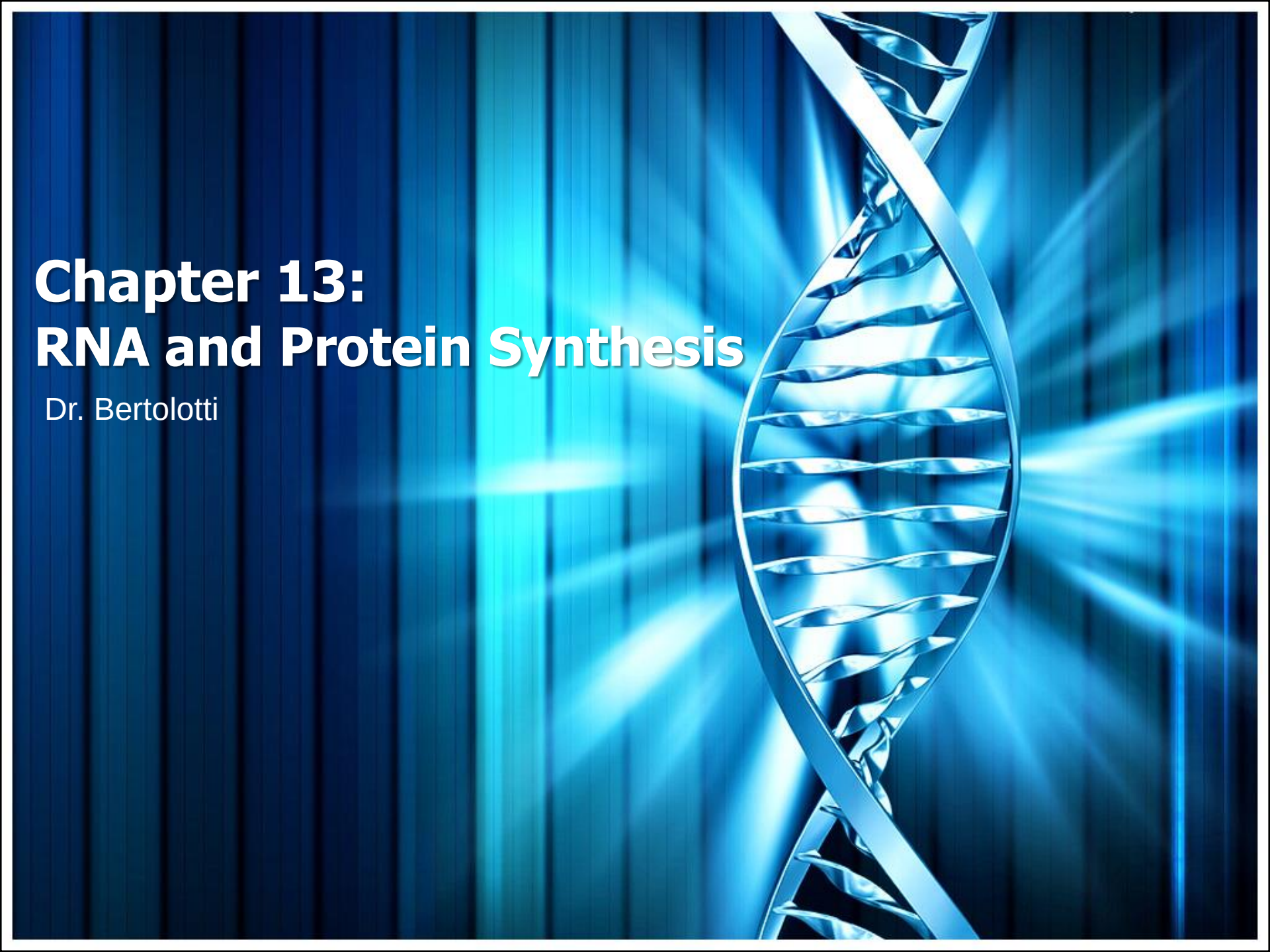
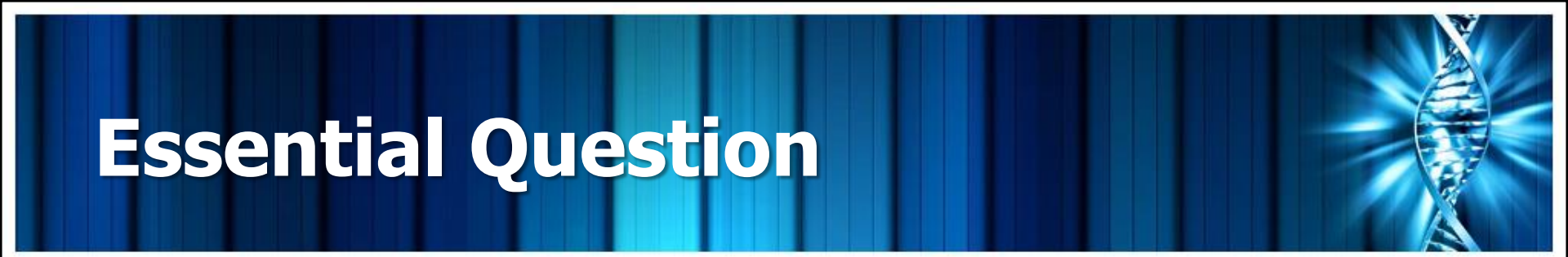


Chapter 13:
RNA and Protein Synthesis

Dr. Bertolotti

Essential Question



How does information flow from DNA to RNA to direct the synthesis of proteins?

How does RNA differ from DNA?

RNA and protein synthesis

- **Genes** are coded DNA instructions that control the production of proteins within the cell.
- The first step in decoding these genetic messages is to copy part of the nucleotide sequence from DNA into RNA or ribonucleic acid.
  - RNA is a Nucleic Acid
    - made up of nucleotides
    - contains the elements – C, H, O, N, P

Structure of RNA

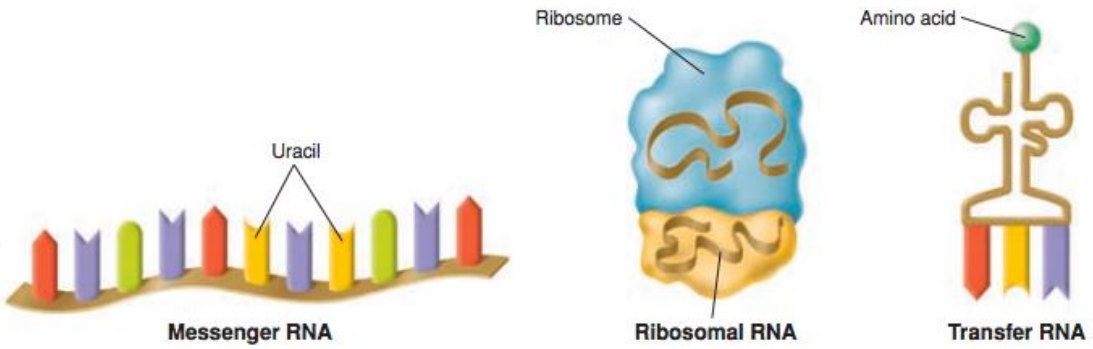
- Single stranded
- Contains the following:
  - Phosphate group
  - 5 carbon sugar (ribose)
  - Nitrogenous base: Adenine, Uracil, Cytosine, and Guanine
- ***The function of RNA is to synthesize proteins***

Differences between RNA and DNA

RNA	DNA
Single stranded	Double stranded
The sugar group is ribose	The sugar group is deoxyribose
Uracil is used	Thymine is used

Types of RNA

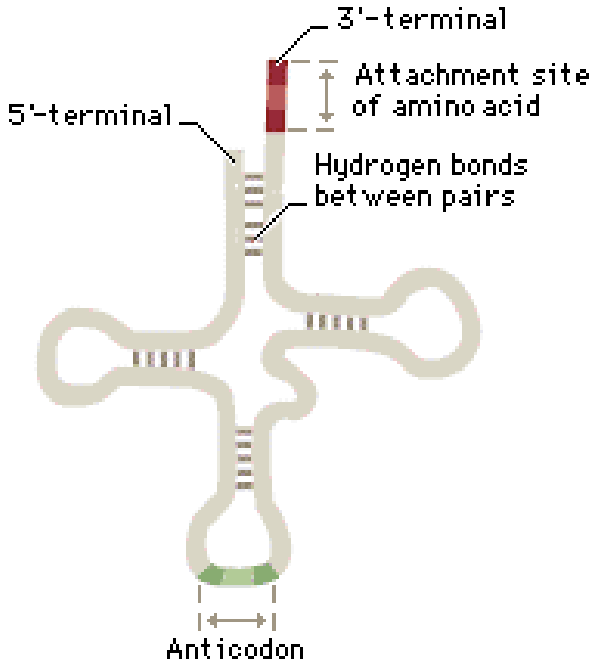
- Three (3) main types
  - 1. **Messenger RNA (mRNA)**
    - transfers DNA code to ribosomes for translation.
  - 2. **Transfer RNA (tRNA)**
    - brings amino acids to ribosomes for protein synthesis.
  - 3. **Ribosomal RNA (rRNA)**
    - Ribosomes are made of rRNA and protein.



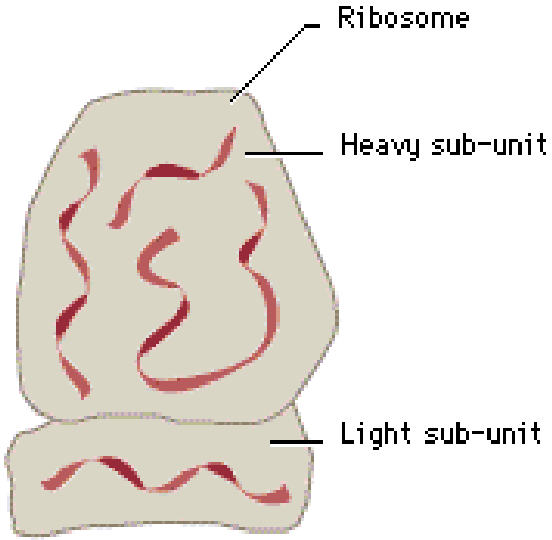
Types of RNA The three main types of RNA are messenger RNA, ribosomal RNA, and transfer RNA. Ribosomal RNA is combined with proteins to form ribosomes.

Types of RNA

Messenger RNA



Transfer RNA



Ribosomal RNA

QUESTION AND ANSWER

How does RNA differ from DNA?

How does the cell make RNA?

Transcription

- RNA molecules are produced by copying part of the nucleotide sequence of DNA into complementary sequence in RNA, a process called **transcription.**
  - This takes place in the nucleus of eukaryotic organisms
  - During transcription, RNA polymerase binds to DNA and separates the DNA strands.
  - RNA polymerase then uses one strand of DNA as a template from which nucleotides are assembled into a strand of mRNA.
  - Example: The DNA strand 5’ TAT CAG TTA 3’ will be transcribed to AUA GUC AAU.

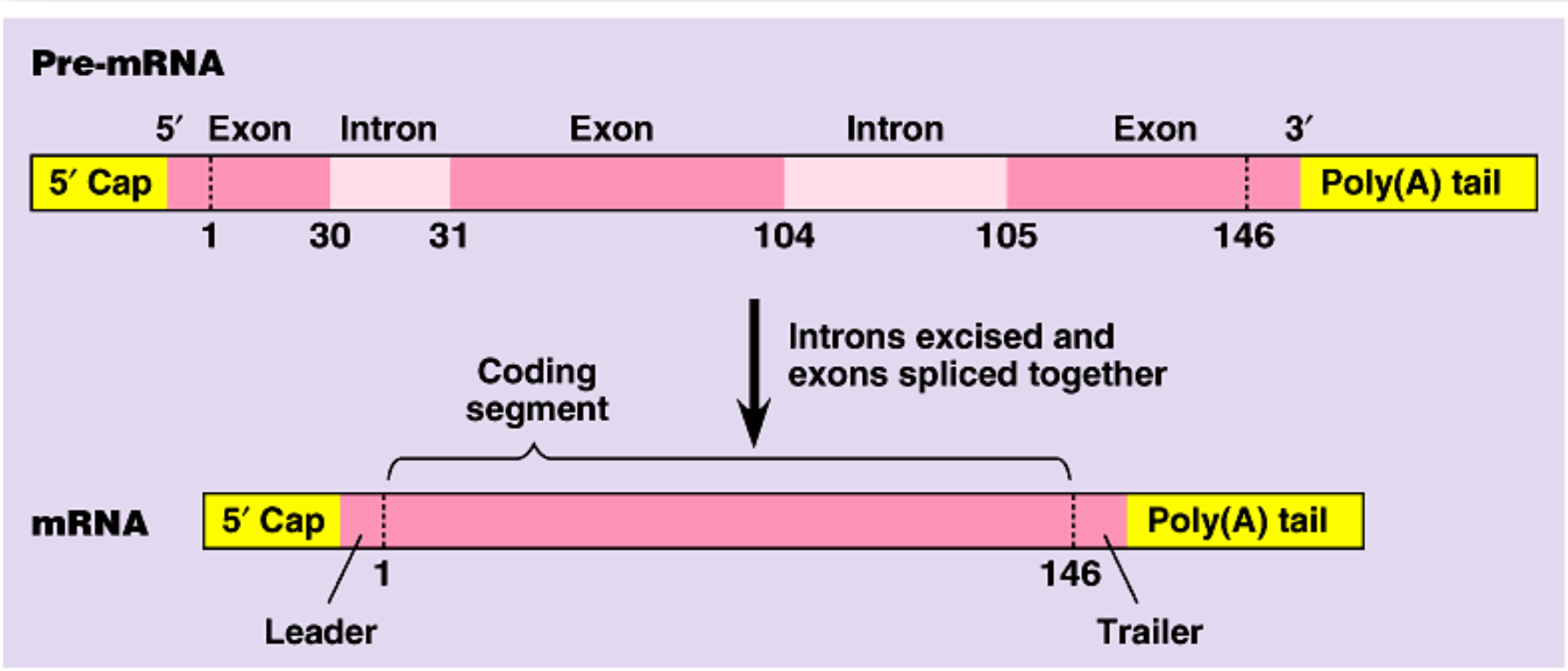
Transcription

Using an enzyme known as RNA polymerase genetic information in DNA is converted, or "transcribed", into RNA

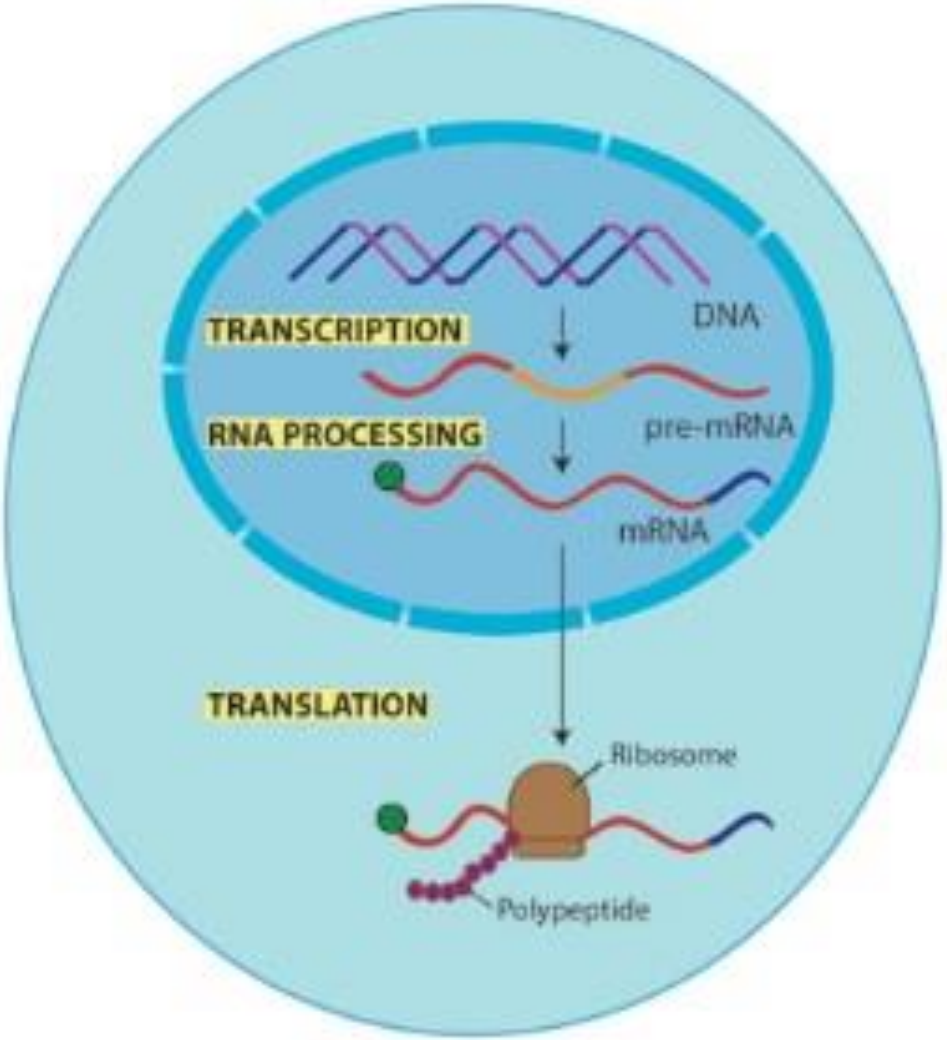
Editing the mRNA

- RNA Polymerase doesn't bind to DNA just anywhere.
  - Instead, RNA Polymerase looks for a region on the DNA known as a **promoter,** regions of DNA that have specific base sequences where it binds and begins transcription.
  - Promoters are signals in the DNA molecule that show RNA Polymerase exactly where to begin making RNA.
  - Similar sequences in DNA cause transcription to stop when a new RNA molecule is completed.
- **RNA splicing** occurs in which RNA strands are then edited. Some parts are removed (**introns**) - which are not expressed – and other that are left are called **exons** or expressed genes. Exons are spliced back together to form the final mRNA.
  - RNA splicing is regulated by both the internal and external environment

Introns and Exons



RNA splicing



QUESTION AND ANSWER

How does the cell make RNA?

What is the genetic code and how is it read?

The Genetic Code

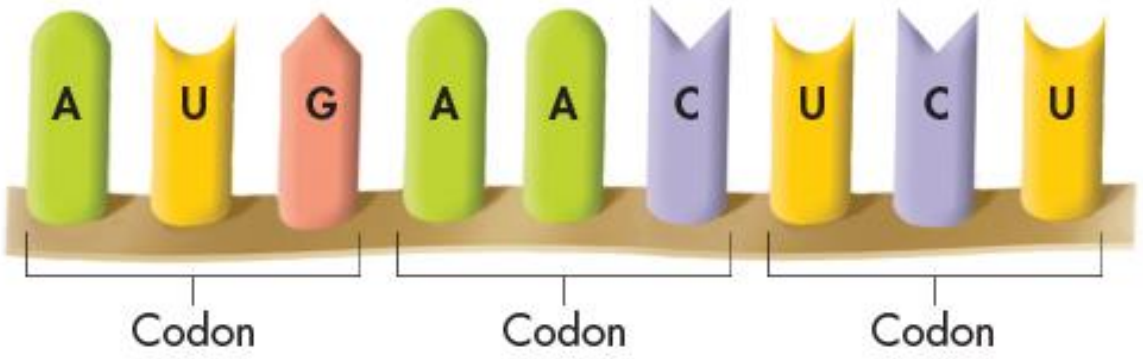
- Proteins are made by joining amino acids together into a long chain called polypeptides held together by peptide bonds.
  - There are as many as **20** different amino acids are commonly found in polypeptides.
  - The specific amino acids in a polypeptide, and the order in which they are joined, determine the properties of different proteins.
  - The sequence of amino acids influences its shape which determine its function.

The Genetic Code

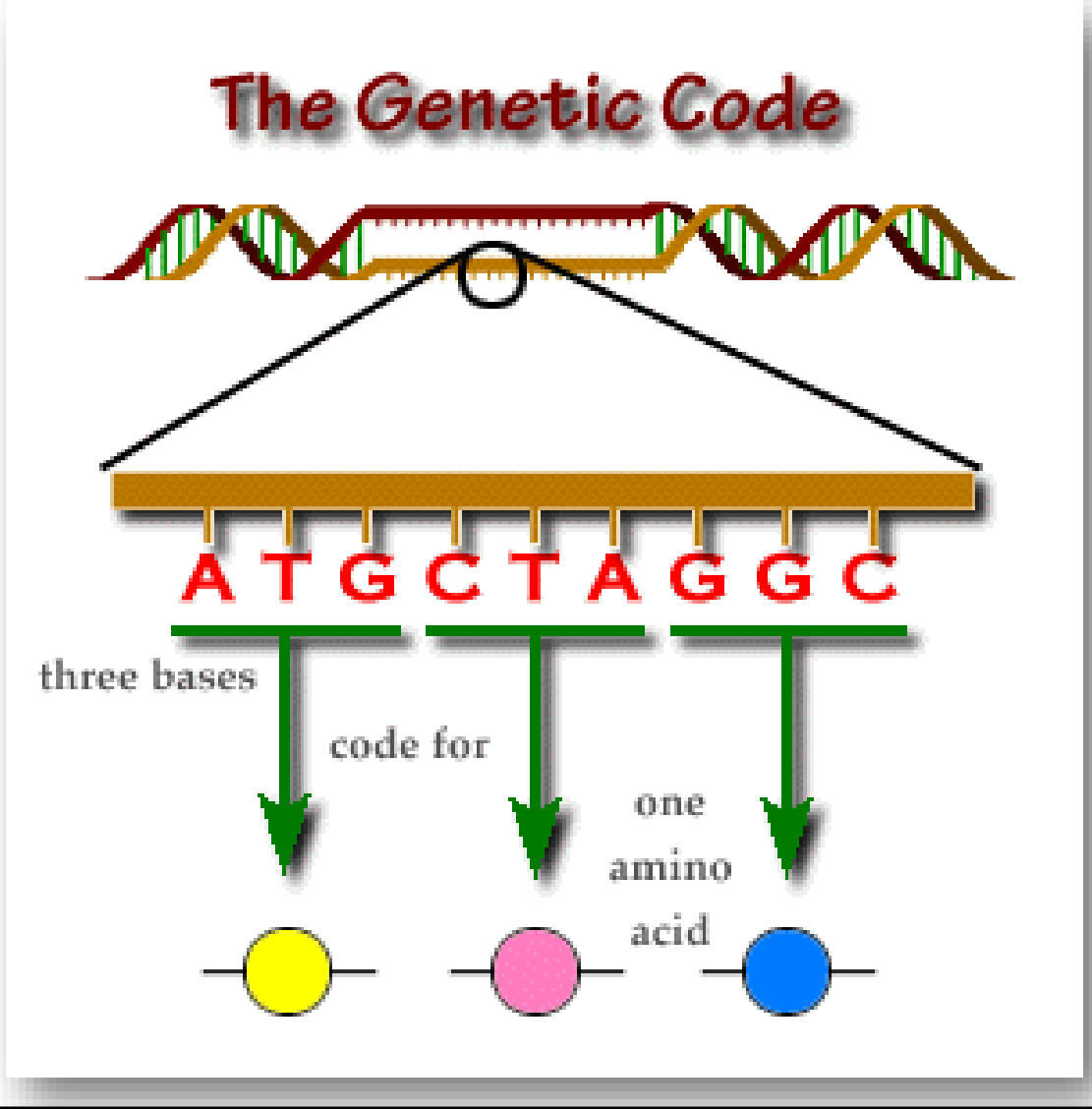
- This is the language of mRNA.
  - Based on the 4 bases of mRNA
    - Adenine, guanine, cytosine, and uracil
  - The genetic code is read three (3) “letters” at a time, so that each “word” is three (3) bases long and corresponds to a single amino acid.
  - “Words” are 3 RNA sequences called **codons**.
    - Because there are 4 different bases in RNA, there are 64 possible three-base codons (4x4x4= 64) in the genetic code.
- The strand aaacguucgccc would be separated as: aaa-cgu-ucg-ccc
  - the amino acids would then be: Lysine – Arginine – Serine– Proline

The Genetic Code

- Each three-letter “word” in mRNA is known as a **codon.**
  - A codon consists of three consecutive bases that specify a single amino acid to be added to the polypeptide chain.
  - Each codon specifies 1 amino acid

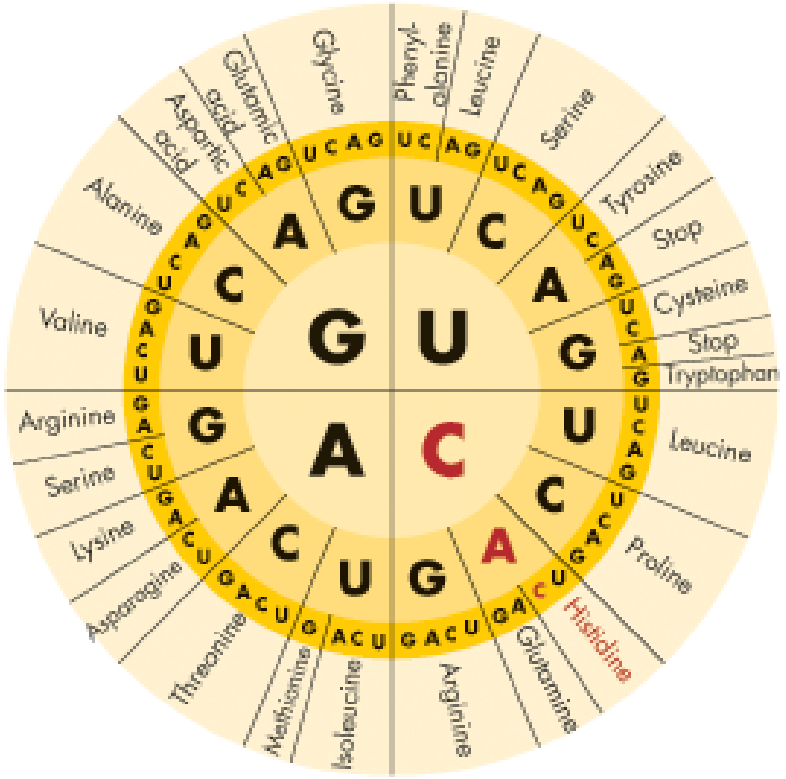


The Genetic Code



How to Read Codons

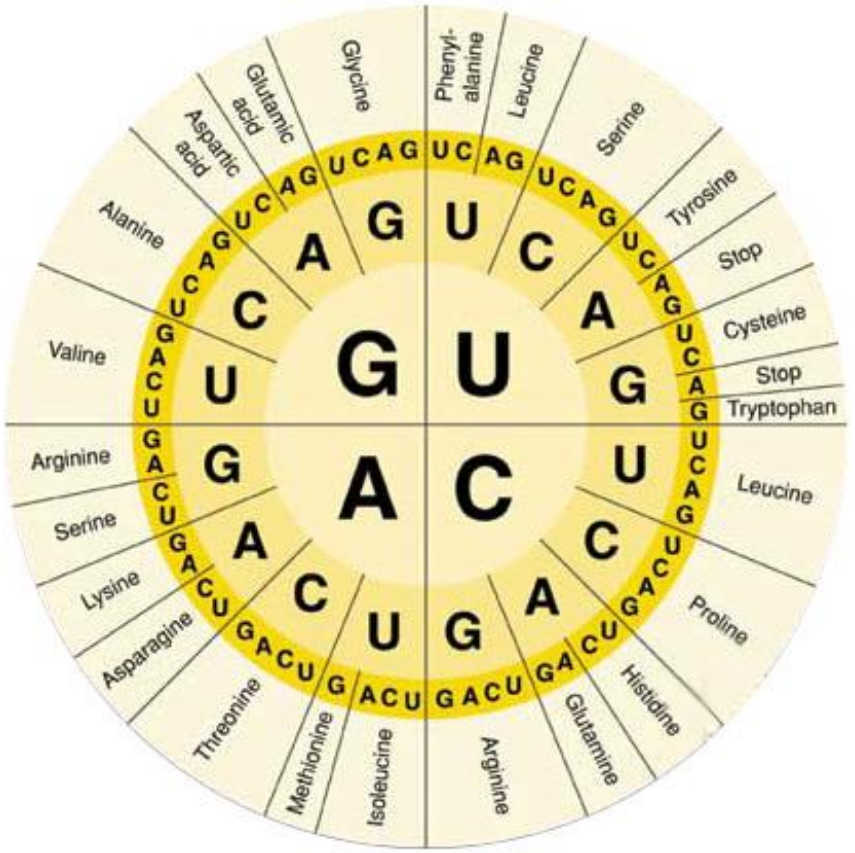
- Because there are four different bases in RNA, there are 64 possible three-base codons (4 × 4 × 4 = 64) in the genetic code.
- This circular table shows the amino acid to which each of the 64 codons corresponds. To read a codon, start at the middle of the circle and move outward.
- Most amino acids can be specified by more than one codon.
- For example, six different codons—UUA, UUG, CUU, CUC, CUA, and CUG—specify leucine. But only one codon—UGG—specifies the amino acid tryptophan.



Genetic Codes

2nd base in codon

1st base in codon	U	C	A	G	3rd base in codon
U	Phe	Ser	Tyr	Cys	U
	Phe	Ser	Tyr	Cys	C
	Leu	Ser	STOP	STOP	A
	Leu	Ser	STOP	Trp	G
C	Leu	Pro	His	Arg	U
	Leu	Pro	His	Arg	C
	Leu	Pro	Gln	Arg	A
	Leu	Pro	Gln	Arg	G
A	Ile	Thr	Asn	Ser	U
	Ile	Thr	Asn	Ser	C
	Ile	Thr	Lys	Arg	A
	Met	Thr	Lys	Arg	G
G	Val	Ala	Asp	Gly	U
	Val	Ala	Asp	Gly	C
	Val	Ala	Glu	Gly	A
	Val	Ala	Glu	Gly	G



QUESTION AND ANSWER

What is the genetic code and how is it read?

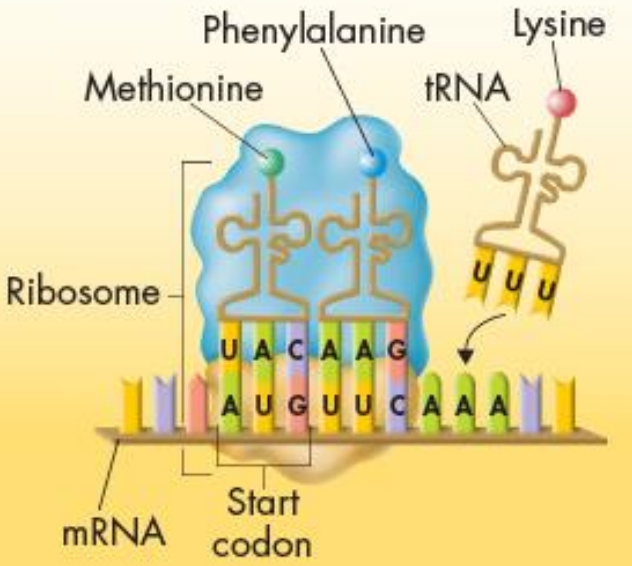
What role does the ribosome play in assembling proteins?

Translation

- ***During translation, the cell uses information from messenger RNA to produce proteins.***
- The steps in translation are:
  - A: Transcription occurs in nucleus.
  - B: mRNA moves to the cytoplasm to the ribosomes. tRNA "reads" the mRNA codon and obtains the amino acid coded for.
    - Each tRNA molecule carries just one kind of amino acid. The tRNA molecule has 3 unpaired bases called **anticodons** that are complementary to one mRNA codon.
  - C: Ribosomes attach amino acids together by a peptide bond forming a polypeptide chain.
  - D: Polypeptide chain keeps growing until a stop codon is reached.
- ***Therefore, ribosomes use the sequence of codons in mRNA to assemble amino acids into polypeptide chain.***

Translation

1



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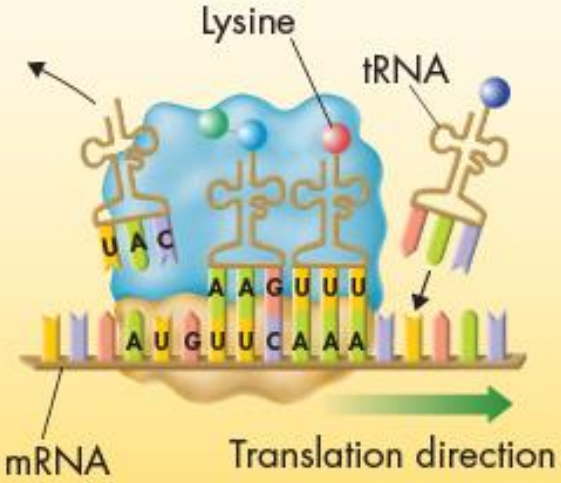

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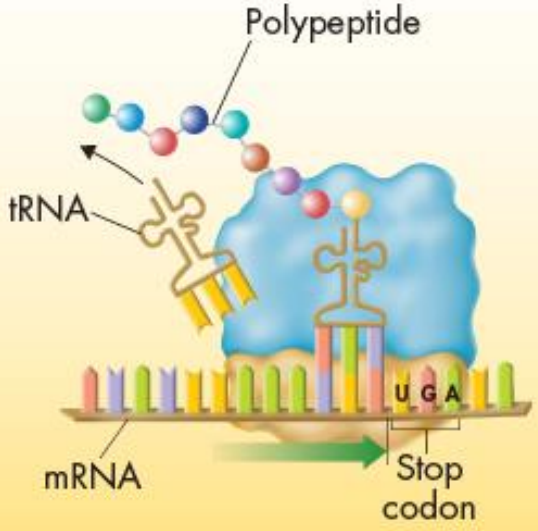
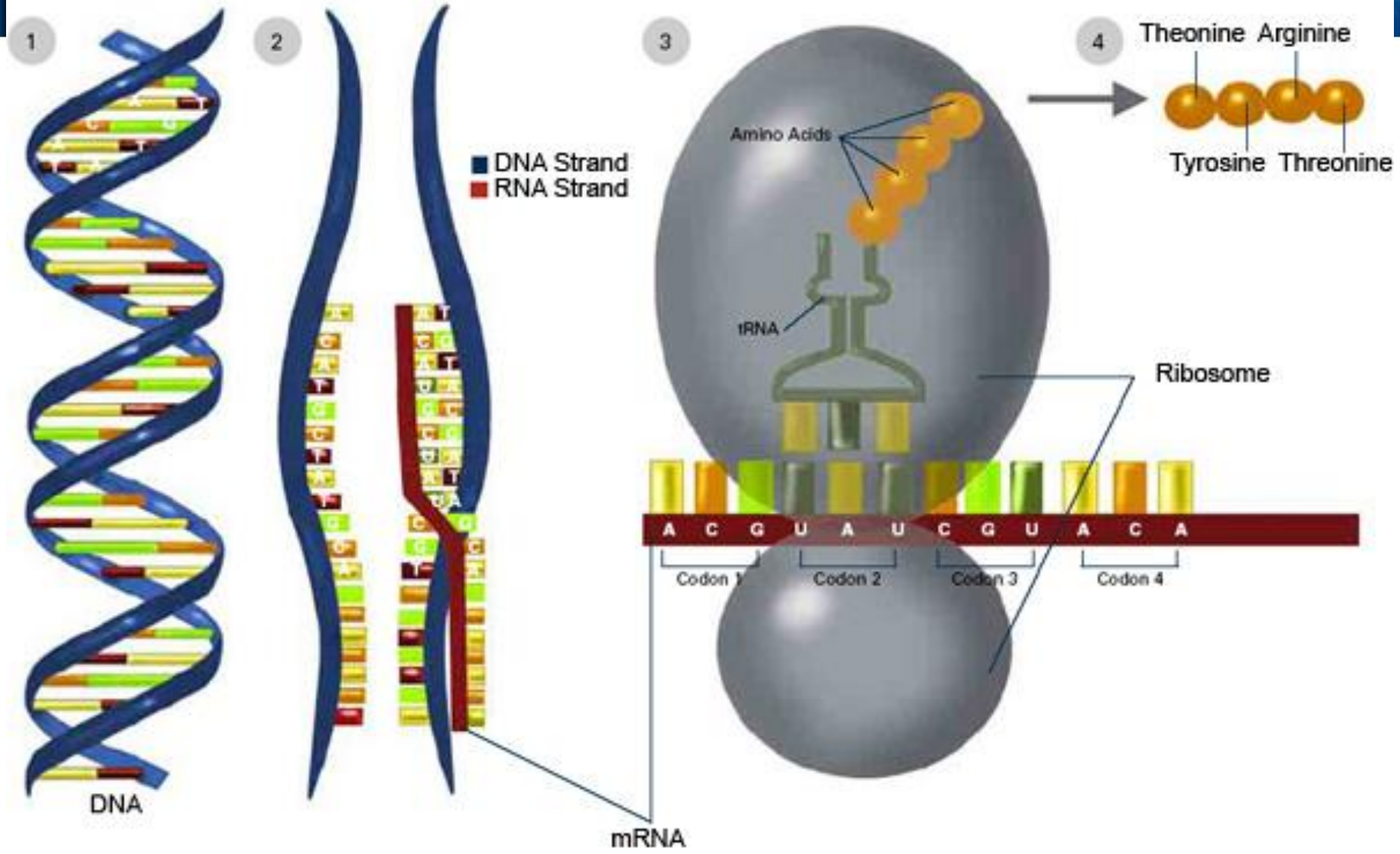
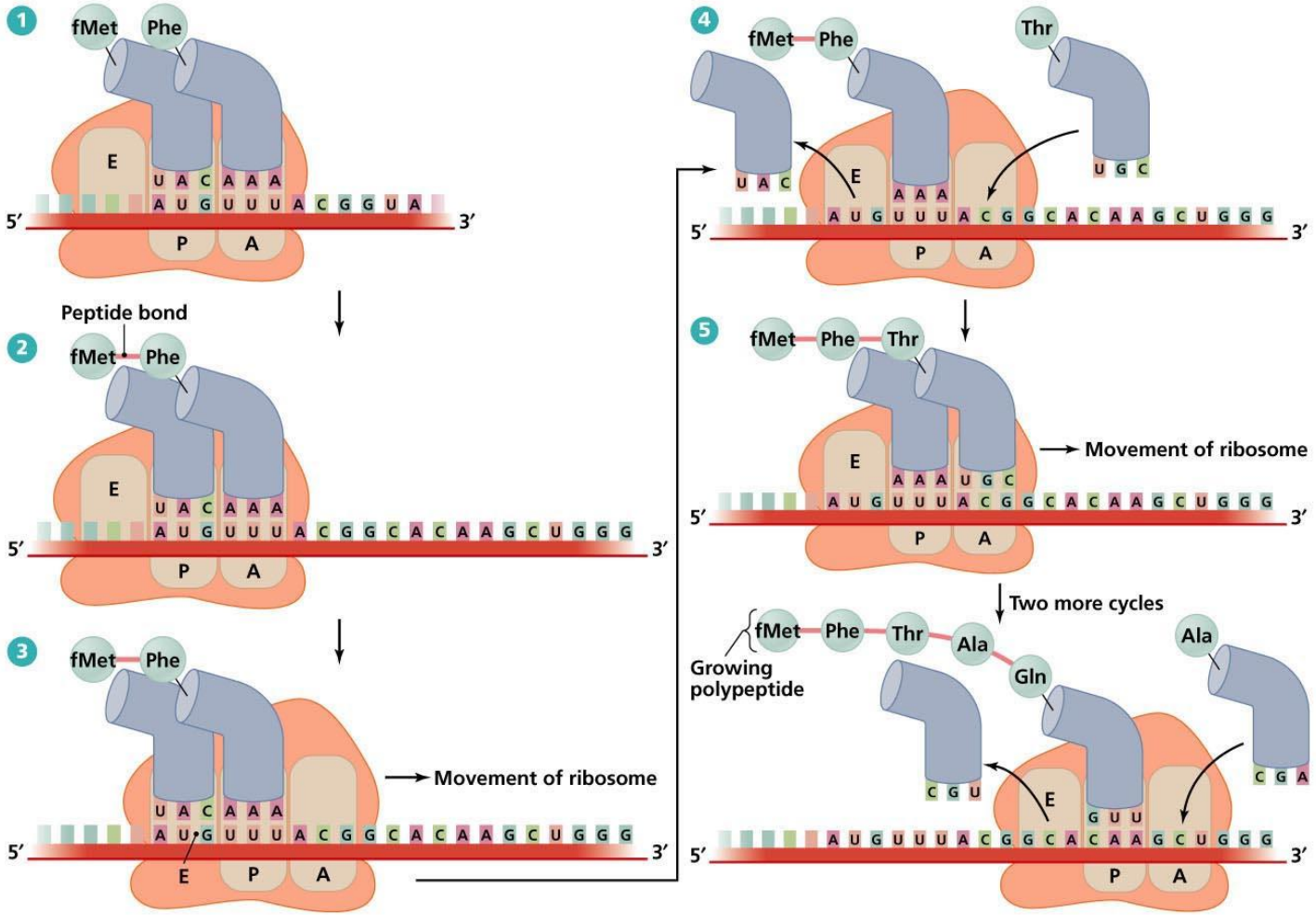


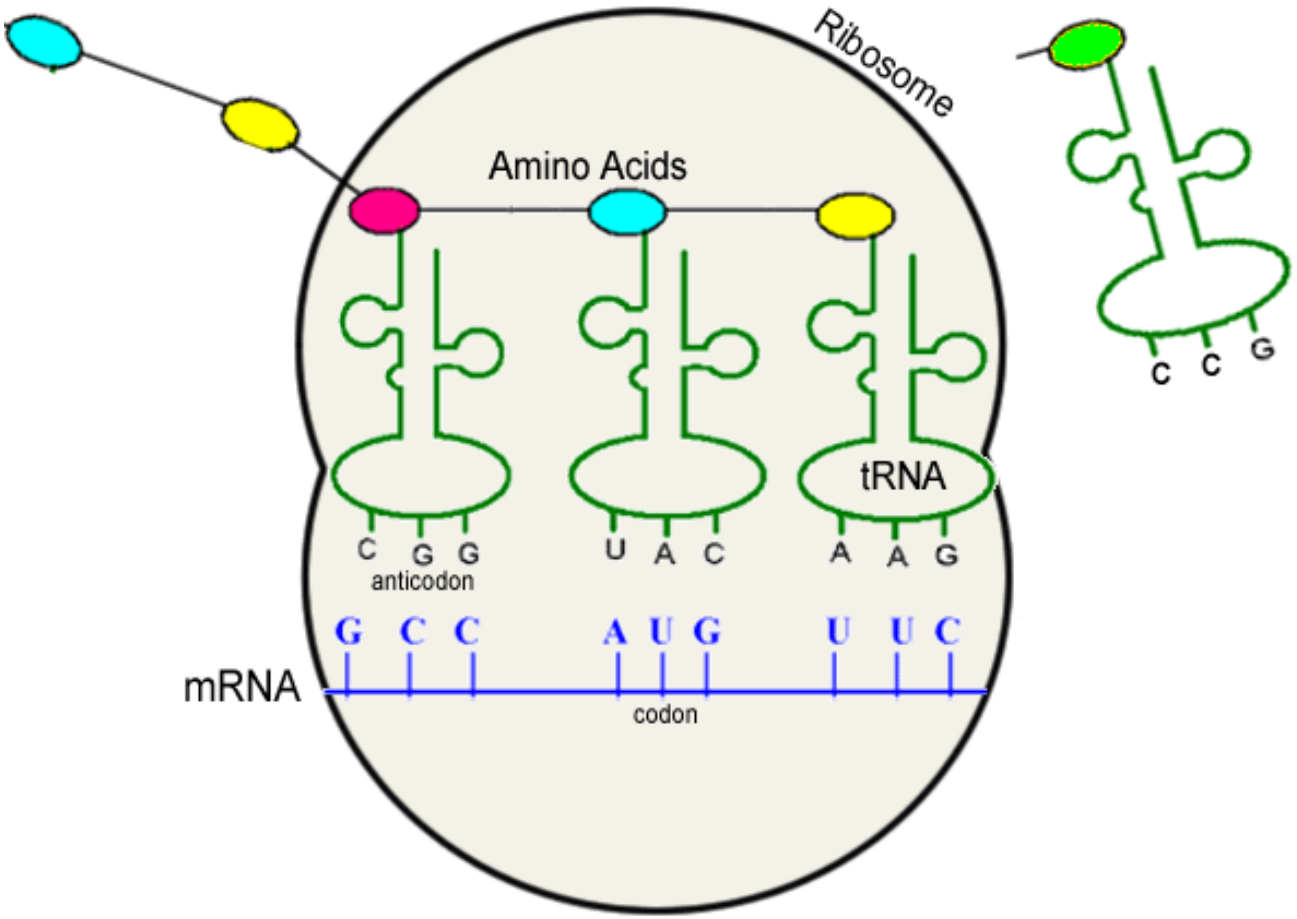
Translation


1
2
3
4
DNA Strand
RNA Strand
Amino Acids
tRNA
Ribosome
Theonine
Arginine
Tyrosine
Threonine
A C G U A U C G U A C A
Codon 1
Codon 2
Codon 3
Codon 4
DNA
mRNA

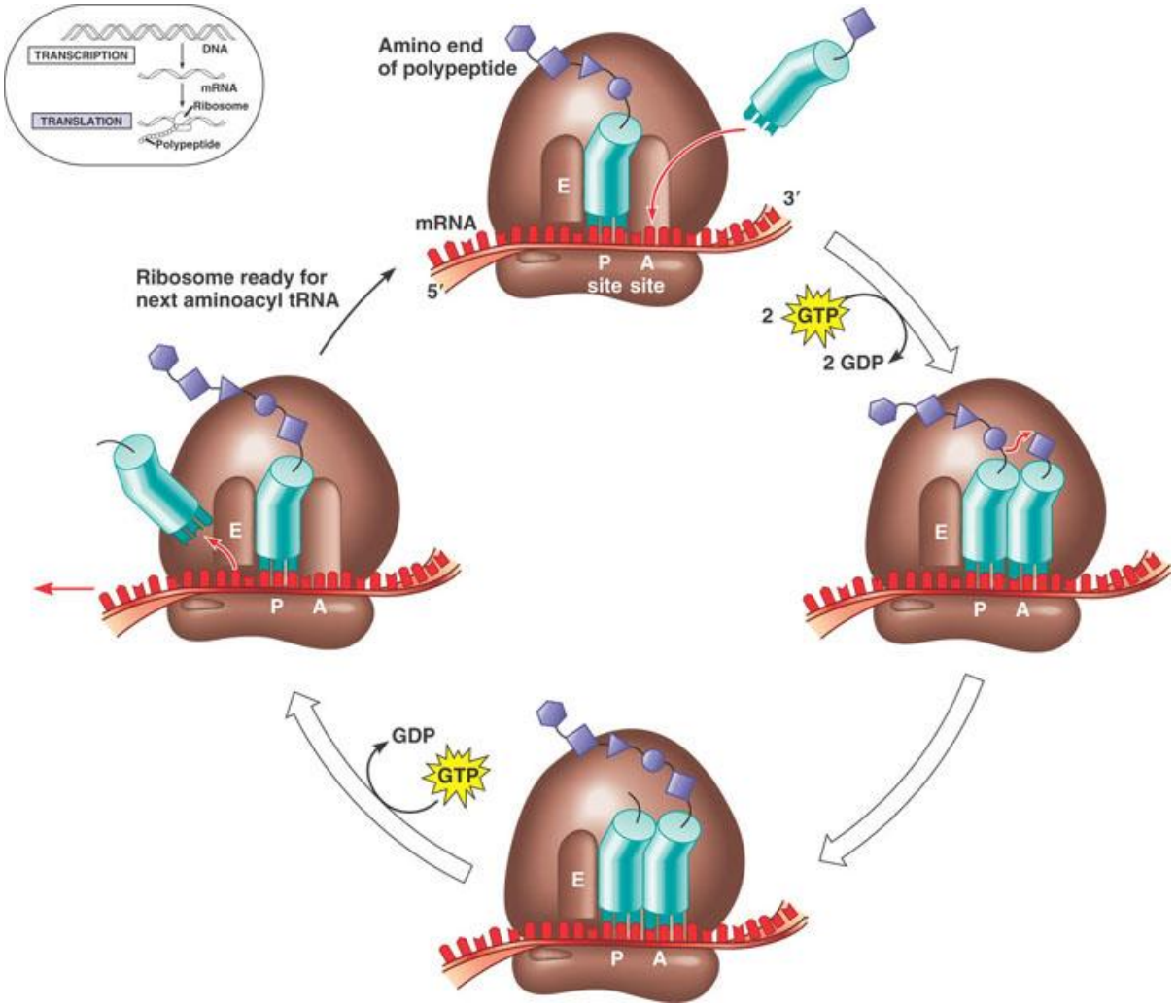
Translation



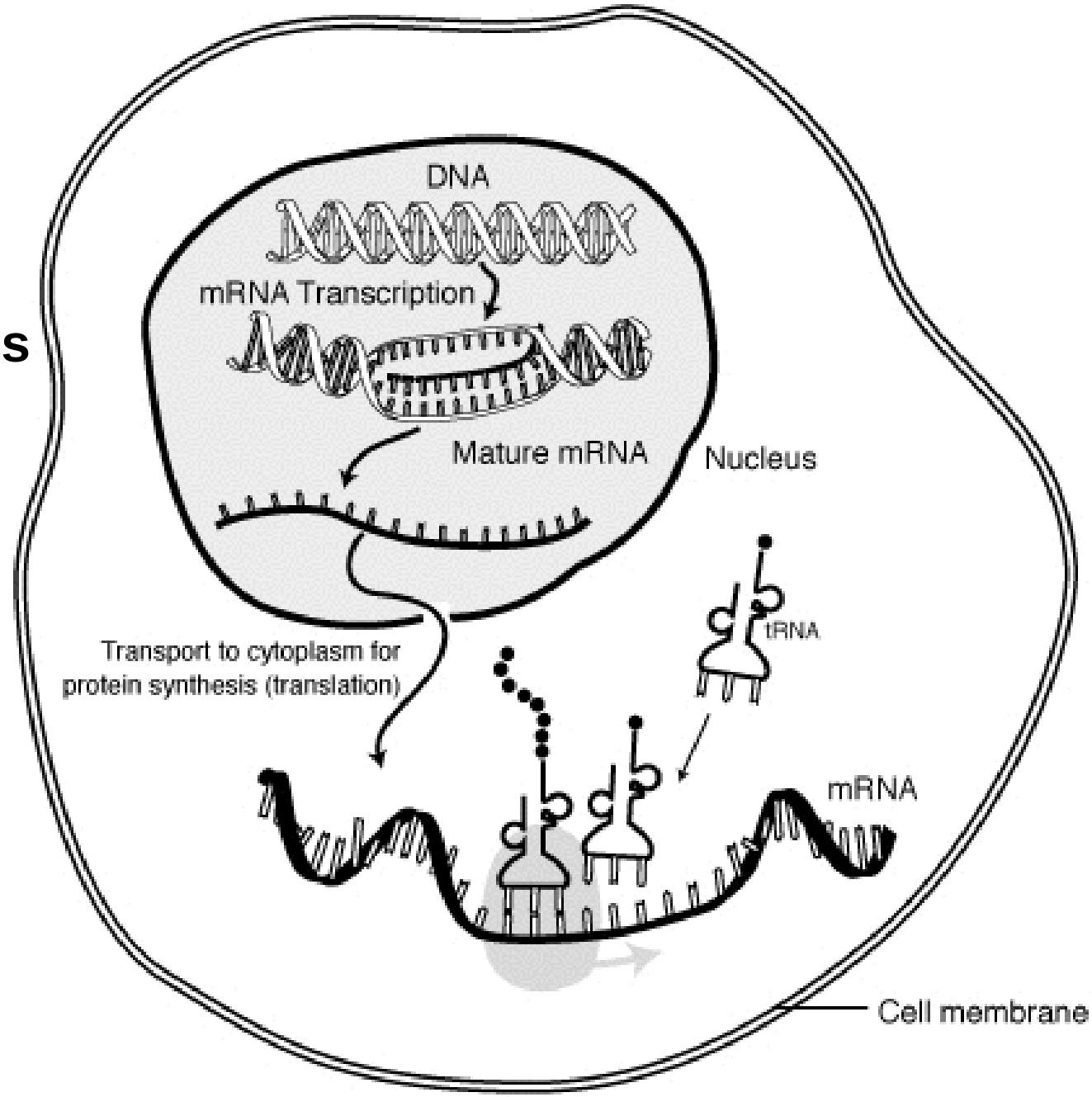
Translation



Translation



Process of protein synthesis



mRNA, tRNA, and protein synthesis

QUESTION AND ANSWER

What role does the ribosome play in assembling proteins?

How do mutations affect genes?

Mutations

- Mutations are changes in DNA sequences
  - changes to the order of A, T, C & G
  - different order = different amino acid in protein
  - different protein structure = different protein function

Gene Mutation

- **Mutations** are changes in genetic information
  - Gene mutations result from changes in a single gene.
  - Chromosomal mutations involve changes whole chromosomes in terms of its number or structure.
- **2 main types of gene mutation:**
  - **Point Mutation** – Affect one nucleotide thus occurring at a single point on the gene. Usually one nucleotide is **substituted** for another nucleotide.
  - **Frameshift Mutation** – **Inserting** an extra nucleotide or **deleting** a nucleotide causes the entire code to "shift". Thus insertions and deletions result in the "shifting" of the genetic code.

Gene Mutations

Original Sentence

TIME TO DREAM

Single Letter Change

T I/A ME TO DREAM → TAME TO DREAM

Reverse Order

I M/T E TO DREAM → EMIT TO DREAM

Deletion

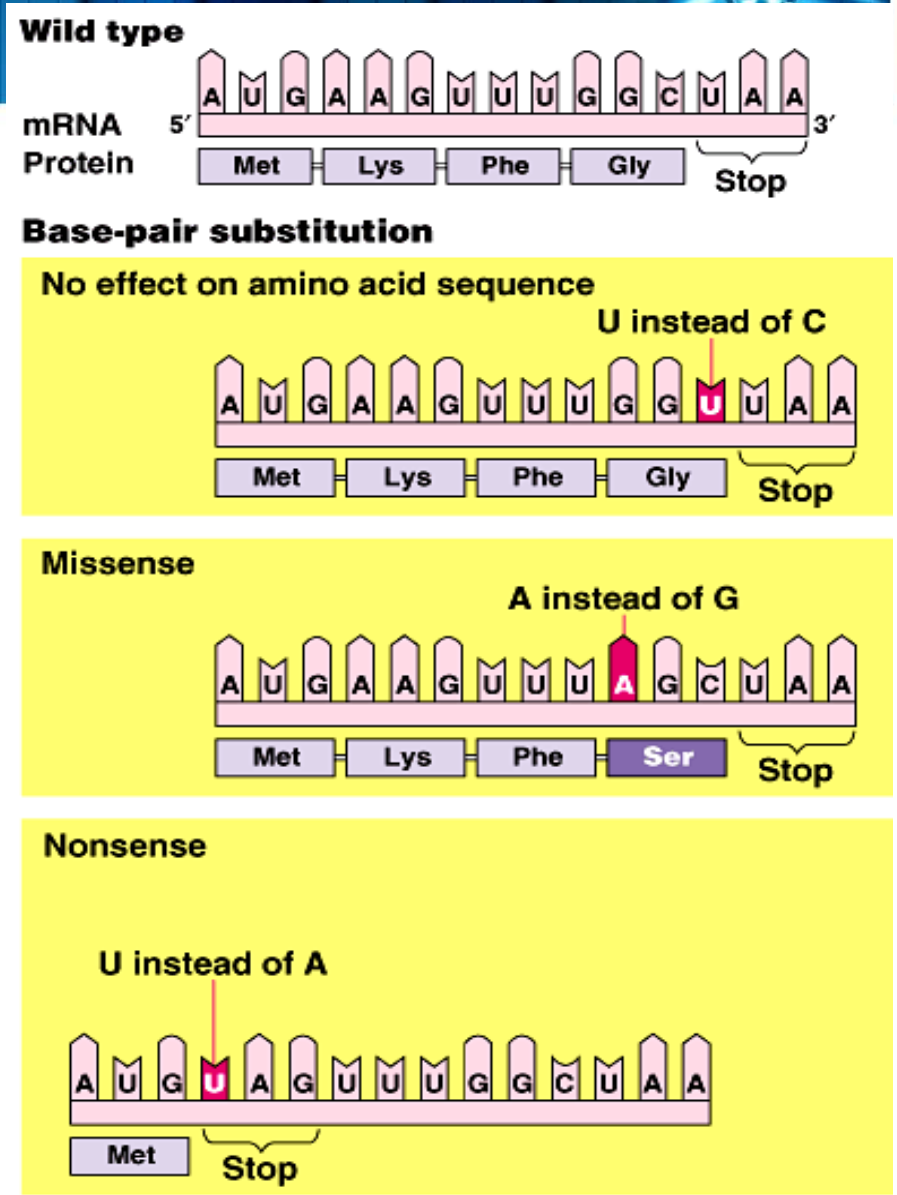
T IM E TO DREAM → TETO DR EAM

Insertion

TI I ME TO DREAM → TIIM ET ODREAM

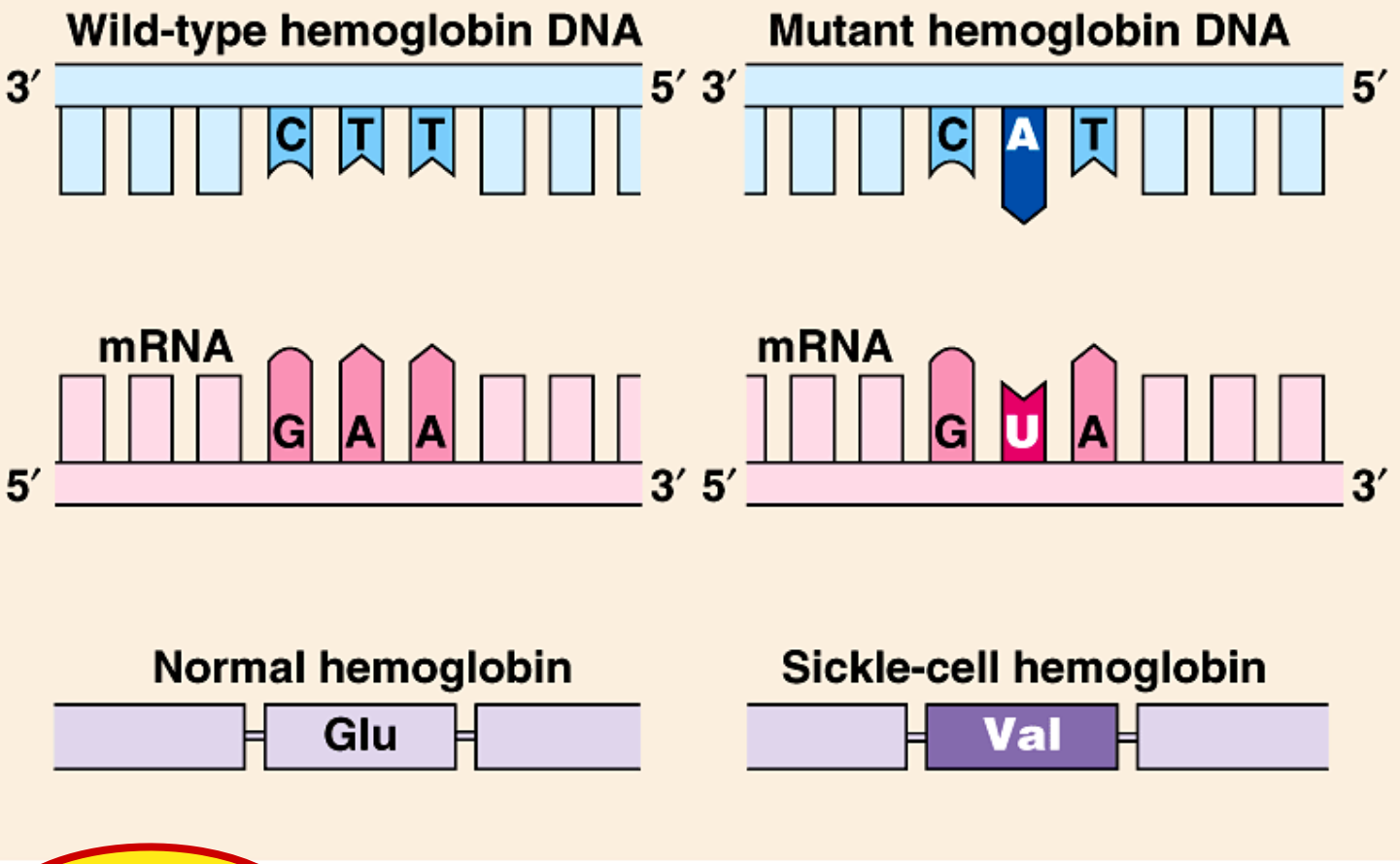
Mutations

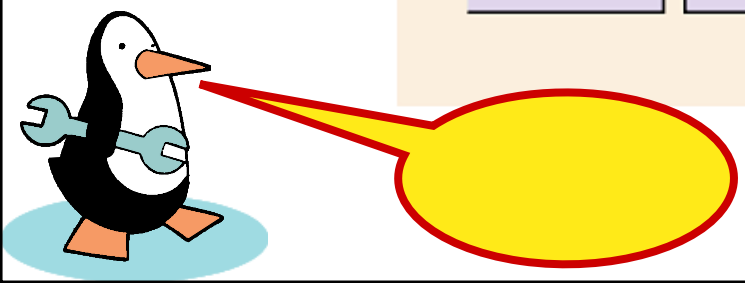
- **Point mutations**
  - single base change
    - silent mutation
      - no amino acid change
      - Due to redundancy in genetic code
    - missense
      - change amino acid
    - nonsense
      - change to stop codon



Point mutation leads to Sickle cell anemia

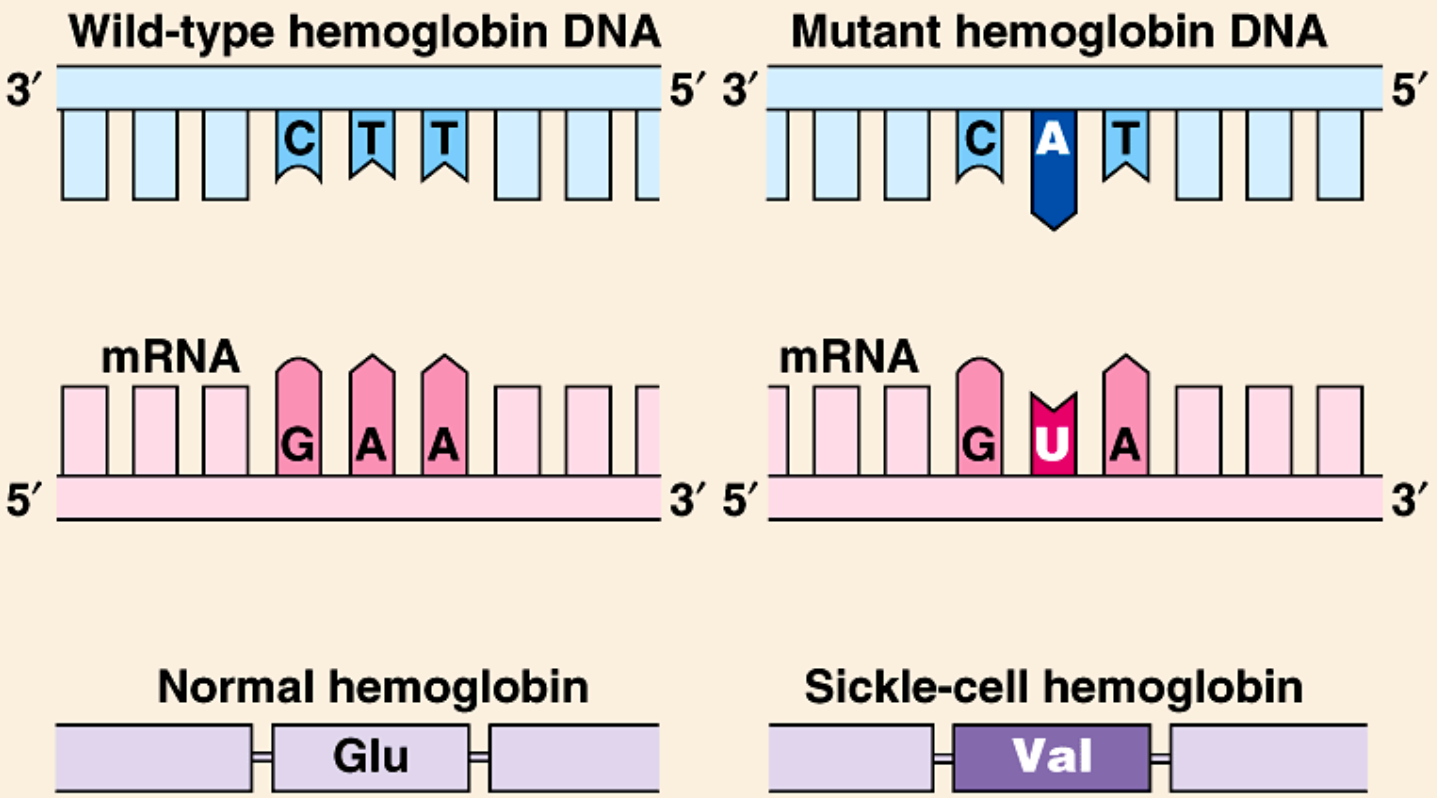
What kind of mutation?

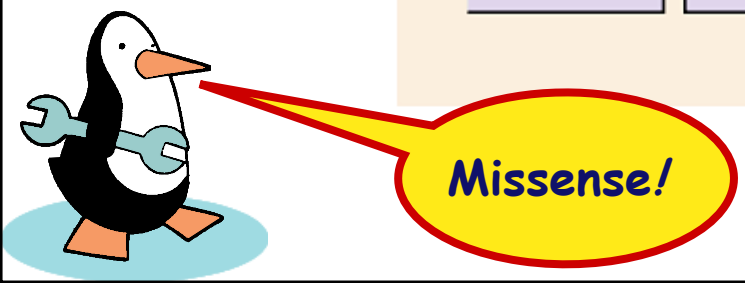




Point mutation leads to Sickle cell anemia

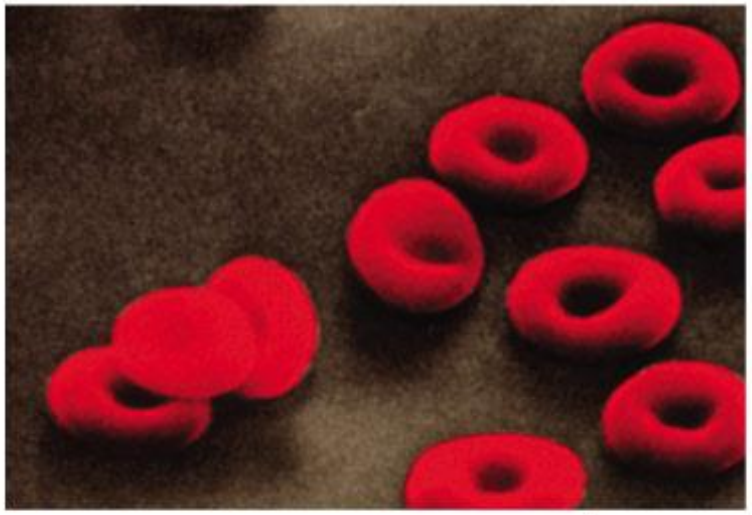
What kind of mutation?





Sickle cell anemia

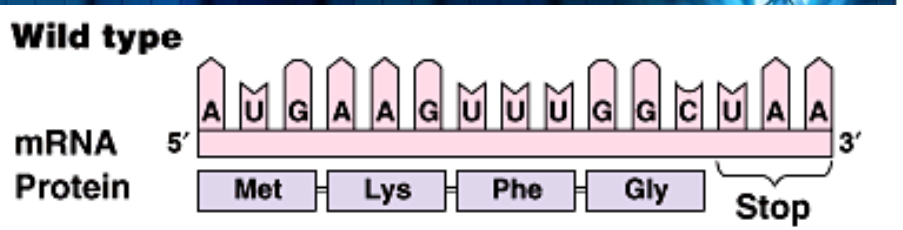
- Primarily Africans
  - recessive inheritance pattern
  - strikes 1 out of 400 African Americans



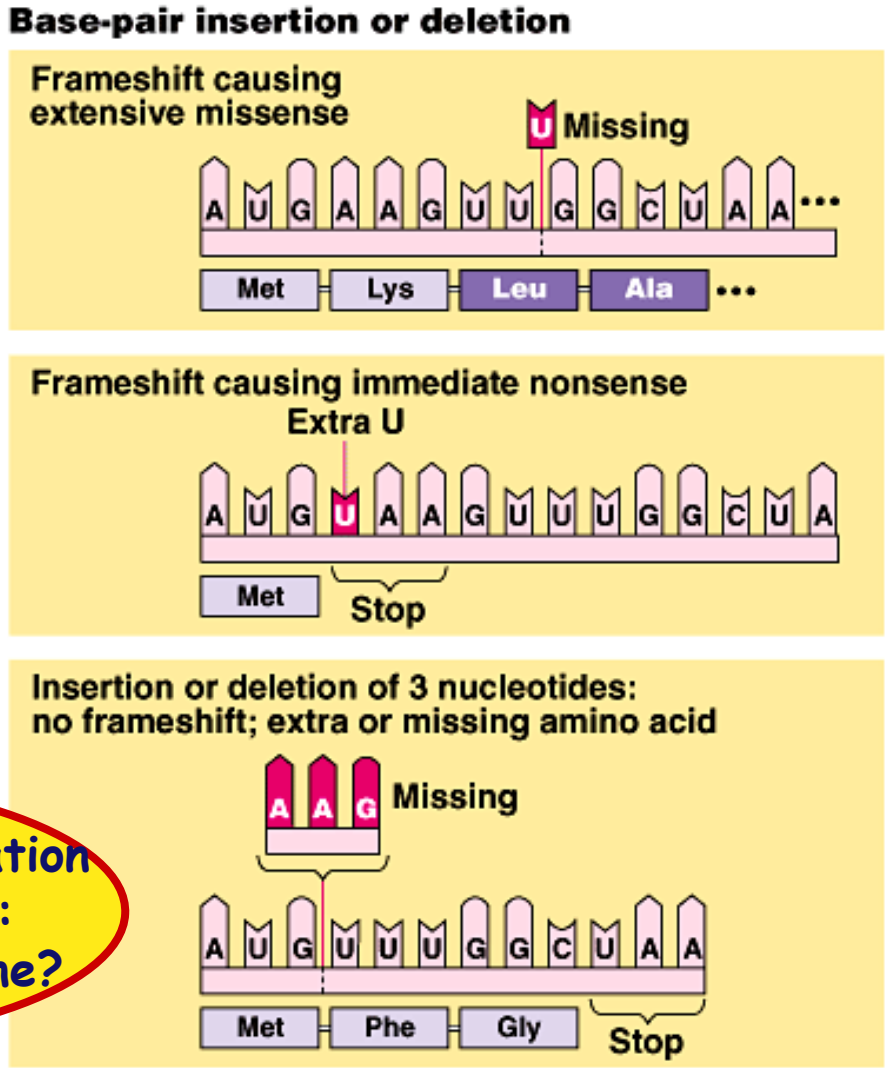
(a) Normal red blood cells and the primary structure of normal hemoglobin

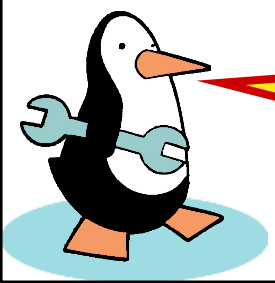
(b) Sickled red blood cells and the primary structure of sickle-cell hemoglobin

Mutations



- **Frameshift**
  - shift in the reading frame
    - changes everything "downstream"
  - insertions
    - adding base(s)
  - deletions
    - losing base(s)





Where would this mutation cause the most change: beginning or end of gene?

Frameshift mutations

THERATANDTHECATATETHEREDBAT

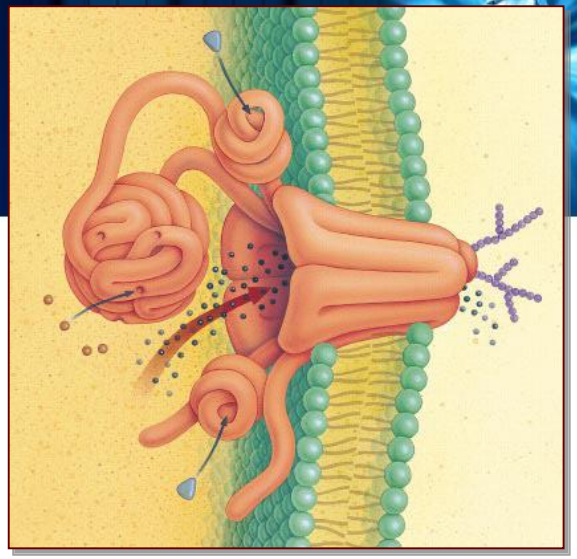
Deletion

THERTANDTHECATATETHEREDBAT

Insertion

THERAATANDTHECATATETHEREDBAT

Cystic fibrosis

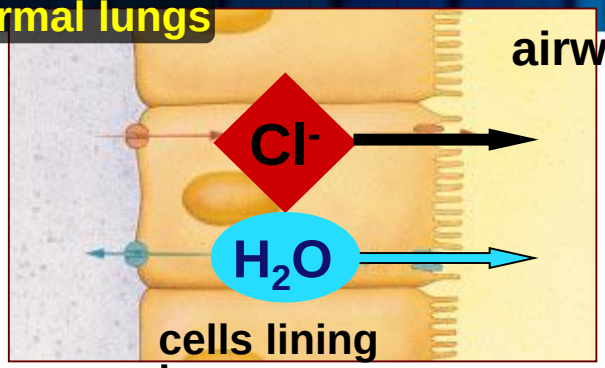


- Primarily whites of European descent
  - strikes 1 in 2500 births
    - 1 in 25 whites is a carrier (Aa)
  - normal allele codes for a membrane protein that moves Cl^- across cell membrane
    - mutant channel limit movement of Cl^- (& H_2O) across cell membrane
    - thicker & stickier mucus coats cells
    - mucus build-up in the pancreas, lungs, digestive tract & causes bacterial infections
  - without treatment children die before 5; with treatment can live past their late 20s

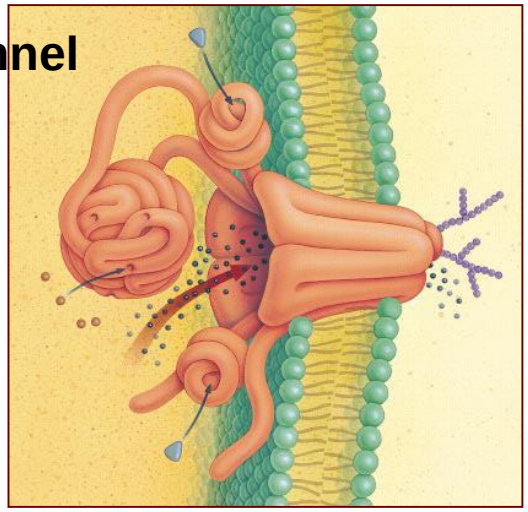
Effect on Lungs

Chloride channel
transports chloride through protein channel out of cell
Osmotic effects: H_2O follows Cl^-

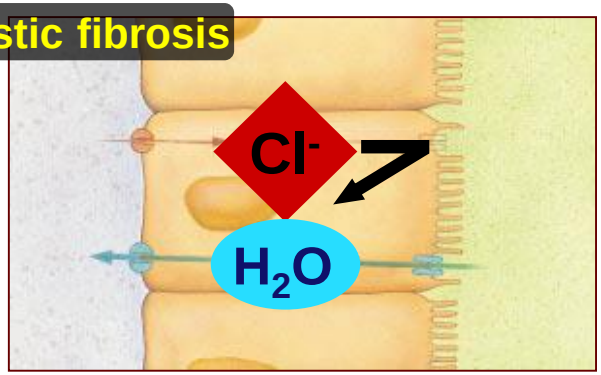
normal lungs



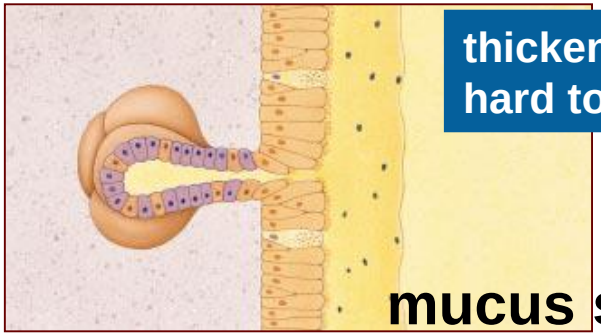
Cl^- channel



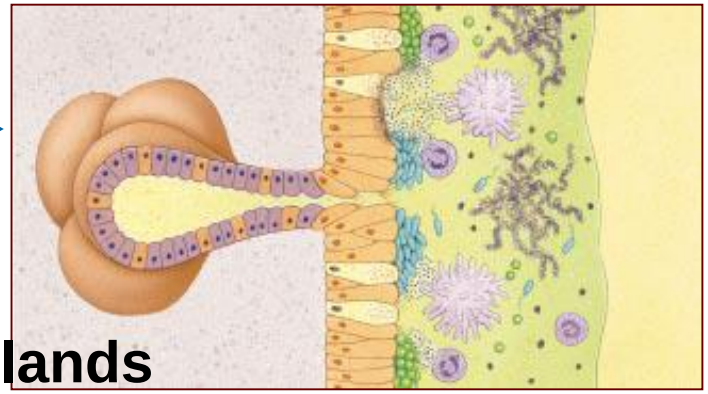
cystic fibrosis



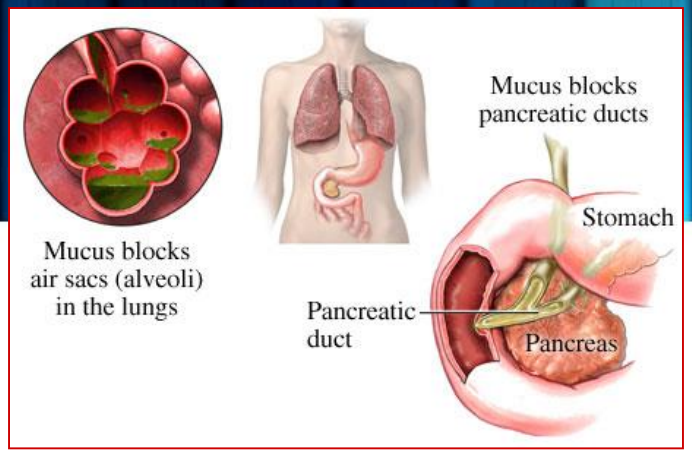
bacteria & mucus build up



thickened mucus
hard to secrete



mucus secreting glands



Chromosome 7

Sequence of nucleotides in *CFTR* gene

Amino acid sequence of CFTR protein

CFTR GENE

A T C — ISOLEUCINE 506

A T — ISOLEUCINE 507

C T T — PHENYLALANINE 508

DELETED IN MANY PATIENTS WITH CYSTIC FIBROSIS

T

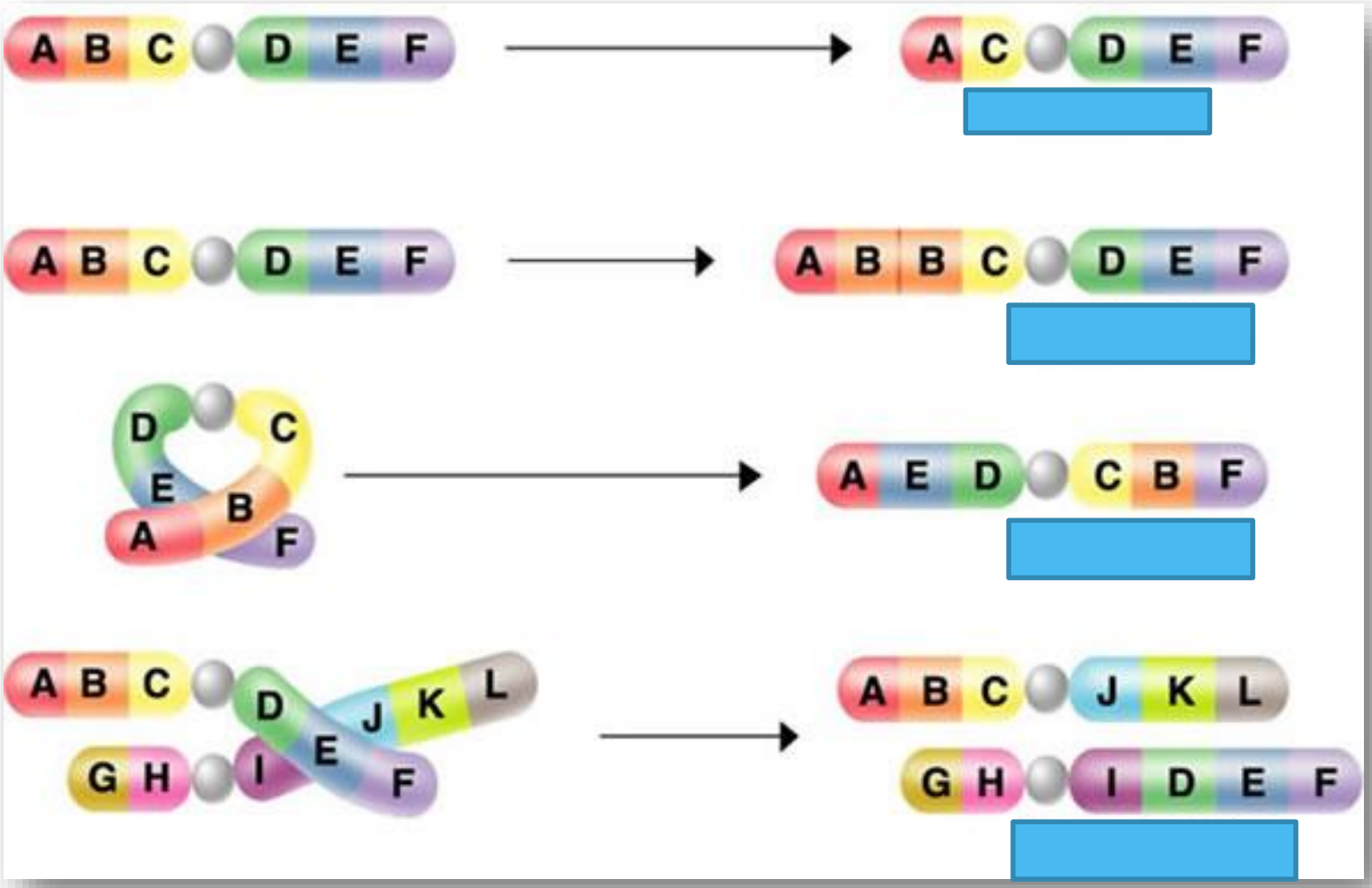
G G T — GLYCINE 509

G T T — VALINE 510

Chromosomal Mutations

- There are 4 types of chromosomal mutations:
  - **1. Deletion** – Part or all of a chromosome is deleted.
  - **2. Duplication** – part or all of a chromosome is duplicated.
    - Can result in **polyploidy** – the condition in which an organism has an extra set of chromosomes.
  - **3. Inversion** – chromosome twists and inverts the code. Thus the direction of parts of the chromosome is reversed.
  - **4. Translocation** – Genetic information is traded between non-homologous chromosomes. Thus one part of the chromosome breaks off and attaches to another.

Chromosomal Mutations



Mutations

Biological changes via mutations

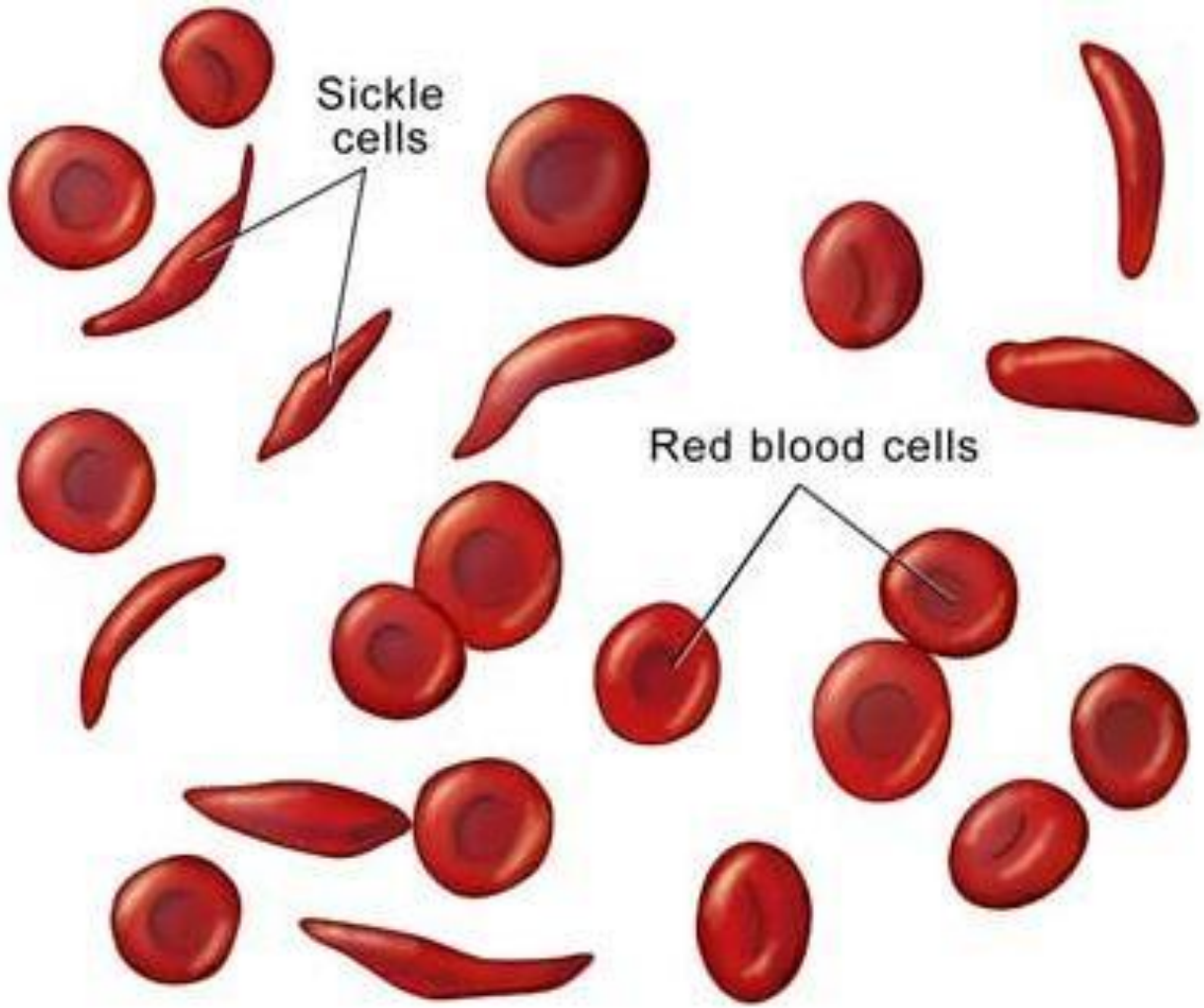
Effects of Mutations

- Mutations may or may not affect an organism
  - Some mutations arise from **mutagens**- chemical or physical agents in the environment.
    - For example: some pesticides, tobacco smoke, X-rays, and environmental pollutants.
  - Some mutations do not change the amino acid specified by the mRNA codon, while others may alter a complete protein or even an entire chromosome.
  - **Thus, the effects of mutations on genes vary widely. Some have little or no effect; and some produce beneficial variations. Some negatively disrupt gene function.**
  - Most mutations are neutral; they have little or no effect on the expression of genes or the function of proteins for which they code.

Effects of Mutations

- Whether a mutation is negative or beneficial depends on how its DNA changes relative to the organism's situation.
- Mutations are often thought of as negative, since they can disrupt the normal function of genes.
- Without mutations, organisms could not evolve, because mutations are the source of genetic variability in a species.
- Some of the most harmful mutations are those that dramatically change protein structure or gene activity. The defective proteins produced by these mutations can disrupt normal biological activities, and result in genetic disorders.
  - Example, sickle cell disease is a disorder associated with the changes in the shape of red blood cells. It is caused by a point mutation in one of the polypeptides found in hemoglobin, the blood's principal oxygen-carrying protein.

Sickle Cell Disease



Effects of Mutations

- Some of the variation produced by mutations can be highly advantageous to an organism or species.
- Mutations often produce proteins with new or altered functions that can be useful to organisms in different or changing environments.
  - Example, some mutations have helped insects resist chemical pesticides.
  - Plant breeders may use of beneficial mutations. For example, the failure of chromosomes to separate during meiosis results in polyploidy.
    - Polyploid plants are often larger and stronger than diploid plants.
    - Example: banana and lime plants.

QUESTION AND ANSWER

How do mutations affect genes?

How are genes regulated in prokaryotic and eukaryotic cells?

Prokaryotic Gene Regulation

- By regulating gene expression, bacteria can respond to changes in their environment.
- Some of the regulatory proteins help switch genes on, while others turn genes off.
- DNA- binding proteins in prokaryotes regulate genes by controlling transcription
  - One of the keys to gene transcription in bacteria is the organization of genes into operons. That determines whether a gene is turned on or off.
    - **Operons** is a group of genes that are regulated together.

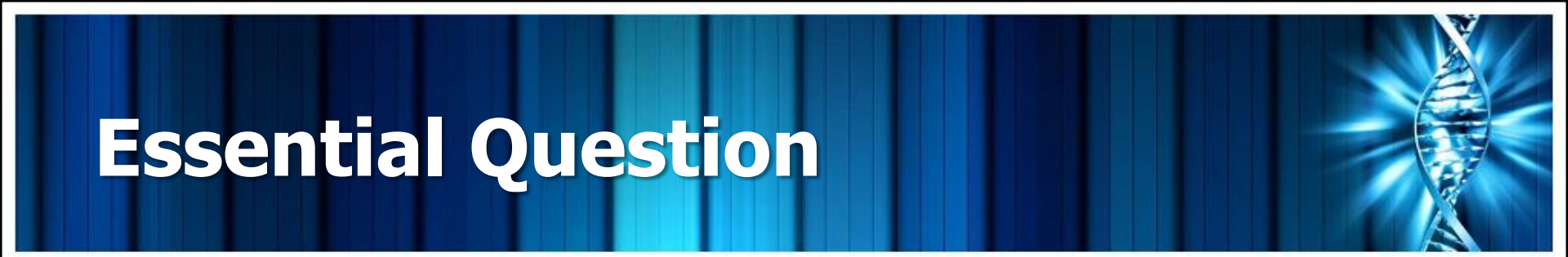
Eukaryotic Gene Regulation

- Most eukaryotic genes are controlled individually and have more complex regulatory sequences than those of the *lac* repressor system.
- Gene expression in eukaryotic cells can be regulated at a number of levels. One of the most critical is the level of transcription, by means of DNA-binding proteins known as transcription factors.
- By binding DNA sequences in the regulatory regions of eukaryotic genes, transcription factors control the expression of those genes.
- Master control genes are like switches that trigger particular patterns of development and differentiation in cells and tissues.

QUESTION AND ANSWER

How are genes regulated in prokaryotic and eukaryotic cells?

Essential Question



How does information flow from DNA to RNA to direct the synthesis of proteins?