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13 RNA and Protein Synthesis

Big idea **Information and Heredity**

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

	WHAT I KNOW	WHAT I LEARNED
13.1 What is RNA?		
13.2 How do cells make proteins?		
13.3 What happens when a cell's DNA changes?		
13.4 How do cells regulate gene expression?		

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13.1 RNA

Lesson Objectives

- Contrast RNA and DNA.
- Explain the process of transcription.

Lesson Summary

The Role of RNA **RNA** (ribonucleic acid) is a nucleic acid like DNA. It consists of a long chain of nucleotides. The RNA base sequence directs the production of proteins. Ultimately, cell proteins result in phenotypic traits. The main differences between RNA and DNA are:

- The sugar in RNA is ribose instead of deoxyribose.
- RNA is generally single-stranded and not double-stranded like DNA.
- RNA contains uracil in place of thymine.

RNA can be thought of as a disposable copy of a segment of DNA. Most RNA molecules are involved in protein synthesis. The three main types of RNA are:

- **Messenger RNA** (mRNA) carries copies of instructions for polypeptide synthesis from the nucleus to ribosomes in the cytoplasm.
- **Ribosomal RNA** (rRNA) forms an important part of both subunits of the ribosomes, the cell structures where proteins are assembled.
- **Transfer RNA** (tRNA) carries amino acids to the ribosome and matches them to the coded mRNA message.

RNA Synthesis Most of the work of making RNA takes place during transcription. In **transcription**, segments of DNA serve as templates to produce complementary RNA molecules. In prokaryotes, RNA synthesis and protein synthesis takes place in the cytoplasm. In eukaryotes, RNA is produced in the cell's nucleus and then moves to the cytoplasm to play a role in the production of protein. The following focuses on transcription in eukaryotic cells.

- The enzyme **RNA polymerase** binds to DNA during transcription and separates the DNA strands. It then uses one strand of DNA as a template from which to assemble nucleotides into a complementary strand of RNA.
- RNA polymerase binds only to **promoters**, regions of DNA that have specific base sequences. Promoters are signals to the DNA molecule that show RNA polymerase exactly where to begin making RNA. Similar signals cause transcription to stop when a new RNA molecule is completed.
- RNA may be "edited" before it is used. Portions that are cut out and discarded are called **introns**. The remaining pieces, known as **exons**, are then spliced back together to form the final mRNA.

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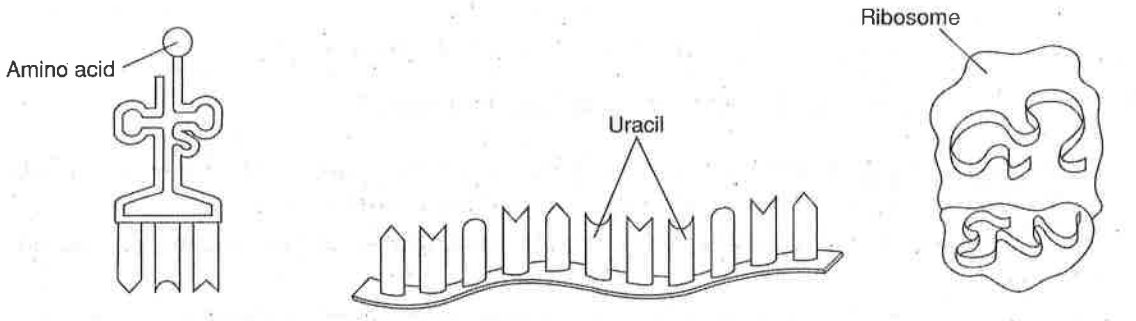
The Role of RNA

1. Complete the table to contrast the structures of DNA and RNA.

	Sugar	Number of Strands	Bases
DNA			
RNA			

2. On the lines provided, identify each kind of RNA.



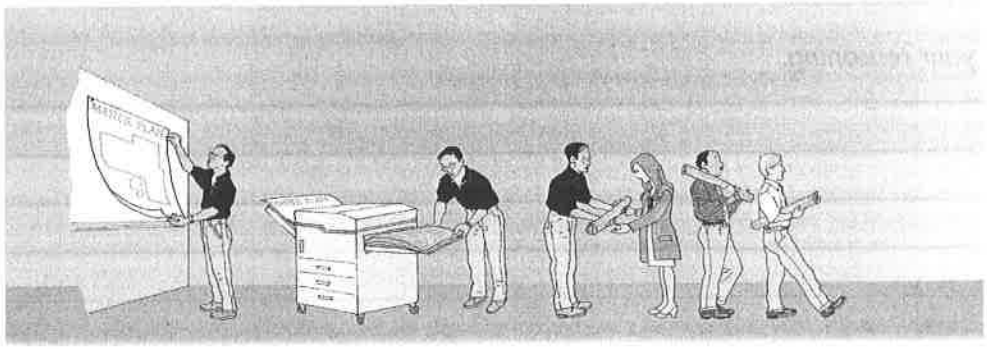
a. _____ b. _____ c. _____

3. VISUAL ANALOGY The master plan of a building shows how to build and place important parts of the building, such as walls, pipes, and electrical outlets. On the building site, workers use copies of the master plan called blueprints to show them what to do. The master plan is kept in the office. Explain how mRNA works like a blueprint in constructing proteins.

_____

_____

_____



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RNA Synthesis

For Questions 4–10, complete each statement by writing the correct word or words.

4. The process of using DNA to produce complementary RNA molecules is called _____.

5. The sequence of _____ in mRNA complements the sequence in the DNA template.

6. In eukaryotes, RNA is formed in the _____ and then travels to the _____.

7. The enzyme _____ binds to DNA during transcription.

8. RNA polymerase binds to regions of DNA called _____, which are "start" signals for transcription.

9. _____ are portions of RNA that are cut out and discarded.

10. _____ are spliced together to make the final mRNA.

11. **THINK VISUALLY** Sketch the sequence in which pre-mRNA is "edited" after it is made on the DNA template and before it is ready to function as mRNA in the cytoplasm. Show the original DNA, the pre-mRNA, and the final mRNA. Be sure to label exons and introns.

Apply the Big idea

12. Use the analogy of the master plan and blueprints used by builders to identify what represents messenger RNA, where the "ribosome" is, and who performs the same kind of job as transfer RNA.

Explain your reasoning.

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13.2 Ribosomes and Protein Synthesis

Lesson Objectives

- Identify the genetic code and explain how it is read.
- Summarize the process of translation.
- Describe the "central dogma" of molecular biology.

Lesson Summary

The Genetic Code A specific sequence of bases in DNA carries the directions for forming a **polypeptide**, a chain of amino acids. The types and order of amino acids in a polypeptide determine the properties of the protein. The sequence of bases in mRNA is the **genetic code**. The four bases, A, C, G, and U, act as "letters."

- The code is read three "letters" at a time, so that each "word" is three bases long and corresponds to a single amino acid. Each three-letter "word" in mRNA is known as a **codon**.
- Some codons serve as "start" and "stop" signals for protein synthesis.

Translation Ribosomes use the sequence of codons in mRNA to assemble amino acids into polypeptide chains. The process of decoding of an mRNA message into a protein is **translation**.

- Messenger RNA is transcribed in the nucleus and then enters the cytoplasm.
- On the ribosome, translation begins at the start codon. Each codon attracts an **anticodon**, the complementary sequence of bases on tRNA.
- Each tRNA carries one kind of amino acid. The match between the codon and anticodon ensures that the correct amino acid is added to the growing chain.
- The amino acids bond together, each in turn. The ribosome moves along the mRNA, exposing codons that attract still more tRNAs with their attached amino acids.
- The process concludes when a "stop code" is reached. The newly formed polypeptide and the mRNA molecule are released from the ribosome.

The Molecular Basis of Heredity Molecular biology seeks to explain living organisms by studying them at the molecular level, using molecules like DNA and RNA.

- The central dogma of molecular biology is that information is transferred from DNA to RNA to protein.
- **Gene expression** is the way in which DNA, RNA, and proteins are involved in putting genetic information into action in living cells.
- The genetic code is generally the same in all organisms.

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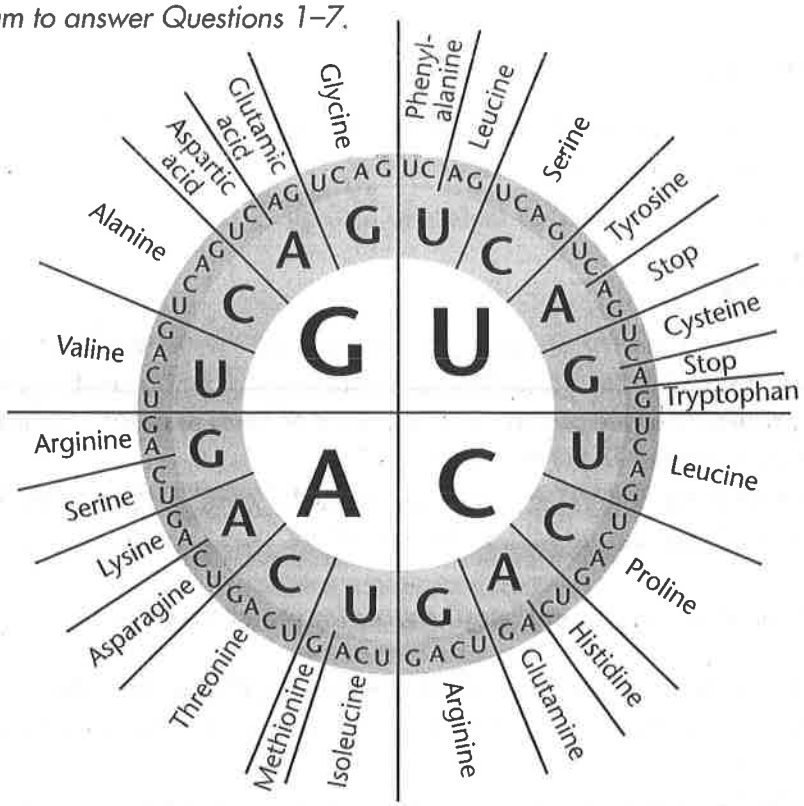
The Genetic Code

Use the diagram to answer Questions 1–7.



1. What are the words along the outside of the circle?

_____

2. What can you find by reading this diagram from the inside out?

_____

3. For which amino acid is AAA a codon?

_____

4. What is the codon for tryptophan?

_____

5. For which amino acid is GGA a codon?

_____

6. What is a codon for alanine?

_____

7. What are three other codons for alanine?

_____

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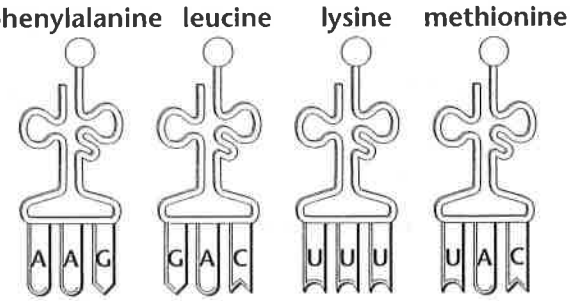
Translation

Use the diagram to answer Questions 8–10.

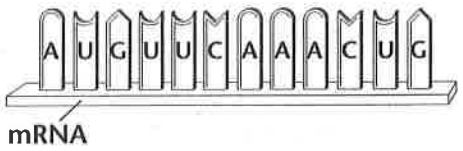


8. What is the anticodon for leucine? _____

9. What is the codon for leucine? _____

10. List the amino acids in the order they would appear in the polypeptide coded for by this mRNA.

_____



11. What is the difference between transcription and translation?

_____

_____

_____

12. Complete the table to describe the steps in protein synthesis.

Step	Description
Beginning of translation	
Assembly of polypeptide	
Completing the polypeptide	

13. Describe the role of rRNA during translation.

_____

_____

_____

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The Molecular Basis of Heredity

For Questions 14–18, write the letter of the correct answer on the line at the left.

_____ **14.** The instructions for assembling proteins are contained in the

A. genes.
B. ribosomes.
C. exons.
D. introns.

_____ **15.** The central dogma of molecular biology is that information is transferred from

A. RNA to protein to DNA.
B. DNA to protein to RNA.
C. protein to DNA to RNA.
D. DNA to RNA to protein.

_____ **16.** An exception to the central dogma is

A. the infection of a virus by a bacteriophage.
B. the ability of some viruses to transfer information from RNA to DNA.
C. the expression of different genes during different stages of development.
D. the translation of the codon into the anticodon of tRNA.

_____ **17.** The way in which DNA, RNA, and proteins are all involved in putting genetic information into action in living cells is called

A. translation.
B. transcription.
C. gene expression.
D. viral transfer.

_____ **18.** All organisms are mostly the same in

A. the proteins they make on their ribosomes.
B. how their proteins catalyze chemical reactions.
C. the size of their genes.
D. the molecular biology of their genes.

Apply the Big idea

19. Whether the organism is a pea plant or a human being, the information in the DNA of the cell's nucleus directs synthesis of proteins in the cytoplasm. Why, then, are pea plants and human beings so different?

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13.3 Mutations

Lesson Objectives

- Define mutations and describe the different types of mutations.
- Describe the effects mutations can have on genes.

Lesson Summary

Types of Mutations **Mutations** are heritable changes in genetic information. There are two categories of mutations: gene mutations and chromosomal mutations.

- Gene mutations produce changes in a single gene. **Point mutations** involve only one or a few nucleotides. Substitutions, insertions, and deletions are all types of point mutations.
  - In a substitution, one base is changed to a different base, which may affect only a single amino acid and have no effect at all.
  - In insertions and deletions, one base is inserted or removed from the DNA sequence. Insertions and deletions are called **frameshift mutations** because they shift the "reading frame" of the genetic message. Frameshift mutations can change every amino acid that follows the point of mutation and can have dramatic effects on the organism.
- Chromosomal mutations produce changes in the number or structure of chromosomes. They include deletions, duplications, inversions, and translocations.
  - Deletion involves the loss of all or part of a chromosome.
  - Duplication produces an extra copy of all or part of a chromosome.
  - Inversion reverses the direction of parts of a chromosome.
  - Translocation occurs when part of one chromosome breaks off and attaches to another.

Effects of Mutations Genetic material can be altered by natural events or by artificial means. Errors can be made during replication. Environmental conditions may increase the rate of mutation. **Mutagens** are chemical or physical agents in the environment that cause mutations.

The effects of mutations on genes vary widely:

- Some mutations have little or no effect.
- Some mutations produce beneficial variations. One example is **polyploidy** in plants, in which an organism has extra sets of chromosomes. Polyploid plants are often larger and stronger than diploid plants. Mutations can also produce proteins with new or altered functions that can be useful to organisms in different or changing environments.
- Some mutations negatively disrupt gene function or dramatically change protein structure. Genetic disorders such as sickle cell disease can result.

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Types of Mutations

For Questions 1–8, match the term with its definition.

Definition

_____ **1.** The change of one base to another in a DNA sequence

_____ **2.** A change in one or a few nucleotides that occur at a single point in the DNA sequence

_____ **3.** Part of one chromosome breaks off and attaches to another

_____ **4.** A heritable change in genetic information

_____ **5.** A mutation that produces an extra copy of all or part of a chromosome

_____ **6.** A chromosomal mutation that reverses the direction of parts of a chromosome

_____ **7.** A kind of mutation that can change every amino acid that follows the point of mutation

_____ **8.** The addition of a base to the DNA sequence

Term

A. mutation
B. substitution
C. point mutation
D. frameshift mutation
E. insertion
F. translocation
G. inversion
H. duplication

9. Complete the table to describe the processes and outcomes of the different types of gene (point) mutations.

Type	Description	Outcome
Substitution		
Insertion		
Deletion		

10. Deletion can happen as a gene mutation or as a chromosomal mutation. What is the difference?

_____

_____

_____

