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PowerPoint Notes on Chapter 10 – How Proteins Are Made

Section 1: From Genes to Proteins

Objectives

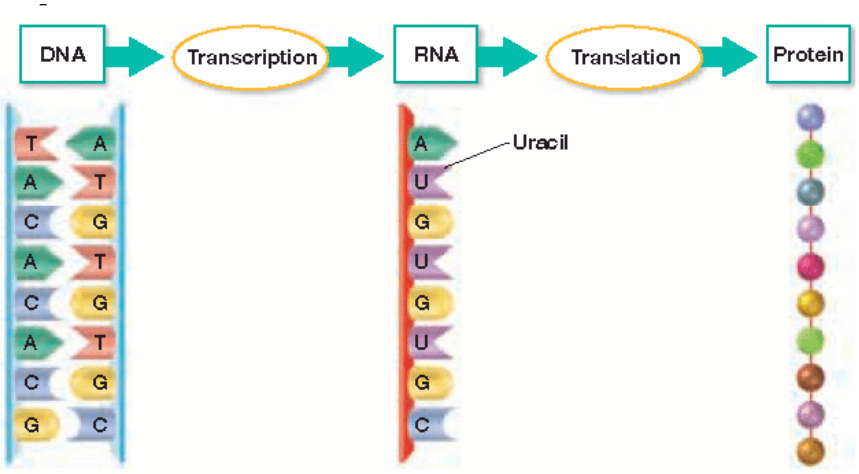
- Compare the structure of RNA with that of DNA.
- Summarize the process of transcription.
- Relate the role of codons to the sequence of amino acids that results after translation.
- Outline the major steps of translation.
- Discuss the evolutionary significance of the genetic code.

Decoding the Information in DNA

- Traits, such as eye color, are determined by proteins that are built according to instructions coded in DNA.
- Proteins, however, are not built directly from DNA. Ribonucleic acid is also involved.
- Like DNA, ribonucleic acid (RNA) is a nucleic acid—a molecule made of nucleotides linked together.
- RNA differs from DNA in three ways:

	RNA	DNA
# of strands of nucleotides	single	double
five-carbon sugar	ribose	deoxyribose
nitrogen bases present	uracil	thymine

- The instructions for making a protein are transferred from a gene to an RNA molecule in a process called **transcription.**
- Cells then use two different types of RNA to read the instructions on the RNA molecule and put together the amino acids that make up the protein in a process called **translation.**
- The entire process by which proteins are made based on the information encoded in DNA is called **gene expression,** or protein synthesis.



Transfer of Information from DNA to RNA

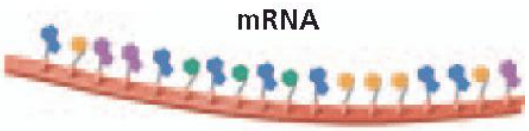
- The three steps of transcription are:

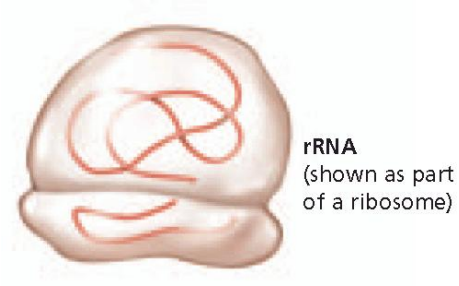
  Step 1 RNA polymerase binds to the gene's promoter.

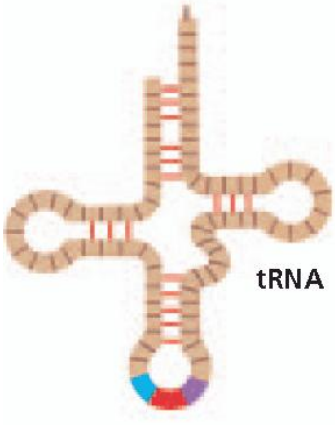
  Step 2 The two DNA strands unwind and separate.

  Step 3 Complementary RNA nucleotides are added.

Types of RNA



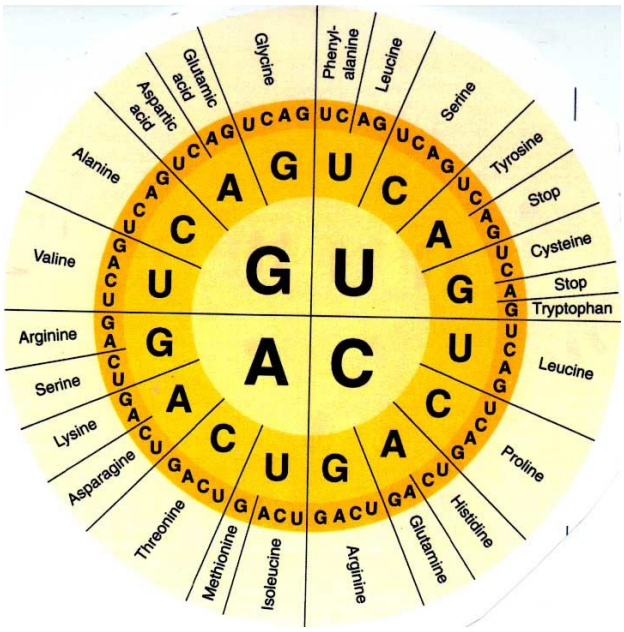




The Genetic Code: Three-Nucleotide "Words"

- Different types of RNA are made during transcription, depending on the gene being expressed.
- When a cell needs a particular protein, it is messenger RNA that is made.
- **Messenger RNA (mRNA)** is a form of RNA that carries the instructions for making a protein from a gene and delivers it to the site of translation.
- The information is translated from the language of RNA—nucleotides—to the language of proteins—amino acids.
- The RNA instructions are written as a series of three-nucleotide sequences on the mRNA called **codons.**
- The **genetic code** of mRNA is the amino acids and "start" and "stop" signals that are coded for by each of the possible 64 mRNA codons.
- **Codes in mRNA**

First base	Second base U	Second base C	Second base A	Second base G	Third base
U	UUU, UUC Phenylalanine UUA, UUG Leucine	UCU, UCC, UCA, UCG Serine	UAU, UAC Tyrosine UAA, UAG Stop	UGU, UGC Cysteine UGA–Stop UGG–Tryptophan	U C A G
C	CUU, CUC, CUA, CUG Leucine	CCU, CCC, CCA, CCG Proline	CAU, CAC Histidine CAA, CAG Glutamine	CGU, CGC, CGA, CGG Arginine	U C A G
A	AUU, AUC, AUA Isoleucine AUG–Start	ACU, ACC, ACA, ACG Threonine	AAU, AAC Asparagine AAA, AAG Lysine	AGU, AGC Serine AGA, AGG Arginine	U C A G
G	GUU, GUC, GUA, GUG Valine	GCU, GCC, GCA, GCG Alanine	GAU, GAC Aspartic Acid GAA, GAG Glutamic Acid	GGU, GGC, GGA, GGG Glycine	U C A G



RNA's Roles in Translation

- Translation takes place in the cytoplasm. Here transfer RNA molecules and ribosomes help in the synthesis of proteins.
- **Transfer RNA (tRNA)** molecules are single strands of RNA that temporarily carry a specific amino acid on one end.
- An **anticodon** is a three-nucleotide sequence on a tRNA that is complementary to an mRNA codon.

tRNA and Anticodon

- The seven steps of translation are:

Step 1 The ribosomal subunits, the mRNA, and the tRNA carrying methionine bind together.

Step 2 The tRNA carrying the amino acid specified by the codon in the A site arrives.

Step 3 A peptide bond forms between adjacent amino acids.

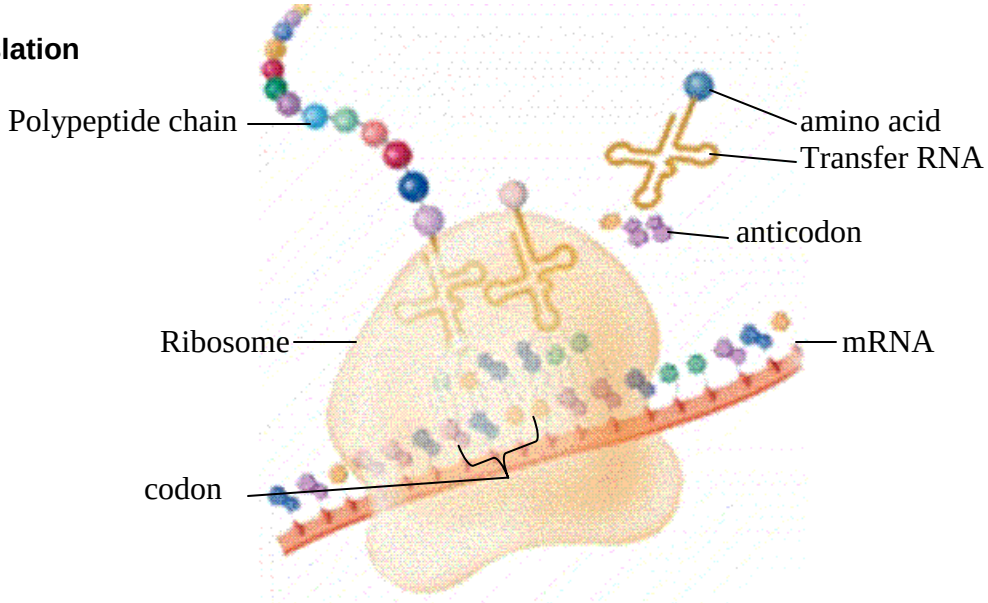
Step 4 The tRNA in the P site detaches and leaves its amino acid behind.

Step 5 The tRNA in the A site moves to the P site. The tRNA carrying the amino acid specified by the codon in the A site arrives.

Step 6 A peptide bond is formed. The tRNA in the P site detaches and leaves its amino acid behind.

Step 7 The process is repeated until a stop codon is reached. The ribosome complex falls apart. The newly made protein is released.

Snapshot of Translation



Section 2 Gene Regulation and Structure

Objectives

- **Describe** how the *lac* operon is turned on or off.
- **Summarize** the role of transcription factors in regulating eukaryotic gene expression.
- **Describe** how eukaryotic genes are organized.
- **Evaluate** three ways that point mutations can alter genetic material.

Protein Synthesis in Prokaryotes

- Both prokaryotic and eukaryotic cells are able to regulate which genes are expressed and which are not, depending on the cell's needs.
- The piece of DNA that overlaps the promoter site and serves as the on-off switch is called an **operator.**
- In bacteria, a group of genes that code for enzymes involved in the same function, their promoter site, and the operator that controls them all function together as an **operon.**

Operon (Video Clip)

- The operon that controls the metabolism of lactose is called the ***lac* operon.**
- When there is no lactose in the bacterial cell, a repressor turns the operon off.
- A **repressor** is a protein that binds to an operator and physically blocks RNA polymerase from binding to a promoter site.

Repression of Transcription in the *lac* Operon

- The regulator gene codes for a repressor protein that binds to the operator preventing RNA polymerase from binding to the promoter thus stopping transcription.

Activation of Transcription in the *lac* Operon

- Repressor proteins inhibit genes from being transcribed.
- An inducer binds to a repressor protein and causes it to detach from the operator.
- RNA polymerase can now bind to the promoter and transcription proceeds.

Protein Synthesis in Eukaryotes (from textbook)

- Eukaryotic cells contain much more DNA than prokaryotic cells do.
- Eukaryotic cells must continually turn certain genes on and off in response to signals from their environment; however, eukaryotes lack operons.

Controlling the Onset of Transcription

- Most gene regulation in eukaryotes controls the onset of transcription—when RNA polymerase binds to a gene.
- Transcription factors help arrange RNA polymerases in the correct position on the promoter.
- An enhancer is a sequence of DNA that can be bound by a transcription factor.

Enhancers for Control of Gene Expression

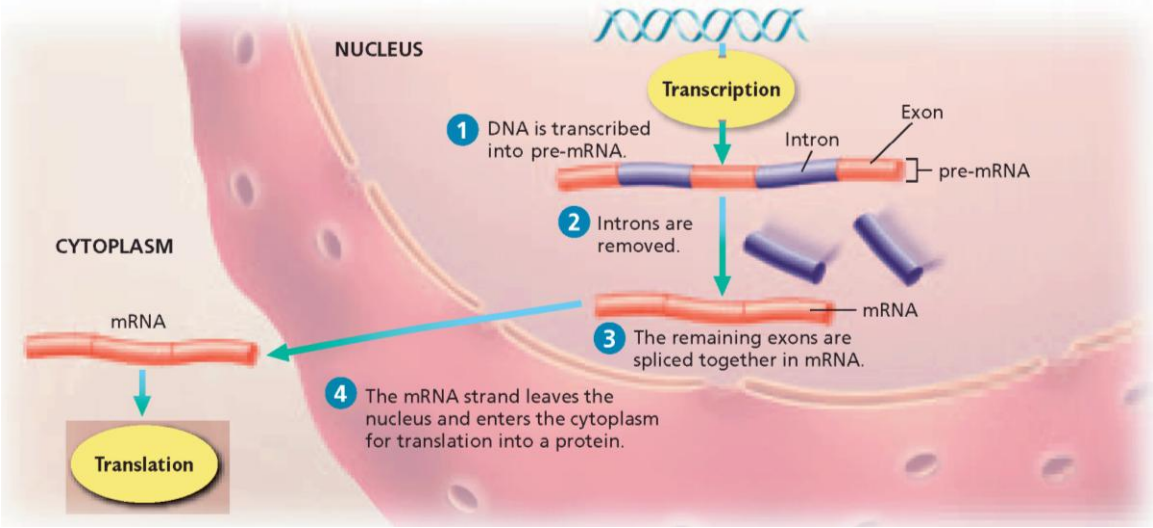
- An enhancer is a noncoding region of DNA that may be far away from the gene it affects.

- Transcription factors bind to DNA and regulate transcription.
- Activators are a type of transcription factor that binds to enhancers.
- Other transcription factors bind to the promoter in eukaryotic genes and help arrange RNA polymerase in the correct position.
- A loop in the DNA allows the activator bound to the enhancer to interact with the transcription factor and RNA polymerase at the promoter, increasing the transcription of the gene.

Intervening DNA in Eukaryotic Genes

- In eukaryotes, many genes are interrupted by **introns**—long segments of nucleotides that have no coding information.
- **Exons** are the portions of a gene that are translated (expressed) into proteins.
- After a eukaryotic gene is transcribed, the introns in the resulting mRNA are cut out by complex assemblies of RNA and protein called spliceosomes.

Removal of Introns After Transcription



DNA Mutations

How Does it happen?

- Environmental influences such as: chemicals or UV rays.
- Inherited: mutations can be passed down from parent to offspring.
- During copying of DNA, mistakes can occur.

Types of Mutations

- **Point mutations:** A mutation in which a single base-pair is changed.
- This mutation does not affect the reading frame.
    - Example: ATG TCG C**A**T TGA CGA Oigninal DNA
      ATG TCG C**T**T TGA CGA Mutated DNA
    - Results in either silent, missense or nonsense mutations.

- **Point Mutation Results:**
    - **Silent Mutation:** The base pair change has no effect on the amino acid produced.
        - Acts as a synonym mutation – meaning it's a different codon that still codes for the same amino.
        - Regardless of 'A' changing to 'G', the amino acid glutamic acid is still produced.
    - **Missense Mutation:** A different amino acid is produced.
        - Example: GAA codes for Glu; when the 'A' is changed to a 'C,' the amino acid produced is Asp.
    - **Nonsense Mutation:** The base pair change results in a STOP codon being produced. This may form a nonfunctional protein.
        - **TAA, TAG or TGA (DNA triplets)** are STOP codons.
        - **AUU, AUC or ACU (mRNA codons)** are STOP codons.
- **Transition:** A purine is changed to a purine (A or G) or a pyrimidine to a pyrimidine (T or C)
- **Transversion:** A purine is changed to a pyrimidine or a pyrimidine to a purine**.**
- **Examples:** Sickle cell anemia
    - **Glu- changes to Val-**
    - What type of mutation is this? Silent, missense or nonsense? missense
    - What type of mutation is this? Transition or transversion? transversion
- **Frameshift Mutations**
    - Frame shift mutations: The reading frame is altered.
- Example:
  Original: THE FAT CA**T** ATE THE WEE RAT
  Mutated: THE FAT CAA TET HEW EER AT
- Types: Deletions, insertions, duplications of base pairs.
    - **Deletion**: a single base pair or millions of base pairs may be deleted or removed from a sequence of nucleotides.
    - **Insertion**: a single base pair or millions of base pairs may be added to a sequence of nucleotides.
        - Example:
        - A nucleotide sequence is inserted into the DNA strand, resulting in Huntington's disease.
        - Original: ACC ATT GGC

    - Mutated: ACC CAG CAG CAG ATT GGC
    - The abnormal protein produced interferes with synaptic transmission in parts of the brain leading to involuntary movements and loss of motor control.
- **Duplication**: a sequence of base pairs may be duplicated or copied and reinserted into the strand of nucleotides.

- **What is more severe? Frameshift or point mutations?**
    - **Frameshift mutations –**
        - Alters the reading frame, thus affecting all proteins created after the point of mutation
        - Mostly fatal
    - **Point mutations –**
        - Does not affect the reading frame, with the chance of not affecting the protein being made
        - Can still be fatal to the carrier, but not always
- **Good mutations?**
    - Mutation of gene CCR5 – deletion of 32 pairs of nucleotides. Leads to resistance of HIV Stemmed from the bubonic plague.
    - Mutation of red blood cells leads to sickle cell anemia (has 2 alleles for the trait)
    - Leads to malaria resistance (has only one allele = sickle cell trait)
    - A mutation on protein Apo-AIM helps remove cholesterol from arteries, thus leading to less heart disease risk.
    - A defective myostatin gene leads to immense muscle strength.
    - NTRK1 gene mutation results in loss of all pain and sensations.
- **Chromosomal Mutations**
    - Occurs during crossing-over of prophase I in meiosis.
    - Types of chromosomal mutations:
        1. Translocations
        2. Inversions
        3. Deletions
        4. Duplications
    - **Translocations –** nonhomologous chromosomes exchange parts of DNA
        - Causes: virus, drugs, and radiation
        - Result: cancer or infertility
    - **Inversions –** a part of a chromosome detaches, flips around, then reattaches to previous spot on chromosome

        - Tends to lead to increase risk of miscarriages and infertility
    - **Deletions –** Genes are removed from the chromosome
        - This can occur anywhere on the chromosome
        - Can cause disorders such as Cri du Chat, or “cry of the cat” syndrome.
    - **Duplications -** with duplication mutations, sections of DNA are repeated on the chromosome.
- **Nondisjunction**
    - Disjunction: When sperm and egg cells form, each chromosome and its homologue separate.
    - Nondisjunction: When one or more chromosomes fail to separate properly. One gamete ends up receiving both chromosomes and the other gamete receives none.
        - Types of Nondisjunction
            - **Monosomy**: A daughter cell only has one chromosome instead of 2
                - Example of Monosomy: -Turner’s Syndrome / X0 – The entire X chromosome on the 23rd pair is missing
            - **Trisomy**: A daughter cell has three chromosomes instead of 2
                - Examples of Trisomy
                    - Down Syndrome / Trisomy 21
                    - Edward’s Syndrome / Trisomy 18