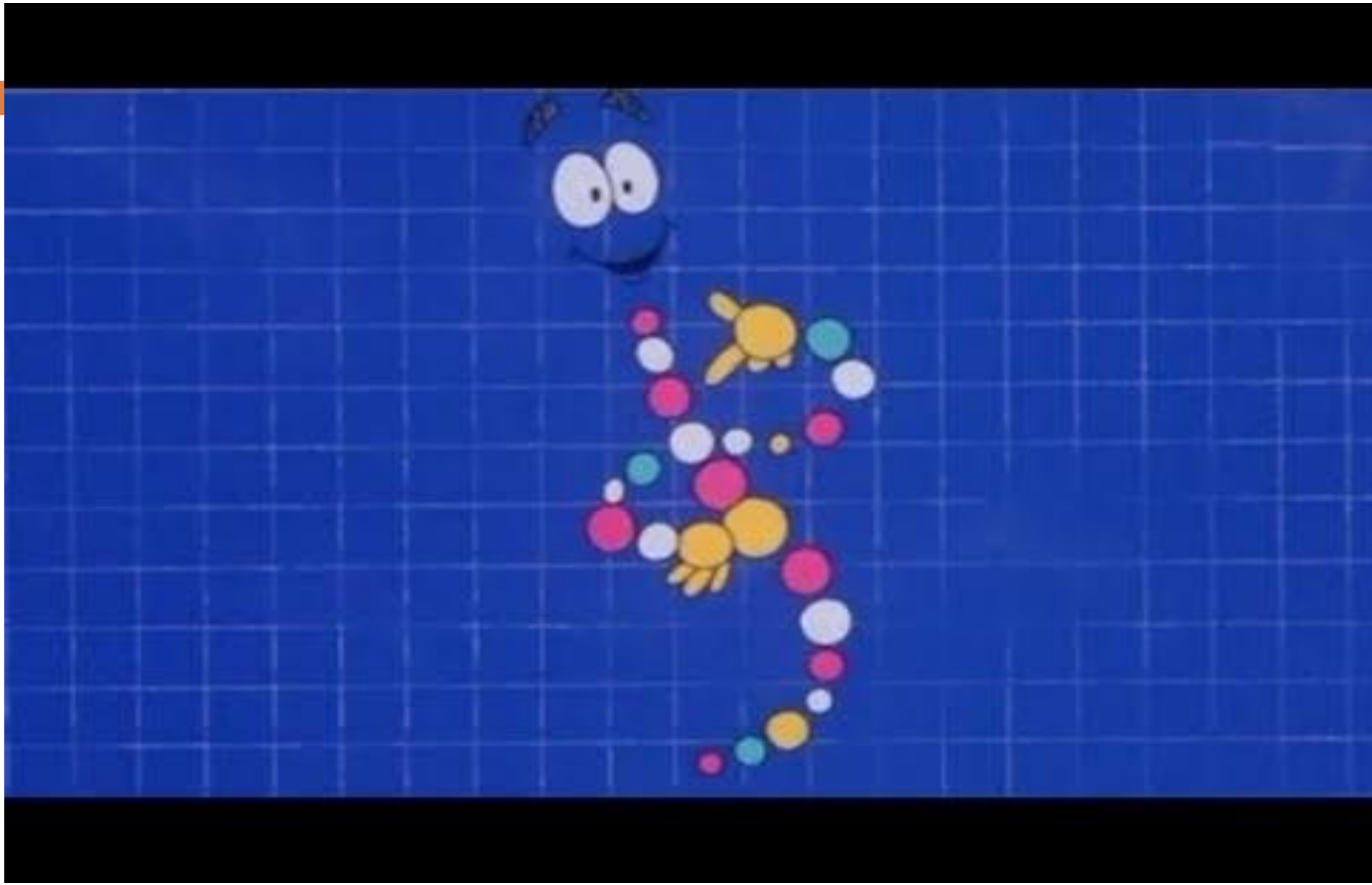
Genetic Engineering

- Genetic engineering is technology that involves manipulating the DNA of one organism in order to insert the DNA of another organism.

- Genetic engineering can be used to increase/decrease the expression of specific genes in selected organisms.

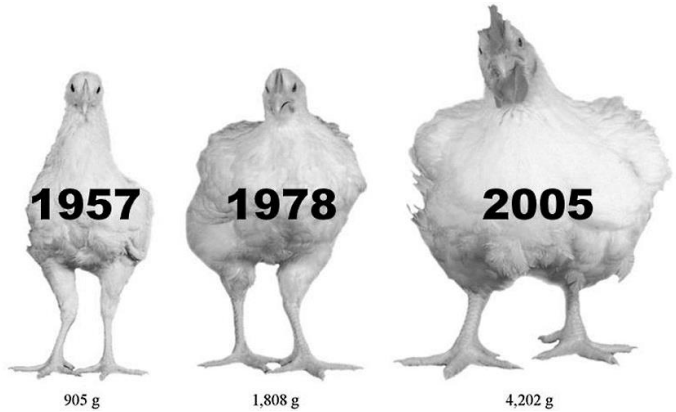
- An organism's genome is the total DNA in the nucleus of each cell.

Jurassic Park – Fact or Fiction?!



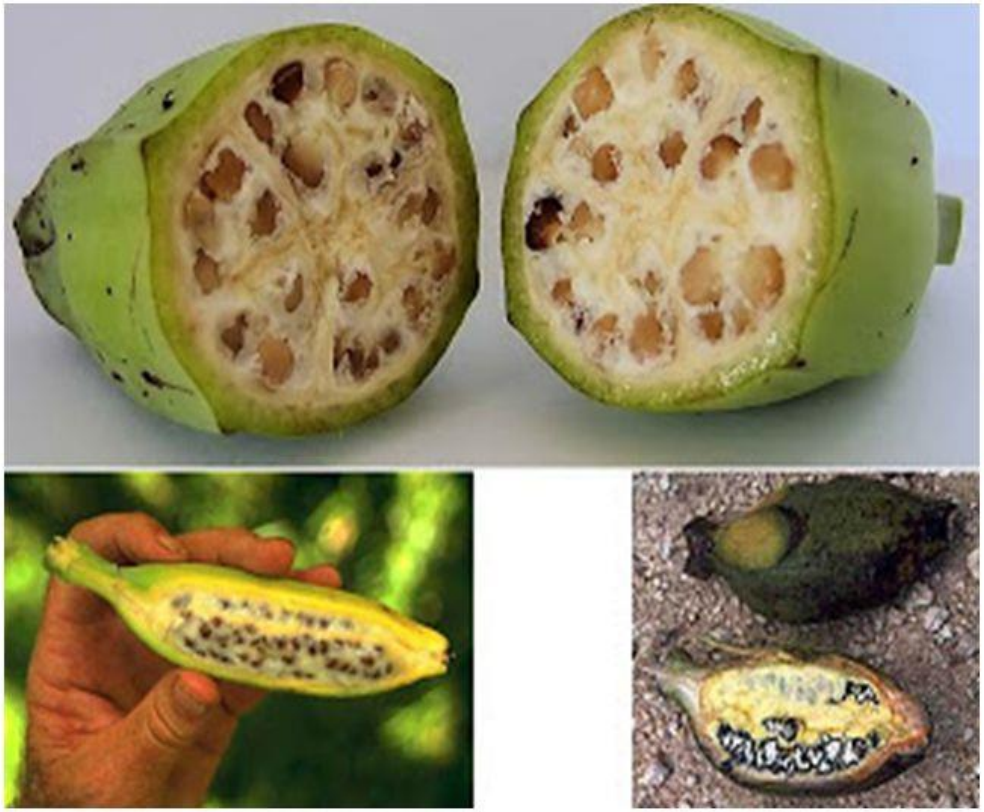
Applied Genetics: is the manipulation of the hereditary characteristics of an organism to improve or create specific traits in offspring.

- **Selective breeding: (aka artificial selection)** human directed breeding to produce plant and animal with desirable traits. Ex: breeding plants to produce larger fruits/vegetable



- **Inbreeding:** Two closely related organism are bred to have the desired traits and to eliminate the undesired ones in future generations

Artificial Selection: Bananas



Mastiff

Big and strong, but lacked speed and aggression

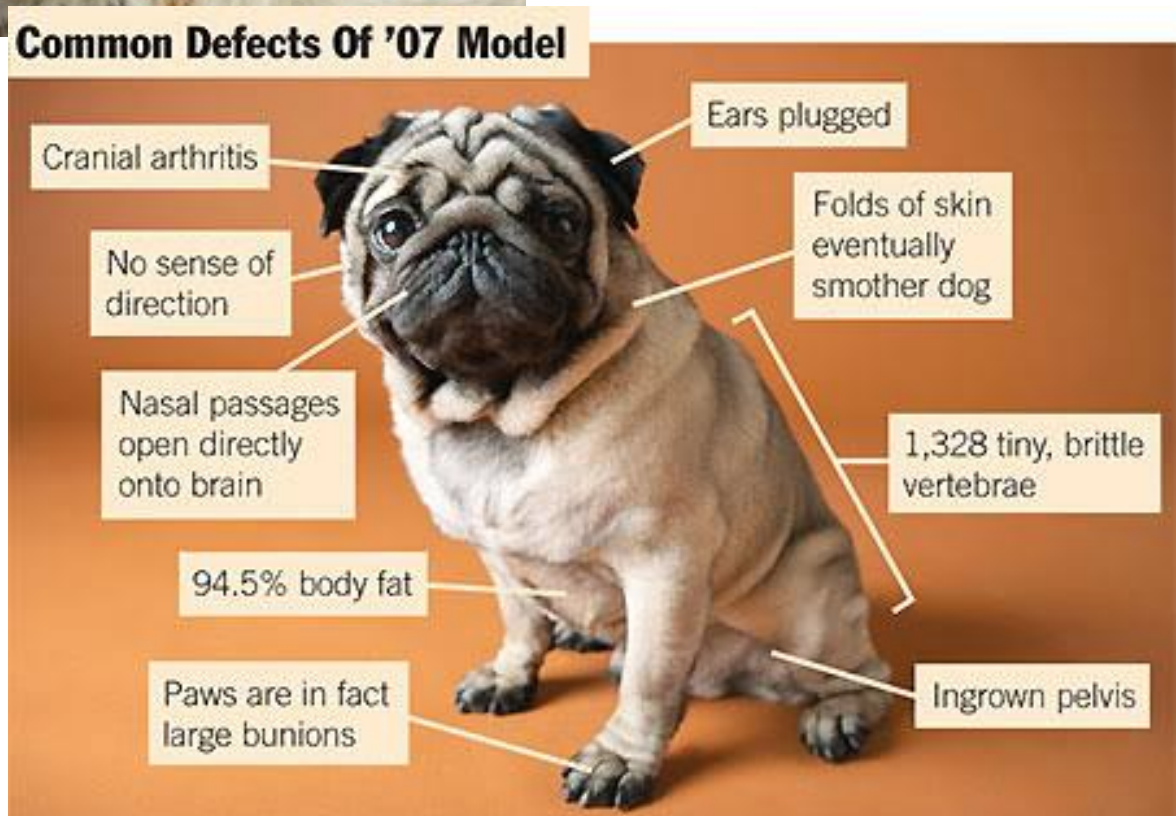
Bulldog

Fast and aggressive, but lacked strength

Bullmastiff

Big, strong, fast, and aggressive

Kenny: White Siberian Tiger
Facial disfigurement due to inbreeding (cubs would be mated with their own parents)

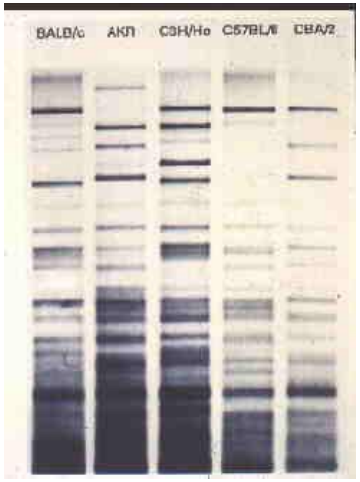


Biotechnology

- **Biotechnology** is the use of genetic engineering to find solutions to problems.
- Goal for the **Human Genome Project** was to sequence all the nucleotides in the human body. (3 Billion nucleotides and 20,000-25,000 genes)
- This was completed in 2003.

Gel Electrophoresis

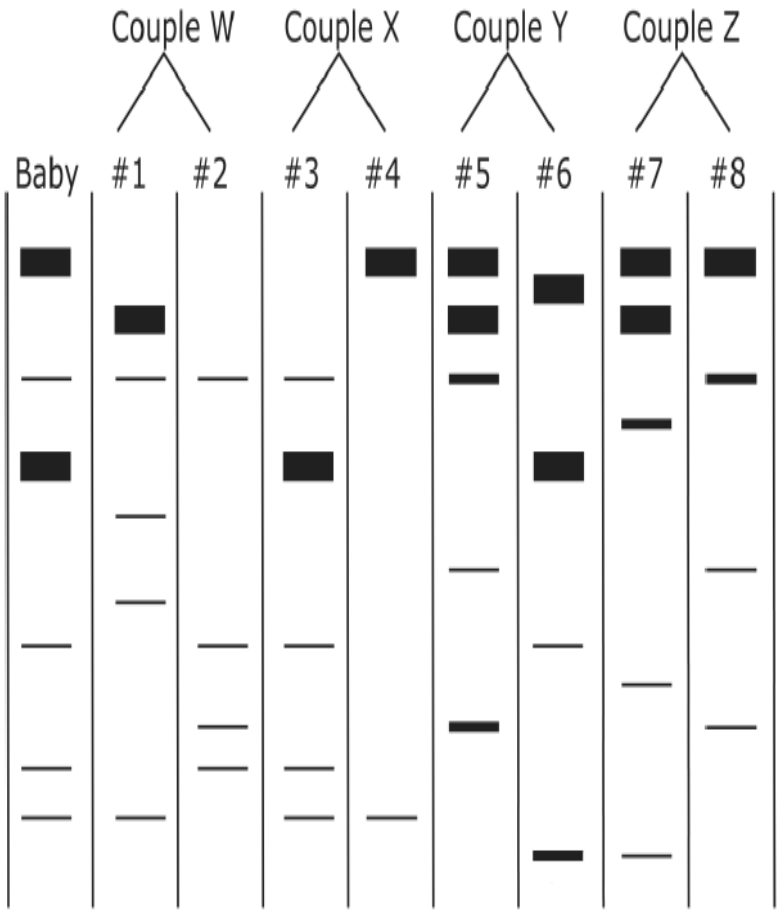
- 1. DNA is cut into smaller pieces using restriction enzymes
- 2. An electrical current is applied
- 3. DNA is separated by size. Shorter fragments move farther down the get than longer fragments



Used in:

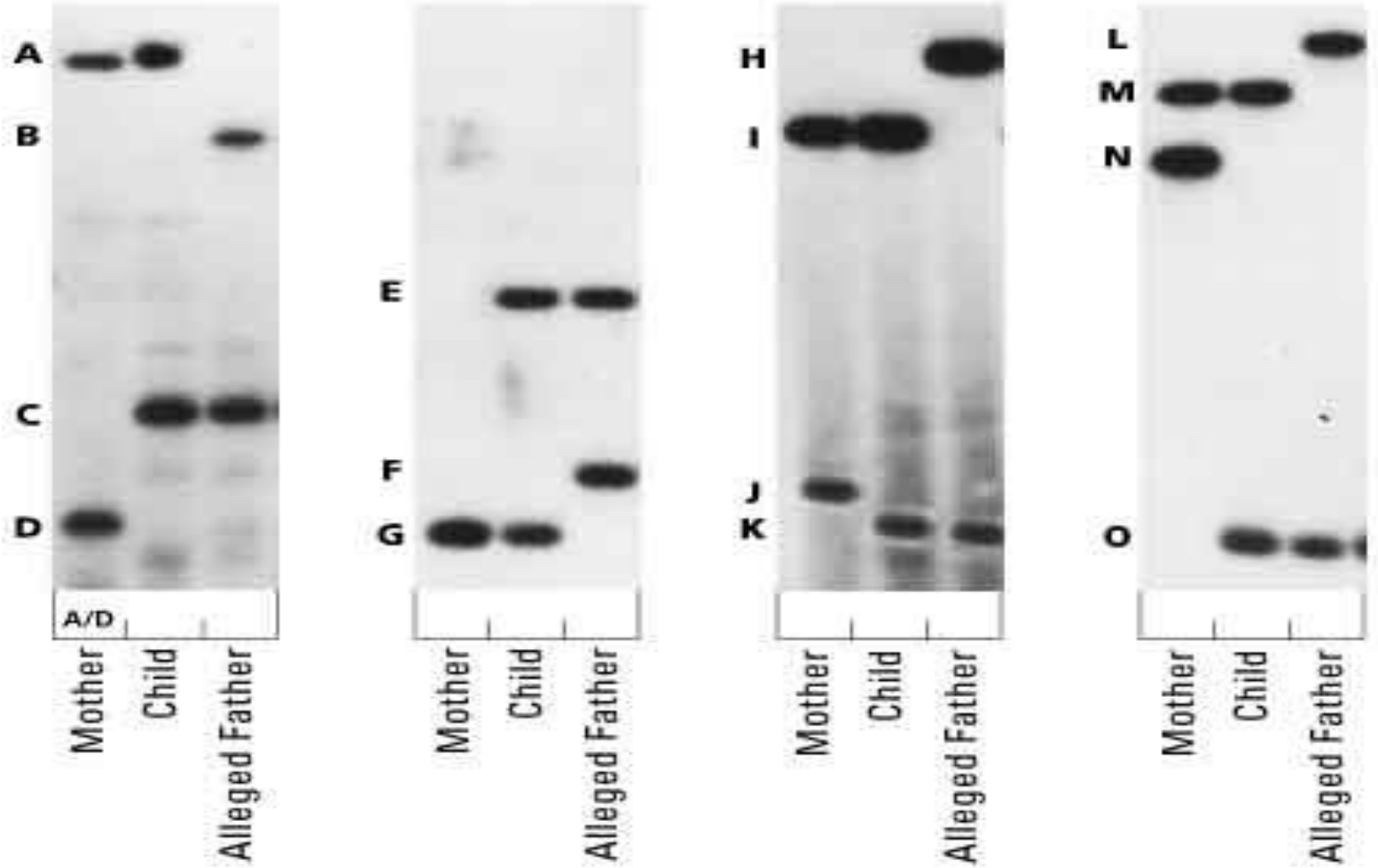
DNA fingerprinting

DNA fingerprinting

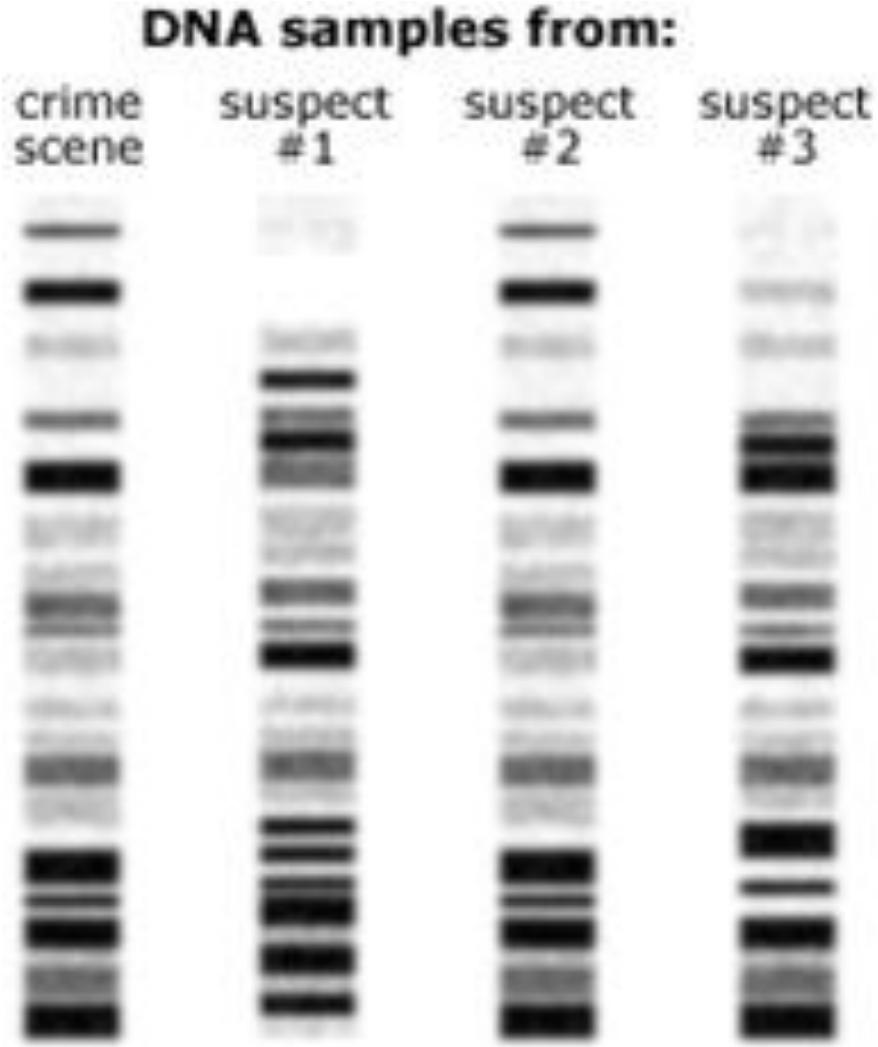


- Best way to determine if two people are genetically related
- Used in genetic counseling, parental testing, crime scenes, classification of new species of organisms.
- **Can you tell…**
  Organism X is most closely related to which sample?

Which one is the correct father?



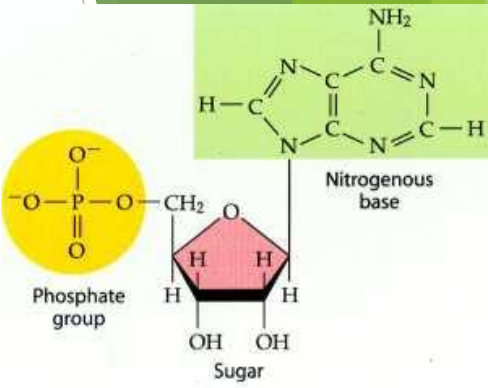
Gel Electrophoresis (example)



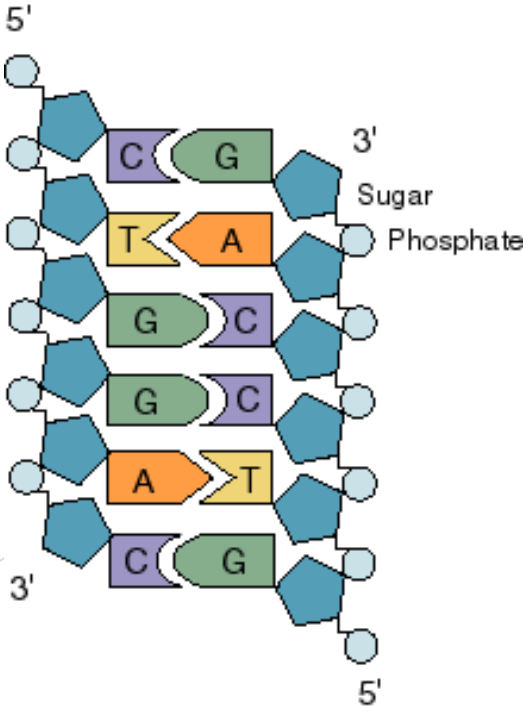
- Look at the example of DNA taken at the crime scene (Column 1).
- Which suspect committed the crime?
  - **Suspect 1**
  - **Suspect 2**
  - **Suspect 3**

DNA/ RNA

- Nucleotide- monomer of nucleic acids
  - Composed of three parts:
    - Deoxyribose Sugar (DNA) OR Ribose Sugar (RNA)
    - Phosphate
    - Base



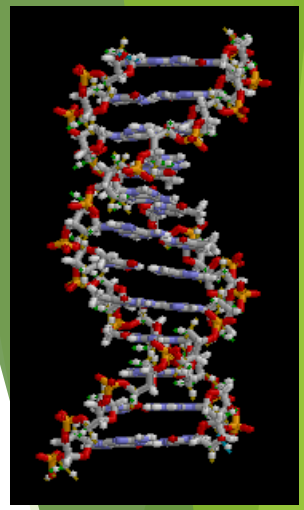
- Function of Nucleic Acids
  - DNA store genetic information
  - RNA transmit the genetic information
- Base Pairing:
  - A-T (DNA) A-U (RNA)
  - C-G
  - Held together by hydrogen bonds
  - DNA= double helix RNA= helix



DNA/ RNA Review

	Polymers	
	DNA	**RNA**
# of Strands	2	1
Shape	Double helix	Single stranded
Monomers	Nucleotide	Nucleotide
Sugar	Deoxyribose	Ribose
Bases	A, T, C, G	A, U, C, G
Location	Nucleus only	Nucleus & cytoplasm

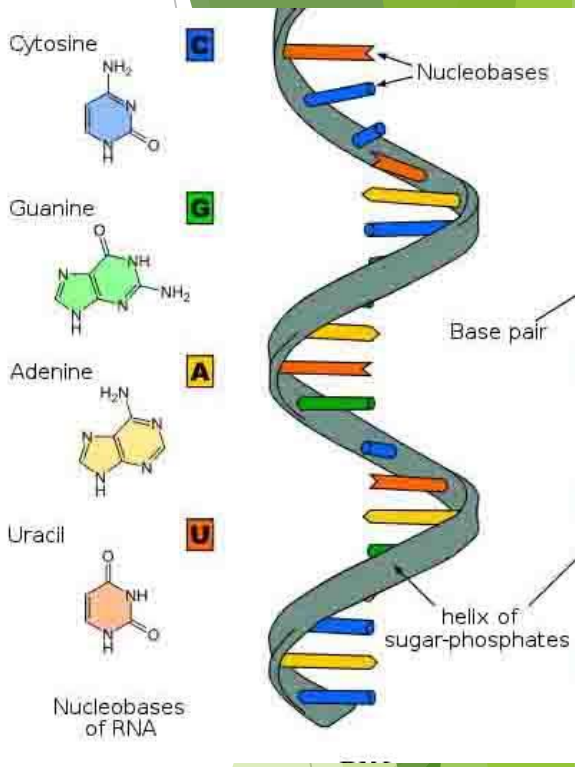
Function of DNA



- The master copy of an organism's information code that contains the instructions (blueprint) used to make proteins
- Determines an organism's characteristics (traits).
- Sometimes permanent changes can occur in the sequence of DNA **(mutations)**

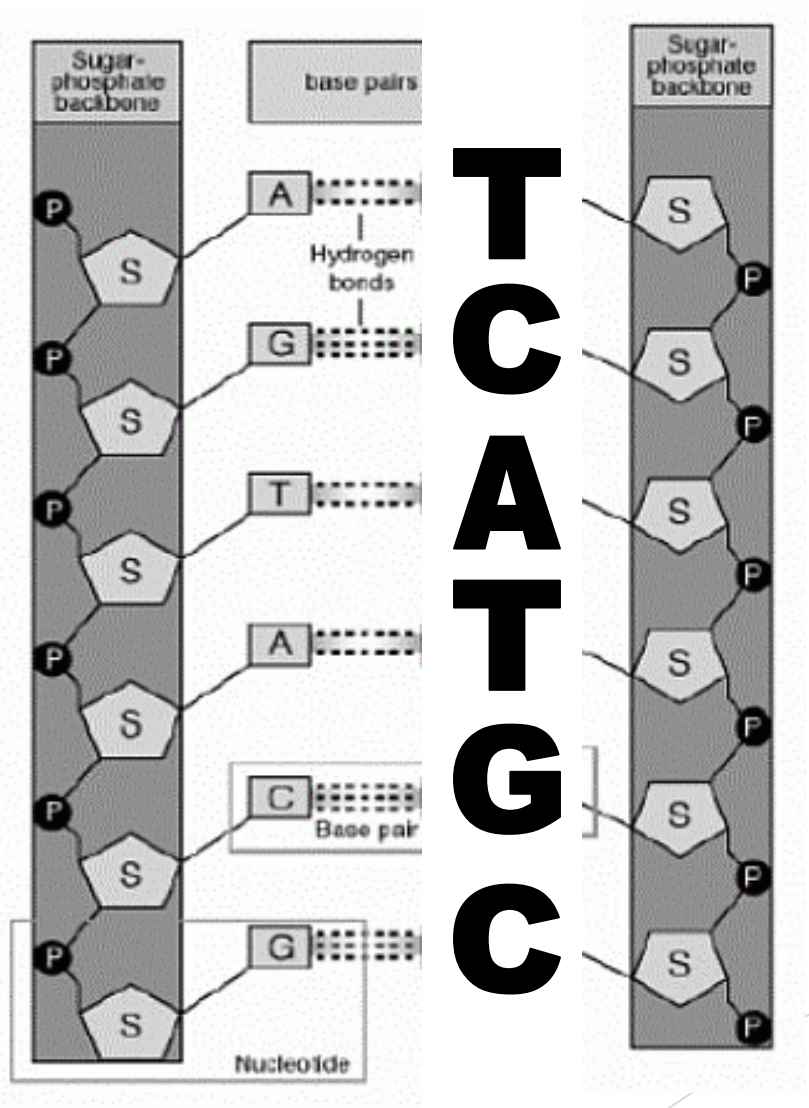
Function of RNA

- A similar copy of stored DNA gene sequence
- Uses the instructions to direct production of proteins



DNA to DNA base pairing review

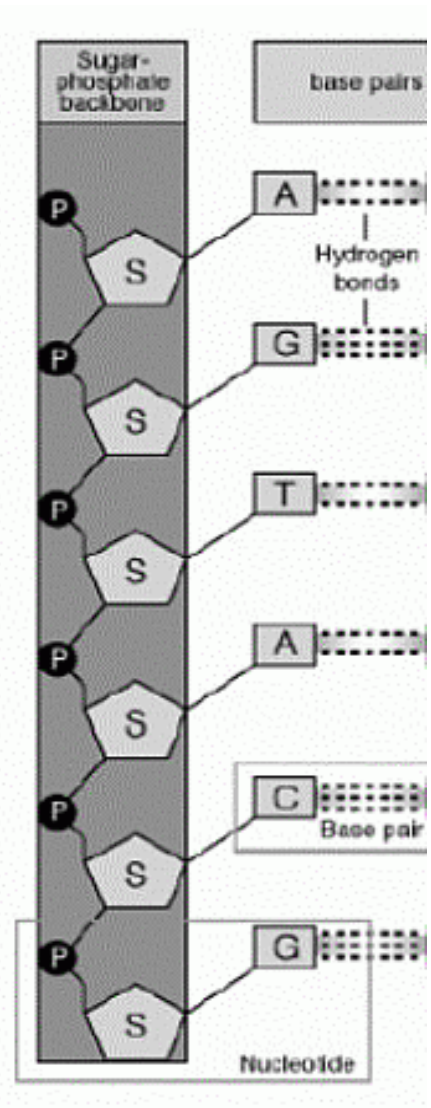
DNA



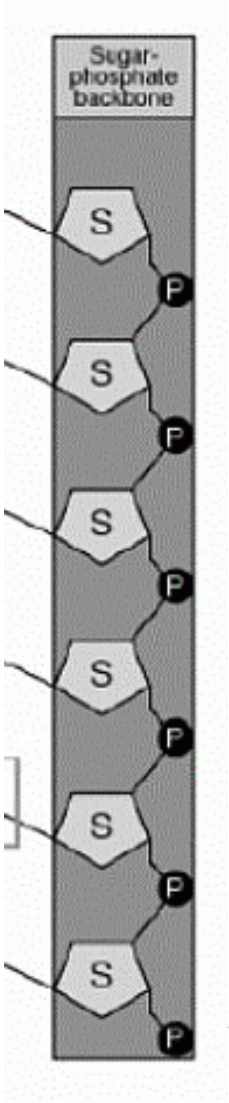
DNA

DNA to RNA base pairing

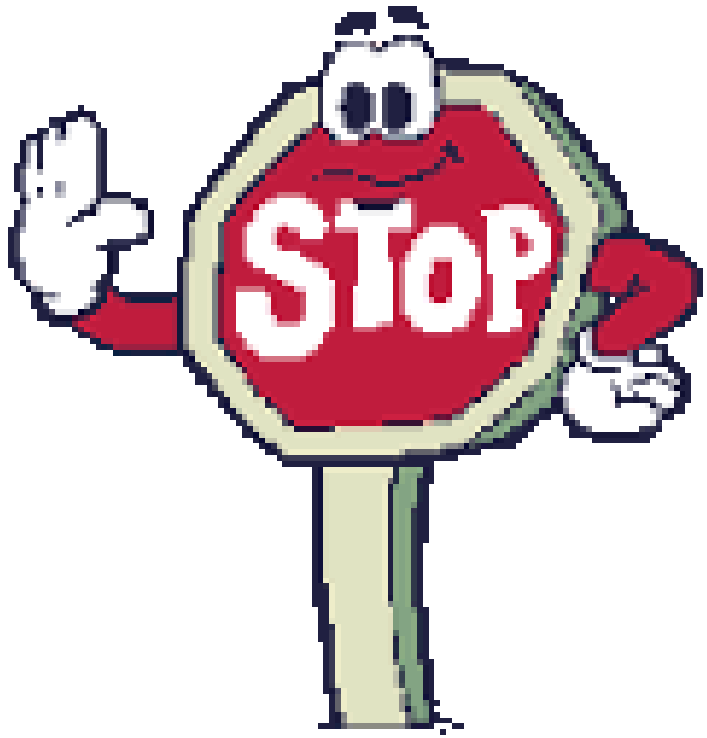
DNA



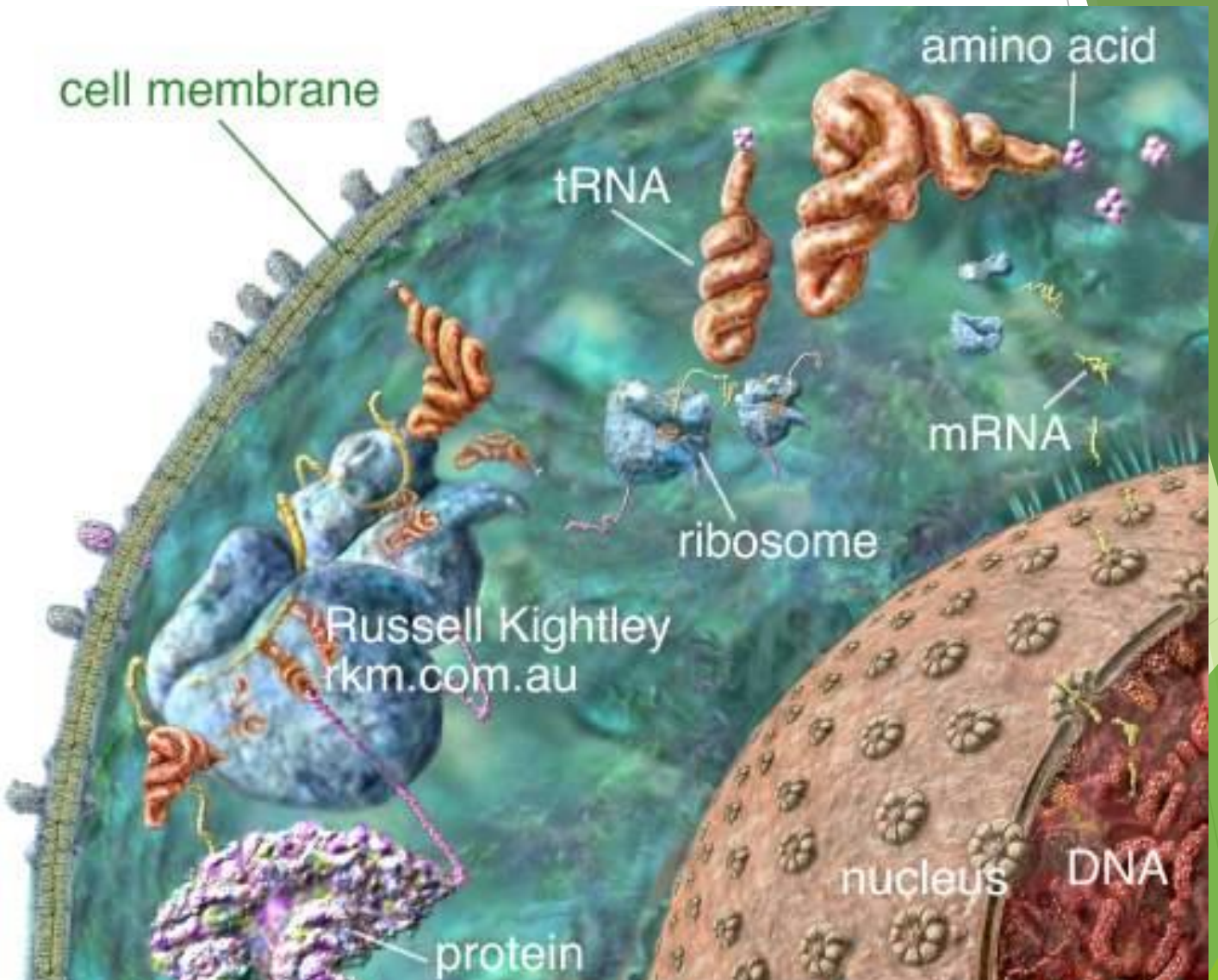
U
C
A
U
G
C



RNA

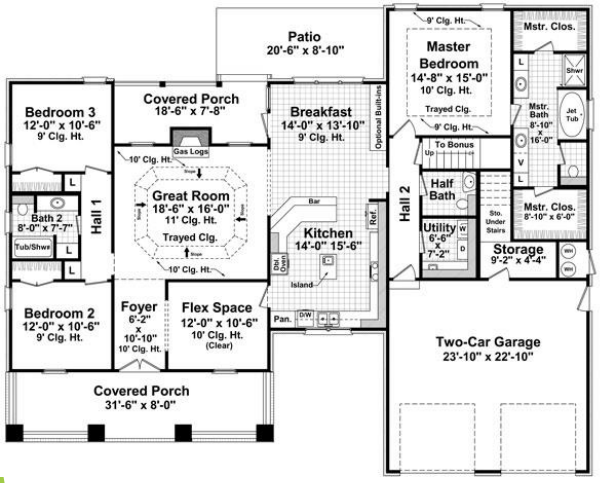

STOP

Protein Synthesis

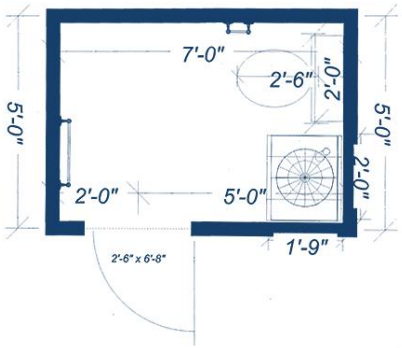


How do I get from the instructions to building a HOUSE?

ALL of the master Instructions



Bathroom instructions



Bathroom materials

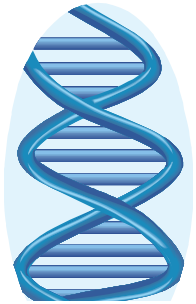
Home

Bathroom

How do I get from the instructions to building YOU?

DNA: The master Instructions

Genes: parts of the instructions



Proteins: building blocks!!!

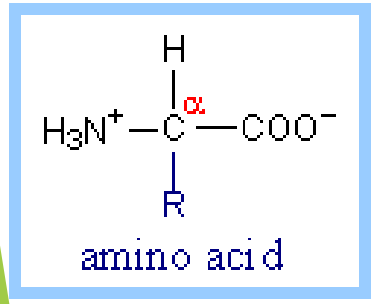
Proteins

Cells: basic unit of life

Structure and Function of Proteins

Structure of Proteins:

- Monomers are amino acids
- Contain the elements Carbon (C), Hydrogen (H), Oxygen (O), and Nitrogen (N)



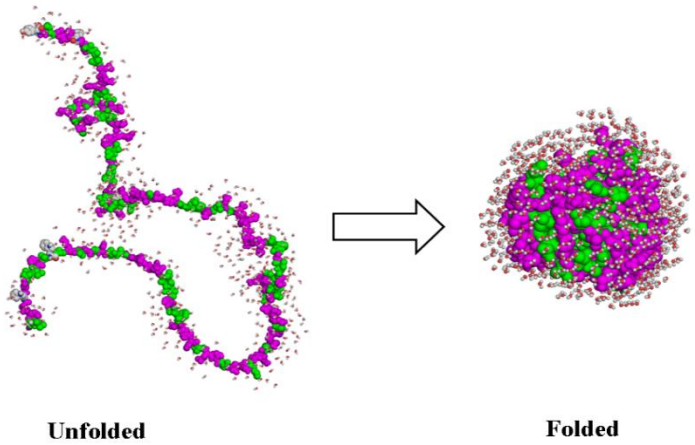
Function of Proteins:

- carries out many functions in the body which include:
  - growth and repair
  - signaling from one cell to another
  - transport channels in cell membranes
  - defense against invaders
  - catalyzing chemical reactions (enzymes are proteins)

Protein Structure and Function

Protein Shape Determines Function

* If the protein folds incorrectly it will not work properly



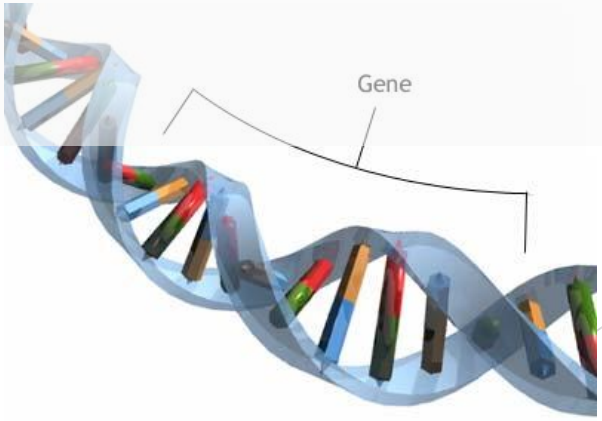
Protein Problem Example: When the oxygen carrying protein hemoglobin differs by one amino acid then it can cause the blood cell's shape to change.
The blood cell is now inefficient at carrying oxygen which affects the organism's health.

Protein Synthesis Background

- Also called Gene Expression
- The process of **cells making new PROTEINS to show genetic TRAITS using DNA instructions.**

DNA → RNA → amino acid → protein → phenotype (traits)

- Genes- sections of chromosomes (DNA) that control the production of proteins and activities within a cell.



3 Types of RNA used in Protein Synthesis

- Messenger RNA (mRNA)- carries copies of instructions for assembling proteins from DNA to ribosome found in cytoplasm.

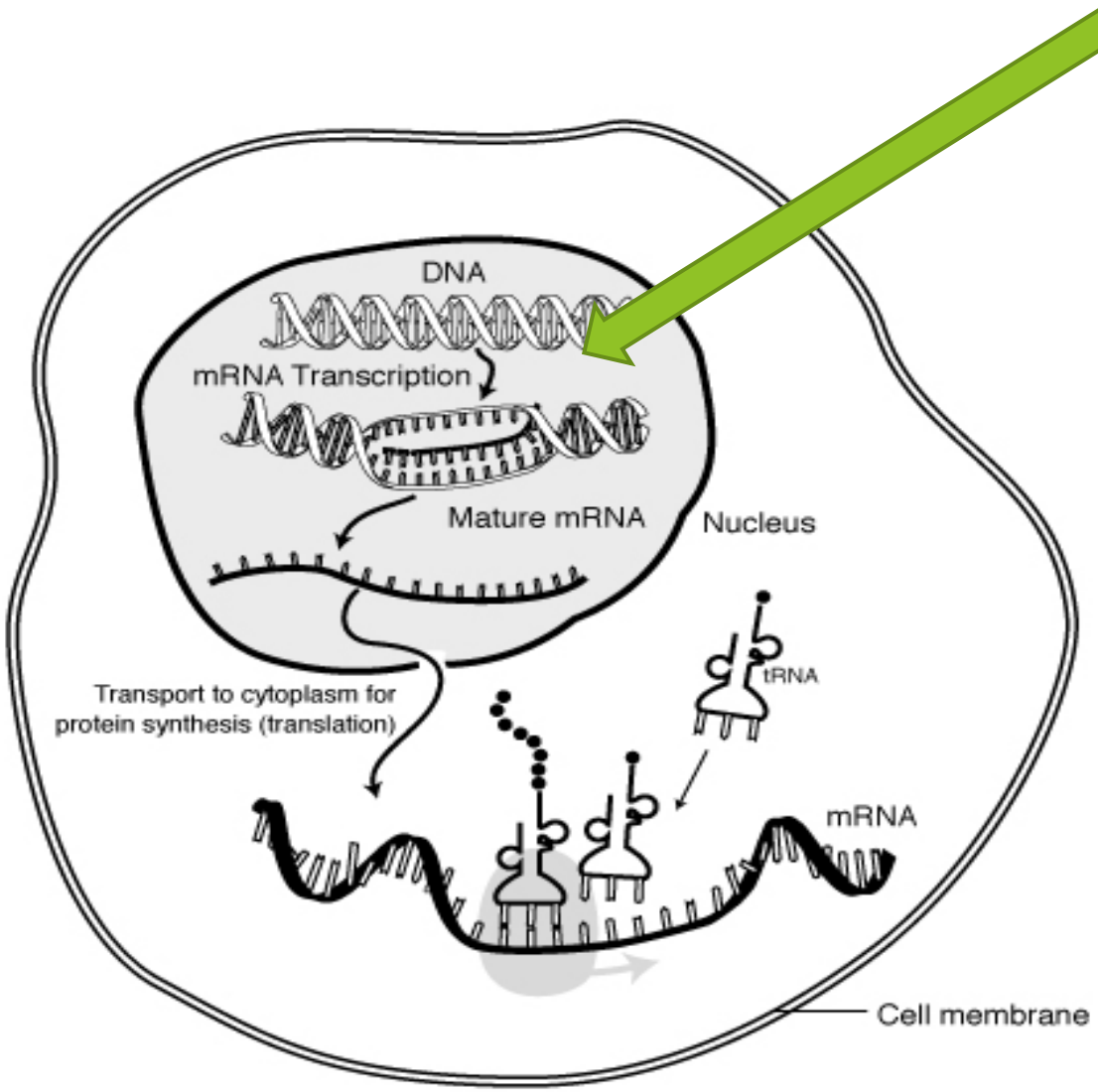
(because DNA CANNOT leave the nucleus or it may get destroyed) Ex: The SCRIBE in the video

- Transfer RNA (tRNA)- transfers amino acids to the ribosome and matches them to the coded mRNA message. tRNA gets reused/recycled after it drops off amino acid. Ex: The CHEF in the video
- Ribosomal RNA (rRNA)- makes up the ribosome (small organelle made of 2 units) and is the site (factory) of protein synthesis. Ex: The BOAT in the video

RNAi Video ~ watch only to 1:50min

Protein Synthesis

- Part 1. Transcription (occurs in the nucleus)



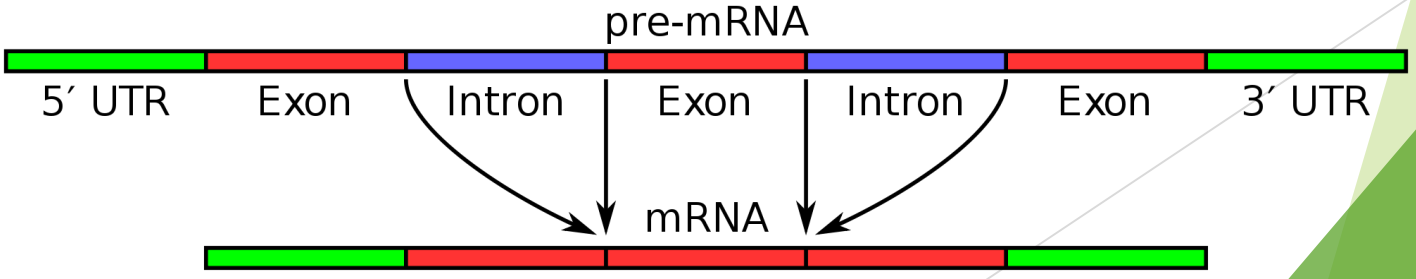
Part 1: Transcription

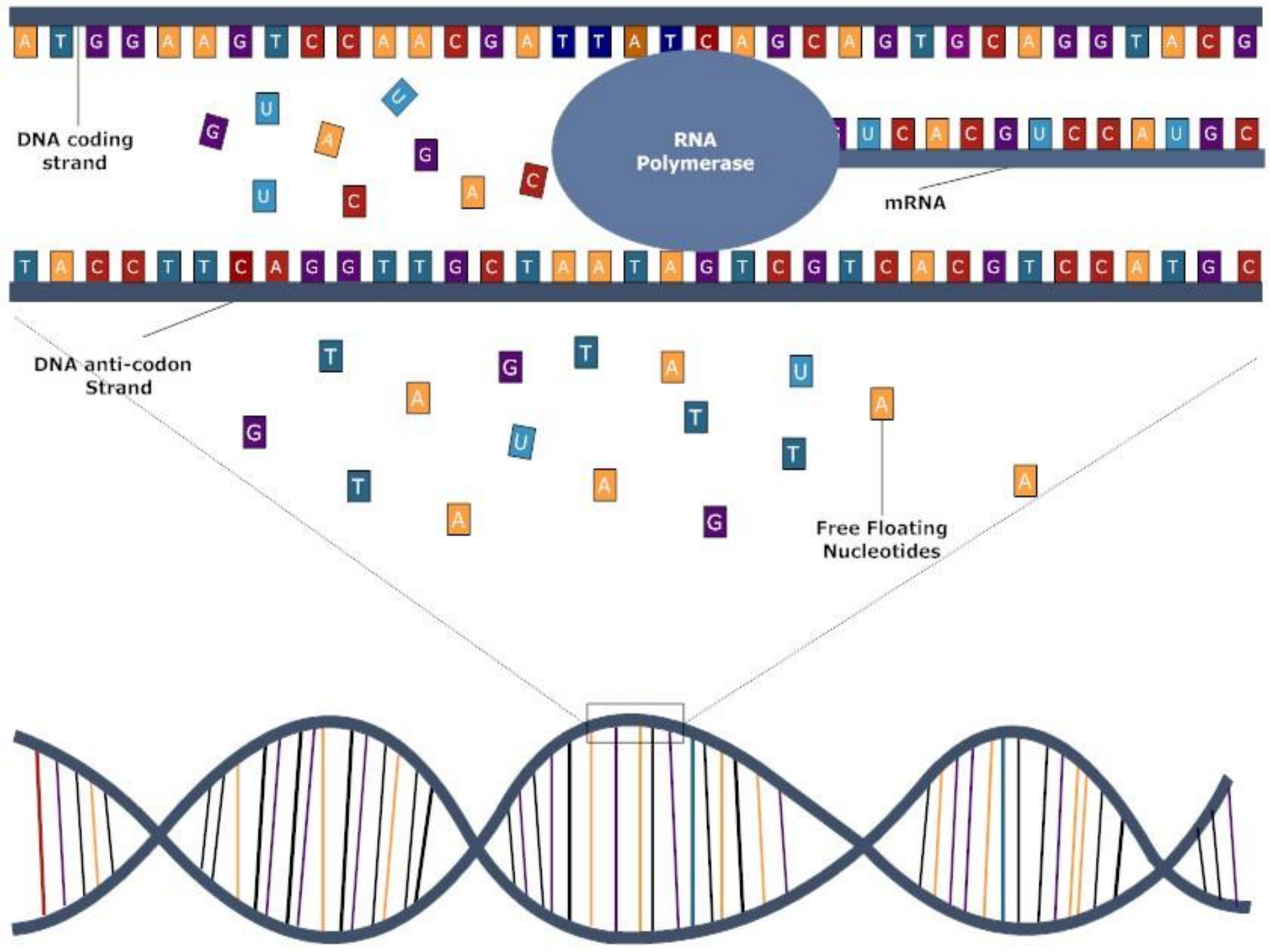
When complementary messenger RNA (mRNA) molecules are produced by **copying** segments of the DNA sequence

- RNA Polymerase enzyme separates DNA at a promoter (region of DNA where sequence instructions begins)
- Free floating nucleotides match up with the DNA template in groups of three bases (**codon**) (A-U and C-G)
- mRNA editing: new RNA **molecules** will be **edited** before the message is complete

  introns- portions that are **cut** out and **discarded**

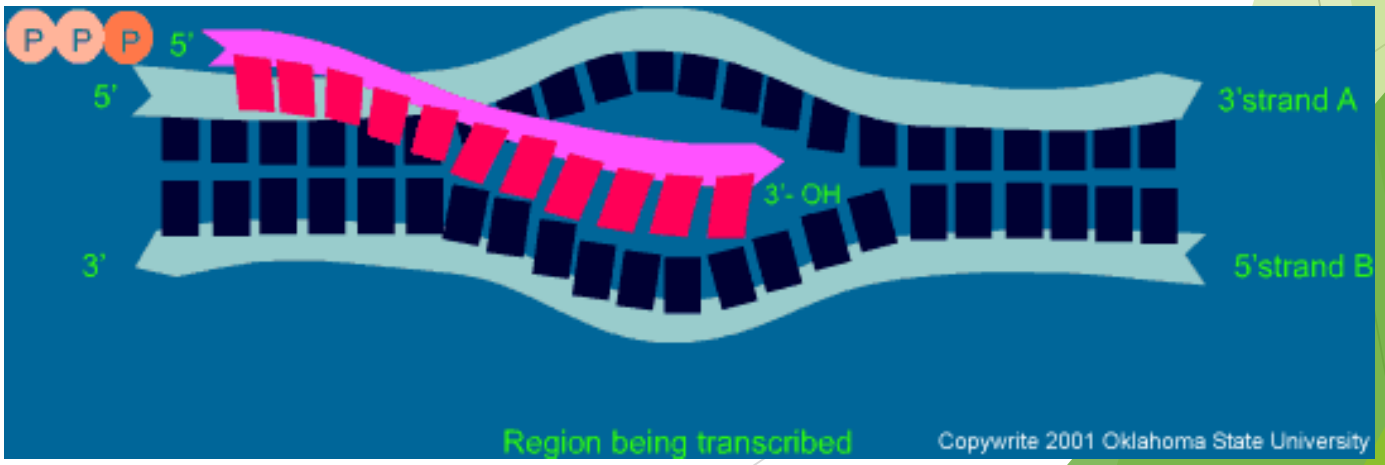
  exons- needed pieces of RNA that are **spliced** back **together** to form **final mRNA**



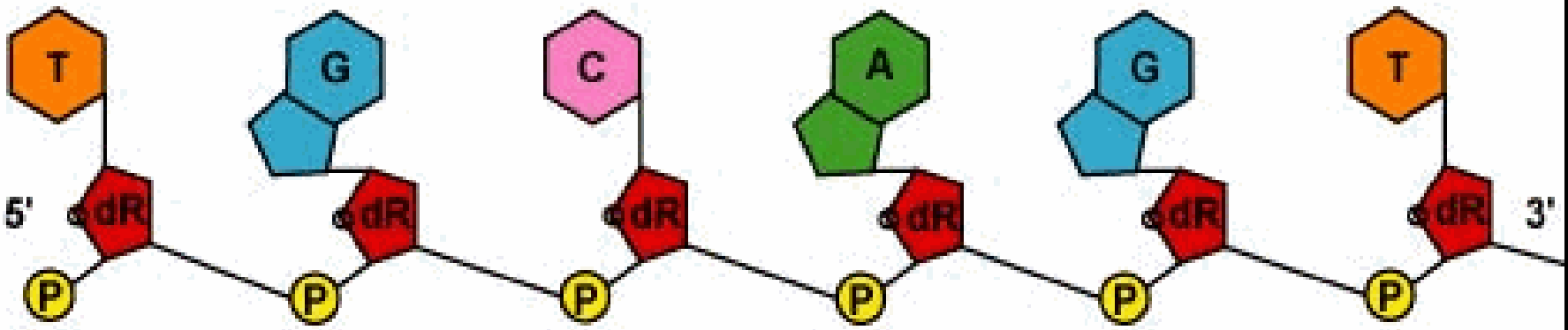

DNA coding strand
RNA Polymerase
mRNA
DNA anti-codon Strand
Free Floating Nucleotides

Part 1: Transcription

- Each **codon** codes for a **specific amino acid** (Ex. 2 codons = 2 amino acids= 6 bases)
- Single new strand of mRNA **leaves** the **nucleus** and **carries** the **instructions** to the **ribosome** where proteins are assembled
- mRNA **attaches** to the **ribosome** and **waits** for the tRNA.



Transcription: mRNA base pairing animation



Portion of unwound DNA with unpaired deoxyribonucleotides.

DNA to RNA base pairing practice

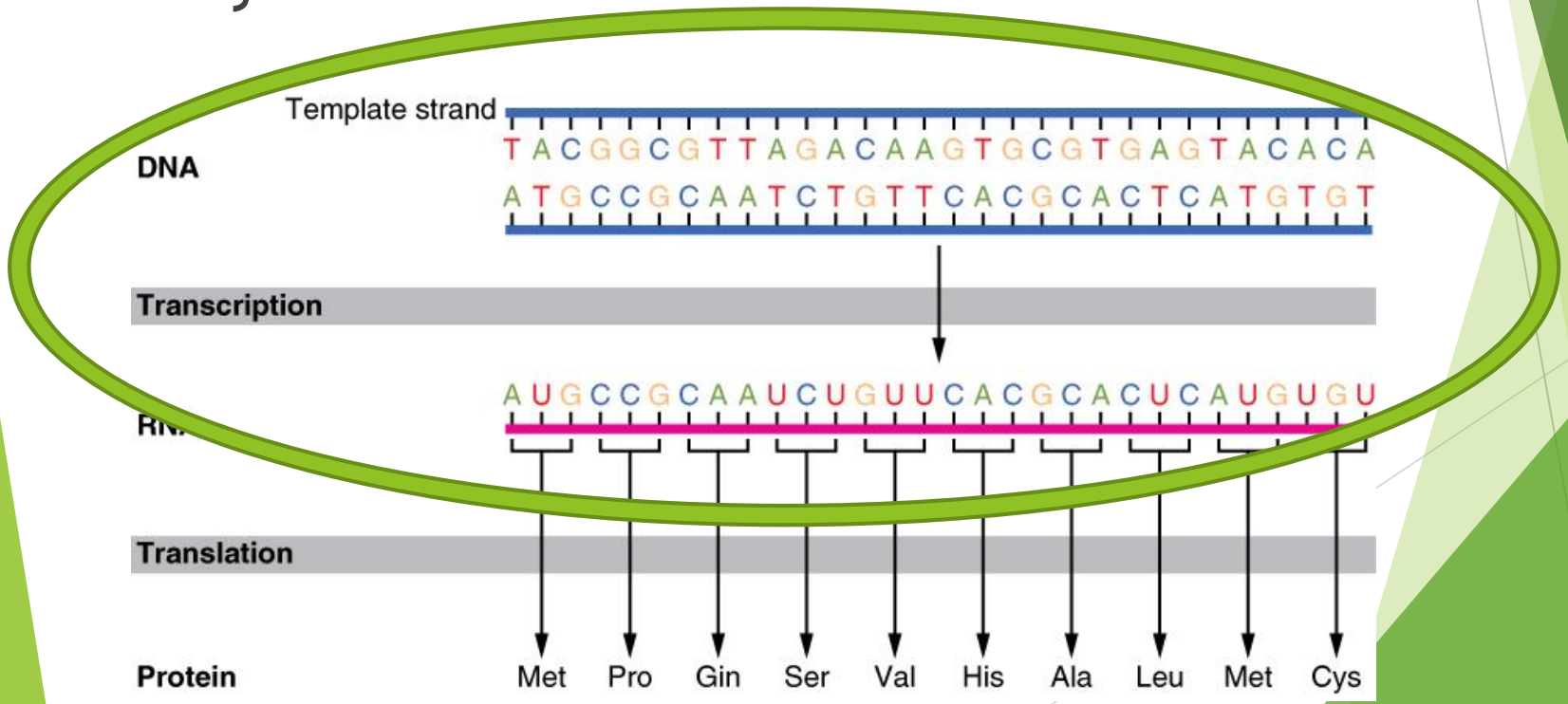
- Which RNA base would pair up with following DNA bases?
  - A T C T G A C G
  - U A G A C U G C

Transcription Summary

Video: in real time

- Transcription **sends** the instructions to make proteins from the **nucleus** to the **ribosomes** in the form of **mRNA**

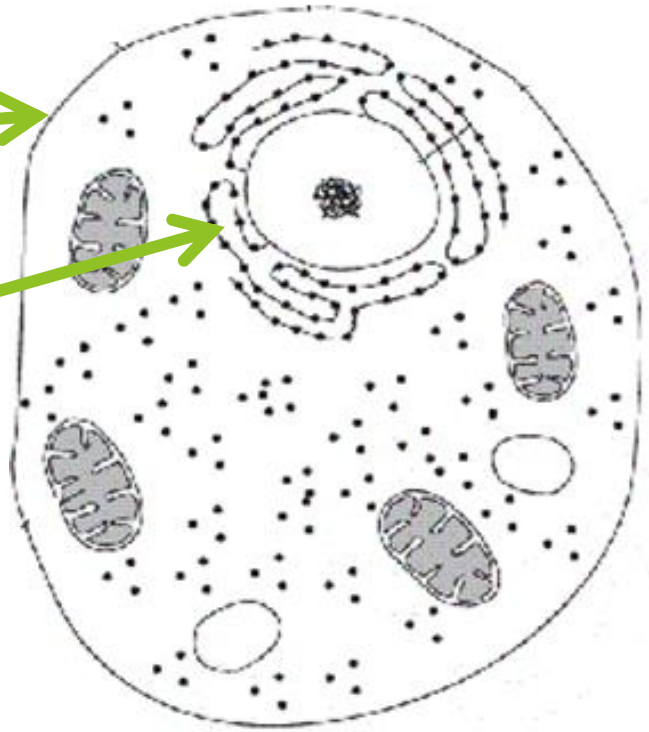
*What happens if the mRNA gets damaged on the way to the ribosomes?



Part 2: Translation

Ribosomes: **makes proteins** using instructions from the nucleus

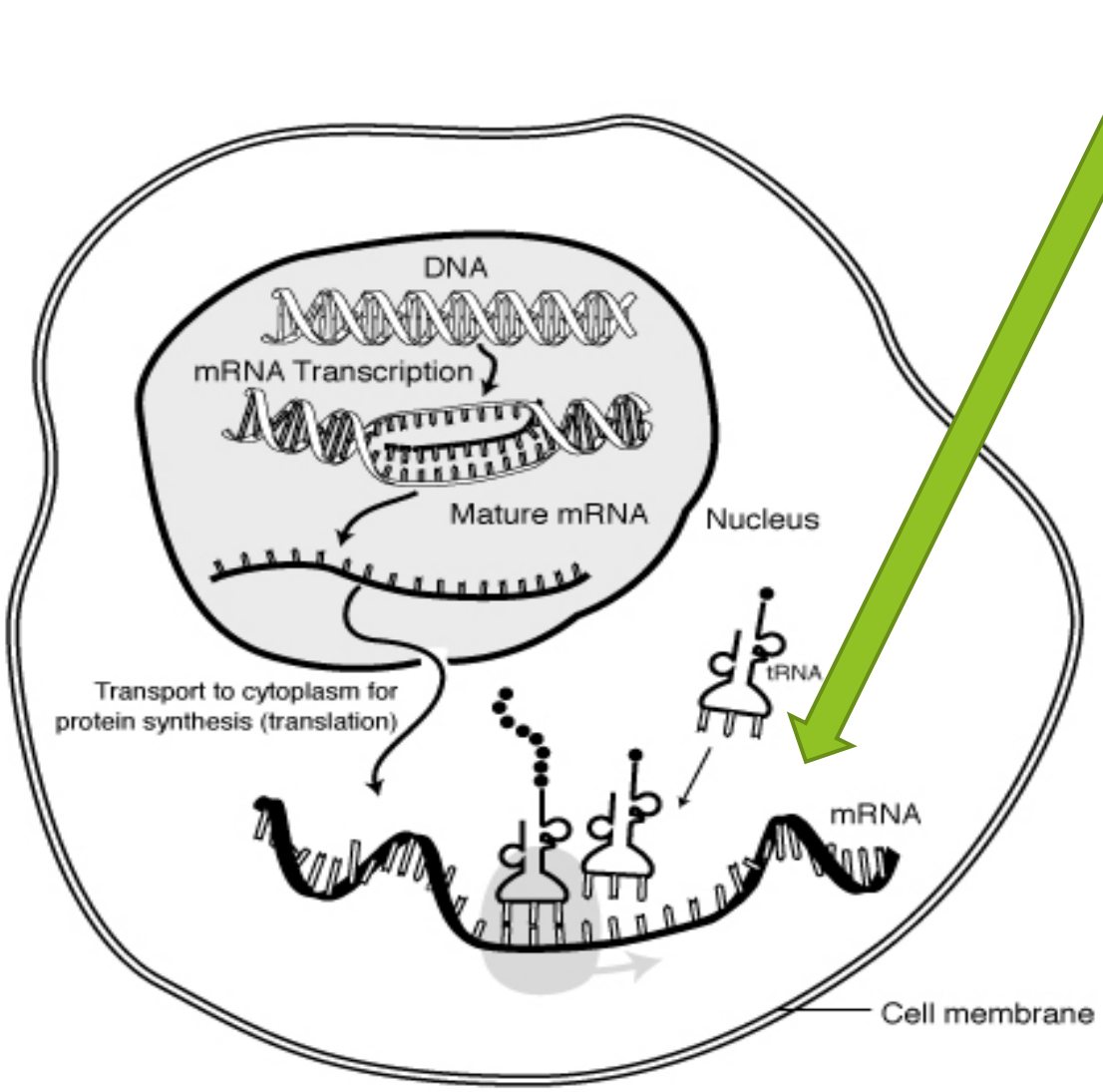
- Can be:
  - Free **Floating**
  - Attached to **rough endoplasmic reticulum**



*What do you think would happen if ribosomes were removed from a cell?

Protein Synthesis

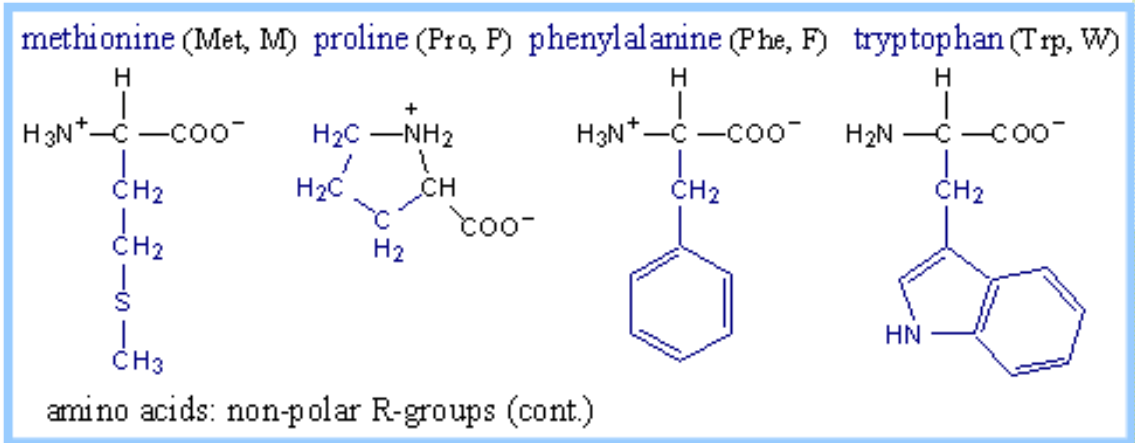
- Part 2. Translation (occurs in the **cytoplasm**)



Part 2 : Translation

Decoding of an **mRNA** into a **polypeptide** chain (protein)

- tRNA (**anticodon**) is composed of **3** bases
- tRNA picks up a **specific** amino acid in the **cytoplasm** and takes it to the **ribosome**.
- tRNA will "read" the **mRNA** and drop of the **amino acid** in the **correct sequence** to build the protein needed
- 20 **different** amino acids- 64 possible **codon** combinations (there are **multiple** ways to **code** for the **same amino acid** in some instances to help **prevent mutations**)

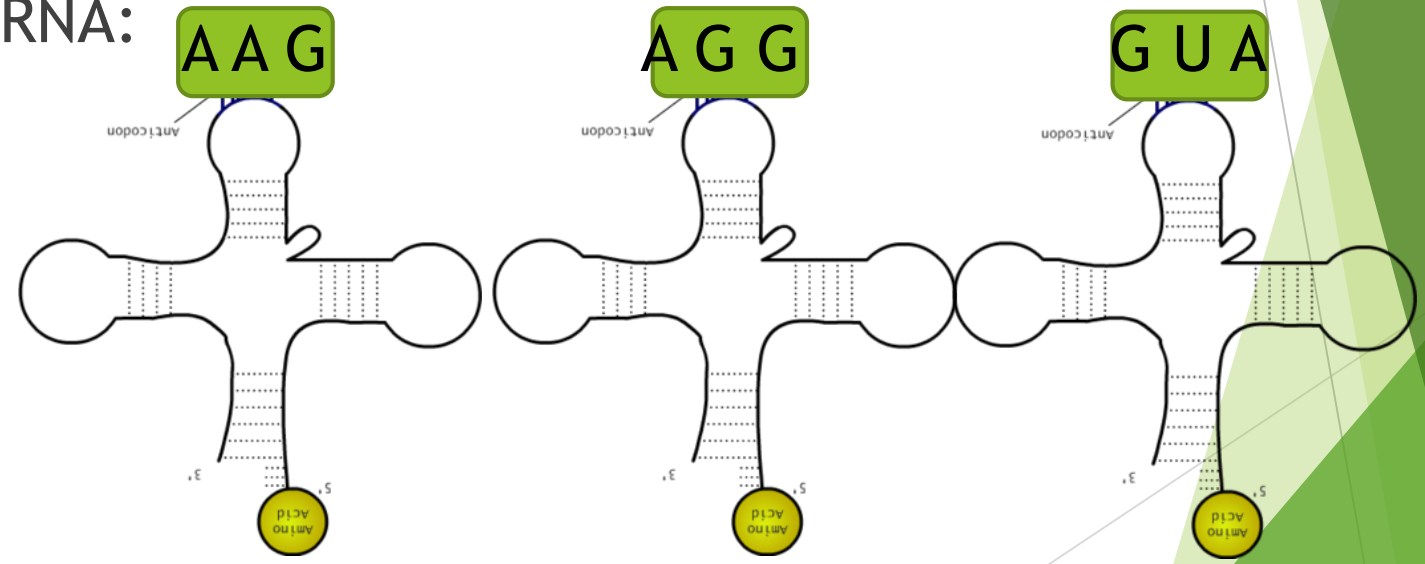


Translation Summary

- The **genetic code** (mRNA codons) matches up with tRNA **anticodons** to put the amino acids in the correct order. Amino acids form a **polypeptide** chain held together by **peptide bonds**; this is a **protein**.

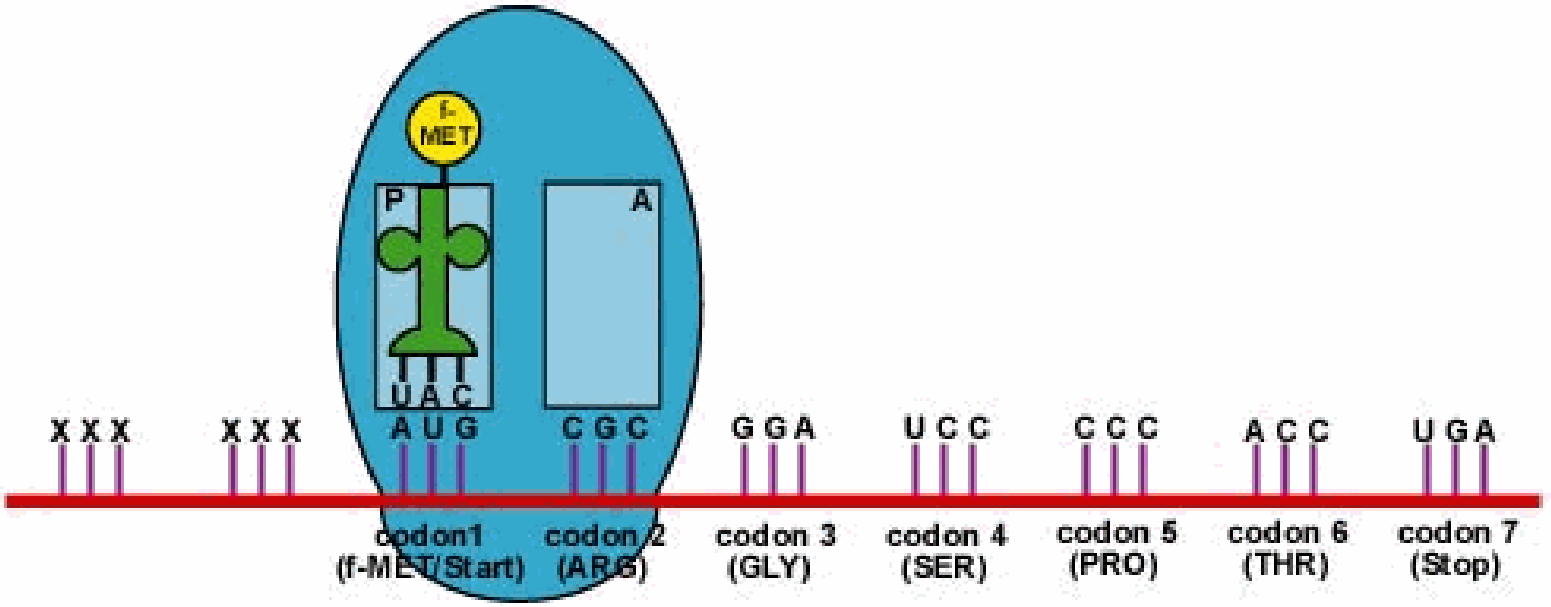
* Practice mRNA: U U C U C C C A U

tRNA: A A G A G G G U A



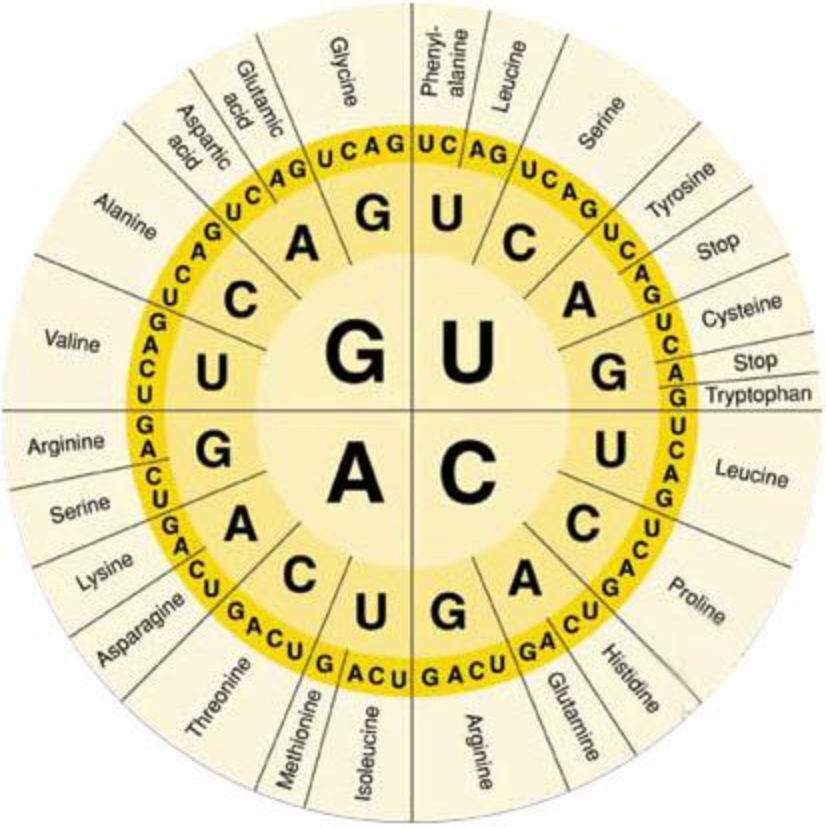
Video: real time

Translation Summary animation



For you to complete translation- you must use the **mRNA** chart (NO DNA or tRNA!!)

- Codon Chart



Second letter

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

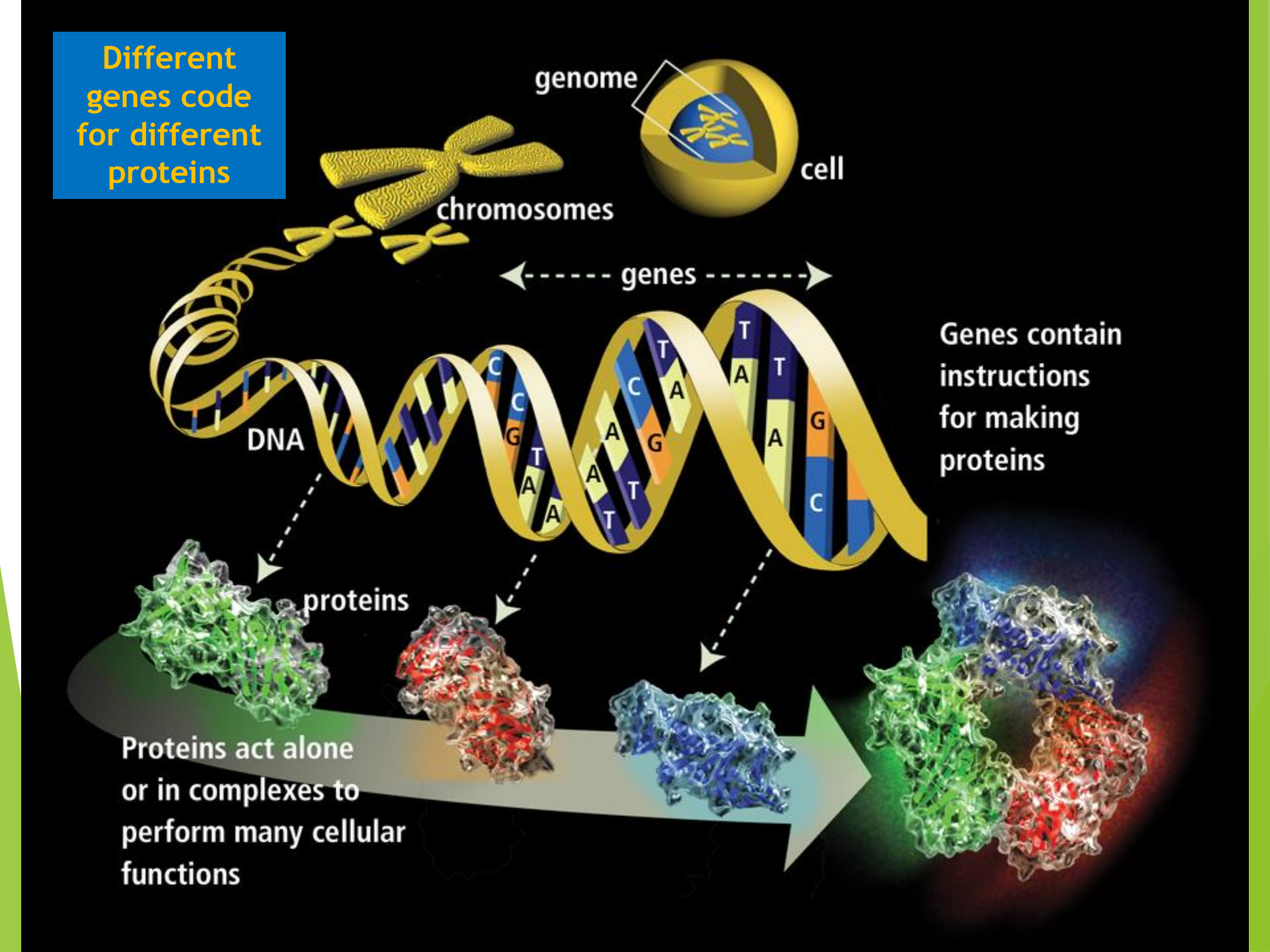
Practice

DNA: GAC CCT TAT

mRNA: **CUG** **GGA** **AUA**

Amino Acid Sequence: **Leucine** **Glycine** **Isoleucine**

tRNA: **GAC** **CCU** **UAU**


Different genes code for different proteins
genome
cell
chromosomes
genes
DNA
Genes contain instructions for making proteins
proteins
Proteins act alone or in complexes to perform many cellular functions

Gene Regulation and Mutations

Gene expression (Review)

- Gene expression = protein produced
- DNA→RNA→A.A.→Protein→ Protein Shape→ Protein Function
- After protein synthesis, the protein is folded into a specific shape
- The shape of the protein and the **order of the amino** acid determines the function of the protein

Example A: Some jellyfish have genes that, when expressed, produce the **protein** called **Green Fluorescent Light** (GFL)

- When the GFL gene is **expressed**, cells produce the GFL protein, which produces **light** (AKA: bioluminescence)
- Scientists have removed the GFL gene from jellyfish and inserted the GFL gene into pigs DNA

Gene expression example

- If the pigs glow in the dark, what can you tell me about the GFL gene that's in the pig's DNA?

  The pigs cells **transcribed** and **translated** the **GFL genes!**

  Gene Expression occurred!

Influences on Gene Expression

- Environmental Influences – factors that influence the **expression** of a gene such as **temperature**, **nutrition**, **light**, **infectious** agents

  ex. Temperature effects the expression of the **coat color** gene in Arctic Foxes

Influences on Gene expression

Mutation's effect on gene expression:

If the Arctic Fox is supposed to produce proteins that give it brown fur in the summer, but those fur color genes have mutated to produce hot-pink fur…

- What do you think will happen to the color of the fox's fur when temperatures increase?
- What do you think will happen to that fox? Will it pass on the hot-pink mutated gene?

Influences on Gene Expression

What if the mutation caused the fox to have better camouflaged fur instead?

- How would you expect this mutation to affect the future of the fox population? **Increase in offspring**
- In this case, the new mutation resulted in is an **adaptation** because it made the foxes better fit.

What effect on gene expression would a mutation that produced the same amino acid sequence have?

Same amino acid sequence = same protein = same trait = no change

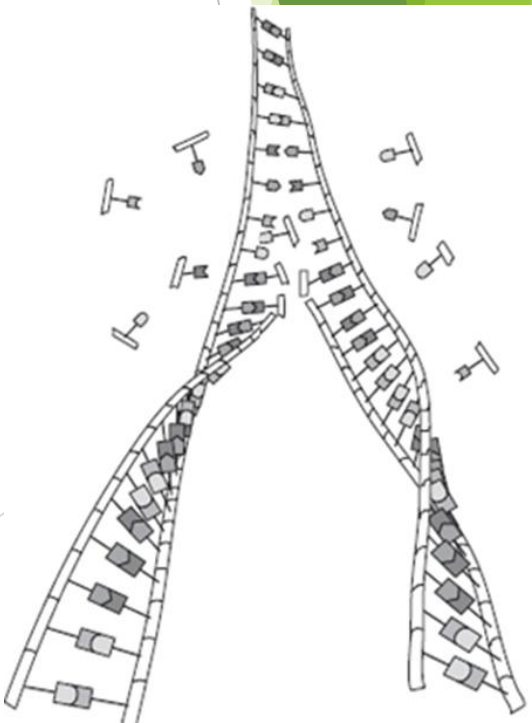
Mutations

Mutations

- any **CHANGE** in the **DNA** sequence
- It's a **MISTAKE** that's made during **replication** or transcription
- occur when a change occurs in nucleotide bases
- Can be positive (adaptations) or negative (disorders)
- a source of genetic diversity

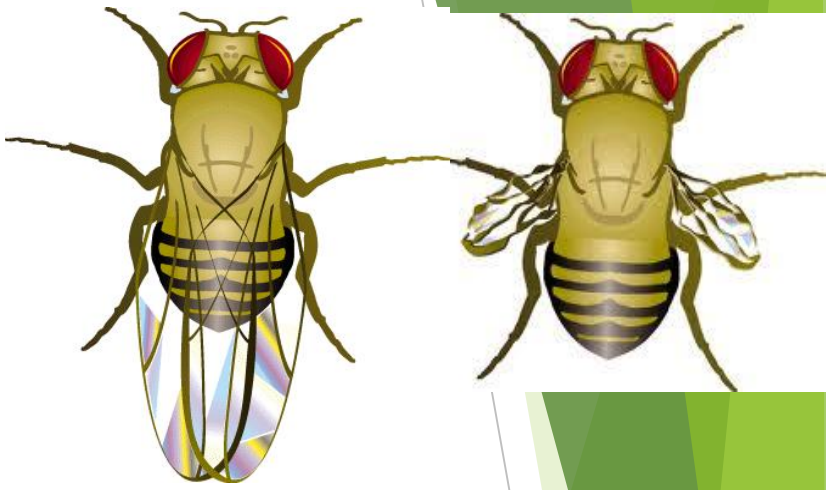
2 types:

~Point Mutations and Chromosomal



Mutations: good or bad?

- **harmful:** <u>diseases</u> or deformities
- **helpful:** organism is better able to <u>survive</u> (camouflage, adaptation)
- **neutral:** organism is <u>unaffected</u>



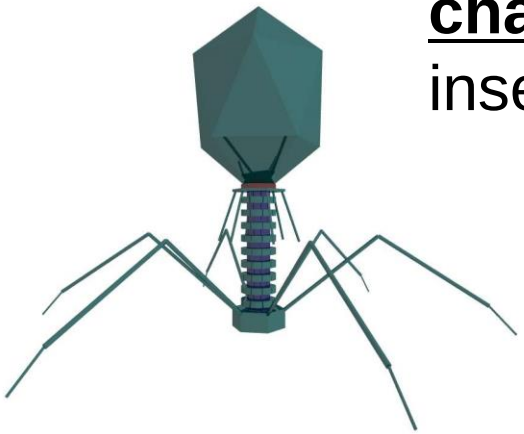
NORMAL MUTATION

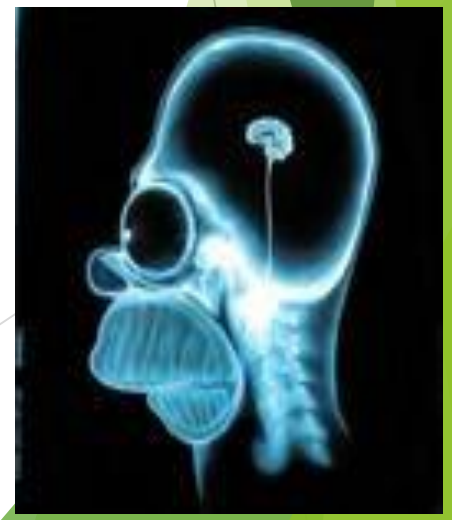
Causes of mutations

- **Mutagens**: anything that causes a change in DNA
- examples: Viruses, X rays, UV light, nuclear radiation, cigarette smoke
- Mutations are random events
  - Chances of mutations occurring naturally 1/1,000,000
  - Mutations due to mutagens usually 1/100,000

What are the mutagens?

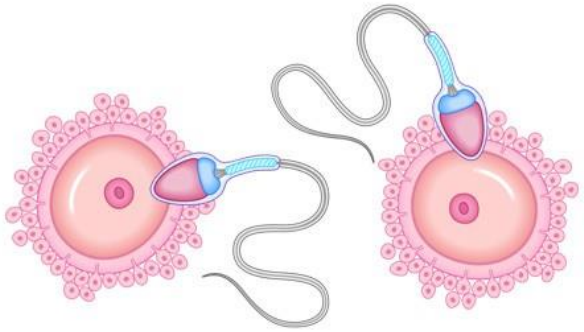
*remember that viruses can cause **changes** in the **HOST** DNA when they insert their viral DNA for replication!





Can you give a mutation (mistake) to your kids?

- YES, if a mutation occurs in a **sperm or egg cell**



- NO, if a mutation occurs in a **body cell** (example skin cell)

Types of GENE Mutations

Point Mutations -change in **one** or a **few** nucleotides

Results in one or a few amino acids changed

(1) Substitutions - **one** base is changed to **a different base**

Ex. TAC GCT AGA → TAC GTT AGA

(2) Frame shift mutations

Insertion - one base is **added**

Ex. TAC GCT AGA → T**T**A CGC TAG A

Deletion - one base is **removed**

Ex. T**A**C GCT AGA → TCG CTA GA

Frameshift vs. Substitution

- THE FOX WAS RED (correct protein)
  - TTE FOX WAS RED (Substitution)
  - TAH EFO XWA SRE D (Insertion) Longer sentence!
  - TEF OXW ASR ED (Deletion) Shorter sentence!

Amino acids and mutations

- **Point Mutation- harmful when amino acid is <u>different</u>**

CAC = histidine
CCC= proline

- **not harmful when amino acid is <u>same</u>**

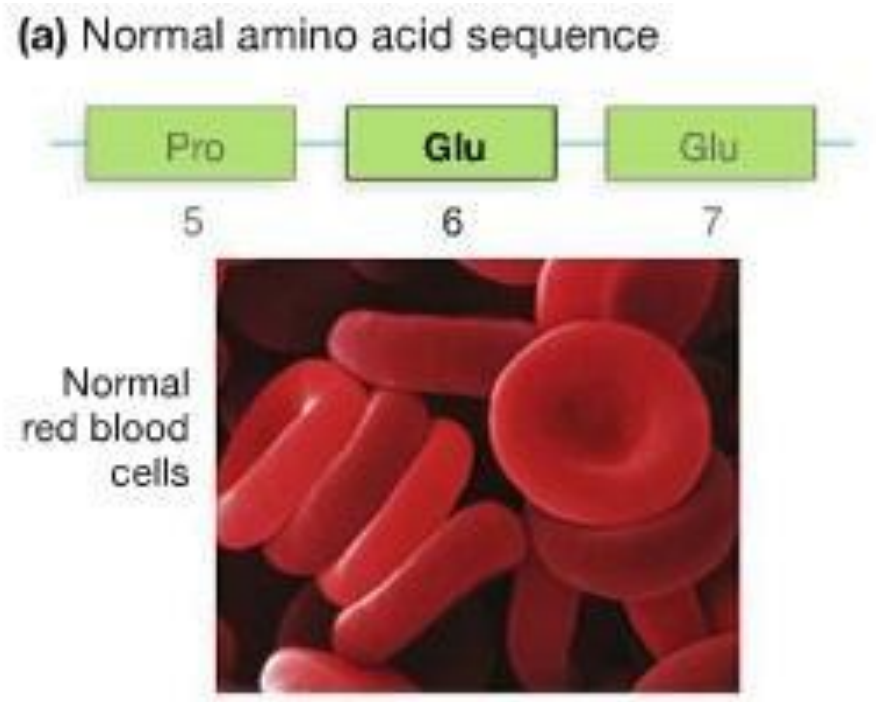
CAC= histidine
CAU= histidine

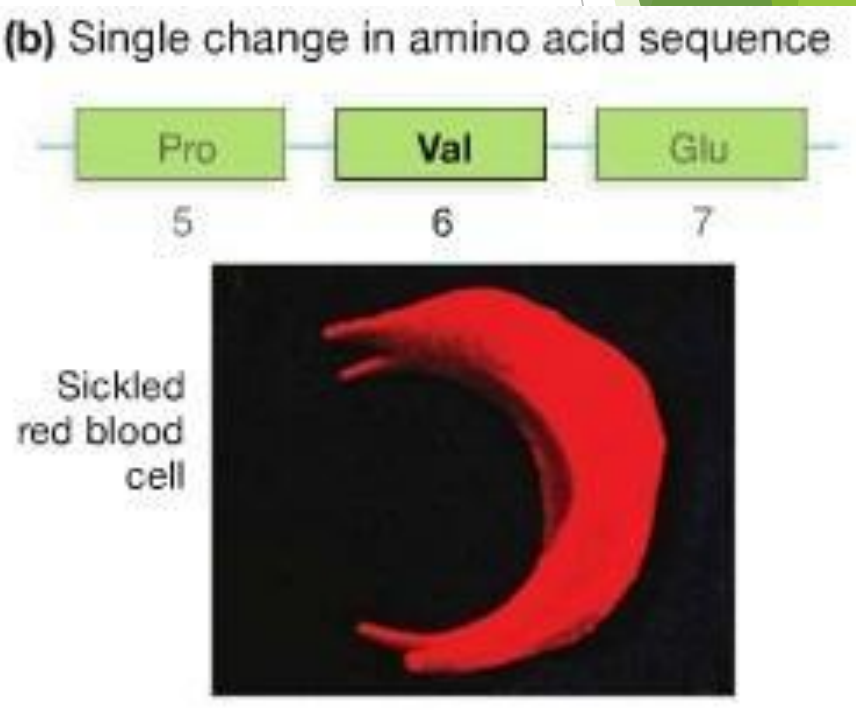
First Position	Second Position: U		Second Position: C		Second Position: A		Second Position: G		Third Position
	code	Amio Acid	code	Amio Acid	code	Amio Acid	code	Amio Acid	
U	UUU	phe	UCU	ser	UAU	tyr	UGU	cys	U
	UUC		UCC		UAC		UGC		C
	UUA	leu	UCA		UAA	STOP	UGA	STOP	A
	UUG		UCG		UAG	STOP	UGG	trp	G
C	CUU	leu	CCU	pro	CAU	his	CGU	arg	U
	CUC		CCC		CAC		CGC		C
	CUA		CCA		CAA	gln	CGA		A
	CUG		CCG		CAG		CGG		G
A	AUU	ile	ACU	thr	AAU	asn	AGU	ser	U
	AUC		ACC		AAC		AGC		C
	AUA		ACA		AAA	lys	AGA	arg	A
	AUG	met	ACG		AAG		AGG		G
G	GUU	val	GCU	ala	GAU	asp	GGU	gly	U
	GUC		GCC		GAC		GGC		C
	GUA		GCA		GAA	glu	GGA		A
	GUG		GCG		GAG		GGG		G

This a **<u>silent</u>** mutation (alters DNA sequence, but has no apparent detectable effect on a phenotype or a function).

Examples of Point Mutation Disorders

1. Sickle cell anemia
2. Color blindness
3. Albinism





Frameshift mutations

- Bases are inserted (put in) or deleted (take out)
- Very **harmful** because a mistake in DNA is carried into mRNA and results in **many wrong** amino acids

- For example, read the following sentence

Original: The fat cat ate the wee rat.

Frame Shift: The fat ca**a tet hew eer at**.

The “t” in cat was deleted causing most of the sentence to be wrong!

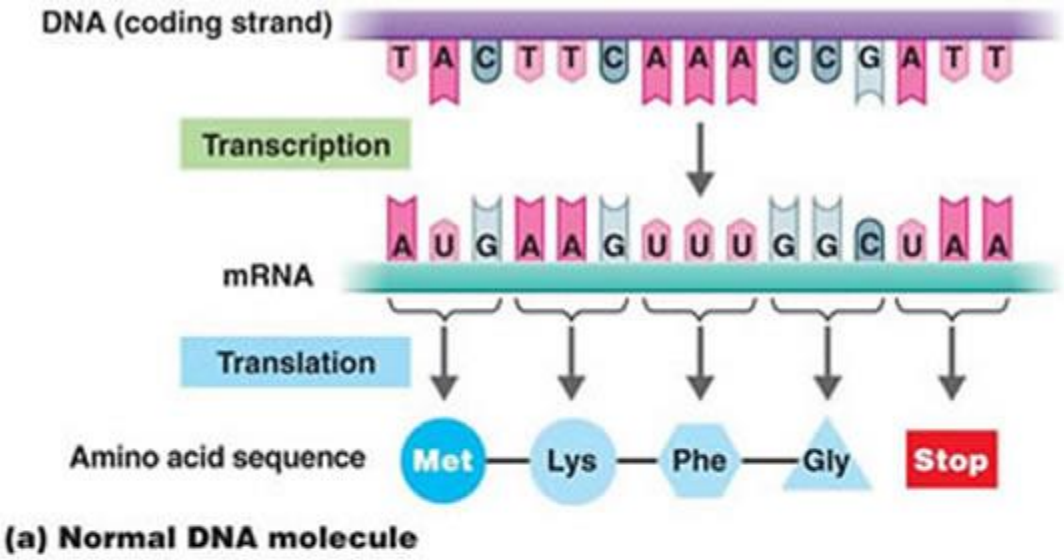
Examples of Frameshift Mutations


57A–57D Note the prominent forehead, proptosis, hypertelorism, hooked nose and small jaw. The young boy in school uniform is the grandfather of 57C.

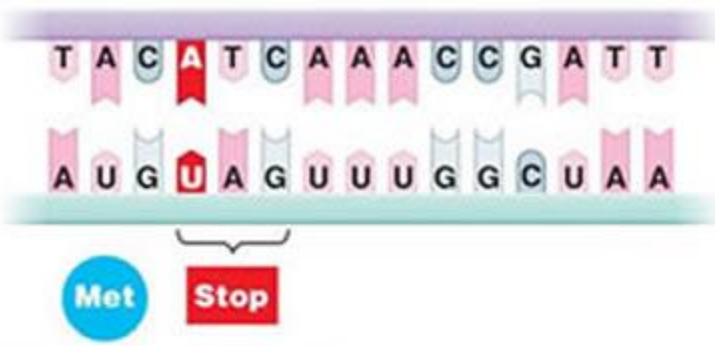
57C

- Tay Sachs: rare inherited disorder that progressively **destroys nerve** cells (neurons) in th brain and spinal cord.
- Cystic Fibrosis: causes mucus to be thick and sticky- can clogs the lungs, causing breathing problems and makes it easy for bacteria to grow.

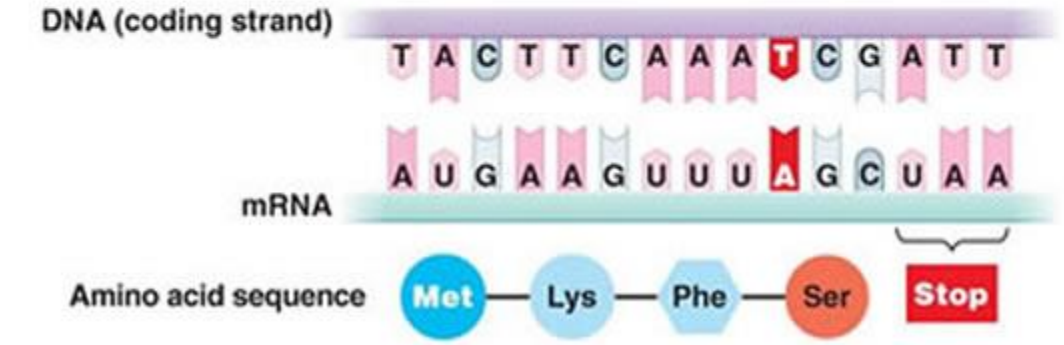
Mutation Consequences



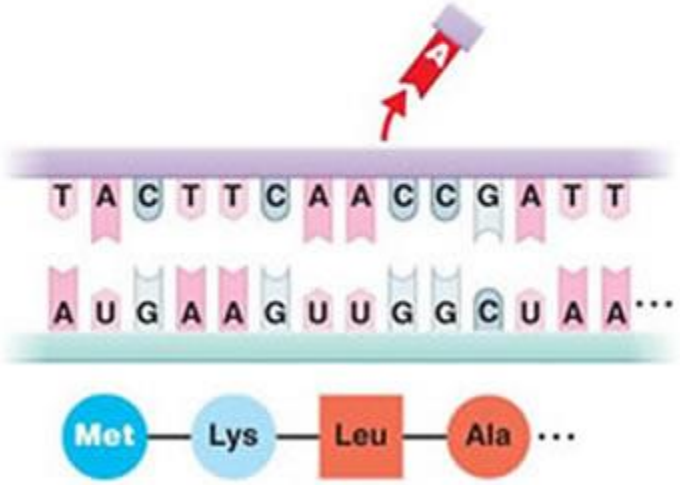
(a) Normal DNA molecule



Substitution



Substitution



Frame Shift- Deletion

Practice…

- DNA: GTAGTAGTA
- What type of single base change is the following mutation? GTAGAGTA
- What type of point mutation is the following mutation? GTAGAAGTA

Chromosomal mutations (*not just a base)

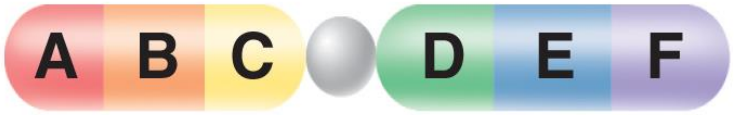
Chromosomal Mutations: produces change in **whole chromosomes**

- Chromosomes **break** or are **lost**
- Broken chromosomes may rejoin incorrectly
- **Almost always lethal (kills)** when it occurs in a **zygote** (fertilized egg that will become a baby)
- Results in **major** changes to proteins produced

Chromosomal Mutations

- Results in major changes to proteins produced
  - **Deletion -** loss of all or part of chromosome
  - **Duplications -** extra copies of a chromosome
    - Also called polyploidy
  - **Inversions -** reverse the direction of chromosomes
  - **Translocation -** when part or a chromosome breaks off and attaches to another

Chromosomal Mutation



Original chromosome

Deletion

Duplication

Translocation

Inversion

Check for Understanding

1. When a change occurs in the DNA nucleotide bases, a _____ has occurred
2. A base substitution in _____ (type of cell) can be inherited.
3. A point mutation will cause _____ amino acids to change