Teacher Guide: RNA and Protein Synthesis

Learning Objectives

Students will …

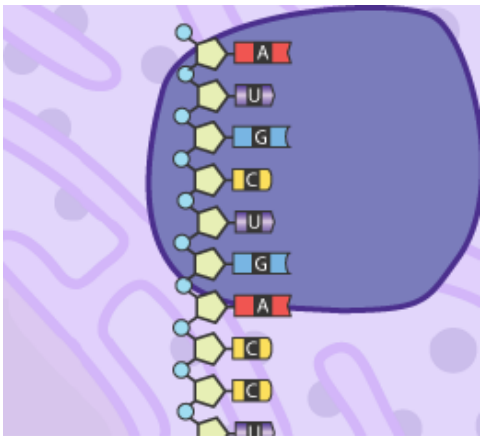
- Identify the differences between DNA and RNA.
- Explain the role of RNA in assembling proteins.
- Describe the processes of RNA transcription and translation.
- Construct a protein molecule by building an amino acid chain.
- Determine which amino acids are specified by different codons.

Vocabulary

amino acid, anticodon, codon, messenger RNA, nucleotide, ribosome, RNA, RNA polymerase, transcription, transfer RNA, translation

Lesson Overview

If an organism's DNA can be thought of as a cookbook containing recipes on how to make and run the organism, than RNA can be thought of as the cook. It is RNA that "reads" DNA's code and translates it into proteins, the main building blocks of an organism. This process is known as protein synthesis.



With the *RNA and Protein Synthesis* Gizmo™, students learn how three different types of RNA—messenger RNA, transfer RNA, and the RNA that makes up ribosomes—work in concert to assemble proteins out of amino acids.

The Student Exploration sheet contains two activities:

- Activity A – Students compare RNA and DNA and build an mRNA molecule.
- Activity B – Students use tRNA to build an amino acid chain and interpret a codon chart.

Suggested Lesson Sequence

1. **Pre-Gizmo activity** (30 – 45 minutes)
   To introduce students to DNA and the genetic code, try the *Building DNA* Gizmo.

   After students have learned about the structure of DNA, explain that DNA contains instructions for making proteins and proteins are assembled by ribosomes in the cell's cytoplasm. Challenge students to hypothesize how the information stored in a DNA molecule is transferred to a ribosome. (Before students write their hypotheses, remind them that DNA does not leave the cell's nucleus.)

   Discuss the various hypotheses that students come up with. After students complete the Gizmo, have them revise their hypotheses.

2. **Prior to using the Gizmo** (10 – 15 minutes)
Before students are at the computers, pass out the Student Exploration sheets and ask students to complete the Prior Knowledge Questions. Discuss student answers as a class, but do not provide correct answers at this point. Afterwards, if possible, use a projector to introduce the Gizmo and demonstrate its basic operations. Demonstrate how to take a screenshot and paste the image into a blank document.

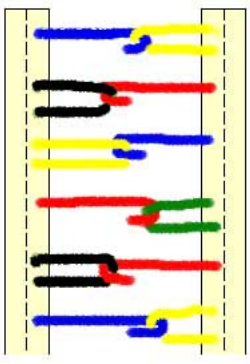
3. **Gizmo activities** (15 – 20 minutes per activity)
Assign students to computers. Students can work individually or in small groups. Ask students to work through the activities in the Student Exploration using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led activity.

4. **Discussion questions** (15 – 30 minutes)
As students are working or just after they are done, discuss the following questions:

   - Suppose a scientist extracted a nucleic acid molecule from a cell. How could the scientist tell whether the nucleic acid was DNA or RNA?
   - What is the difference between translation and transcription?
   - What ensures that a molecule of tRNA carrying a specific amino acid will bind to the correct location on a molecule of mRNA?
   - What is an example of a transcription error that would have no effect on the resulting protein? What is an example of a transcription error that would have a major effect on the resulting protein?
   - Why is protein synthesis also known as gene expression?

5. **Follow-up activities** (30 – 60 minutes)
If your students used pipe cleaners (chenille stems) to create a DNA molecule while working with the *Building DNA* Gizmo, have them return to their models. To demonstrate transcription, ask students to unhook the two strands of DNA. Have students position one of the strands across their desks. Parallel to this, students should lay out a 50-cm strip of masking tape. Tape the ends of the strip to the desk so that it remains flat.

   Tell students that now they will build an mRNA molecule using the DNA strand as a template. Remind students to use red pipe cleaners for adenine, blue for guanine, and yellow for cytosine. For uracil, students should use black or purple pipe cleaners.

   Build the mRNA molecule by laying out the pipe-cleaner segments so they overlap half of the tape, as shown. Be sure to lay out complementary pairs of nitrogenous bases. Join each pair by folding the end of the straight segment into a hook around the loop. Fold the tape lengthwise to secure the pipe cleaners.

   Once the mRNA molecule is complete, it can be removed from the DNA strand. Have students reform their DNA molecule. Then challenge students to think of a way they can use their pipe-cleaner mRNA molecule to model the process of translation. Ask students to come up with ideas on how they can model a ribosome, tRNA, and a growing amino acid chain. Encourage students to complete their models and share them with their classmates.

If time allows, have your students take part in this fun codon activity: Students should write a 5–10 word secret message. Then have students make a codon chart similar to the chart on the Student Exploration worksheet except with one difference: instead of representing amino acids, the codons on the students' charts should represent words, including the words in the secret message.

Students should use their charts to construct a strand of DNA that can be used to make a complementary strand of mRNA, which codes for the message. Have partners exchange their charts and DNA strands. Each partner should transcribe the DNA strand into an mRNA strand. The partner should then use the mRNA strand and codon chart to interpret the secret message.

Scientific Background

All of an organism's inherited traits are determined by the instructions coded in DNA. These instructions are also known as genes. Genes are expressed during the process of protein synthesis. Protein synthesis occurs in two stages: transcription and translation.

Transcription starts in a cell's nucleus when an enzyme called RNA polymerase binds to a specific sequence of DNA. The RNA polymerase causes a portion of the DNA to unwind and separate. The RNA polymerase then begins to add complementary RNA nucleotides to the exposed template strand of DNA, thus building a molecule of messenger RNA (mRNA). When the RNA polymerase reaches a stop signal on the DNA, it disengages from the DNA and releases the strand of mRNA. The mRNA moves out of the nucleus into the cell's cytoplasm. There, a ribosome and a *transfer RNA* (tRNA) molecule bind to the start codon on the mRNA and start the *translation* process.

A second tRNA molecule carrying the anticodon for the mRNA's second codon binds to the mRNA. A peptide bond forms between the amino acids on the two tRNA molecules. The first tRNA molecule is released from the ribosome. The second tRNA molecule, which is still attached to the mRNA, moves to the empty site left by the first tRNA molecule. This makes space for the next tRNA molecule to bind to the adjacent codon on the mRNA.

The chain of amino acids continues to grow in this manner until the stop codon is reached. At this point, the ribosomal complex breaks apart, releasing the new protein.

With a few minor variations, the translation of RNA codons to specific amino acids is universal. For example, the mRNA sequence GGA codes for the amino acid glycine in plants, animals, fungi, and bacteria. This universality indicates that the genetic code probably developed very early in the history of life.

Selected Web Resources

DNA and protein synthesis: http://web.jjay.cuny.edu/~acarpi/NSC/12-dna.htm
Codons: http://commons.wikimedia.org/wiki/File:Codontable1.PNG
Transcription: http://www-class.unl.edu/biochem/gp2/m_biology/animation/gene/gene_a2.html
Translation: http://www-class.unl.edu/biochem/gp2/m_biology/animation/gene/gene_a3.html

Related Gizmos:
Building DNA: http://www.explorelearning.com/gizmo/id?439
Cell Structure: http://www.explorelearning.com/gizmo/id?450