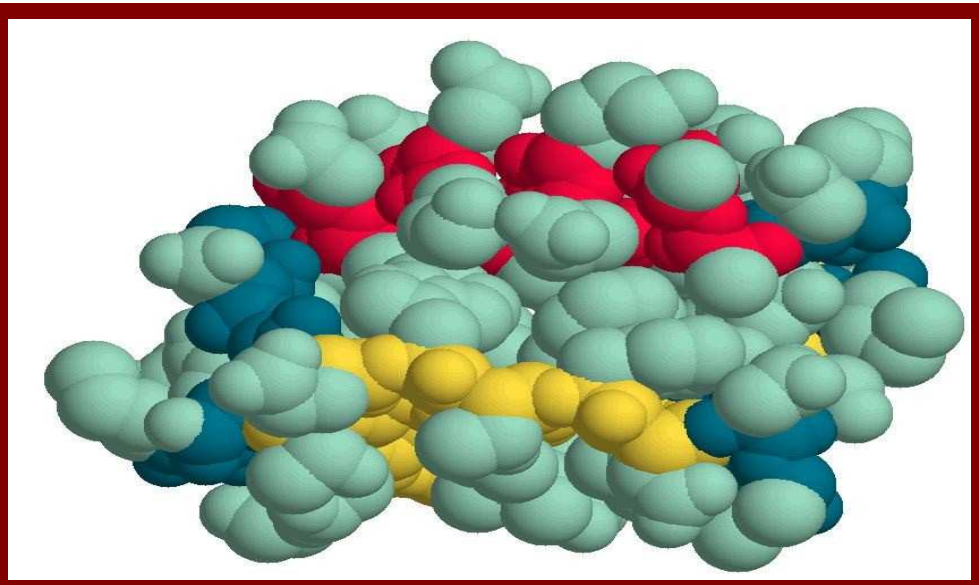
Protein Synthesis

- Read and take notes on pages 336-340



What is protein?

- Proteins
  - Polypeptide chains of amino acids
  - Are enzymes that catalyze biochemical reactions and are vital to metabolism.
  - They have structural or mechanical functions, such as actin and myosin in muscle and the proteins in the cytoskeleton, which form a system of scaffolding that maintains cell shape.
  - Involved cell signaling
  - immune responses
- Through the process of digestion, animals break down ingested protein into free amino acids that are then used in metabolism.

Protein Functions

http://biology.about.com/od/molecularbiology/a/aa101904a.htm

Antibodies - are specialized proteins involved in defending the body from antigens (foreign invaders). One way antibodies destroy antigens is by immobilizing them so that they can be destroyed by white blood cells.

Contractile Proteins - are responsible for movement.

Enzymes - are proteins that facilitate biochemical reactions.

Examples: Lactase breaks down the sugar lactose found in milk. Pepsin is a digestive enzyme that works in the stomach to break down proteins in food.

Hormonal Proteins - are messenger proteins which help to coordinate certain bodily activities.

Examples: Insulin regulates glucose metabolism by controlling the blood-sugar concentration. Oxytocin stimulates contractions in females during childbirth. Somatotropin is a growth hormone that stimulates protein production in muscle cells.

Structural Proteins - are fibrous and stringy and provide support. Examples include keratin, collagen, and elastin.

Keratins strengthen protective coverings such as hair, quills, feathers, horns, and beaks.

Collagens and elastin provide support for connective tissues such as tendons and ligaments.

Storage Proteins - store amino acids. Examples include ovalbumin and casein.

Ovalbumin is found in egg whites and casein is a milk-based protein.

Transport Proteins - are carrier proteins which move molecules from one place to another around the body. Examples include hemoglobin and cytochromes. Hemoglobin transports oxygen through the blood. Cytochromes operate in the electron transport chain as electron carrier proteins.

Traits such as eye color are determined by proteins that are built according to instructions specified in an organism's DNA.

Your body contains over 50,000 proteins that are coded for by combinations of approximately 20 amino acids.

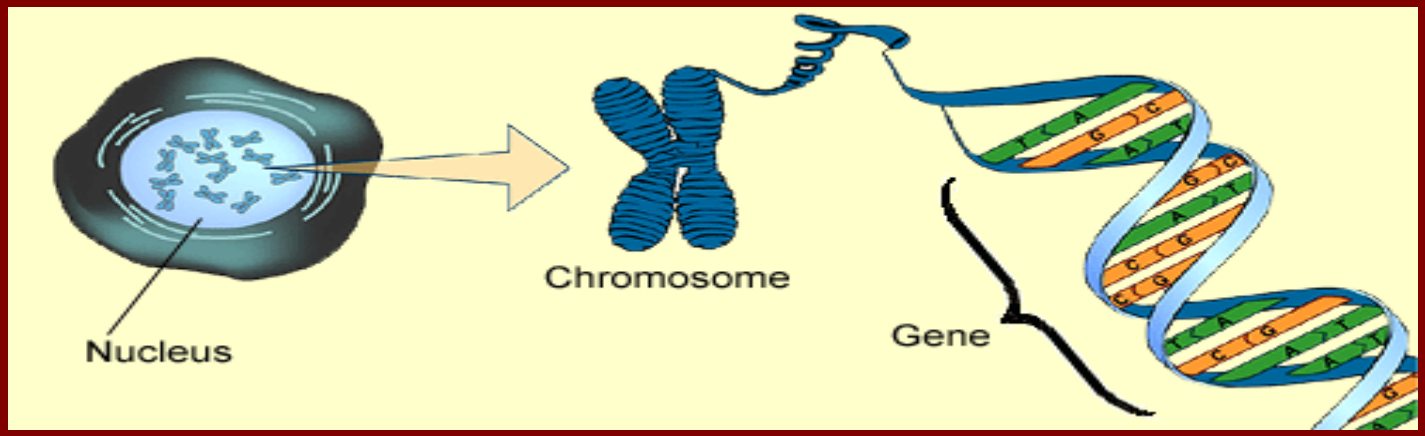
Your phenotype will be determined by the way in which your genes are expressed by these proteins.

What is protein synthesis?

- Protein synthesis is how the code in DNA is used to make polypeptide chains of amino acids (aka. Protein)
- The process includes two steps:

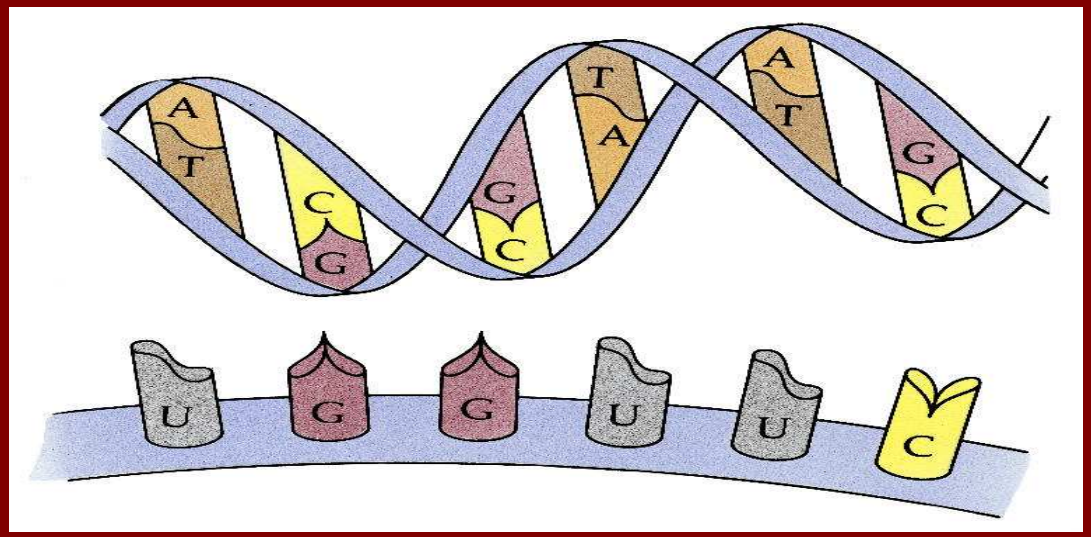
1. Transcription
2. Translation

Remember:



- DNA can be found in the nucleus
- DNA is coiled up and spooled onto chromosomes
- Each chromosome holds several thousand genes
- We inherit particular chromosomes through egg and sperm
  - We therefore also inherit the particular characteristics coded for by the genes on those chromosomes.

Before we begin protein synthesis discussion, it is important to understand the differences between DNA and RNA



What do they have in common?

- Both are types of nucleic acids which are polymers found in all living cells.

What are the differences?

- Location:
  - **Deoxyribonucleic Acid (DNA)** is found mainly in the nucleus of the cell, while **Ribonucleic Acid (RNA)** is found mainly in the cytoplasm of the cell (although it is usually synthesized in the nucleus).
- Function:
  - DNA contains the genetic codes to make RNA and the RNA in turn then contains the codes for the primary sequence of amino acids to make proteins.
- Structure:
  - DNA is double stranded and RNA is single stranded
- Sugars:
  - DNA has deoxyribose and RNA has ribose
- Bases:
  - DNA has A,T,G,C and RNA has A, U, G, C (uracil replaces thymine)

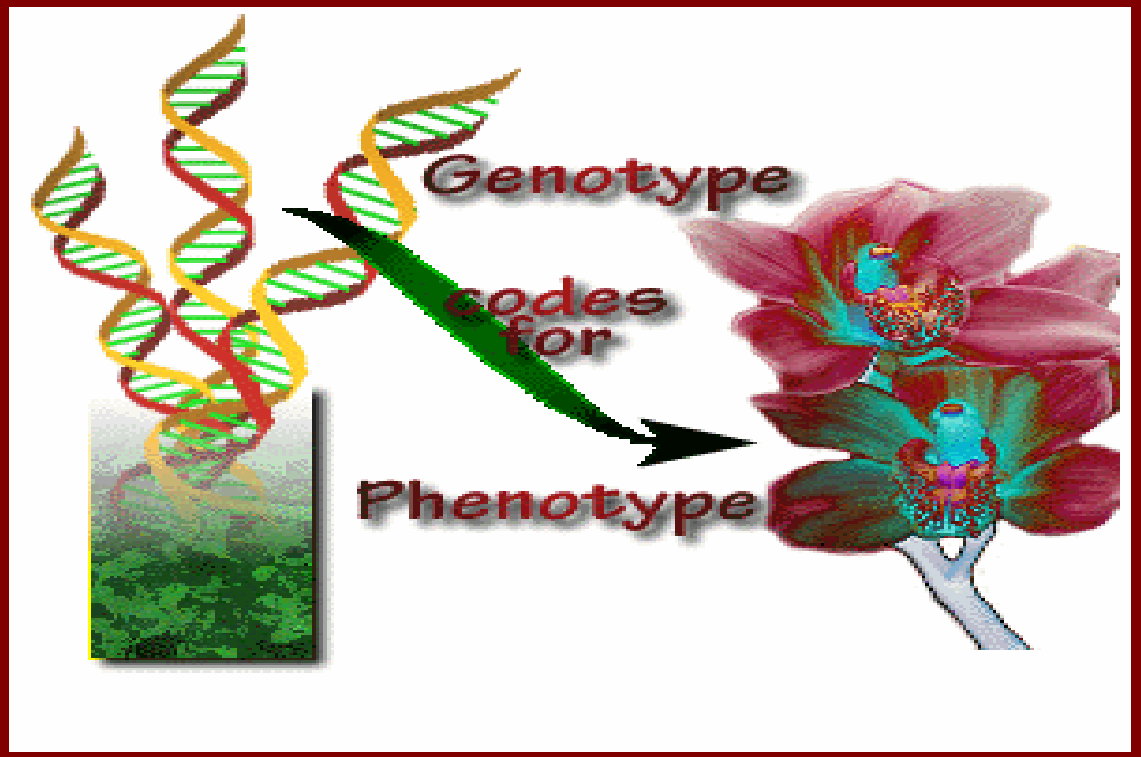
So Why Protein?

- **Each gene acts as a code or set of instructions for *making a particular protein*.**

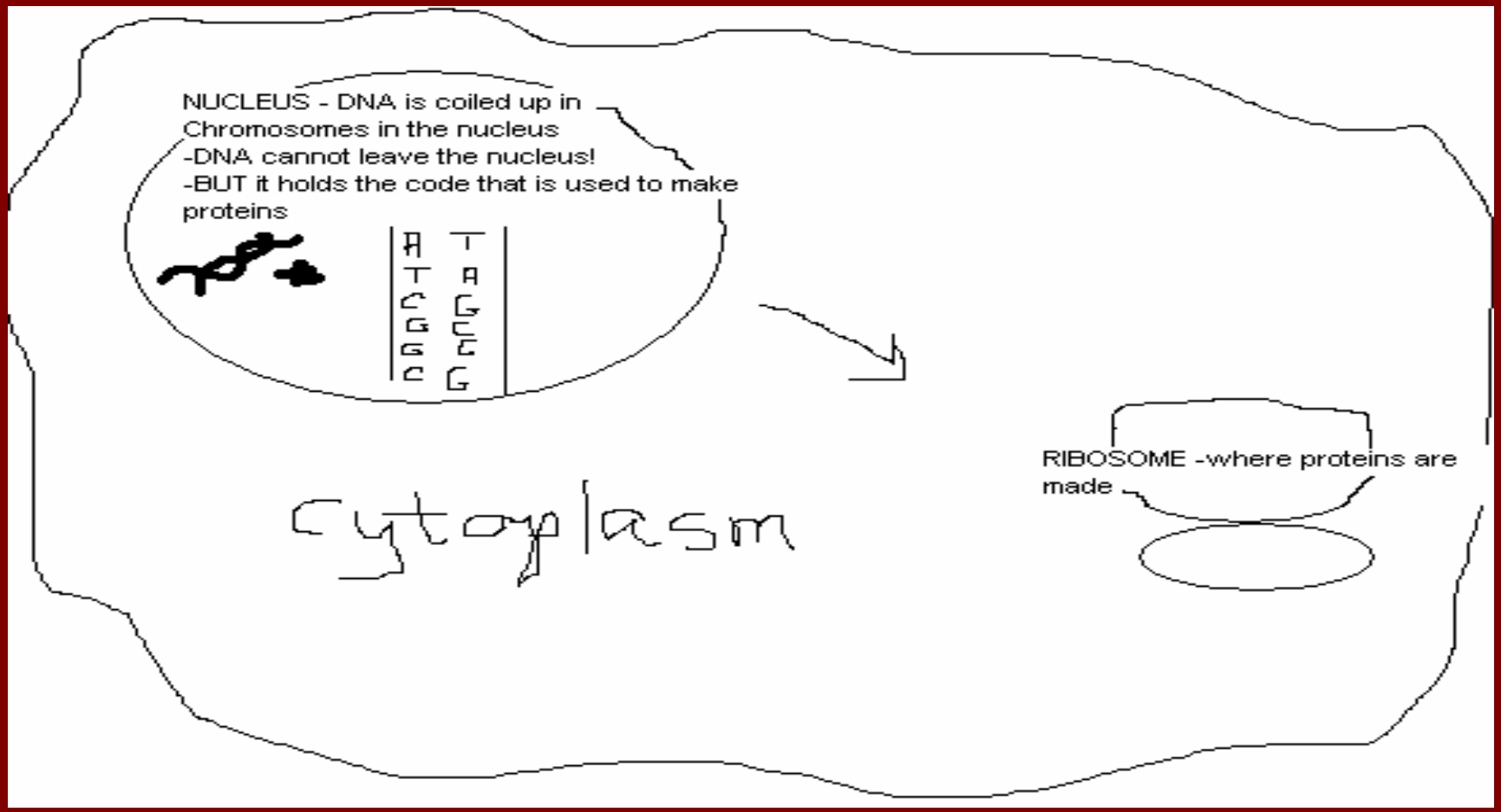
- **These proteins control the cell's internal chemistry - telling the cell what to do, giving the organism particular characteristics and determining the way its body functions.**

Genotype-an organisms genetic makeup

DNA provides a template for making proteins.



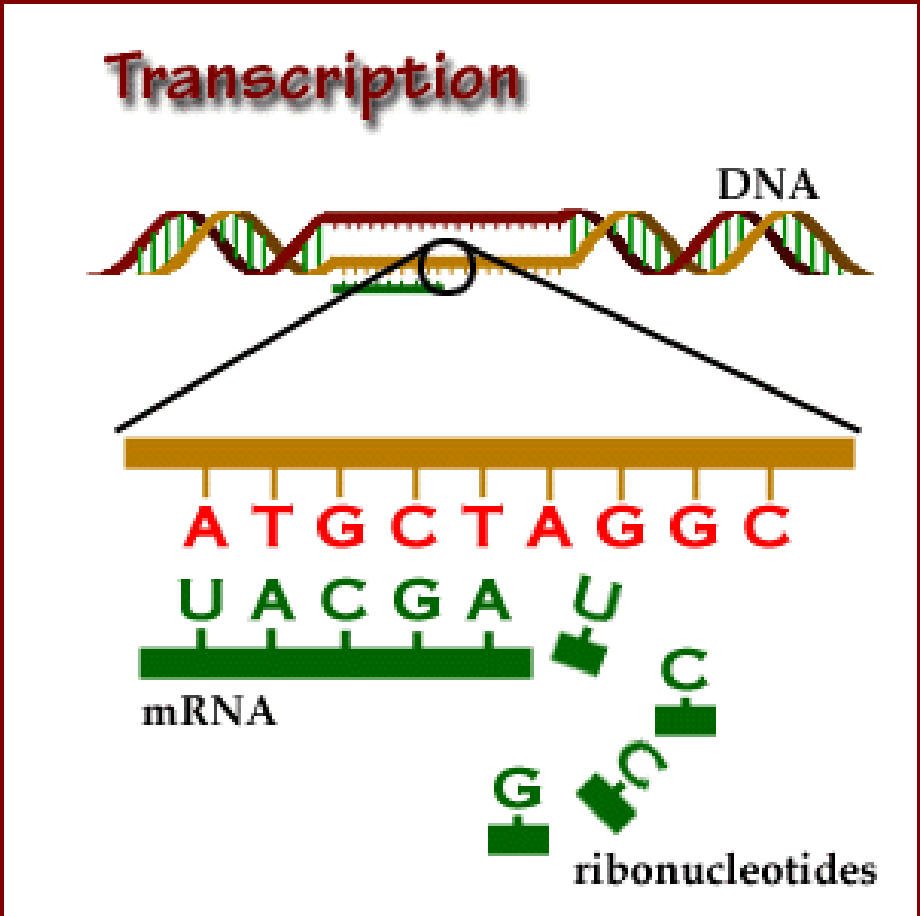
Phenotype-(think protein) the observable characteristics of an organism



Protein Synthesis occurs in two stages

1. <u>Transcription</u> occurs in the nucleus
   - Makes a mRNA transcript of the DNA
2. <u>Translation</u> occurs at the ribosome
   - Codons on the mRNA are read and translated into amino acids
   - Polypeptide chains of amino acids = proteins

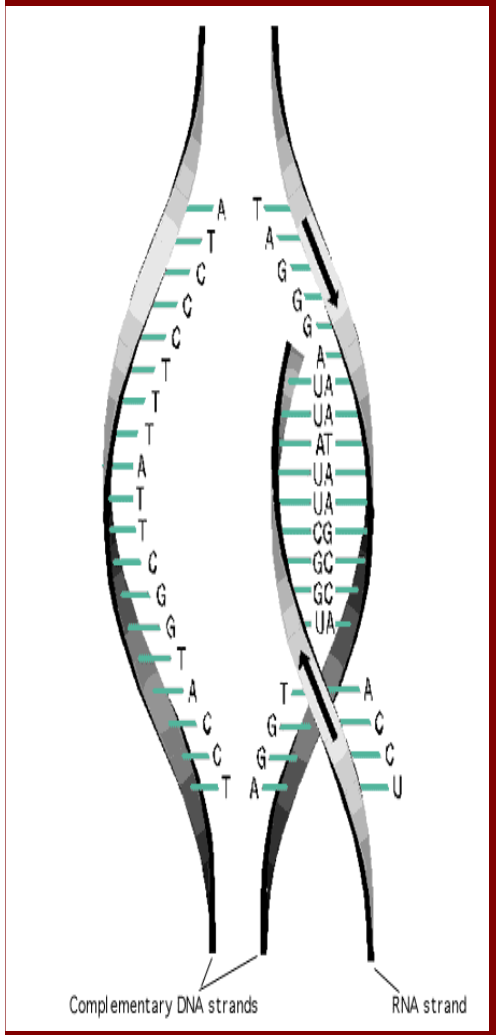
Part I of Protein Synthesis: Transcription



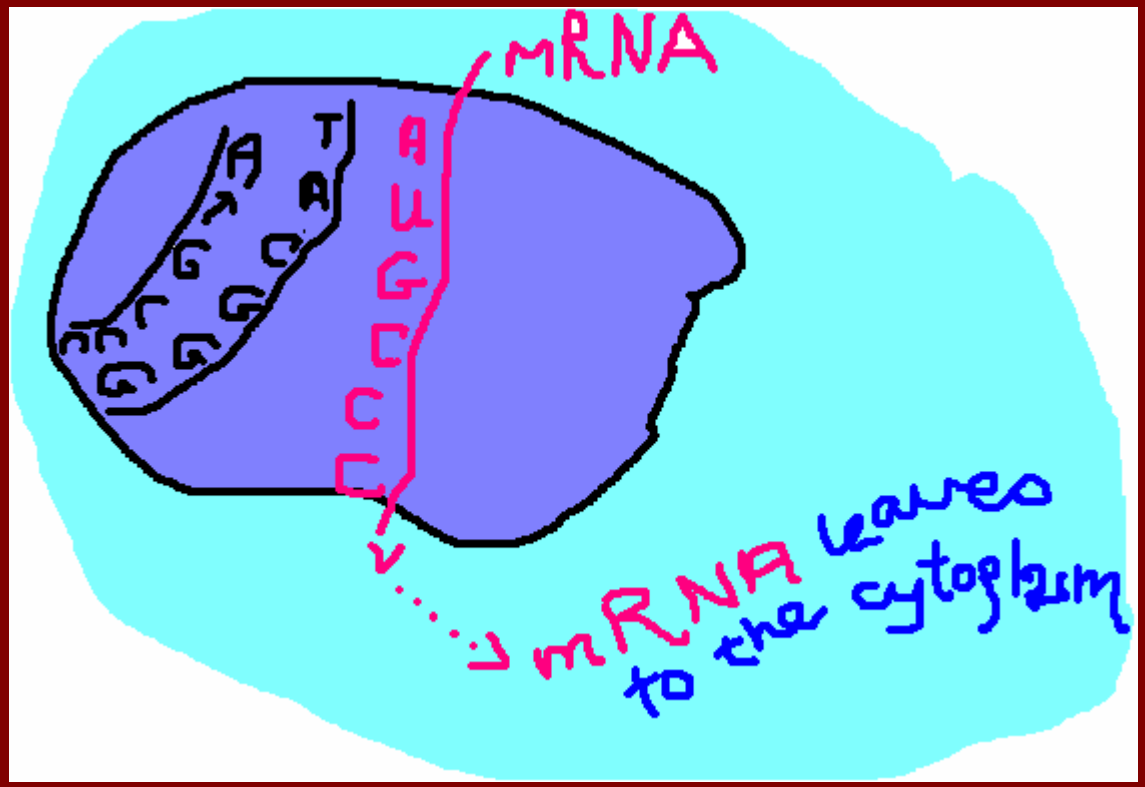
Transcription Introduction

- DNA holds the code that can be used to make a protein
- BUT DNA is unable to leave the nucleus
  - Thus, a strand of RNA is made from the DNA in the nucleus
- The RNA strand carries the code from the DNA out of the nucleus to the cytoplasm

Transcription = DNA → RNA



- RNA polymerase reads the section of DNA that needs to be coded for
- The enzyme brings in the complementary nucleotide and bonds them together forming a strand of mRNA (messenger RNA)
  - NOTE RNA is different from DNA
- When complete, the nucleotides break free from the DNA and the DNA folds back into a double helix

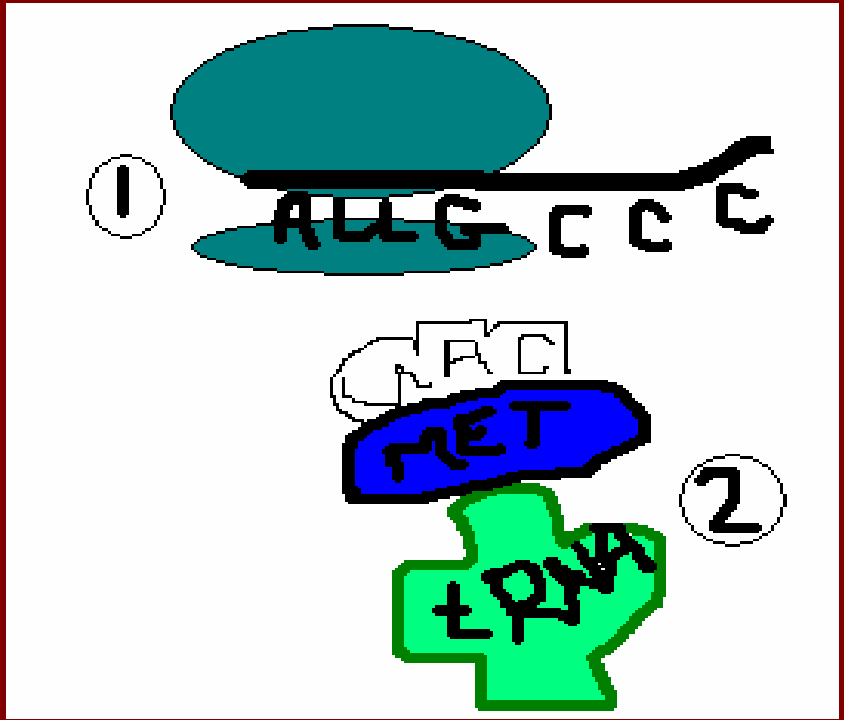


Transcription Summary

Trancription

1. A mRNA (messenger RNA) transcript is made from the DNA template (one side of the DNA)
2. RNA Polymerase adds the nucleotides to make the mRNA
3. mRNA is able to leave the nucleus and carry the code to the ribosome

Transcription → Translation



1. mRNA arrives at the ribosome
2. Codons (triplet base pairs) are read on the mRNA
3. tRNA (transfer RNA) brings in the anticodon and amino acid that matches up with the codon

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

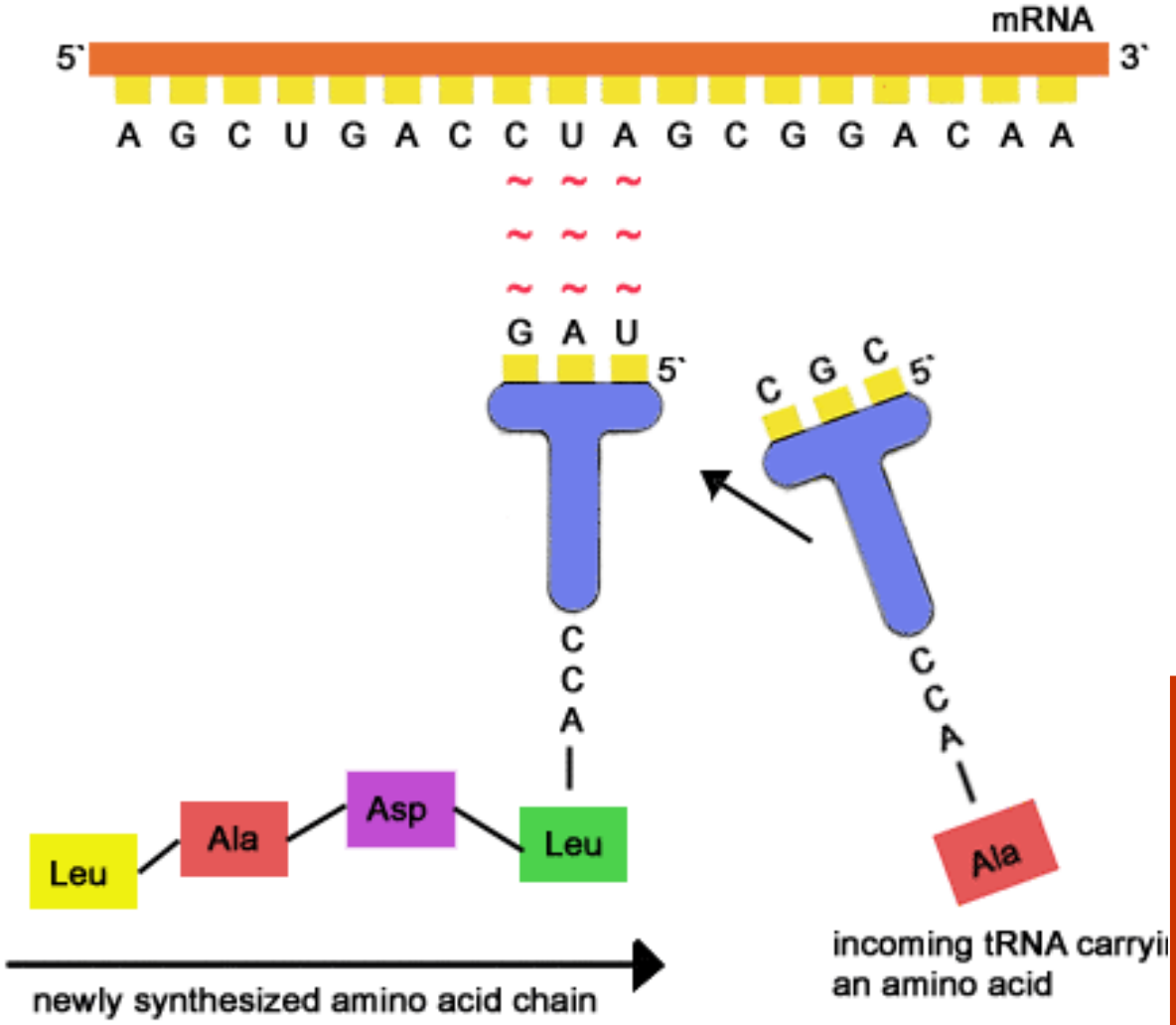
- Proteins are chains of amino acids
- There are 20 amino acids
- Amino acids are coded for by groups of 3 nucleotides, called codons
- There are 4 x 4 x 4 = 64 possible codons.

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

The Genetic Code

- What would the codon “CCC” code for?
- How about “GAG”?



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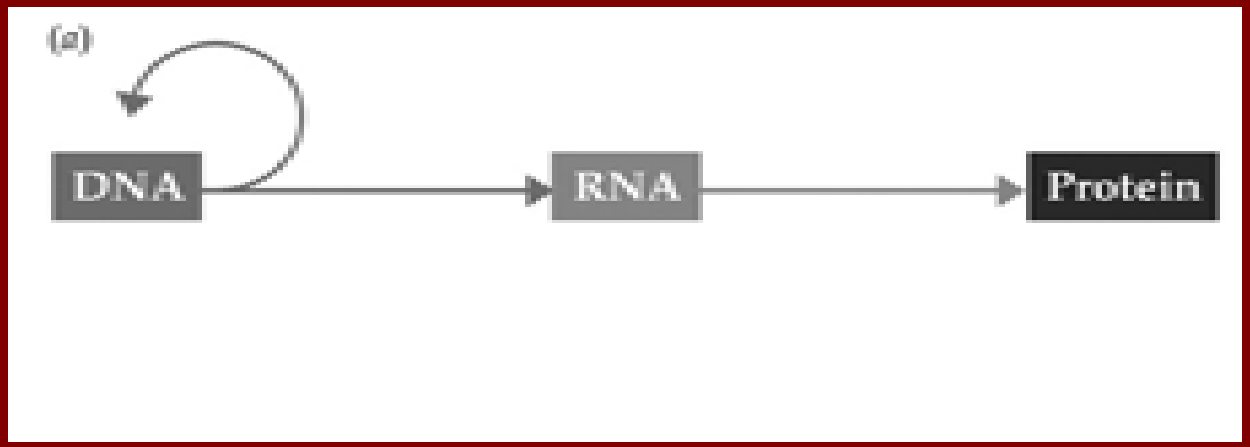
C	CUU, CUC, CUA, CUG — Leu	CCU, CCC, CCA, CCG — Pro	CAU, CAC — His CAA, CAG — Gln	CGU, CGC, CGA, CGG — Arg
A	AUU, AUC, AUA — Ile AUG — Met	ACU, ACC, ACA, ACG — Thr	AAU, AAC — Asn AAA, AAG — Lys	AGU, AGC — Ser AGA, AGG — Arg
G	GUU, GUC, GUA, GUG — Val	GCU, GCC, GCA, GCG — Ala	GAU, GAC — Asp GAA, GAG — Glu	GGU, GGC, GGA, GGG — Gly

- Work by Francis Crick (1950s) produced a model for the **flow of information** in cells

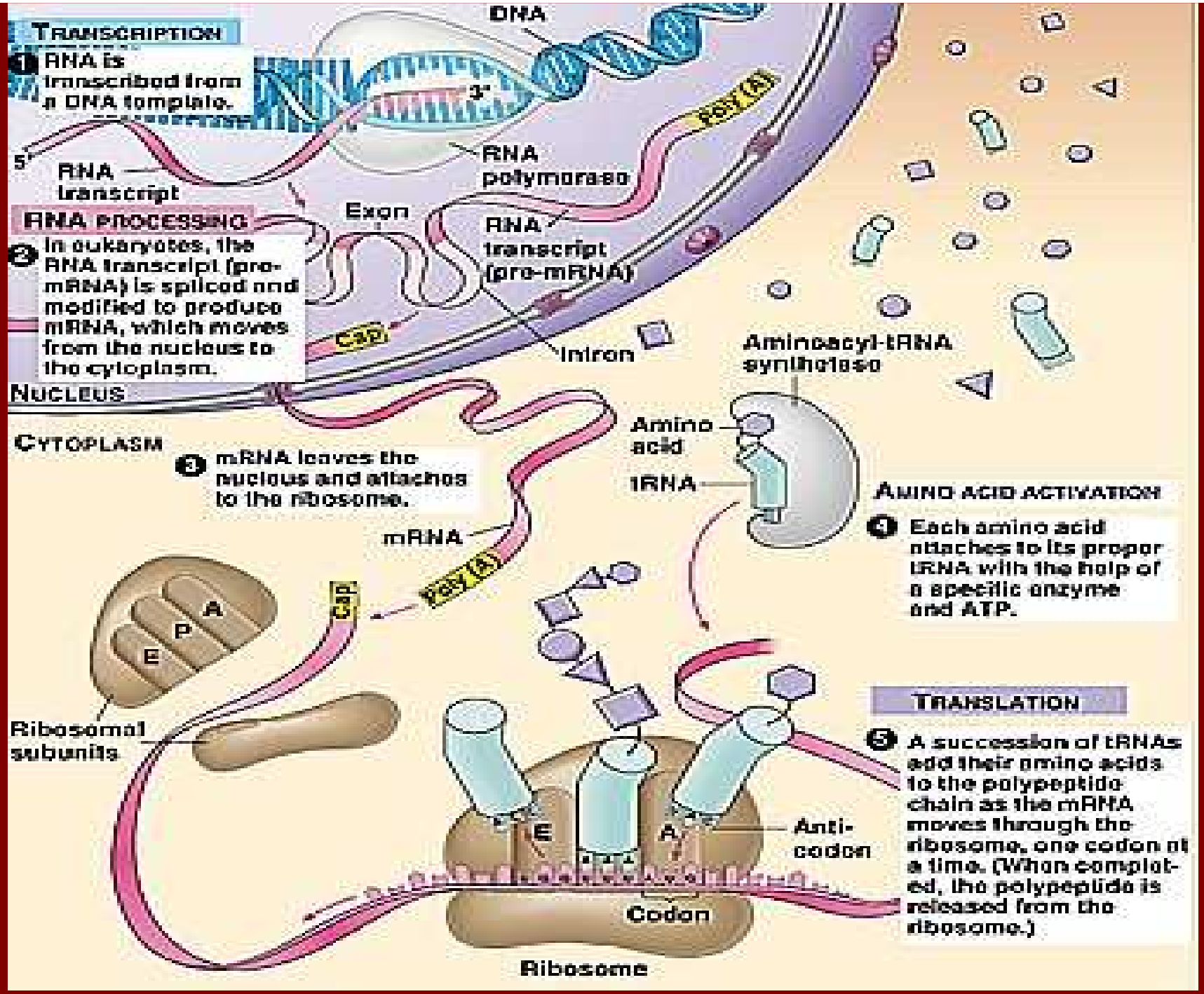


- This model incorporates DNA, RNA and proteins
  - DNA may replicate itself
  - DNA may be transcribed to RNA
  - RNA may be translated into protein
  - RNA and DNA are **not** made from protein
  - DNA is **not** made from RNA

Translation = RNA → protein

SUMMARY

- Occurs at the RIBOSOME
- Triplet base pairs on the mRNA are read as codes
  - Called CODONS
- tRNA (transfer rna) brings in the base pairs and amino acid that pairs up with the codon
  - Base pairs = anticodon
  - Amino acid
- **Translation** involves the transfer of the genetic code in an mRNA molecule into the amino acid sequence of a polypeptide
- This involves four components:
  - mRNA
  - ribosomes (with large and small subunits)
  - tRNA
  - amino acids


TRANSCRIPTION
1 RNA is transcribed from a DNA template.
DNA
3'
5'
RNA transcript
RNA polymerase
Poly (A)
RNA PROCESSING
2 In eukaryotes, the RNA transcript (pre-mRNA) is spliced and modified to produce mRNA, which moves from the nucleus to the cytoplasm.
Exon
RNA transcript (pre-mRNA)
Cap
Intron
NUCLEUS
CYTOPLASM
3 mRNA leaves the nucleus and attaches to the ribosome.
mRNA
Poly (A)
Cap
Ribosomal subunits
A
P
E
Aminoacyl-tRNA synthetase
Amino acid
tRNA
AMINO ACID ACTIVATION
4 Each amino acid attaches to its proper tRNA with the help of a specific enzyme and ATP.
TRANSLATION
5 A succession of tRNAs add their amino acids to the polypeptide chain as the mRNA moves through the ribosome, one codon at a time. (When completed, the polypeptide is released from the ribosome.)
E
A
Anti-codon
Codon
Ribosome