Teacher Guide: Building DNA

Learning Objectives

Students will…

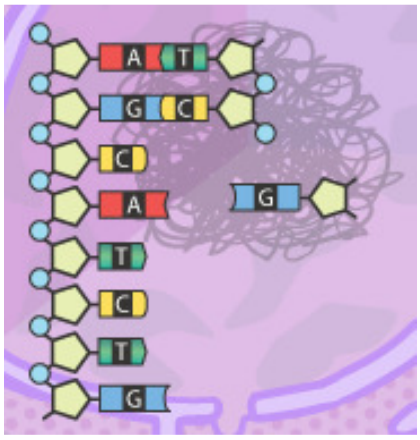
- Build a molecule of DNA from a set of components.
- Observe how nitrogenous bases bond to form the central "rungs" of the DNA molecule.
- Explain how DNA replication occurs.
- Describe the roles of DNA helicase and DNA polymerase in replication.
- Observe that the result of DNA replication is two identical molecules of DNA.

Vocabulary

double helix, DNA, enzyme, lagging strand, leading strand, mutation, nitrogenous base, nucleoside, nucleotide, replication

Lesson Overview

The double-helix structure of a DNA molecule is one of the greatest wonders of the natural world. The rungs of this twisted ladder contain a set of instructions for building any living thing on Earth. The DNA molecule can be split apart, with the strands used as templates to build two daughter DNA molecules, each identical to the original. This process, called *DNA replication*, is the basis of reproduction for all living things.



With the *Building DNA* Gizmo™, students build and then replicate a DNA molecule. Over 2,500 distinct DNA molecules can be built using the Gizmo.

The Student Exploration sheet contains two activities:

- Activity A – Students build a DNA molecule and observe how nitrogenous bases bond.
- Activity B – Students replicate a DNA molecule.

Suggested Lesson Sequence

1. **Pre-Gizmo activity** (5 – 10 minutes)
   Have students examine an image of the DNA molecule. Explain that the DNA molecule encodes genetic information, and that when a cell divides, an identical set of DNA must be passed down to each daughter cell. Discuss the following questions:
   - Where in the DNA molecule do you think the genetic information is stored?
   - How do you think the DNA molecule makes a copy of itself?
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.

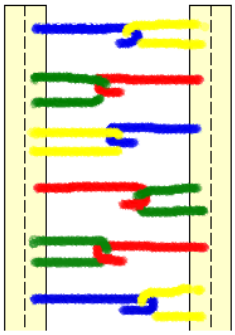
3. **Gizmo activities** (15 – 20 minutes per activity)
Assign students to computers. Students can work individually or in small groups. Ask students to work through the activities in the Student Exploration using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led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

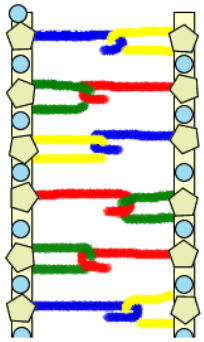
4. **Discussion questions** (15 – 30 minutes)
As students are working or just after they are done, discuss the following questions:
   - Which two components make up the "sides" of a DNA molecule?
   - What molecules make up the central "rungs" of the DNA molecule?
   - What pairs of nitrogenous bases can be found in a DNA molecule?
   - What sequence of nitrogenous bases would you find opposite the following:

     A A G C G T C T C? [Answer: T T C G C A G A G]
   - What are the steps in DNA replication?
   - Most *mutations* (errors in DNA synthesis) occur during DNA replication. What are some of the kinds of mutations that you can imagine happening?

5. **Follow-up activity: Pipe-cleaner DNA** (30 – 60 minutes)
Your students can build realistic DNA molecules with pipe cleaners (also called chenille stems, available in craft stores), masking tape, and stickers (optional). Use red pipe cleaners for adenine, green for thymine, blue for guanine, and yellow for cytosine.

First, lay out two 50-cm strips of masking tape, with the sticky side up. Tape the ends of each strip to the table so they remain flat. The strips should be parallel and about 12 cm (5 inches) apart. Fold all of the green and yellow pipe-cleaner segments in half, forming loops. Leave all of the blue and red segments straight for now.





Build a DNA 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: blue/yellow and red/green. 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. If you like, you can finish each model with stickers to represent the phosphate and deoxyribose components. Student models can be linked together and twisted into a long double helix.

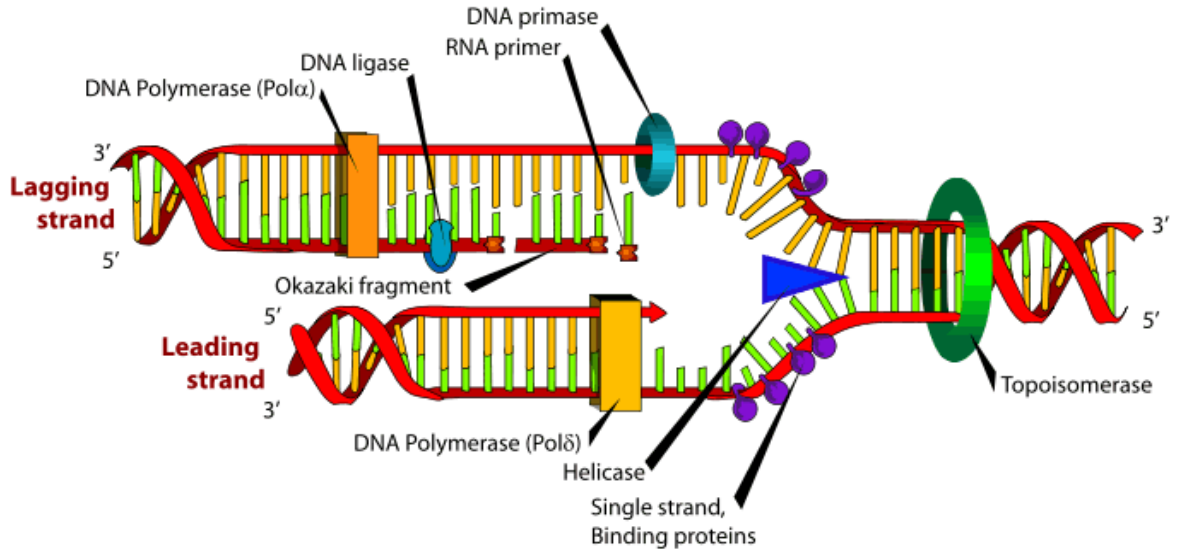
To model DNA replication, first unhook the base pairs to form two separate strands. Attach new bases to each strand, and join these bases together with tape to form complementary strands. At this point you will have two DNA molecules, each identical to the original. The same models can be used to illustrate mutations and protein synthesis. (See the **Selected Web Resources** for a link to the *RNA and Protein Synthesis* Gizmo.)

Scientific Background

DNA is an abbreviation for deoxyribonucleic acid. The DNA molecule has the shape of a double helix—a structure that can be described as a "twisted ladder." The sides of the ladder consist of alternating deoxyribose molecules ($C_5H_{10}O_4$) and phosphate groups (PO_4). The "rungs" of the ladder encode genetic information. Each rung consists of a pair of nitrogenous bases, A-T (adenine-thymine) or G-C (guanine-cytosine). Adenine and guanine are larger molecules, known as *purines*. Thymine and cytosine are called *pyrimidines*. Each purine-pyrimidine pair is joined by hydrogen bonds.

Segments of DNA, called *genes*, encode genetic information in many ways. Some genes are instructions for building specific proteins. In these genes, each sequence of three bases codes for a specific amino acid. The long chain of amino acids specified by the gene will fold itself into a protein. Other genes serve a regulatory function, helping to "turn on" or "turn off" the protein-making genes. Other segments of DNA appear to have no function at all.

DNA replication occurs with the help of several enzymes. First, *DNA helicase* breaks the hydrogen bonds that hold the two strands of DNA together. On one of the resulting strands, *DNA polymerase* adds new complementary bases in a continuous sequence to form a new *leading strand*. On the other strand, new bases are added in the opposite direction, forming short segments called *Okazaki fragments*. The Okazaki fragments are then joined together to form a new *lagging strand*. Other enzymes and helper molecules—*DNA primase*, *DNA ligase*, and *RNA primers*—are involved in this complex process, illustrated below.



Selected Web Resources

DNA history: http://www.dnaftb.org/15/concept/
DNA resources, history, and lesson plans: http://www.dnai.org/
DNA replication (animation): http://www.johnkyrk.com/DNAreplication.html
DNA replication (detailed animation):
http://www.wiley.com/college/pratt/0471393878/student/animations/dna_replication/index.html

Related Gizmos:
RNA and Protein Synthesis: http://www.explorelearning.com/gizmo/id?442
DNA Fingerprint Analysis: http://www.explorelearning.com/gizmo/id?406