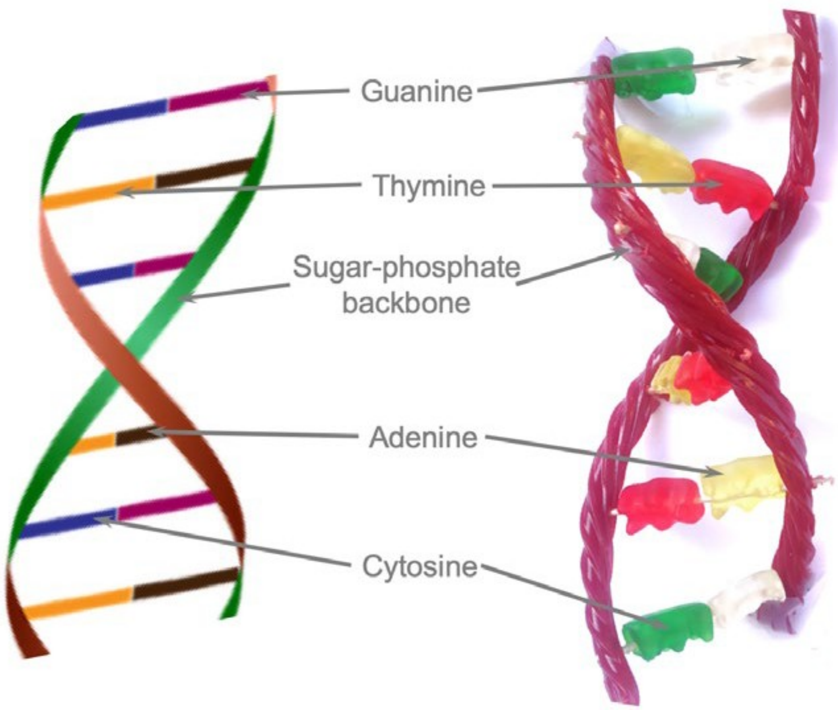
MAKE A CANDY

DNA Model

ESTIMATED LENGTH: 85-115 MIN*

AMGEN® Foundation
biotech101
FOR THE CLASSROOM



In this small group activity, MIDDLE SCHOOL students will make an edible model of a DNA double helix.

Different colored candy represents the four bases (adenine, guanine, thymine and cytosine) whereas long strands of candy mimic the DNA sugar-phosphate backbone. As students put together their DNA model, they will learn about the base pairing rules and how DNA encodes each organism's genetic information.

ATTENTION: This activity includes the use of food. Please discuss the potential of student allergies with teacher before running this activity.

*These time estimates don't include the cleanup and the material shopping.

TABLE OF CONTENTS

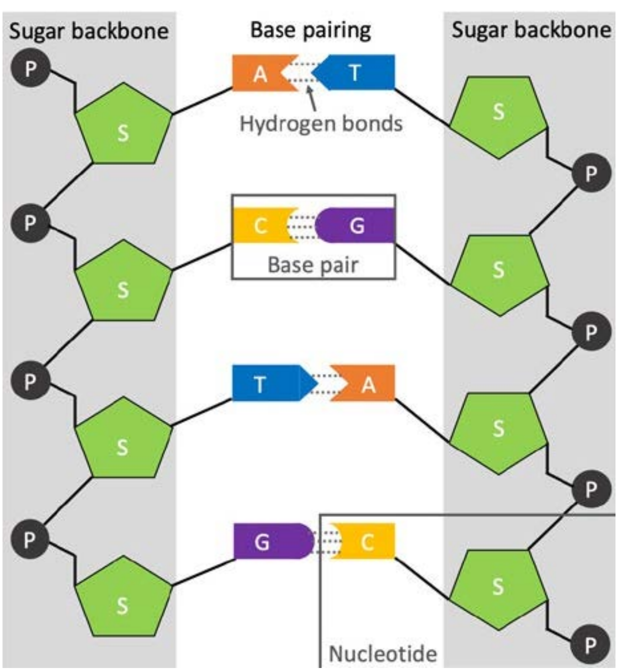
Volunteer Background Information

Volunteer topical information to feel confident with the science concepts in this activity.

Plants, animals, and humans might seem very different from each other, but they are all made up of tiny building blocks called cells, and—with very few exceptions—each of these cells has in its center a molecule encoding the blueprint of the organism. This molecule is called **DNA**: **d**eoxyribo**n**ucleic **a**cid. DNA contains the instructions for how an organism develops, looks and functions. The blueprint for each organism is different—after all, plants, animals, and humans are very different organisms— but the way their instructions are encoded in DNA is identical.

The DNA molecule's unique structure allows it to encode a large amount of information. DNA molecules contain four different kinds of building blocks, called nucleotides. These nucleotides consist of a sugar molecule (deoxyribose), a phosphate group, and a chemical called a nitrogen base. Whereas the sugar molecule and phosphate group are the same in all four types of nucleotides, the bases vary (Figure 1). There are four different bases within a DNA molecule. Their names are cytosine [C], guanine [G], adenine [A], and thymine [T]. In a DNA molecule, the nucleotides are linked together in a long chain.

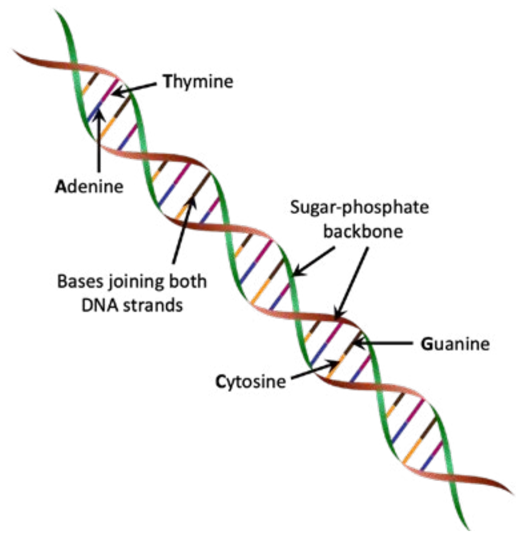
FIGURE 1.



Schematic view of the molecular structure of DNA showing the sugar-phosphate backbone and the base pairing of two complementary DNA strands.

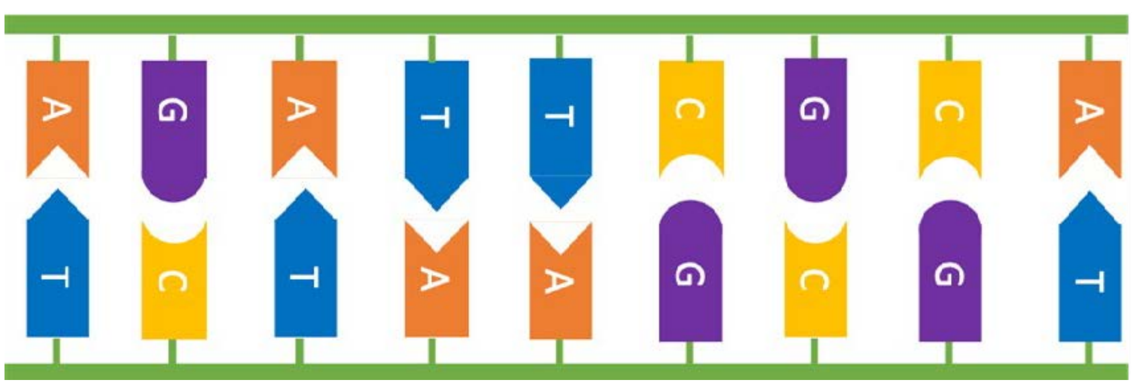
In fact, the DNA molecule is composed of two nucleotide chains that coil around each other to form a double helix (Figure 2). The sugar and phosphate molecules are the backbone of the double helix whereas the bases on each strand link the strands together. The bases join according to the following base pairing rules: adenine [A] only pairs with thymine [T], and guanine [G] only pairs with cytosine [C].

FIGURE 2.
Simplified structure of the DNA double helix showing the sugar-phosphate backbone of each DNA strand and the base pairs linking both strands.



The instructions on how an organism functions are stored in the sequence of nucleotides within a DNA strand. Certain nucleotide sequences encode a gene. A gene such as a protein, codes for a molecule that has a specific function in our body. Due to the base pairing rules, both DNA strands are complementary, which means that both DNA strands store the same biological information (Figure 3).

FIGURE 3. Schematic view of two complementary DNA strands.



This is important for DNA replication, the process of making new DNA molecules. When organisms grow, their cells divide and in almost all cases, each cell receives a duplicate of the DNA molecule. DNA's complementary structure allows for easy replication: each strand of the double helix contains all the information needed to create a new DNA molecule. When both DNA strands separate and the two bases let go of each other, each backbone with its sequence of bases can be the template for a new identical DNA molecule. As A and T always pair up and C and G also always go together, one strand is enough to recreate a new DNA copy.

Further Reading

- Morse Code
- What is DNA?
- Discovery of DNA Structure and Function: Watson and Crick
- The Structure and Function of DNA
- DNA Replication and Causes of Mutation
- DNA replication

Vocabulary

Depending on your students, you might want to introduce some of these terms during the activity.

Adenine: one of the four bases present in a DNA molecule.

Base: a molecule that in aqueous solution releases hydroxide (OH-) ions.

Cytosine: one of the four bases present in a DNA molecule.

DNA: abbreviation for deoxyribonucleic acid, carrier of genetic information in almost every cell.

DNA replication: the process of producing two identical copies of DNA from one DNA molecule.

DNA sequence: the order of nucleotides in a DNA molecule.

Double Helix: the structure formed by double-stranded molecules such as DNA.

Enzyme: a protein that puts molecules together or breaks them apart.

Gene: a DNA sequence that codes for a molecule that has a function such as a protein or enzyme.

Guanine: one of the four bases present in a DNA molecule.

Molecule: a group of two or more atoms held together by chemical bonds.

Mutation: an alteration of the nucleotide sequence within the DNA.

Nucleotide: building blocks of the DNA consisting of a sugar molecule, a phosphate group and a base.

Protein: a large biomolecule that performs a specific function within an organism.

Thymine: one of the four bases present in a DNA molecule.

Real World Relevance

Susceptibility to many human diseases or disorders is an inherited genetic trait, and through study of inheritance patterns in families, the underlying gene variants for many serious genetic diseases have been identified. For example, a deletion in the cystic fibrosis transmembrane conductance regulator gene (CFTR) causes Cystic Fibrosis, and mutations in clotting factor genes cause some forms of Haemophilia. Human genetics plays an important role in Amgen's target discovery and target validation pipeline. In 2012, Amgen acquired deCODE Genetics, a company based in Iceland that uses knowledge of the genetics of the Icelandic population to link variants in the human genome with disease risk. An example of where the linkage of a rare variant to a disease has led to a drug discovery program at Amgen is in the case of TREM2 and Alzheimer's Disease. deCODE Genetics discovered that a rare variant that changes a single amino acid in the TREM2 protein is associated with late-onset Alzheimer's Disease. TREM2 is a receptor expressed on microglial cells in the brain and is critical for clearing degenerated tissue and resolving damage-associated inflammation. Amgen researchers demonstrated that this amino acid changes alters the protein's function, and now TREM2 is being pursued as a novel therapeutic target for the treatment of Alzheimer's Disease.

Materials

Per student group

- Twizzlers (5)
- Soft candy that comes in four different colors such as gummy bears, gum drops or mini marshmallows (15 of each color)
- Toothpicks (20)
- Post-it flags (6)
- Paper
- Pen
- Piece of paper towel
- Sealable bag to hold all the candy
- Scissors
- Printout of the DNA structure provided in the Supplementary Materials

Safety Tip(s)

Before you start the activity, please take note of the following safety tips.

- Remind students to be careful with the toothpicks, so they don't poke themselves or each other.
- Before students eat the candy of their DNA model, make sure they have removed all the toothpicks from the candy.

Prep Work

1. Put four strands of Twizzlers, 15 colored candies of each color, 20 toothpicks and 6 post-it flags in a sealable plastic bag for each group. It might be advisable to have spare candy parts in case students need them.

2. Print out any necessary handouts from the Supplementary Materials.

3. Several days before your class visit, send the teacher these video links and ask that he or she ensure they can be shown in class during your visit. Bookmark the videos, so you can access them quickly in class.
   - DNA Structure
   - The Structure of DNA

Procedure

ENGAGE

1. **Introduce the concept of code to your students. Start by delivering a simple message to your students via Morse code. You can either show the message to your students or signal it to them by tapping with your fingers. An example message that spells “Good morning” is shown below.**

`– – ·   – – –   – – –   – · ·       – –   – – –   · – ·   – ·   · ·   – ·   – – ·`

How do you think these dashes and dots (or the sent signal) contain(s) any useful information?

Listen to student’s replies. Elicit responses that mention how the dashes and dots encode the letters of the alphabet. Then explain to your students that this is a message written in Morse code. The Morse code consists of dashes and dots that represent long and short signals. Different combinations of dots and dashes code for one letter. As you combine the dots and dashes you can write or signal complete messages.

What do you think are codes such as the Morse code useful for?

Have students speculate. Use their replies to explain that codes are used to communicate information from one place or person to another. Morse code allows the communication over long distances using signals and without the need to use actual letters. Another example of a code is a computer code. This code gives the computer instructions on what tasks it needs to perform in what order.

2. **Tell students that there is also a code for life. This code is called the genetic code and contains all the instructions for how a specific organism is built, how it looks or functions.**

3. **Introduce the DNA molecule as the carrier of our genetic information.**

Does anybody know where all our genetic information is stored in our bodies?

Find out what students already know about DNA. Then fill in the gaps and explain that our genetic information is stored in our DNA. The DNA is a large molecule that is found in almost every cell inside our body.

Do you know how the DNA molecule encodes all our genetic information?

Listen to student's replies. Then remind them of the Morse code message that you have shown them before. Tell students that while the Morse code uses only 2 types of signals (dots and dashes), the DNA uses 4 different molecules (nucleotides) to encode information. Similar to how a certain sequence of dots and dashes encode for a specific letter in the Morse code, a specific nucleotide sequence encodes for a specific gene. The nucleotide sequence within a gene contains information on how to build a molecule (protein) that has a specific function in our body. Let your students know that our human DNA contains more than 22,000 different protein encoding genes. Each gene contains the instructions of how to build a specific protein or enzyme.

4 **Introduce the molecular structure of DNA.**

What do you know about the components of a DNA molecule (nucleotides) and its shape?

Again, listen to what students already know. Then use either of these two videos and the images provided in the Supplementary Materials to explain the structure of a DNA molecule.

- DNA Structure
- The Structure of DNA

Make sure students get familiar with each individual component of the DNA molecule (sugar-phosphate backbone, the two individual DNA strands, the four bases, the base pairing, etc.). Also explain the base pairing rules (A pairs with T, G pairs with C). Tell students that our (human) DNA contains about 3 billion of these base pairs. Write every new vocabulary term on the board and define them together with the students.

5 **Tell students that in the activity they are going to do now they will build their own DNA model – and they will use candy to do so!**

EXPLORE PART I: BUILD A DNA MODEL

While students are working, walk around and check in with them. The teacher can help you with that. Listen to their discussions and provide support where needed. Where indicated below, engage students by asking them about their thoughts or observations during the activity. Ask the teacher to help you with making sure every group is building their DNA model correctly.

1. **Divide the class into groups of 2-3 students and provide each group with a bag of materials and a printout of the DNA double helix provided in the Supplementary Materials.**

2. **Ask students to sort their candy into the four different colors. They can work on top of a piece of paper towel to keep the candy clean.**

   What do you think these candy pieces represent in the DNA molecule?

   Why are there four different colors?

   Each of the four colors represent one base within the DNA molecule, adenine [A], guanine [G], cytosine [C] and thymine [T].

3. **Ask the class to assign one of the DNA bases (A, T, C, G) to one of the candy colors. Let the students label the cups respectively. Every group should have assigned the same color to the same base.**

4. **Then have students take the Twizzlers and have them flex the candy in their hands.**

   What do the Twizzlers represent in the DNA molecule?

   The Twizzlers represent the sugar-phosphate backbone of the DNA molecule.

5 **Before building the DNA molecule, ask how students would build a DNA model out of the candy.**

Based on what you know about the DNA molecule so far, how would you build a DNA model out of the different candy that you have in front of you?

Listen to students' ideas. Remind them that a DNA molecule has two chains of nucleotides. Each chain consists of a sugar-phosphate backbone (Twizzlers) and bases. The bases on the two strands link together, following the pairing rules (A pairs with T, and G pairs with C), to form the double stranded DNA molecule.

6 **Have students build their own DNA model based on what they have learned about the structure of DNA and the information on their DNA structure printout. Let them choose the sequence of their DNA molecule themselves. Give students about 5-10 minutes to finish their DNA model. Check in with each group and provide guidance where needed.**

7 **Once all groups are done, make sure every group followed the base pairing rules correctly. Have students describe how their model looks.**

What does your DNA model look like?

At this stage, the DNA model should resemble a ladder as shown in Figure 4.

FIGURE 4. Assembled DNA model.

8 **Instruct students to hold one end of their model flat and flip the other end over (180 degrees). This should create a twist.**

What does the DNA model look like now?

The twisted DNA model now represents the DNA double helix as shown in Figure 5.

FIGURE 5. The twisted DNA model resembles a DNA double helix.

REFLECT PART I: BUILD A DNA MODEL

1. **Have one or two groups briefly present their DNA model to the rest of the class. Ask each group to use the extra toothpicks and post it flags to label the individual components of their DNA model as shown in Figure 6. The components should include each of the four bases adenine, thymine, guanine, cytosine (candy), the sugar-phosphate backbone (Twizzlers) and optionally the hydrogen bonds between the bases that hold both DNA strands together (the toothpick).**

What does each piece of candy in your DNA model represent?

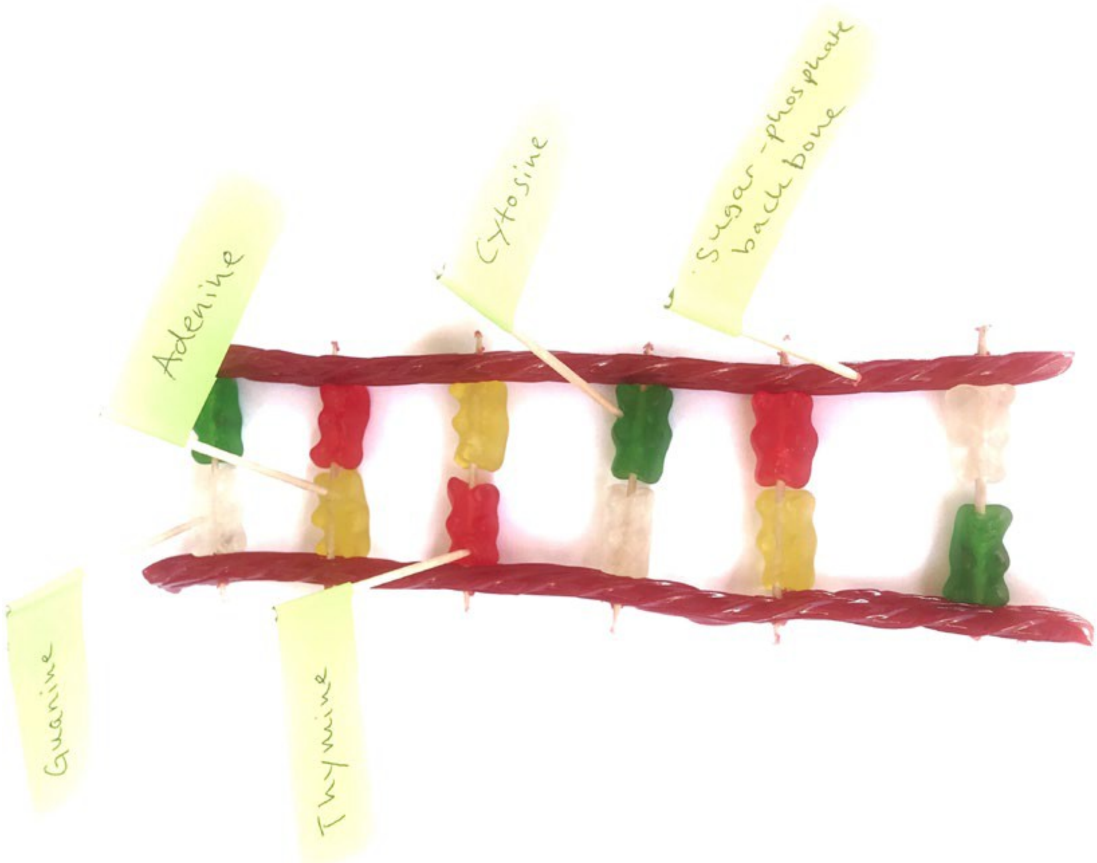


FIGURE 6. Labeled DNA model.

2. **Ask one or two students how they labeled their model and make sure all students understand what the individual components of their DNA model are. You can again write each component on the board for everyone to see.**

3. **Tell students to put their DNA model flat on a piece of paper. Ask them to write the letter of the base (A, T, C, G) next to the respective base on each side of both of their DNA strands (Figure 7).**

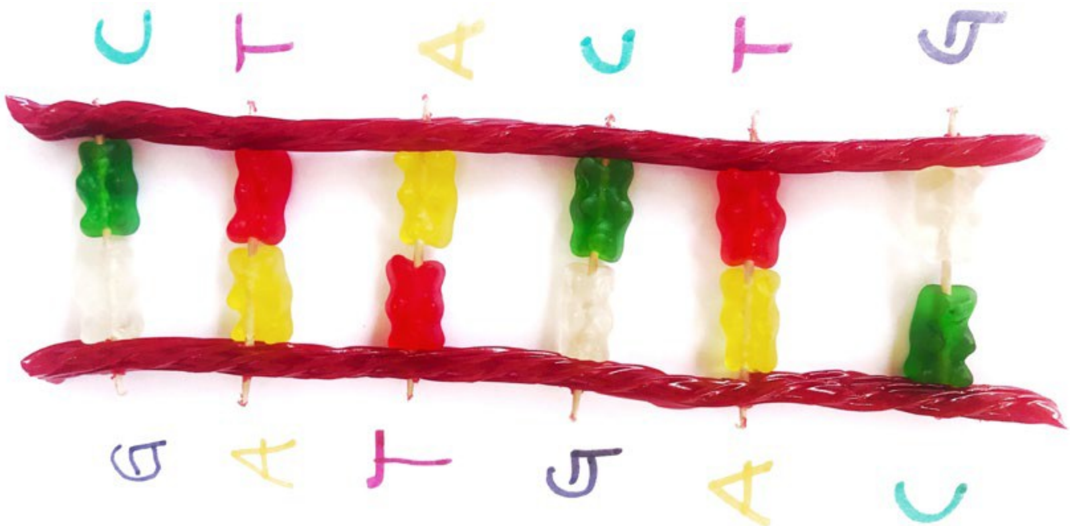


FIGURE 7. DNA model with written DNA sequence.

Each student group should end up with a sequence of 6 different base pairs.

What is this letter sequence called?

Remind students that the order of nucleotides or bases within DNA is called a DNA sequence. Different DNA sequences encode for different genes. Each of these genes encodes for a specific molecule that has a certain function within our body such as proteins or enzymes.

EXPLORE PART II: MODEL DNA REPLICATION

1. **Tell students that our body constantly makes new DNA copies from its existing DNA. When organisms grow, their cells divide and in almost all cases, each cell receives a duplicate of the DNA molecule. This means our body has to constantly make new DNA molecules. This process is called DNA replication (write vocabulary on board). Point out that DNA's complementary structure allows for easy replication: each strand of the double helix contains all the information needed to create a new double stranded DNA molecule. When both DNA strands separate and the two bases let go of each other, each backbone with its sequence of bases can be the template for a new DNA molecule. This is what they are going to do in the following activity.**

2. **Point out to students that the first step of DNA replication is the unzipping of the double-stranded DNA into two single strands. Tell them they will do that by cutting apart their DNA model in the middle, so they have two individual DNA strands (Figure 8). Students might need help with cutting the toothpick in between the two candy pieces or bases.**

FIGURE 8. The double strand of DNA is cut into two single strands.

2. **Tell students that the next step of DNA replication is to use the single DNA strand as a template for building the complementary DNA strand. This is what they will be doing next.**

3. **Ask each group to swap <u>one</u> strand of their DNA model with another group. Each group should now have two single stranded DNAs – one from their original DNA molecule and one from another group's DNA molecule. Have each group work independently to transform both single stranded DNA molecules into two double stranded DNA molecules. Students should use a new toothpick and their remaining candy to build the second strand for each of their single stranded DNA molecules. If they run out of a certain candy color, they should trade with other groups. Again, students should keep the base pairing rules in mind when completing both of their DNA models.**

4. **Give students another 10-15 minutes to complete both of their DNA models.**

5. **Once all groups have completed their models, ask students to swap back their completed DNA models with the same group as before. Each group should get the completed DNA model of their original DNA strand back.**

REFLECT PART II: MODEL DNA REPLICATION

1. **Ask students to compare both of the DNA models that they now have.**

   What do you notice when comparing both of your DNA models?

   How are both models similar or different?

   If students have assembled their DNA model correctly, both of the DNA models should be exactly the same.

   Can you explain why both DNA models are identical?

   The complementary structure of the DNA allows for easy replication of DNA from one single-stranded DNA template. The base pairing rules tell which base needs to be added at what location. This way, and identical DNA double strand is generated consisting of one old strand and one new strand.

2. **Discuss DNA mutations with your students.**

   What do you think would happen if during DNA replication something went wrong and the DNA sequence was messed up, for example by accidently swapping one of the bases?

   Have students share their ideas. Guide them to conclude that any change in the DNA sequence (mutation) would mean that the encoded protein would get messed up as well. This means that the protein won't be able to perform its proper function anymore.

3. **Point out that DNA mutations in many cases have detrimental effects on a human's health. For example, diseases such as cystic fibrosis or sickle cell anemia can result from the substitution of one single nucleotide that occurs in a specific position in a gene. Another disorder, lactose intolerance, has been linked to changes in the DNA sequence that encodes for the lactase gene which is responsible for breaking down milk sugar in our body.**

4 **If applicable, tell your students about related work that you do at Amgen. Then conclude the activity by having students summarize what they did and what they learned about the structure and function of DNA. Ideally, they should leave class with the following knowledge:**

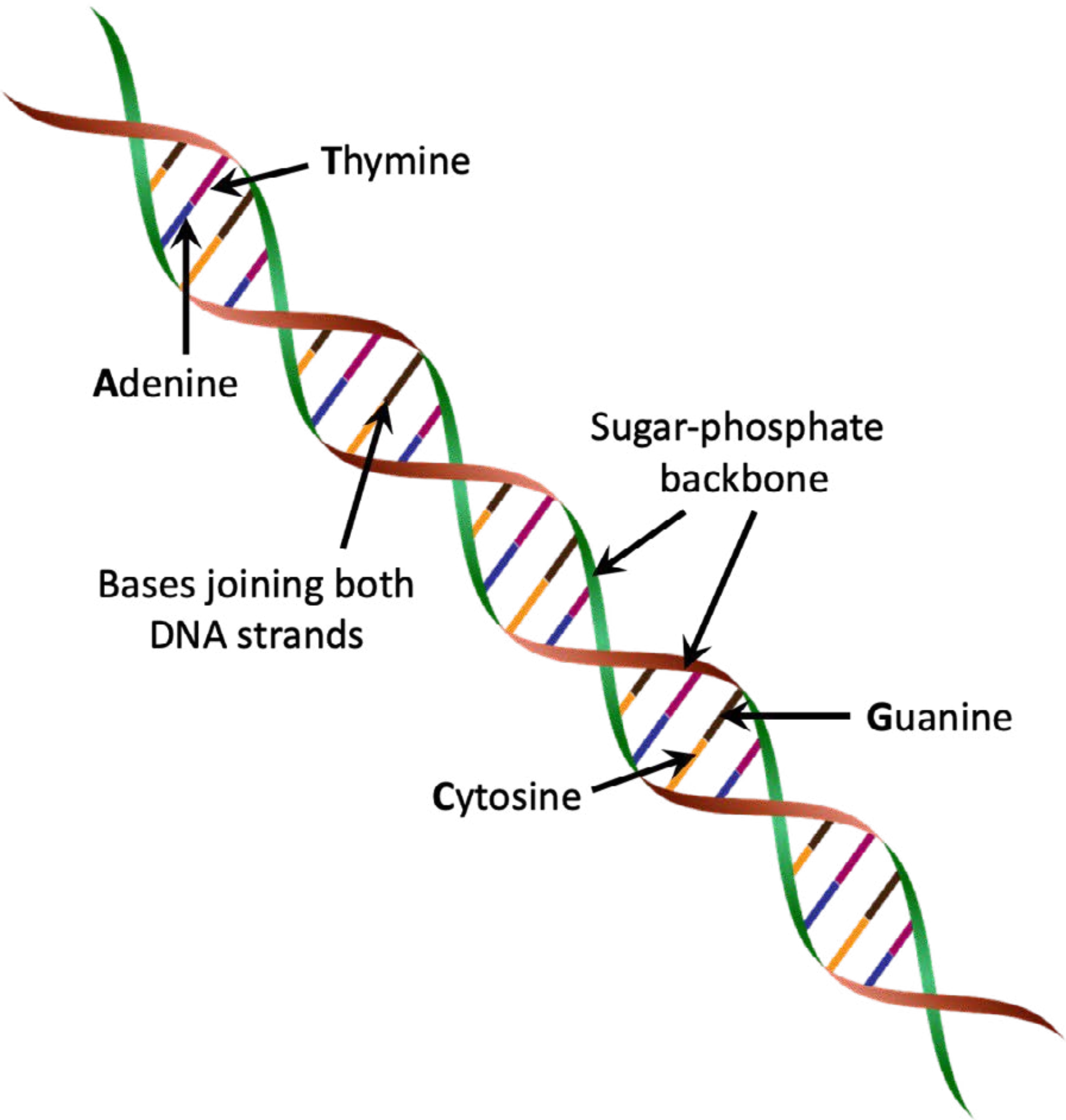
- DNA is the carrier of all our genetic information.
- DNA molecule is composed of two nucleotide chains that coil around each other to form a double helix.
- The main components of a DNA molecule are the sugar-phosphate backbone and the four bases guanine, cytosine, thymine and adenine.
- Within a DNA molecule A always pairs with T, and G always pairs with C.
- DNA is replicated by unzipping the double-stranded DNA and generating a new complementary DNA strand from a single-stranded DNA template (the old strand).
- DNA mutations can cause certain diseases or disorders.

Cleanup

Students can disassemble their DNA model and eat the candy.

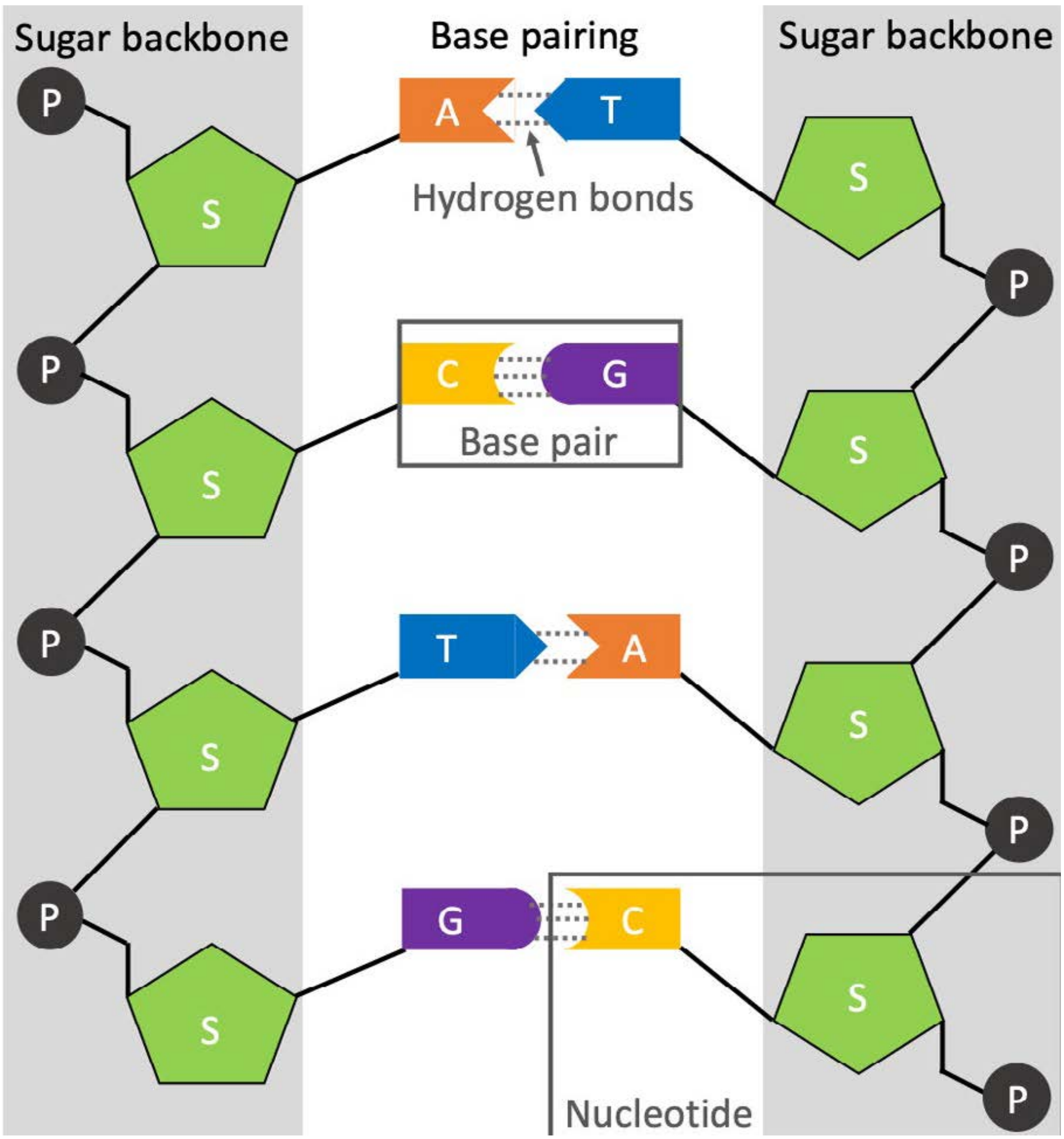
SUPPLEMENTARY MATERIALS

Schematic view of the DNA double helix



SUPPLEMENTARY MATERIALS

Schematic view of the molecular structure of DNA



SUPPLEMENTARY MATERIALS

Schematic view of two complementary DNA strands