DNA And RNA

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Deoxyribonucleic acid (DNA) is a complex molecule found in all living organisms. DNA is the chemical of which genes are composed. An understanding of the organization of this molecule has answered many questions. Scientists now know how chromosomes can duplicate during cell division and transfer their genetic information to new chromosomes. Scientists also understand how chromosomes in the cell nucleus can direct the formation of specific proteins outside the nucleus.

In this investigation, you will

(a) learn the names of the molecules which make up DNA.
(b) use models to construct a molecule of DNA and show how it replicates.
(c) learn the names of the molecules which make up RNA.
(d) use models to show how the base sequence code in DNA is transcribed exactly to RNA.

Materials

4 pages of paper models
scissors
NOTE: SAVE ALL MODEL PARTS. THEY WILL BE NEEDED FOR INVESTIGATION 25.

Procedure

Part A. Structure of DNA Nucleotides

Two important molecules which make up DNA are deoxyribose and phosphoric acid. Their models and structural formulas are shown in Figure 24-1.

1. Give the simple formula for

(a) deoxyribose C__H__O__

(b) phosphoric acid H__P__O__

Deoxyribose is a carbohydrate. Phosphoric acid was studied previously as a molecule in ATP.

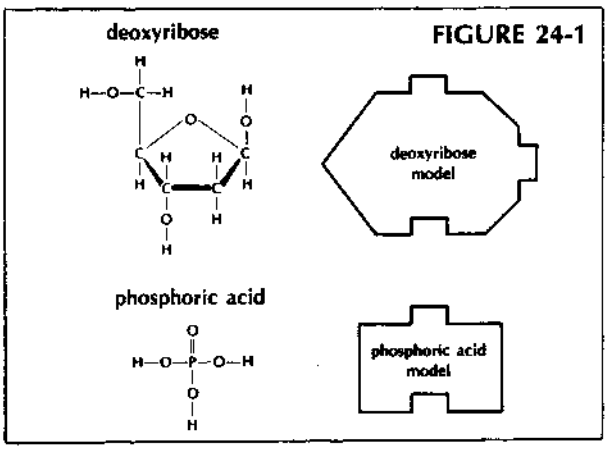
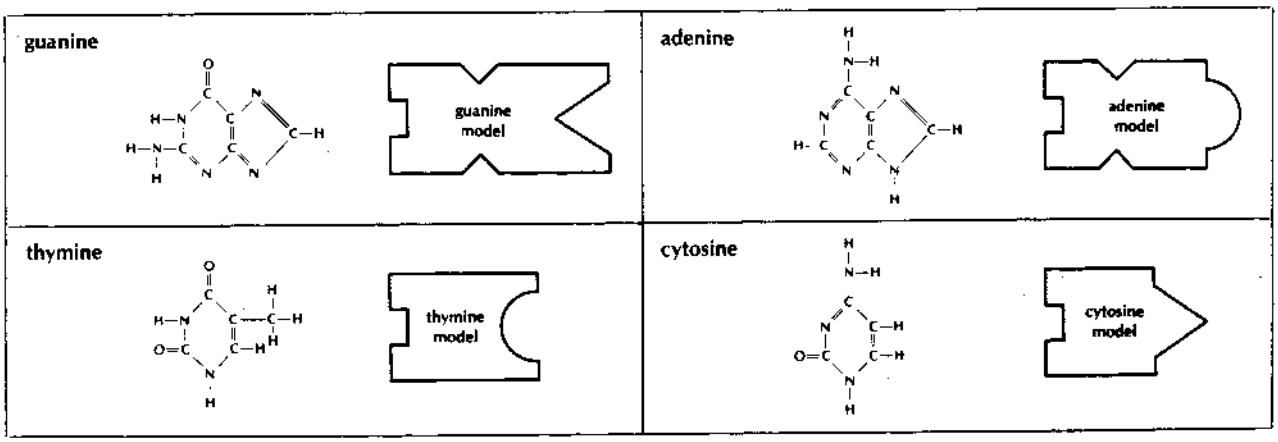


FIGURE 24-1



In addition, there are four different molecules called bases. Their structural formulas and models are shown on page 93.

2. Of the four bases, which other base does

   (a) adenine most resemble in shape? _____

   (b) thymine most resemble in shape? _____

A molecule of deoxyribose joins with phosphoric acid and any one of the four bases to form a chemical compound called a nucleotide. A nucleotide is named for the base that joins with the deoxyribose. For example, if thymine attaches to deoxyribose, the molecule is called a thymine nucleotide.

• Use the pages of nucleotide models to answer questions 3 and 4.

3. List the four different nucleotides. _____

_____

4. (a) How is each nucleotide alike? _____

_____

   (b) How does each nucleotide differ? _____

_____

_____

Part B. Structure of a DNA Molecule

A DNA molecule is "ladderlike" in shape. Deoxyribose and phosphoric acid molecules join to form the sides or uprights of the ladder. Base molecules join to form the rungs of the ladder.

• Cut out the 24 nucleotide models provided by your teacher. *Cut only on solid lines.* **CAUTION:** *Always be careful when using scissors.*

• Fit six nucleotides together in puzzlelike fashion to form a row in the following sequence from top to bottom:

Cytosine nucleotide
Thymine nucleotide
Guanine nucleotide
Adenine nucleotide
Guanine nucleotide
Cytosine nucleotide

Let this arrangement represent the left half of a ladder molecule. It should consist of one side or upright plus six half rungs.

5. If DNA is "ladderlike," which two molecules of a nucleotide form the sides, or upright portion of the ladder? _____

6. To which molecule does each base attach?

_____

7. Name the molecules of each nucleotide that form part of the ladder's rungs. _____

• Complete the right side of the DNA ladder by matching the bases of other nucleotides to form complete rungs. It may be necessary to turn molecules upside down in order to join certain base combinations. NOTE: The ends of each base will allow only a specifically shaped matching new base to fit exactly.

Your completed model should look like a ladder with matched bases as the rungs. Besides being shaped like a ladder, a DNA molecule is twisted. It looks like a spiral staircase. However, your paper model cannot show this shape.

8. Is the order of half-rung bases exactly the same from top to bottom of each side of your model?

_____

9. Only two combinations of base pairings are possible for the rungs. Name these molecule combinations or pairs. _____

_____

10. If four guanine bases appear in a DNA model, how many cytosine bases should there be?

_____

11. Your DNA model has four guanine bases.
   (a) Does the number of cytosine bases in your model agree with your prediction? _____
   (b) The following are the bases on the left side of a DNA molecule. List the bases that would make up the right side of a DNA molecule.

Thymine _____

Adenine _____

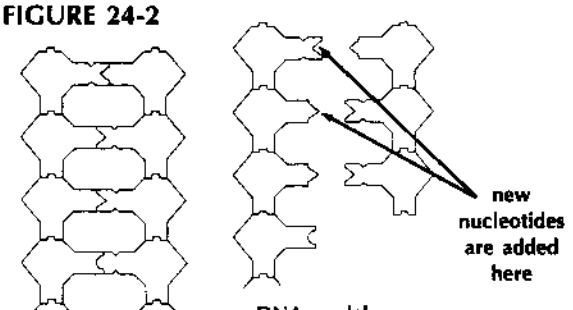
Guanine _____

Guanine _____

Cytosine _____

Name _____ Date _____

FIGURE 24-2



Part C. DNA Replication

A chromosome contains DNA. Your DNA model represents only a short length of the DNA portion of a chromosome. An entire chromosome has thousands of rungs rather than only six. Although your model is only a small part of a chromosome, its replication is the same as that of an entire chromosome during mitosis and meiosis.

- Open your DNA model along the point of attachment between base pairs (rungs) and separate the two ladder halves. (A chromosome untwists and "unzips" in a similar way prior to replication.) See Figure 24-2 as a guide.

- Using the left half of your model as a pattern, add new nucleotides to form a new right side.

- Build a second DNA model by adding new nucleotides to the right half of the original model.

12. Do the two new molecules contain the same number of rungs? _____

13. Is the order from top to bottom of base pairs (rungs) different or the same for each new DNA molecule? _____

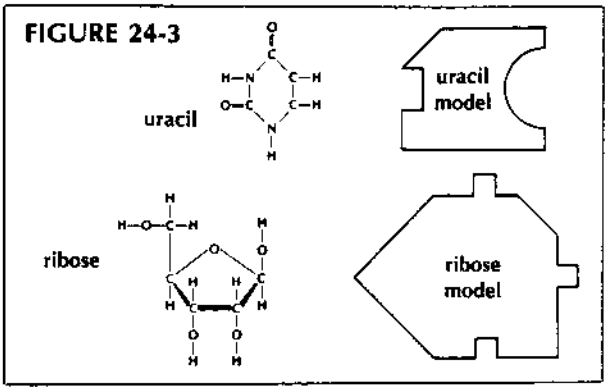
14. How many molecules of adenine and thymine are in each DNA molecule? _____

15. Do the numbers agree? _____

16. Are the two DNA molecules exact copies of each other? _____

The specific order of bases in DNA serves as a code or language. When a chromosome replicates, the code (the order in which the bases occur) is carried over to the new chromosome.

FIGURE 24-3



17. What is the code of a chromosome? _____

_____

Part D. RNA Structure

Besides ensuring the exact replication of chromosomes, the sequence (order) and pairings of bases are a genetic code of the instructions for the entire cell. How does a cell "read" the chemical message coded in its DNA in the form of specific base sequences? Part of the answer lies with a second molecule in the nucleus of cells called ribonucleic acid (RNA).

RNA is similar to DNA in that its molecules are also formed from nucleotides. However, deoxyribose and thymine are not found in RNA. Two other molecules, ribose and uracil, are present. Ribose replaces deoxyribose, and uracil replaces thymine. Looking at their structural formulas and models, you will see certain similarities between the molecules that they replace. Formulas and models are shown in Figure 24-3.

18. (a) Which base is replaced in RNA by uracil?

_____

(b) What chemical replaces deoxyribose in RNA? _____

19. To which base in DNA do the following RNA bases pair?

(a) guanine _____

(b) adenine _____

(c) cytosine _____

(d) uracil _____

Part E. RNA Transcription

• Cut out the six RNA nucleotide models. *Cut only along solid lines.*

• Open or unzip one of the DNA chromosomes along the base pair points of attachment and separate the two halves.

• Using the left side of your DNA model as a pattern, match RNA nucleotides with the proper nucleotides of the DNA half.

20. Do the RNA half-rung bases pair exactly as they would if this were DNA replication?

_____

• Remove the RNA nucleotide series from the DNA pattern.

• Close the DNA molecule back up with its original right side. (DNA molecules "unzip" temporarily during RNA production.)

RNA is a single-stranded (or ½ ladder) molecule. Thus, the series of RNA nucleotides formed from DNA represents an RNA molecule. After its formation, this RNA leaves the nucleus of the cell and goes to the ribosomes. It carries the DNA message of base sequences in the exact same order. Therefore, the formation of this series of RNA nucleotides is called transcription.

Analysis

1. Complete Table 24-1 by using check marks to indicate to which molecule each characteristic applies.

TABLE 24-1. SIMILARITIES AND DIFFERENCES BETWEEN DNA AND RNA

	DNA	RNA
Deoxyribonucleic acid		
Ribonucleic acid		
Ribose present		
Deoxyribose present		
Phosphoric acid present		
Adenine present		
Thymine present		
Uracil present		
Guanine present		
Cytosine present		
Formed from nucleotides		
Double stranded		
Single stranded		
Remains in nucleus		
Moves out of nucleus		
Contains a chemical message or code		

tRNA And Protein Building

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RNA produced in the nucleus of a cell moves out of the nucleus to the cell's ribosomes. This RNA is a specific sequence of bases copied from the DNA which carries the chromosomal genetic message to the cytoplasm. Thus, it is called messenger RNA (mRNA). At the ribosomes, mRNA directs the building of proteins. Proteins are made up of smaller molecules called amino acids. How does a cell construct the proper amino acids into protein molecules? Formation of proteins involves another kind of RNA. Transfer RNA (tRNA) brings specific amino acids to mRNA according to the code sequence of bases found on mRNA.

In this investigation, you will

(a) use paper models to show how base shapes in mRNA match only with specific base shapes of tRNA.
(b) use paper models to show how tRNA molecules bring specific amino acid molecules to the ribosome where building of proteins occurs.
(c) learn to transcribe a DNA code to a mRNA message and translate the mRNA to the tRNA—amino acid code.
(d) study the molecular basis for gene mutations.

Materials

models of RNA nucleotides from Investigation 24 page of paper models of tRNA scissors

Procedure

Part A. Structure of tRNA

• Build a molecule of mRNA using the paper molecules from Investigation 24. Make sure you are using only RNA nucleotides. Join the RNA nucleotides to form a row of molecules in this order:

Guanine
Adenine
Cytosine
Uracil
Cytosine
Guanine

• Recall that molecules of mRNA leave the cell nucleus and move out to the cell's ribosomes. Meanwhile, transfer RNA (tRNA) is present in the cell cytoplasm. Models of tRNA were supplied to you by your teacher. Molecules of tRNA are composed of many base nucleotides. However, tRNA has a three base sequence (a triplet) that can match up with the bases of mRNA.

• Cut out the two models of tRNA. *Cut only along solid lines.* **CAUTION:** *Always be careful with scissors.*

1. (a) Name the four nucleotide bases present in tRNA. _____
   (b) Do these bases differ from those found in mRNA? _____
   (c) How does the tRNA molecule differ from mRNA in shape? _____

• Join the tRNA molecules to the model of mRNA.

2. What base in mRNA can only join with the
   (a) adenine base of tRNA? _____
   (b) uracil base of tRNA? _____
   (c) guanine base of tRNA? _____

3. What order of bases on mRNA will match a sequence on tRNA of

   (a) UUA? (uracil, uracil, adenine) _____

   (b) UCA? (uracil, cytosine, adenine) _____

   (c) UGA? (uracil, guanine, adenine) _____

   (d) AAA? (adenine, adenine, adenine) _____

Transfer RNA picks up amino acids in a series of chemical steps. A tRNA molecule only picks up a certain amino acid. The amino acid is attached to the tRNA at the end opposite the three bases that will attach to mRNA.

• Cut out the two remaining models of amino acids, serine and aspartic acid, from the page provided by your teacher. Join these models to their proper tRNA models. Only a specific amino acid will fit along the top of each tRNA model. Remember that each tRNA model has a three sequence base called a triplet.

4. What amino acid connects to a tRNA molecule with a triplet of

   (a) AGC? _____

   (b) CUG? _____

5. What molecule receives the amino acids on tRNA? _____

6. How many base molecules or nucleotides of mRNA are responsible for the coding of one amino acid? _____

Part B. Forming a Protein Molecule During Translation

When many amino acid molecules are brought to the mRNA by tRNA, the amino acids join to form a protein molecule. When tRNA molecules with their attached amino acids join to the bases of the mRNA, the formation of a protein molecule is begun. This entire process is called translation. The DNA message has been translated into a protein molecule.

7. What amino acid is attached to a tRNA molecule having a base sequence of

   (a) UUU? (Read from Table 25-1.) _____

   (b) GCU? _____

8. What tRNA triplet is needed to join with the following amino acids:

   (a) phenylalanine? (Read from Table 25-1.) _____

   (b) valine? _____

   (c) glutamic acid? _____

Depending on the type and order of amino acids, an almost endless variety of proteins can be produced. Because of the repeated matching of base sequences, the base sequence in the DNA of chromosomes codes for and controls the formation of protein molecules at ribosomes.

9. A protein molecule consists of the following amino acid sequence: leucine, glutamine, tyrosine, leucine, serine, serine. What would be the sequence of tRNA bases responsible for forming this protein? (Use Table 25-1.) _____

10. A ribosome receives the following mRNA message: AAA, CGA, GAA, GUU.
    (a) What will be the sequence of tRNA bases joining the mRNA molecule? _____

    (b) What will be the sequence of amino acids formed from this code? _____

TABLE 25-1. tRNA TRIPLET CODES OF SOME AMINO ACIDS

AMINO ACID	tRNA CODE
Serine	AGC
Proline	GGG
Leucine	AAU
Glutamic acid	CUU
Tyrosine	AUA
Arginine	GCU
Glutamine	GUU
Phenylalanine	AAA
Valine	CAA
Lysine	UUU

As a review, you should now be able to transcribe (decode) a message in DNA base code into mRNA and then translate it into a protein molecule.

A portion of DNA on a chromosome has the sequence of bases along one strand of DNA as indicated in Table 25-2.

• Transcribe or decode this message first into mRNA code, then translate it into tRNA code and proper amino acids using Table 25-1.

TABLE 25-2. TRANSCRIBING AND TRANSLATING OF A DNA SEQUENCE

CHROMOSOME DNA CODE OF BASES	mRNA BASE CODE	tRNA BASE CODE	AMINO ACID SEQUENCE
AAT			
GGG			
ATA			
AAA			
GTT			

• Rework the cell's code language backward by completing Table 25-3.

TABLE 25-3. TRANSCRIBING AND TRANSLATING OF AN AMINO ACID SEQUENCE

AMINO ACID SEQUENCE	tRNA BASE CODE	mRNA BASE CODE	DNA BASE CODE
Proline			
Glutamic acid			
Lysine			
Serine			
Leucine			

Part C. Mutations and Base Sequence Errors

Not often are there errors in the process of forming proteins from the DNA code of instructions. An error in the process is a mutation and will result in formation of a different type of protein.

Hemoglobin is a protein in red blood cells. Hemoglobin results from the proper arrangement of almost 600 amino acids. Most humans have the correct type of hemoglobin. However, in some people the arrangement is incorrect. These people have a disease called sickle-cell anemia. Their red blood cells are sickle-shaped rather than round. As a result, the red blood cells cannot transport oxygen as well.

The following amino acid sequence represents a portion of the normal hemoglobin molecule: proline, glutamic acid, glutamic acid, lysine.

11. Translate the sequence of amino acids in normal hemoglobin into

(a) tRNA base codes. _____

_____

(b) mRNA base codes. _____

_____

(c) DNA base codes. _____

_____

In sickle-cell anemia, the sequence of amino acids is slightly different. It is proline, valine, glutamic acid, lysine.

12. Translate the sequence of amino acids in sickle-cell hemoglobin into

(a) tRNA base codes. _____

_____

(b) mRNA base codes. _____

_____

(c) DNA base codes. _____

_____

13. In terms of base nucleotides, explain the only difference between the DNA message for normal hemoglobin and the DNA message for

sickle-cell hemoglobin. _____

_____

_____

A mutation, therefore, is a difference from what we consider to be the normal sequence of bases in a molecule of DNA. The difference or error does not have to be very great. As you have just determined, a base sequence of only one triplet (three bases) can cause the formation of the wrong type of hemoglobin. A change at only one base site of the triplet can cause mutation.

14. How are mutations passed on to offspring?

Analysis

1. What is the function of mRNA?

2. What is the function of tRNA?

3. How do tRNA and mRNA differ in their location within the cell?

4. (a) Briefly describe what is meant by translation.

   (b) What is being translated?

5. Complete this chart by using check marks to indicate to which molecule each characteristic applies.

SIMILARITIES AND DIFFERENCES BETWEEN mRNA AND tRNA		
	mRNA	tRNA
deoxyribose present		
ribose present		
phosphoric acid present		
adenine present		
thymine present		
uracil present		
guanine present		
cytosine present		
contains a chemical message or code		
carries an amino acid to a ribosome		