LESSON 1: DNA STRUCTURE AND REPLICATION

Lesson Guide
Page 1-13 of DNA /RNA Booklet 1

LEARNING GOALS

The student will be able to…

1. Build a model DNA molecule from the smaller molecules, the nucleotides.
2. Demonstrate the DNA nucleotides that correctly pair together (A-T and C-G).
3. Name the 4 DNA nucleotides: A, T, G, and C. The full names are: adenine, thymine, guanine, and cytosine.
4. Name the three parts of the nucleotide: phosphate, sugar and base. The bases are named above.
5. Demonstrate that a DNA molecule is easily separated into two long strands to indicate how the real DNA strands are easily separated and rejoined by hydrogen bonds.
6. Explain how the words "double helix" refer to the structure of DNA.
   - » Double refers to the 2 strands and helix refers to the spiral shape that both strands assume.
7. Demonstrate how the two DNA strands are oriented in opposite directions by building anti-parallel DNA strands.
   - » On the models, arrows on the bases indicate directionality.
8. Demonstrate that DNA replication is semi-conservative.
   - » The student will produce 2 double helices with one side containing the original DNA strand conserved (saved) in each of the 2 molecules.

VOCABULARY

Additional vocabulary words not in bold:

NOTE ON USAGE

Use the terms **strand** and **chain** in a consistent manner.

- » Use **strand** only for nucleotides e.g. DNA or RNA **strands**.
- » Use **chains** only for proteins e.g. protein chains.

SET UP FOR LESSON 1

1. **Create an exciting DNA molecule to display as the double helix from your teacher DNA kit (#14) before students enter the room.** Make the model at least 12 base pairs long so it will show a nice twist. You will need this model early in the lesson today.
2. **Optimize student work space and set up student teams. Plan ahead on seating two students to a team and have them use the same kit # each day if possible.**
   - » Students should be arranged in teams of two or three. Two is ideal. Avoid threes if you can. It's easier for teams of two to stay focused.
   - » **Seat the partners adjacent to each other.** Teams should be seated on same side of the table next to each other. Both students need to be able to read instructions in the booklet. (Do not let partners sit across the table from each other.)
   - » Students need an **open space in front of them** for building. They also need space for the DNA/RNA kit and the booklet. (Have them clear their belongings.)
3. Photocopy Team Kit Care Record.
4. **Organize the classroom materials.**
   - » Set up a Lost & Found box in the front of the room for easy exchange of extra or missing nucleotides.
   - » Plan a space in the room to put the kit materials, ready to hand out.
   - » Each team for Lesson 1 requires:
     - 1 DNA/RNA kit (with photocopied Kit Check Record paper inside.)
     - 1 DNA/RNA Booklet #1

BEST PRACTICES # 1-4

Remember hands-on teaching is different. It requires a lot more back and forth. There will be periods of time for student hands-on work and times for listening to the teacher. Please Review these Best Practices #1-4 before each DNA lesson.

#1

Direct the students' attention.

- » Students should open the kits only when directed and not beforehand.
- » For lively or large classes, it is helpful to use a hand-bell or other signal so teams will know to when to stop working. (Try it!?) Be sure to wait for silence. Do not let students continue to work.
- » To focus student listening, cue the students for new directions. Say, for example: "Please listen for new directions now. Look at page 7. Each person on your team will build this DNA molecule."

#2

Keep the class together. Compliment good teamwork.

- » Tell students to stop when they finish each activity. Tell quicker teams to double check their work.

#3

Circulate throughout the room to observe and correct building in progress.

- » Students often forget to make DNA strands anti-parallel. Catch this as soon as possible because it takes a lot of valuable time to correct. Each nucleotide must be separated and turned around.
- » Say repeatedly, "Remember to use the pinch technique! Release those hydrogen bonds!"

#4

Check for misconceptions. Ask questions. Also encourage students to ask you questions.

- » Use the yellow-highlighted questions in the booklet during the lesson.
- » Summarize at the end of the lesson. You can select appropriate questions from "Check your Understanding" at the back of the booklet.

LESSON GUIDE: DNA /RNA BOOKLET 1

45 minutes is the minimum time, 55-60 min better

1. LESSON INTRODUCTION

Minimum time: 5 minutes | Total class time spent: 05 minutes

PURPOSE

The teacher's model DNA is used to focus student attention. This initial DNA activity relies both on prior knowledge and on observational skills in this question and answer introduction.

The collective observations made about the model will help summarize DNA structure and connect to prior knowledge.

Also the intro provides an opportunity to:

» Show where the hydrogen bonds are.

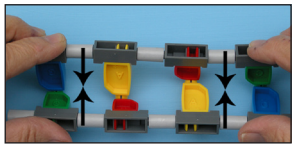
» Demonstrate how to pinch open the model DNA.

» Show the two strands.

BOOKLET PAGES

N/A: Introduction happens before the booklet is introduced.

Teacher holding up double helix



Pinch technique

DIRECTIONS

Students make observations about the teacher's model of the DNA double helix:

☞ **Demonstrate the DNA twist.**

Q: Why is it called a double helix?

A: Clarify that "helix" means a spiral or coiled shape.

☞ **Demonstrate how the DNA has two separate strands and is "double."**

» Show how to pinch the DNA apart!

» Demonstrate this while holding it up vertically and pinching the top few nucleotides. Point out the separated two strands.

» Mention ALL students will need to know how to do this. Demonstrate how they will separate the strands using the pinch technique with the DNA on a table.

☞ **Put the strands back together on the table. Hold it up again.**

» Point out the sugar-phosphate backbone. This looks and works like a backbone.

» Point out the bases that reach across the strands to the other backbone.

» Remove one nucleotide to show that the complicated molecule is made of repeating units. The units are called nucleotides.

MEDIA

Teacher Training Video Introduction- DNA Molecule. Video to com

Teacher Training Video The pinch-Show how. Video to come

2. KIT CHECK

Minimum time 7 min | Total class time spent: 12 minutes

PURPOSE

Explain the use of the booklet before opening the kits. There will be better focus on the booklet, this way. Teach P2 and P3. Secondly, teach how to perform and record the team kit check. It will become a regular class routine. Note if teams work efficiently together, they will have more time for building.

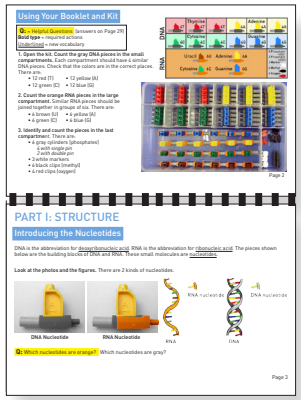
» Teams verify contents.

» Teams check kits at beginning of each lesson.

» Teams will be checking the previous team's use, not their own.

BOOKLET PAGES

2-3



DIRECTIONS

☞ **Hand out booklets and kits. (Keep kits closed.) Open the booklets to P2 and 3.**

» Show how to keep both top and bottom pages visible. Tell teams to use the booklet in this way.

» Point out on P2 the info in the text box on how to use the booklet:

- yellow highlight = question to answer
- **bold type** = required action, Do this! (Directions for building are bold, for example.)
- underline = new vocabulary word

☞ **Point out on P3 that there are two kinds of nucleotides, DNA and RNA in the kit.**

Q: What color is RNA?

A: 'R'–ange. Teachers says it like a pun on the word or'ange.

Easy to remember! Note DNA is the double helix, RNA is single.

Now have them open kits.

» Explain use of the Team Kit Care Record.. Read the instructions on the Kit Check papers to the students. Be sure they take this responsibility seriously.

» Check kit contents using the diagram on P2 or the kit's inner label.

» Announce and show the Lost & Found Box for any extra piece found in their kits.

MEDIA

PDF
Team Kit Care Record

3. INTRODUCTION TO NUCLEOTIDES

Minimum time 10 min | Total class time spent: 22 minutes

PURPOSE

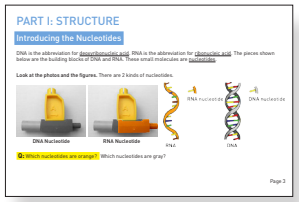
Get the models into their hands!

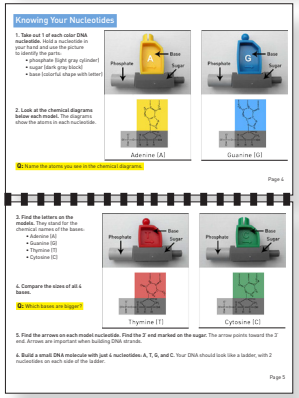
With tactile reinforcement with the models, students will learn

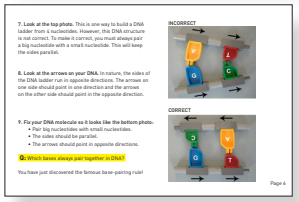
» the difference between DNA and RNA,
» the three parts of a nucleotide, and
» the 4 different kinds of DNA nucleotides.

BOOKLET PAGES

3, 4-5, 6


PART I: STRUCTURE
Introducing the Nucleotides


Knowing Your Nucleotides



DIRECTIONS

Emphasize the distinction between nucleotides: DNA=gray; RNA= orange. Tell students they will not be using the orange RNA today! Students learn three parts of nucleotide (base, sugar, phosphate).

The base is what makes a nucleotide unique.

☞ **Do a very quick drill. Ask the class to hold up their nucleotide by the individual part you will name. Hold it by the phosphate group. Hold it by the base. Hold it by the sugar.**

» Name some atoms in the nucleotide? This reinforces that the model represents a molecule. Have students look at the figures.

Q: Which two bases are bigger? Look at your models!

A: A & G

☞ **Discuss the differences in sizes of the bases in the model and in th chemical structure in booklet. Discuss at appropriate grade level. Example question:**

Q: Look at the chemical structure. Can you see why A&G are bigger?

A: There are more atoms or two ring structures on A & G while there is only one ring on T and C.

Q: What might the dotted lines represent?

A: Hydrogen bonds

Q. How many hydrogen bonds are there on each base?

A: Two for A & T and three for G & G

Explain the objective of the exploratory task very clearly. Step 6 on P5.

» Try to make a ladder shape with these 4 nucleotides.
» Your ladder should have 2 "steps" and 2 nucleotides on each side.

MEDIA

Teacher Training Video #3 Lead the class-Intro to nucleotides. Video to come

3. INTRODUCTION TO NUCLEOTIDES (CONT'D)

Minimum time 10 min | Total class time spent: 22 minutes

PURPOSE

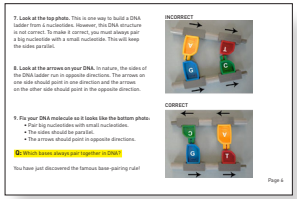
Let students explore base pairing.

» Encourage students to try different ways to do this.

» Teach the directionality of DNA strands last.

BOOKLET PAGES

3, 4-5, 6


7. Look at the top photo. This is one way to build a DNA ladder from 4 nucleotides. However, this DNA structure is not correct. To make it correct, you must always pair a big nucleotide with a small nucleotide. This will keep the sides parallel.

8. Look at the arrows on your DNA. In nature, the sides of the DNA ladder run in opposite directions. The arrows on one side should point in one direction and the arrows on the other side should point in the opposite direction.

9. Fix your DNA molecule so it looks like the bottom photo.
- Pair big nucleotides with small nucleotides.
- The sides should be parallel.
- The arrows should point in opposite directions.

Q: Which bases always pair together in DNA?

You have just discovered the famous base-pairing rule!

INCORRECT

CORRECT

Page 4

DIRECTIONS (CONT'D)

☞ **Give students some time to explore building a small DNA molecule with 4 nucleotides.**

Tell them you will now give them some guidance about the base pairs.

☞ **Hold up all 4 nucleotides attached end to end in one strand.**

Q: What's wrong?

A: It is not a ladder shape. Surprisingly, students do build this !

☞ **Hold up the "wrong" base pairing as shown on P6, pairing two big nucleotides and two little nucleotides together.**

Q: What's wrong with this ladder?

A: The sides are not parallel. The nucleotides can not be added onto it. Explain that a big and little nucleotide paired together make the right width and will keep the sides parallel.

☞ **Hold up the correct DNA model.**

☞ **Next, explain DNA directionality with the correct model.**

» The sides are like a two-way street. Use your hands to illustrate a two-way street.

» Arrows should align in opposite directions on the DNA strands. Point to the arrows on the nucleotide model.

» Have students correct their own model now if needed.

For high school level or above:
Explain directionality by introducing the term 3 prime (3'). It is marked on one end of the gray sugar. Teach this saying: "The 3 is free." Explain: The 3' end is free of phosphate (gray cylinder). The other end of the sugar is the 5' end and it has the phosphate. The 3' end is free of phosphate (gray cylinder). The other end of the sugar is the 5' end and it has the phosphate.

MEDIA

Teacher Training Video #3 Lead the class- Discover the base pairs. Video to come

4. BUILDING A DOUBLE HELIX

Minimum time 5 min | Total class time spent: 27 minutes

PURPOSE

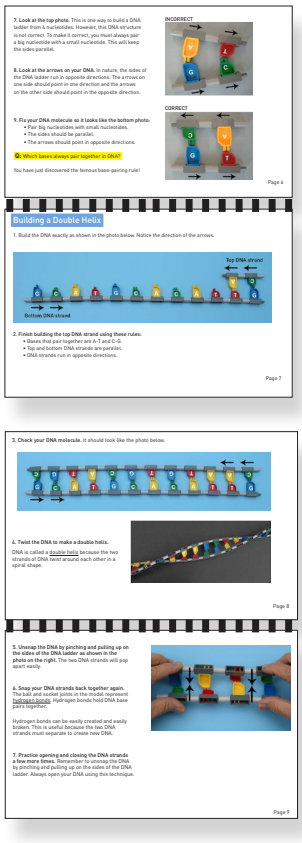
Make models of the DNA double helix.

Reinforce opposite directionality of strands and base pairing rules.

Learn about hydrogen bonds. Practice pinching open the DNA correctly and snapping it back together on the table. This physical and repetitive activity helps students recognize that hydrogen bonds come apart and go back together very easily.

BOOKLET PAGES

6-7, 8-9



DIRECTIONS

▶ **Optional Demo Video #4:** You can play it before or after building.

☞ **You will need to explain very clearly: Say "Listen to these instructions. Each person builds their own molecule! Each kit will produce two DNA molecules."**

- » Watch for strand directionality with arrows! The two strands should be pointed in opposite directions.
- » When completed, students should pick up and practice twisting the DNA model into a helix.
- » **Very important**: Have each student practice opening and closing the strands at least three times now using the "pinch and lift" technique. Explain this action represents *hydrogen bonding* between the bases. This bond is very weak, easily broken, and easily reformed in nature.
- » Remind students the pinch is the method they will always use in opening up the strands. They will also use this method when putting away the strands

For high school level or above ask:

Q. When does DNA need to open up?

A. For replication, transcription and repair.

MEDIA

Demonstration Video: Building the double helix. Video to come

Stop Motion Video #4 Building the double helix. Video to come

Teacher Training Video Hydrogen bonds- Holding the two DNA strands together. Video to come

5. REPLICATION

Minimum time 10 min | Total class time spent: 37 minutes

PURPOSE

The students will experience basic replication and practice base pairing.

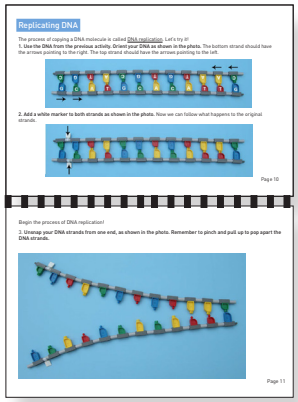
Students should see for themselves why replication is semi-conservative: one side of each molecule contains an original DNA strand. This is a key concept.

This exercise can dispel the misconception that DNA replication produces an entirely new copy from the original double helix.

This exercise also provides a repetitive, kinesthetic activity to help students learn their base pairs.

BOOKLET PAGES

10-11, 12-13


Replicating DNA

The process of copying a DNA molecule is called DNA replication. Let's try it!

1. Use the DNA from the previous activity. Orient your DNA as shown in the photo. The bottom strand should have the arrows pointing to the right. The top strand should have the arrows pointing to the left.

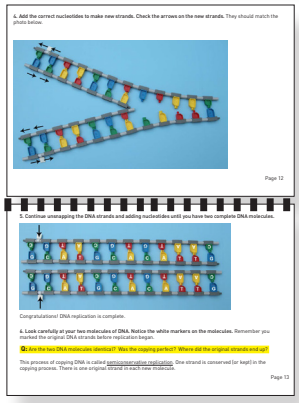
2. Add a white marker to both strands as shown in the photo. Now we can follow what happens to the original strands.

Page 10

Begin the process of DNA replication!

3. Unwrap your DNA strands from one end, as shown in the photo. Remember to pinch and pull up to pop apart the DNA strands.

Page 11


4. Add the correct nucleotides to make new strands. Check the arrows on the new strands. They should match the photo below.

Page 12

5. Continue unwrapping the DNA strands and adding nucleotides until you have two complete DNA molecules.

Congratulations! DNA replication is complete.

6. Look carefully at your two molecules of DNA. Notice the white markers on the molecules. Remember you marked the original DNA strands before replication began.

Q: Are the two DNA molecules identical? Was the copying perfect? Where did the original strands end up?

This process of copying DNA is called semiconservative replication. One strand is conserved (or kept) in the copying process. There is one original strand in each new molecule.

Page 13

DIRECTIONS

The teacher will need to direct a "take apart" step now. Teams need instruction on how to transition from one activity to another.

☞ **Tell students to keep one DNA molecule per kit. Ask them to take apart the other molecule. Remind them to pinch and separate all the nucleotides. They will need their individual nucleotides for replication.**

▶ **Demonstration Video #5 Replication:** Show prior to building

» Teams should follow instructions on P 10-13. Teams replicate their double stranded DNA.

» Check to make sure students mark the original strands with the two white markers! They will need to discover where these strands go in this process.

» Again, circulate! Check all the teams for strand directionality right away! The teams can lose a lot of time if they do this wrong. They will need to take apart the whole strand and turn each nucleotide around.

» When students finish, emphasize the idea of semi-conservative replication and how it works to make perfect copies..

» Point out that white markers were put on the DNA to track where the 2 strands went. At the end of the building session, ask:

Q. Where are the white markers located now?

A. The white markers were placed on the original DNA molecule. Now each of the new molecules has one of the original strands! That is why this process of replication is called semi conservative. "Semi" means "partly" or "half." And "to conserve" means "to save."

MEDIA

Teacher Training Video #8 Class time saver – Quick transition to replication. Video to come

Demonstration Video #5 Replication-The basic version. Video to come

Teacher Training Video #9 Summarize replication. Key concept - The process is semi-conservative. Video to come

6. ADDITIONAL CONNECTIONS

Minimum time 5 min | Total class time spent: 42 min)

PURPOSE	BOOKLET PAGES	DIRECTIONS	MEDIA
Summarize and connect DNA replication to the cell process of mitosis. Refer back to any previous teaching about cell division or cell cycle like mitosis. This is an opportunity to make the lesson more meaningful by connecting to prior knowledge.	N/A	**Remind students DNA replication occurs before mitosis (cell division) happens. The cell needs to have enough DNA for 2 cells before it begins to split into 2 cells.** For high school level or above: Be sure to connect the DNA replication process with the cell cycle diagram. Show the diagram to make the connection.	N/A

7. CLEAN UP

Minimum time 3 min |Total class time spent: 45 minutes

PURPOSE	BOOKLET PAGES	DIRECTIONS	MEDIA
Set aside time for clean up. Students return models to the correct compartments inside the kit. Students take responsibility for this.	N/A	**Ask students to put away all model nucleotides.** » Remind students to pinch to create two strands before taking the DNA apart. » Remind students that the Lost and Found box up front is for extra or missing pieces. » Ask students to return kits & booklets.	N/A

8. ADDITIONAL SUMMARY / REVIEW OR HOMEWORK OPTION

Use questions 1-5 on page 28 to check understanding.

LESSON 2: INTRODUCTION TO GENES AND DECODING DNA

Lesson Guide
Page 14-21 of DNA /RNA Booklet 1

LEARNING GOALS

The student will be able to…

1. Describe and build a DNA codon as a sequence of 3 nucleotides, indicating a specific amino acid.
2. Describe why DNA is an important molecule. DNA stores the codes/instructions for making proteins.
3. Build and decode a gene, a sequence of DNA nucleotides that specifies the order of the amino acids in a protein chain.
   - » Novice students can utilize a DNA Codon Chart in the booklet (P21) to decode the DNA codons. This chart needs no instruction.
   - » Advanced students can utilize the RNA Codon Charts (p26 or P27). (RNA Charts require instruction. Not all students find them easy to interpret.)
4. Build and decode a gene where one nucleotide has been changed and a different protein will be produced.
5. Build and decode a gene where one nucleotide has been changed but in this case a different protein will not be produced. It remains the same. Mistakes in the DNA do not always create a new protein.
6. Demonstrate a short chromosome by adding two or more genes end to end.
7. Describe a genome as all the genes needed to produce a living organism.

VOCABULARY

NOTES ABOUT VOCABULARY

Vocabulary on P17 can be introductory for students in the middle school grades. It is not included on most state's middle school science standards.

Use the terms **strand** and **chain** in a consistent manner.

- » Use **strand** only for nucleotides e.g. DNA or RNA **strands**.
- » Use **chains** only for proteins e.g. protein chains.

SET UP FOR LESSON 2

1. **Create a DNA molecule** from your teacher DNA kit (#14) beforehand. Make the model at least 12 base pairs long for a good twist. You will need this model to review Lesson 1 at the beginning of class.
2. **Optimize student work space. Plan ahead on seating two students to a team and have them use the same kit # each day if possible. Remember the following:**
   - » **Seat the partners adjacent to each other.** Students share materials. Both students need to read instructions in the booklet and have access to the kit. Do not let partners sit across the table.
   - » **Have students clear the table of books and personal items before building!** Today they will need space to work with a DNA/RNA kit, a booklet, and a gene strip 36 inches long.
3. **Organize the classroom materials.**
   - » Put a Lost & Found box in the same place for easy exchange of extra or missing nucleotides.
   - » Keep a space in the room where the kit materials are accessible. Today each team for Lesson 2 will require:
     - **1 DNA/RNA kit** (The Kit Care Record remains folded up inside.)
     - **1 DNA/RNA Booklet #1**
     - **1 Gene Strip** per team. Make sure one of each kind of gene is represented in the room: alpha, alpha mutated, beta, beta mutated.
     - **1 Codon Card pack**. Always have the students shuffle the 12 cards before returning them to the bag. One pack has:
     - 6 Yellow: Cys, Met, Pro,Val, Leu, Ala
     - 3 Green: Ser, Gln, Thr
     - 1 Blue: Arg
     - 1 Red: Glu
     - 1 Stop

BEST PRACTICES # 1-4

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#1

Direct the students' attention.

- » Students should open the kits only when directed and not beforehand.
- » For lively or large classes, it is helpful to use a hand-bell or other signal so teams will know to when to stop working. (Try it!?) Be sure to wait for silence. Do not let students continue to work.
- » To focus student listening, cue the students for new directions. Say, for example: "Please listen for new directions now. Look at page 7. Each person on your team will build this DNA molecule."

#2

Keep the class together. Compliment good teamwork.

- » Tell students to stop when they finish each activity. Tell quicker teams to double check their work.

#3

Circulate throughout the room to observe and correct building in progress.

- » Students often forget to make DNA strands anti-parallel. Catch this as soon as possible because it takes a lot of valuable time to correct. Each nucleotide must be separated and turned around.
- » Say repeatedly, "Remember to use the pinch technique! Release those hydrogen bonds!"

#4

Check for misconceptions. Ask questions. Also encourage students to ask you questions.

- » Use the yellow-highlighted questions in the booklet during the lesson.
- » Summarize at the end of the lesson. You can select appropriate questions from "Check your Understanding" at the back of the booklet.

LESSON GUIDE: DNA /RNA BOOKLET 1

45 minutes is the minimum time, 55-60 min better

1. REVIEW OF PREVIOUS LESSON

Minimum time: 3 minutes | Total class time spent: 03

PURPOSE

Use the DNA model to focus the students' attention for a review exercise and to refresh students' memory on the vocabulary and content of Lesson 1. This review helps students who were absent to catch up and gives other students practice in recalling the recently acquired knowledge.

BOOKLET PAGES

N/A
Review

DESCRIPTION

☞ **Hold up the model of DNA to focus students' attention and to help students recall the structural information. Review Lesson 1 vocabulary to be ready to move on.**

In this review, either 1. Create an atmosphere of a snappy or rapid fire question /answer activity over the following vocabulary and content; or 2. Have students raise their hands and provide some 'wait time' before choosing a student to answer. The latter method encourages more students to think about the questions. Letting students immediately call out denies some students the opportunity to reflect and participate.

Q: Why is this called a double helix?

Q: What are parts of a nucleotide?

Q: What are base pairing rules (A-T) and (C-G)

Optional: How can you remember this? (Example: A &T are straight-sided letters. C & G are curvy letters.)

Q: How should we open up the DNA strands? What is the name of the weak bond?

Q: What is the name of the process where DNA makes a complete copy of itself?

A: Replication

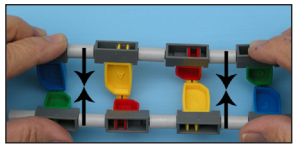
Q: When does the cell need to have double its normal amount of DNA?

A: Before the cell divides into two cells. (..before mitosis because each cell needs its own DNA)

MEDIA

N/A
Introduction

Teacher holding up double helix



Pinch technique

2. KIT CHECK

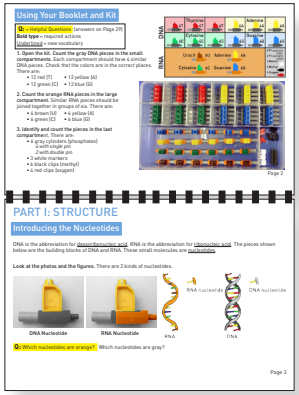
Minimum time 7 min | *Total class time spent: 12 minutes*

PURPOSE

Teams verify kit contents. The kit check is competed prior to the start to ensure that the lesson won't be interrupted by a missing piece. Teams will be checking the previous team's use, not their own.

BOOKLET PAGES

2-3


Using Your Booklet and Kit

PART I: STRUCTURE

Introducing the Nucleotides

DIRECTIONS

☞ **Hand out materials or have one student from the team pick up their own kit # and booklet. Remind students to keep both top and bottom pages visible.**

Have students open kits.

» Student teams now check kit contents using the diagram on p 2 or the kit's inner label.

» Teams complete "Team Kit Care Record".

» Mention the location of the Lost & Found Box for any extra piece found in the kits.

MEDIA

PDF
Team Kit Care Record

3. CELL DIAGRAM

Minimum time 3 min | Total class time spent: 13 minutes

PURPOSE

Help students recognize size relationships of cell to molecules.

Connect the DNA model with prior knowledge about the nucleus and chromosomes. Add the new vocabulary word gene.

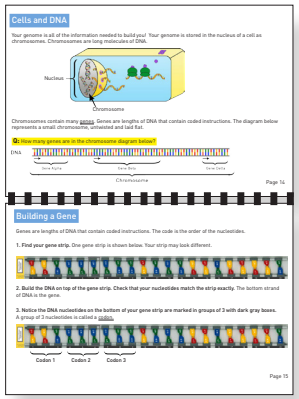
Reminders

» Keep this part of the lesson short. Students will need time to work with the model.

» The full new list of DNA vocabulary will be summarized on p 16.

» DNA vocabulary will also be reviewed for the student with a catchy stop action video.

PAGES: 14-15



DIRECTIONS

Begin the lesson. Ask students to turn to P14.

» Note: Don't get into details of protein synthesis steps yet. These steps are provided later on 17.

» Use the diagram (P14) to put the DNA models into context inside the cell.

» The diagram shows that cells are made up of molecules and that molecules are smaller.

» The point here is to help students recognize that chromosomes and genes are located inside the nucleus.

Q: To create focus, ask, "What parts of the cell are labeled in the diagram?"

A: Nucleus, chromosome.

Optional: See if students can interpret the diagram. Mention "DNA stays locked up in the nucleus." Ask, "What about the mRNA? (Review the distinction between nucleotides if needed: DNA = gray, RNA = orange in the diagram.) The orange mRNA is leaving the nucleus shown through a pore in the diagram.

Now look at the diagram of a chromosome below the yellow highlighted question and ask.

Q: What is a gene?"

A: A gene is length of DNA containing coded instructions.

You may want to add that a chromosome contains many genes joined together, end to end. In reality, one chromosome can contain 100s to 1,000s of genes. The diagram has been simplified greatly and only shows 3 genes. You can explain that the name "alpha," "beta," and "delta" are not specific and are often used in biology as general names.

Next the students will build a gene.

MEDIA

Demonstration Video
How to do gene strips
Video to come

4. BUILDING A GENE AND SUMMARIZING DNA VOCABULARY

Minimum time 10 min | Total class time spent: 23 minutes

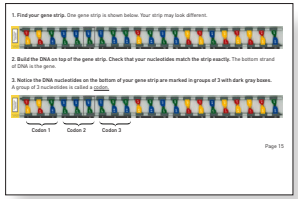
PURPOSE

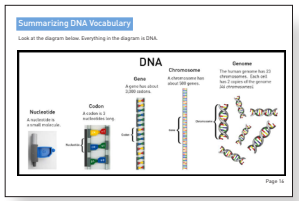
Students create hands-on models to help define genes as messages in the DNA.

This activity helps to set the stage to teach about DNA function. Students will discover a key concept. Changes in the nucleotide order can affect the proteins that the cell will produce.

BOOKLET PAGES

15-16





DIRECTIONS

Announce to students,"We are moving on to P 15." Explain what is next.

"You can see from the booklet that each team will build a gene from the DNA nucleotides. Remember that genes are coded messages. The code is formed by the order of the nucleotides."

"To make the coding interesting, different teams are getting different genes to build. Your team will need to build the gene very carefully. That is why I am handing out these gene strips."

Cue students about building: "Listen to these specific building instructions: To make the gene correctly, you should place each nucleotide on top of its picture. Double check your work, too! Remember to be careful with the arrows. Any questions? You may begin."

☞ **Hand out gene strips.** Make sure to hand out least 1 alpha, 1 alpha mutated, 1 beta, and 1 beta mutated. You will need all 4 strips of genes, built to teach the class in the next activity.

As students are finishing up, have them quickly double check by comparing their work with the gene strips. Call attention to the black bars on the bottom of the gene strip.

Q: How many nucleotides are there in each group?

A: (3) A group of 3 nucleotides is called codon. The codons are important. They instruct the cell how to make a protein.

Q: How many codons do you have in your gene?

A: All the gene strips are 7 codons long.

Summarize the DNA vocabulary by asking questions about the diagram on P16. Begin with the nucleotide on the left. Use the video as a review activity for students.

» The genome includes all DNA instructions needed to create an organism. Specifically, the genome includes one chromosome from each pair of chromosomes since the second is redundant.

MEDIA

Teacher Training Video
Building different genes using the gene strips.
Video to come

5. THE IMPORTANCE OF DNA

Minimum time 4 min | *Total class time spent: 27 minutes*

PURPOSE

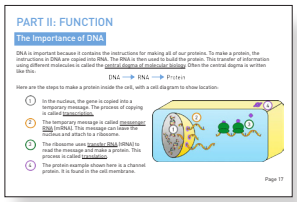
Emphasize that DNA is important because DNA carries the information for building proteins.

The purpose of this page is to point out that there are many steps to making a protein from the DNA. For example, the codes must be copied into RNA and must leave the nucleus.

Make it clear that the class is not going to do all these steps right now. Instead the task will be to learn how to read the DNA coding system.

BOOKLET PAGES

17


PART II: FUNCTION

The Importance of DNA

DNA is important because it contains the instructions for making all of our proteins. To make a protein, the instructions in DNA are copied into RNA. The RNA is then used to build the protein. This transfer of information using different molecules is called the central dogma of molecular biology. When the central dogma is written like this:

DNA → RNA → Protein

Here are the steps to make a protein inside the cell, with a cell diagram to show location.

1. In the nucleus, the gene is copied into a temporary message. The process of copying is called transcription.
2. The temporary message is called messenger RNA (mRNA). This message can leave the nucleus and attach to a ribosome.
3. The ribosome uses transfer RNA (tRNA) to read the message and make a protein. This process is called translation.
4. The protein example shown here is a channel protein. It is found in the cell membrane.

Page 17

DIRECTIONS

This should be an overview. Introduce the idea that information is transferred from DNA to RNA to protein. These steps are referred to as the central dogma of molecular biology.

» Read through the steps of protein synthesis and review where they take place in the cell.

» Tell students they will model this process later!

Right now they will learn how to decode the instructions in their gene for making a protein.

MEDIA

Demonstration Video #4
Building the double helix
Building a gene on top of the strip and decoding.
Video to come

6. DECODING A GENE

Minimum time 7 min | *Total class time spent: 34 minutes*

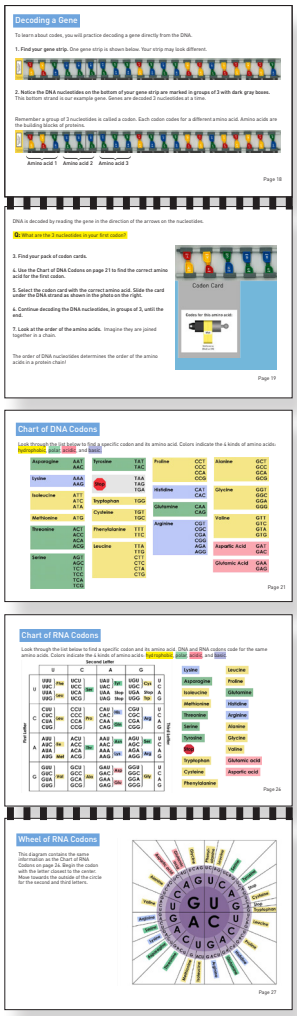
PURPOSE

Teach how to decode a gene from the DNA codons and visualize the protein chain the gene can create.

Learning about the triplet code concept prior to translation on the ribosome is advantageous. It reduces translation complexity. However be sure no student takes this activity literally. (Amino acids are not assembled on the DNA strand!) Also help the students appreciate that they are reading nature's amazing code. This code is universally used by all living things like plants, animals, and bacteria.

BOOKLET PAGES

18-19, 21, 26-27



DIRECTIONS

☞ Hand out the Codon Card packs, one to each team.

Lead the class, keeping them all together with you. Decode the first DNA codon together as a class so that every team will have experienced success on how to decode and can then do the rest on their own.

Q: What do you have for the first three nucleotides in your gene?

A: (ATG)

Q: Does everyone have a first codon that reads ATG?

A: Yes. All gene strips have ATG as the first codon. ATG is the start codon for making proteins.

"**OK. Let's look up the codon and see what it means on P21**.

Q: Can you find ATG?

Q: What is the name of the amino acid that goes with ATG?

A: Scan down the 3 letter codes and find Methionine. It is yellow.

» For novice DNA students, use the DNA reference chart for amino acids P21.

» There is a huge advantage in using this DNA chart although it may be unfamiliar to you. A teacher does not have to interrupt the flow of learning to teach students how to interpret this codon chart. The students just search with their eyes. No training necessary! (Use it, it works!)

» For students already familiar with RNA charts, instruct them to use references on p 26 (or 27) Chart of RNA Codons. Students will need to know to substitute U for T and follow the different charts' look-up procedures.

"**So we now know the 'ATG' codon in DNA always means place a Methionine molecule here in the protein chain. Let's show that with our codon cards.**"

MEDIA

Teacher Training Video #3
Decoding a gene
Video to come

Demonstration Video
Decoding a gne
Video to come

6. DECODING A GENE (CONT'D)

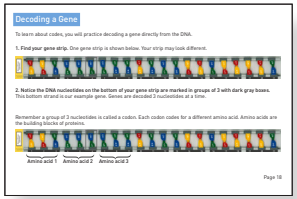
Minimum time 7 min | Total class time spent: 34 minutes

PURPOSE

See previous page

BOOKLET PAGES

19-


Decoding a Gene

To learn about codes, you will practice decoding a gene directly from the DNA.

1. Find your gene strip. One gene strip is shown below. Your strip may look different.

2. Notice the DNA nucleotides on the bottom of your gene strip are marked in groups of 3 with dark gray boxes.
This bottom strand is our example gene. Genes are decoded 3 nucleotides at a time.

Remember a group of 3 nucleotides is called a codon. Each codon codes for a different amino acid. Amino acids are the building blocks of proteins.

Amino acid 1 Amino acid 2 Amino acid 3

Page 18

DIRECTIONS CONT'D

☞ **Find the Codon Card in your pack with the picture of an amino acid called Methionine or Met. Slide the card under the gene strip. Position it exactly under the first codon, the black bar with the nucleotides 1-2-3. "**

☞ **Instructors should show the Met Codon Card. Demonstrate sliding the Codon Card under the gene strip at the first codon position. Make sure to mention that the amino acid's picture should remain visible. This is because when all cards are in position , the cards will be used will show the order of the amino acids in the protein.**

» Be sure to explain the Codon Cards use as shown the training videos. Students should understand they are translating a code and the cards only show the meaning of the code. Be clear, the DNA does not do this. There is a long process for making proteins as shown on P17 in the booklet that they will learn later.

» Tell students to continue and decode the rest of the gene.

» Circulate around the room to help teams place the cards correctly. When all the teams are ready, then the instructor will guide the students in interpreting the results.

MEDIA

Teacher Training Video #3
Decoding a gene
Video to come

Demonstration Video
Decoding a gne
Video to come

7. GENES FOR DIFFERENT PROTEINS

Minimum time 5 min | *Total class time spent: 39 minutes*

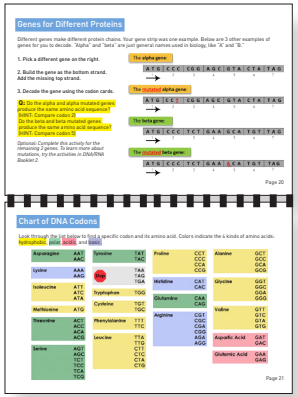
PURPOSE

NOTICE! Ignore the instructions on P20 that call for building 3 additional genes! In the classroom setting, all 4 genes have been built by the student teams. You will call on different teams to illustrate the lesson. (P20 contains information needed for the independent learner who must complete all 4 genes to learn this content.)

» Help students to interpret this activity with the normal and mutated genes they have decoded.

BOOKLET PAGES

20-21


Genes for Different Proteins

Different genes make different protein chains. Your gene strip was one example. Below are 3 other examples of genes for you to decode. "Alpha" and "beta" are just general names used in biology, like "A" and "B."

1. Pick a different gene on the right.
2. Build the gene as the bottom strand. Add the missing top strand.
3. Decode the gene using the codon cards.

Q: Do the alpha and alpha mutated genes produce the same amino acid sequence? (HINT: Compare codon 2)
Do the beta and beta mutated genes produce the same amino acid sequence? (HINT: Compare codon 5)

Optional: Complete this activity for the remaining genes. For more information on mutations, try the activities in DNA/RNA Booklet 2.

The alpha gene
A T G | C C C | C G G | A G C | G T A | C T A | T A G

The mutated alpha gene
A T G | C C | C G G | A G C | G T A | C T A | T A G

The beta gene
A T G | C C C | T C T | G A A | G C A | T G T | T A G

The mutated beta gene
A T G | C C C | T C T | G A A | C A | T G T | T A G

Page 20

Chart of DNA Codons

Look through the list below to find a specific codon and its amino acid. Colors indicate the 4 kinds of amino acids: hydrophobic, polar, acidic, and basic.

Asparagine	AAT AAC	Tyrosine	TAT TAC	Proline	CCT CCC CCA CCG	Alanine	GCT GCC GCA GCG
Lysine	AAA AAG	Stop	TAA TAG TGA	Tryptophan	TGG	Glycine	GGT GGC GGA GGG
Isoleucine	ATT ATC ATA	Cysteine	TGT TGC	Glutamine	CAA CAG	Valine	GTT GTC GTA GTG
Methionine	ATG	Phenylalanine	TTT TTC	Arginine	CGT CGC CGA CGG AGA AGG	Aspartic Acid	GAT GAC
Threonine	ACT ACC ACA ACG	Leucine	TTA TTG CTT CTC CTA CTG			Glutamic Acid	GAA GAG
Serine	AGT AGC TCT TCC TCA TCG						

Page 21

DIRECTIONS

NOTICE! All four genes have already been built in the classroom. Therefore **do not** have teams build the different genes on P20 as directed. There is no need for this! All four of the genes strips have been completed and decoded in the classroom.

Now is the time to interpret the results from all four genes by calling on different teams. First clarify the following:

"Under the gene (the bottom DNA strand) you can see the amino acids, arranged in order. It takes a very complex process inside the cell to assemble and link amino acids together

» Emphasize: Today we are not going to show you all the steps to assemble the protein! Today we are just looking at how the DNA codes for making the proteins.

» "Let's compare some genes. The name of your gene is in a box on the left end of the gene strip. First let's look for differences between beta and the beta mutated gene. Everyone can look at the two beta genes on p 20."

Q. What is the difference between these two genes?

A. Codon 5

Q. Which nucleotide ... in what number codon is different?

A. In codon 5 the beta gene has a G. In codon 5 the beta mutated gene has an A.

Hint for students: Look for the box around a nucleotide on the gene strip.

MEDIA

Independent Learners please watch this teacher training video for summary.

Teacher Training Video #4
How mutations affect proteins
Video to come

7. GENES FOR DIFFERENT PROTEINS (CONT'D)

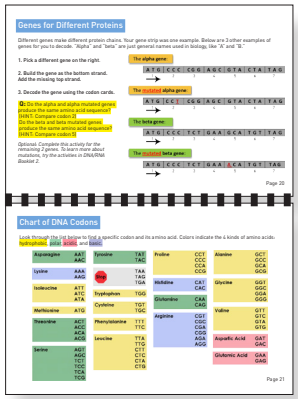
Minimum time 5 min | *Total class time spent: 39 minutes*

PURPOSE

Se previous page

BOOKLET PAGES

20-21



DIRECTIONS CONT'D

» Ask the team(s) with beta gene(s) to raise their hand and give their amino acid sequence. Then compare the amino acid sequence with mutated beta – identifying that the mutation in codon 5 changes the amino acid in the sequence (Ala becomes Thr). Conclude that one nucleotide in DNA can change a protein into completely different protein!

Next, continue in the same way, comparing amino acid sequences for alpha and mutated alpha – Identify the mutated nucleotide first. (Previously a C, mutated now to T) in codon 2.

» Then ask for the amino acid sequence. Students may be surprised when both amino acid sequences are the same! After establishing there isn't a mistake, ask the students to figure out why this mutation in the DNA did NOT change the amino acid sequence.

» Amino acids can be coded for in several different ways. Example: CCC and CCT both code for Proline. Another way of saying this is: Some amino acids have more than one codon. Ask the students to find another example. Look on P21. (Numerous answers… the most extreme include Serine, Leucine and Arginine with each having 6 different codons. Methionine has the least number. Only 1 codon.)

Summarize:

» The order of the DNA nucleotides predicts the order of the amino acids in the protein chain. (Amino acids are the building blocks of proteins). So now we know the function of the DNA, to give the order of the amino acids in the protein.

» A DNA change is called a mutation. A DNA nucleotide sequence change can create a different protein. A mutation can have a bad effect, or good effect, or no effect at all on an organism.

MEDIA

Teacher Training Video #4
How mutations affect proteins
Video to come

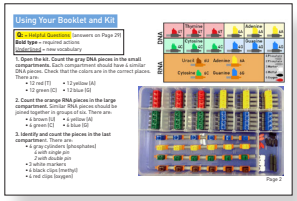
8. ADDITIONAL CONNECTIONS

Minimum time 3min | Total class time spent: 42 minutes

PURPOSE	BOOKLET PAGES	DIRECTIONS	MEDIA
Connect Mendel's genes and traits with modern biology's molecular details about genes and proteins. It's important to connect these new molecular concepts with students' prior knowledge about chromosomes and inheritance. Observable traits are actually caused by proteins.	N/A	**Transition by saying, "Let's connect this information to what you know about genes and traits."** » Ask students to name examples of observable traits? » Emphasize that proteins are responsible for traits – for example, eye color is mostly created by the amount of melanin deposited by a protein. Here's the key concept. Genes produce observable and non-observable traits through protein production. This will help students connect Mendel's genes and traits with modern molecular biology.	N/A

9. CLEAN UP

Minimum time 3 min | Total class time spent: 45 minutes

PURPOSE	BOOKLET PAGES	DIRECTIONS	MEDIA
Clean up/kit responsibility	*2*  	**Time for students put away all materials**. » Ask students to shuffle the order of the Codon Cards and return the cards to the bag. » Remind students to pinch open their DNA before taking it apart; bring extra pieces to the Lost & Found Box; and hunt in the Lost & Found for any pieces that they may be missing. ☞ **Collect all kits, booklets, gene strips, and Codon Cards.**	N/A

10. ADDITIONAL SUMMARY / REVIEW OR HOMEWORK OPTION

Use questions 6-8 on page 28 to check understanding.

LESSON 3: mRNA AND TRANSCRIPTION

Lesson Guide
Page 17 and 22-28 of DNA /RNA Booklet 1

LEARNING GOALS

Learning goals can be best achieved by teaching proteins prior to teaching protein synthesis. Refer to the Essentials for Teaching document #3. Teach Proteins Before DNA.

The student will be able to…

1. Describe and demonstrate the three ways mRNA is different from DNA.
   - » mRNA has a different sugar from DNA.
   - » Uses Uracil (U) instead of Thymine (T).
   - » mRNA is single stranded, while DNA is double stranded.
2. Demonstrate how to transcribe a gene into mRNA from DNA with the following steps.
   - » Pair new RNA nucleotides with the DNA strand opposite to the gene. New RNA nucleotides are individually added onto the 3' end of the growing mRNA strand.
   - » Release the mRNA from the DNA strand. Close up the 2 DNA strands afterwards.
   - » Check the mRNA produced in transcription. The mRNA will have the same nucleotide sequence as the gene, with U replacing DNA's T.
3. Interpret mRNA Charts for the Genetic Code to convert the mRNA codons to an amino acid sequence. Recognize that a stop codon does not signify an amino acid. This codon causes the protein chain to fall off the ribosome. (Use Genetic Code as on p 26, 27 or use other Genetic Code Charts as the teacher selects.)
4. Predict the sequence of amino acids in the protein from one or more mRNA sequences.
5. Describe what happens to the mRNA after it is created in the nucleus. The mRNA exits the nucleus through a nuclear pore and travels to a ribosome.

Learning the concept of transcription (and translation) is not required in some US states for 6-8th graders. If these concepts are not required, Lesson 3 can be shortened significantly:

- » Keep Objectives 1 and 5 (Describe how DNA and mRNA are different) and (Describe the exit of the mRNA from the nucleus.)
- » Omit Objectives 2, 3, and 4.
- » Many young students are quite capable of learning and mastering both transcription and translation processes with the Edgerton Center's Sets. This teaching method is most effective when proteins are taught before DNA, as we highly recommend.

VOCABULARY

Introduced in Lesson 2 P17

NOTES ABOUT VOCABULARY

Use the terms **strand** and **chain** in a consistent manner.

- » Use **strand** only for nucleotides e.g. DNA or RNA **strands**.
- » Use **chains** only for proteins e.g. protein chains.
- » When teaching transcription, new vocabulary words are often introduced to distinguish the two DNA strands. This causes confusion. For example, coding strand, gene, non-template strand, template strand, non-coding strand, complementary strand are often used. To avoid confusion, we use "gene" and do not introduce any additional vocabulary.
- » The term gene expression is recommended vocuabulary for advanced students. See Guide Lesson 3 P9.

SET UP FOR LESSON 3

1. **Optional:** Before class build a DNA molecule from your Teacher #14 Kit to focus the attention of the class at the beginning of the review session. Create an mRNA strand as well.
2. **Optimize student work space. Continue to seat two students to a team if possible. Have the teams continue to use the same kits. This encourages good kit care. Remember the following:**
   - » **Seat the partners adjacent to each other.** Students share materials. Both students need to read instructions in the booklet and have access to the kit.
   - » **Have students clear the table of books and personal items before working.**
3. **Organize the materials for the classroom use.:**
   - » **Set up the Lost & Found Box in the room for the collection of extras.** Remind students to bring up extras and look for missing pieces in the box.
   - » Keep the kit materials in an accessible space. For Lesson 3 each team will require:
   - » **1 DNA/RNA kit** (The Kit Check Record is folded up inside.)
     1 DNA/RNA Booklet #1
     1 Gene Strip per team. Make sure one of each kind is represented in the room: alpha, alpha mutated, beta, beta mutated.

BEST PRACTICES # 1-4

Remember hands-on teaching is different. It requires a lot more back and forth. There will be periods of time for student hands-on work and times for listening to the teacher. Please Review these Best Practices #1-4 before each lesson.

#1

Direct the students' attention.

- » Students should open the kits only when directed and not beforehand.
- » For lively or large classes, it is helpful to use a hand-bell or other signal so teams will know to when to stop working. (Try it!?) Be sure to wait for silence. Do not let students continue to work.
- » To focus student listening, cue the students for new directions. Say, for example: "Please listen for new directions now. Look at page 7. Each person on your team will build this DNA molecule."

#2

Keep the class together. Compliment good teamwork.

- » Tell students to stop when they finish each activity. Tell quicker teams to double check their work.

#3

Circulate throughout the room to observe and correct building in progress.

- » Students often forget to make DNA strands anti-parallel. Catch this as soon as possible because it takes a lot of valuable time to correct. Each nucleotide must be separated and turned around.
- » Say repeatedly, "Remember to use the pinch technique! Release those hydrogen bonds!"

#4

Check for misconceptions. Ask questions. Also encourage students to ask you questions.

- » Use the yellow-highlighted questions in the booklet during the lesson.
- » Summarize at the end of the lesson. You can select appropriate questions from "Check your Understanding" at the back of the booklet.

LESSON GUIDE: DNA /RNA BOOKLET 1

45 minutes is the minimum time, 55-60 min better for questions, etc.

1. REVIEW OF PREVIOUS LESSONS

Minimum time: 7 minutes** | **Total class time spent: 07

PURPOSE	PAGES	DIRECTIONS	MEDIA
Use the DNA model to focus the students' attention for a class review at the beginning of the class. This class review helps students who were absent catch up. This class review also helps all students retrieve newly acquired knowledge from lesson 1 & 2 by refreshing student vocabulary and key concepts.	N/A Review by teacher	Again use the teacher's DNA model up front to focus students' attention. You can quickly review lessons 1 & 2. You can create the atmosphere of a snappy "question & answer show" if this works to engage the class. **Lesson 1:** Begin with a question from Lesson 1 that they will need to know the answer for today: **Q:** Which nucleotide has the gray sugar? **A:** DNA **Q:** Which nucleotide has an orange sugar? **A:**RNA "R" NA is "R"ange **Q:** How should we open up the DNA strands with the model? **A:** with the pinch technique Q: What is the name of weak bond between the bases? **A:** Hydrogen bond **Q:** What is the name of the process where DNA opens up and makes more DNA? **A:** Replication **Q:** When does a cell need to have twice its normal amount of DNA? **A:** A cell has twice its normal amount of DNA before it splits into two separate cells. (Replication occurs before mitosis. Mitosis is the process of dividing up the DNA and moving it into two cells.)	

1. REVIEW OF PREVIOUS LESSONS (CONT'D)

Minimum time: 7 minutes | Total class time spent: 07

PURPOSE	PAGES	DIRECTIONS CONT'D	MEDIA
Next, continue to review Lesson 2 material.	N/A Review by teacher	**Lesson 2:** In Lesson 2 we learned about hidden codes in the DNA that are needed for making protein molecules. **Q:** What part of a protein do the DNA nucleotides code for? **A:** The nucleotides code for specific amino acids **Q:** How many DNA nucleotides are needed to code for each amino acid? **A:** 3 nucleotides **Q:** What is the name of the group of 3 nucleotides that codes for an amino acid? **A:** Three nucleotides that code for an amino acid are called a codon. Q: What's a gene? **A:** The length of DNA needed to contain the information for building a protein (or another molecule like RNA) **Q:** What's a chromosome? **A:** A chromosome is a long molecule of DNA. It is made up of many genes joined end to end. Different animals and plants have different numbers of chromosomes. Optional: Suggest the students look up a favorite plant or animal online. Compare the numbers of chromosomes? **Q:** What's a genome? A: The amount of DNA needed to build an organism (such as animal, plant or a microorganism.) Note: The genome is considered to be <u>one</u> of every pair of chromosomes since the second chromosome is redundant information.	

1. REVIEW OF PREVIOUS LESSONS (CONT'D)

Minimum time: 7 minutes | Total class time spent: 07

PURPOSE

Introduction to Lesson 3.

Hand out only the booklets first. Open to P 16-17 to see the cell diagram.

Purpose of the booklet right now is to provide the class with a diagram of the cell. (If you have a cell diagram on a PPT slide or a poster, you can use it instead.) The diagram will help you emphasize two important facts:

1. The process of transcription takes place in the nucleus of the cell. Additional steps take place in other parts of the cell.
2. Transcription is just the first step in the process of protein synthesis.

PAGES

N/A
Review by teacher

DIRECTIONS CONT'D

Begin Lesson 3

☞ **Hand out the booklets first, without the kits. Announce to students that today they are going to model the first steps in protein synthesis. "We are going to reenact how cells make proteins from DNA instructions."**

» Request that students open their booklets P16- 17 and look at the cartoon of the cell on P17.

» The genes with the DNA instructions are located inside the cell nucleus, but the ribosomes (in green) that manufacture the proteins are located in the cytoplasm. The mRNA makes it possible for the instructions to reach the ribosome manufacturing sites.

» Next, review the overall process of protein synthesis in the cell. Refer to the circled numbers on the page to emphasize we are only going to do steps 1 and 2 (circled on the page) in class today.

1. DNA is transcribed into messenger RNA (mRNA) because DNA can't leave the nucleus.
2. mRNA leaves the nucleus through a nuclear pore and travels to a ribosome.
3. On the ribosome, the mRNA codons will read and the protein will be assembled.

MEDIA

None

Suggest for High School and above

Video
DNA Video Transcription
Video to come

2. KIT CHECK

Minimum time 5 min | Total class time spent: 12 minutes

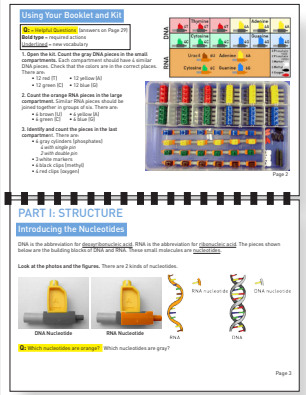
PURPOSE

Teams are checking the previous team's use, not their own. Initialing the record also helps keep the kits in good shape.

Teams do this at the start of class. Therefore, they will have all the necessary materials before the lesson begins. This check minimizes disruptions that might otherwise occur in the flow of the lesson.

BOOKLET PAGES

2-3



DIRECTIONS

☞ **Now hand out the kits (or have one team member pick it up from the materials station in the room.)**

Tell students it's OK to open the kits and begin.

» Remind students to use P2 & 3 and sign the "Team Kit Care Record".

» Announce the Lost & Found Box for any extra pieces found in the kits. If missing anything, teams should check the Lost & Found.

» Point out on page 3 that there are two kinds of nucleotides, DNA and RNA (color orange).

MEDIA

PDF
Team Kit Care Record

3. BUILD GENES ON TOP OF THE GENE STRIPS

Minimum time 5 min | Total class time spent: 17 minutes

PURPOSE

Assembling the DNA model right on top of the full-sized gene strip minimizes student errors.

These gene strips were added to the kits after observing students' high error rate in building the DNA sequence when the sequence was just listed in the booklet. Gene strips solved the problem.

BOOKLET PAGES

N/A

DIRECTIONS

☞ **Hand out the gene strips. Make sure at least 1 alpha, 1 alpha mutated, 1 beta, and 1 beta mutated are built in the classroom. Distributing the alpha and beta strips to different teams than last time is OK.**

» Students should build directly on top of the gene strip again!

» Upon completion, have the teams check for errors. Compare the gene strip sequence with the DNA model. As the teacher, you should circulate and check the arrows on the models. Directionality matters!.

☞ **Collect the gene strips!**

The strips will not be needed for the rest of the lesson. Removing the strips clears the visual clutter – helps with focus.

MEDIA

Teacher Training Video #2
Video to come.

4. COMPARING DNA AND RNA NUCLEOTIDES

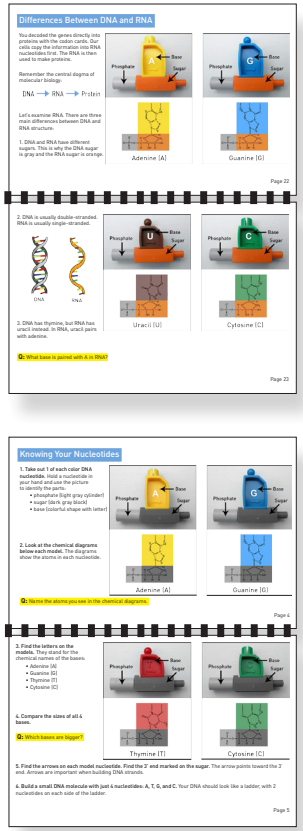
Minimum time 5 min | Total class time spent: 22 minutes

PURPOSE

Use the models with the booklet to teach students about the difference between DNA and RNA nucleotides.

BOOKLET PAGES

22-23, 4-5



DIRECTIONS

☞ **Ask students to pick up one of every kind of an RNA nucleotide (A, G, C, U).**

Q: What are the 3 major differences between DNA and RNA nucleotides? How do the models show the differences?

Difference #1
A: The nucleotides have sugar molecules that differ in one oxygen. (ribose= sugar)
Students may say 'deoxy' means 'without oxygen.'
The models have different colors (orange = ribose, gray = deoxyribose).

Q: Optional follow-up question, "Can you find where the oxygen atom missing on the DNA? Compare P4 and 5 with P22 and 23."

A: The carbon atom on the bottom of the DNA in the sugar ring (gray on the left side) is missing an oxygen. The sugar in the orange RNA has an oxygen atom in this exact place on the ribose.

Difference #2
A: Uracil in RNA replaces each thymine in DNA. The models have different colors (brown=uracil, red = thymine)

Q: Optional follow up question, "These two bases, U and T are very similar. Can you find the small difference? Compare Thymine on p 5 with Uracil on p 23."

A: Uracil has an H where Thymine has a CH3. (CH3 is a methyl group.)

Difference #3
A: DNA is usually double stranded. RNA is usually single stranded.

Hold the class on this page (P23) if possible without explaining why.
P24 contains the answer to a question that is better achieved by students experimenting with the models.

MEDIA

Teacher Training Video #3
Compare RNA with DNA
Video to come

5. TRANSCRIBE THE GENE INTO RNA

Minimum time 10 min | Total class time spent: 32 minutes

PURPOSE

The models make it possible for transcription to be experienced in a concrete way.

The learner must engage: deciding what to do using tactile feedback. These steps reinforce the mental imagery needed to recall the process.

Many students and teachers gain clarity about how the mRNA "copying" actually works.

Initially, students will test each one of the two DNA strands to learn which strand the mRNA nucleotides base-pair with to make the mRNA strand correctly.

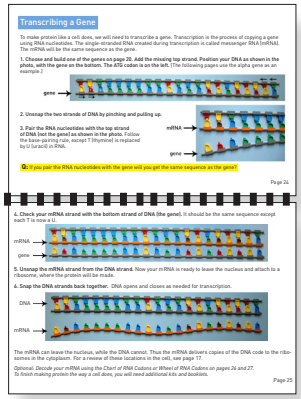
Key points the models can teach us about transcription:

1. mRNA will be the same sequence as the DNA nucleotides in the gene (U for T) .
2. mRNA nucleotides base-pair (bond) with the DNA strand that is opposite the gene.

BOOKLET PAGES

Note: Hold the class on P23 until the class decides which DNA strand (top or bottom) is the correct strand to base-pair with the RNA.

24-25


Transcribing a Gene

To make protein like a cell does, we will need to transcribe a gene. Transcription is the process of copying a gene using RNA nucleotides. The single-stranded RNA created during transcription is called messenger RNA (mRNA). The mRNA will be the same sequence as the gene.

1. Choose and build one of the genes on page 20. Add the missing top strand. Position your DNA as shown in the photo, with the gene on the bottom. The ATG codon is on the left. (The following pages use the alpha gene as an example.)

gene

2. Unwrap the two strands of DNA by pinching and pulling up.

3. Pair the RNA nucleotides with the top strand of DNA (not the gene) as shown in the photo. Follow the base-pairing rule, except T (thymine) is replaced by U (uracil) in RNA.

mRNA

gene

Q: If you pair the RNA nucleotides with the gene will you get the same sequence as the gene?

Page 24

5. Unwrap the mRNA strand from the DNA strand. Now your mRNA is ready to leave the nucleus and attach to a ribosome, where the protein will be made.

6. Snap the DNA strands back together. DNA opens and closes as needed for transcription.

DNA

mRNA

The mRNA can leave the nucleus, while the DNA cannot. Thus the mRNA delivers copies of the DNA code to the ribosomes in the cytoplasm. For a review of these locations in the cell, see page 17.

Optional: Decode your mRNA using the Chart of RNA Codons or Wheel of RNA Codons on pages 26 and 27.
To finish making protein the way a cell does, you will need additional kits and booklets.

Page 25

These pages above will give away the answers.

DIRECTIONS

An RNA copy of the gene is needed because:

- » DNA cannot leave the nucleus.
- » mRNA can leave the nucleus! mRNA delivers the code to the ribosome where the protein is produced.

OPTIONAL TEACHER TALK
mRNA production helps explain the presence of different cell types.

- » First, every cell in your body has all the information to make all of you! Therefore, different cell types produce only proteins they need. Example:
- » Bone cells select the bone-making genes.
- » Red blood cells wouldn't select bone-making genes, these cells would select hemoglobin genes, creating the mRNA strands to produce hemoglobin proteins to carry oxygen.
- » Cells select the right genes for the cell's job. mRNA production helps control which genes get made into proteins. "Not all genes are made into proteins in every cell!"
- » Optional vocabulary that is helpful to describe this function is the term "gene expression." When a gene is expressed, the gene makes a product like a protein.

☞ **Begin transcription together as a class.**

Important First ask students to check: 1. That the first three bases ATG are on the left 2. ATG is on the bottom, not the strand. ATG is the beginning of the gene. Tell the students to pinch open their DNA and then wait. (NOTE: Don't let the students see P 24. This page contains the answer to the question you are about to ask.)

> **Q:** Which DNA strand do I need to base pair the RNA nucleotides with, to make an exact copy of the gene? The top strand… or the bottom strand?"

Repeat this question. Don't give them the answer. **Tell the students to test both possibilities. Pair 3 RNA with the top and pair 3 RNA with the bottom strand. Which RNA follows the rules and will work to make an** RNA strand?

MEDIA

Teacher Training Video #4
How to teach which strand to use for transcription
Video to come.

Demonstration of Transcription Video
Doing the mRNA base-pairing with the top strand and also the release of the mRNA strand.
Video to come.

5. TRANSCRIBE THE GENE INTO RNA (CONT'D)

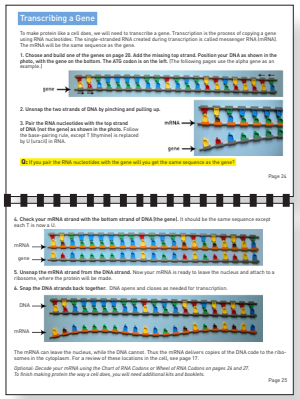
Minimum time 10 min | Total class time spent: 32 minutes

PURPOSE

See previous page

BOOKLET PAGES

24-25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2. Unwrap the two strands of DNA by pinching and pulling up.

3. Pair the RNA nucleotides with the top strand of DNA (not the gene) as shown in the photo. Follow the base-pairing rule, except T (thymine) is replaced by U (uracil) in RNA.

mRNA

gene

Q. If you pair the RNA nucleotides with the gene will you get the same sequence as the gene?

Page 24

4. Check your mRNA strand with the bottom strand of DNA (the gene). It should be the same sequence except each T is now a U.

mRNA

gene

5. Unsnap the mRNA strand from the DNA strand. Now your mRNA is ready to leave the nucleus and attach to a ribosome, where the protein will be made.

6. Snap the DNA strands back together. DNA opens and closes as needed for transcription.

DNA

mRNA

The mRNA can leave the nucleus, while the DNA cannot. Thus the mRNA delivers copies of the DNA code to the ribosomes in the cytoplasm. For a review of these locations in the cell, see page 17.

Optional: Decode your mRNA using the Chart of RNA Codons or Wheel of RNA Codons on pages 26 and 27. To finish making protein the way a cell does, you will need additional kits and booklets.

Page 25

DIRECTIONS CONT'D

1. Again, tell the students to begin base-pairing but just do the first 3 RNA nucleotides! Then stop and wait!
2. Also remind them to check their RNA nucleotides for the anti-parallel rule. (The arrows should go in opposite directions.)

OPTIONAL TEACHER TALK - (Advanced)

Advanced students aware of the 3' and 5' ends may notice that the base-pairing of mRNA nucleotide with the DNA strand leaves the 3' end of the mRNA free. Also, the RNA polymerase can add onto the mRNA strand here on the 3'end. This explains why mRNA polymerization proceeds in this direction and not in the opposite direction. (Students frequently ask how polynerase knows which way to go.)

3. Now ask the students to look at the RNA strand. Is this RNA code the same as the gene? It should be the same! (ATG = DNA) (AUG= RNA). The mRNA sequence should always be the same as the gene (with U replacing T). So if it is the same, your team may now continue. If not-- pinch it apart, begin again. Pair with the side that is not the gene.

Announce to students to go to P24 and 25. Finish the activity using these directions. Circulate throughout the class. The students will finish by double checking the mRNA sequence. Again tell them it should be the same as the gene (except U instead of T).

Pinch apart the DNA-RNA strands. Remove the mRNA strand by lifting it up. The mRNA is now free to travel out of the nucleus, through the nuclear pore to the ribosome.

Rejoin the two DNA strands into the double helix. The gene may be used again and again to generate more mRNA, if more proteins are needed.

MEDIA

6. OPTIONS: FOR PRACTICE DECODING MRNA

Minimum time 7min | Total class time spent: 42 minutes

PURPOSE

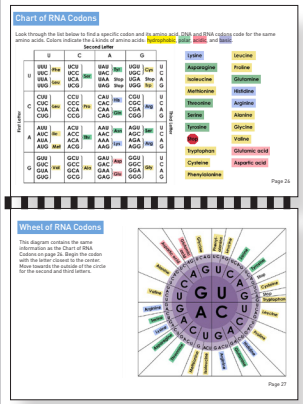
This activity gives students more practice with various Charts for the Genetic Code.

The Genetic Code is typically listed by RNA nucleotides not DNA nucleotides. (Genetic Codes use U and not T.)

The goal of the activity is for the students to gain familiarity with Genetic Code—how to read the charts, and to become acquainted with the start codon (AUG) and at least one example stop codon (UAG). There are two more stop codons.

BOOKLET PAGES

26-27



DIRECTIONS

☞ **Choose an activity below to suit your student needs or give the students some individual choice.**

6.1 Practice decoding mRNA with a simple example.

» Students decode the model mRNA using the different mRNA Charts.

» (Use the models and codon cards with p 26 and 27. Less experienced students will need coaching on how to read charts.)

» Teams can visit other teams' mRNA to decode different mRNA strands.

OR

6.2 Practice decoding mRNA with a creative approach.

» Students create their own mRNA strand with the model and write down the amino acid sequence it codes for.

» Coach students about the need for a start and stop codon. You may want to have students build both the AUG and UAG codons first. (There are only 6 of each A, G, U, C in a kit.)

» Alternatively, you can have teams go to the board and write mRNA sequences up there. Other teams decode using p 26 and 27 and compare amino acid sequences answers.

OR

6.3 Practice decoding RNA with a mutation.

» After decoding the original mRNA correctly, ask students to delete (remove) the fourth nucleotide from the mRNA strand.

» Now have the students decode what amino acid sequence is produced in this (frame shift) mutation.

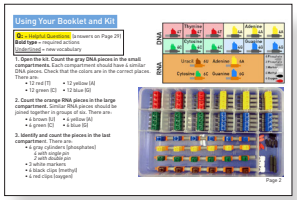
» Be prepared to discuss what would happen in case there is no stop codon. (The amino acid chain would continue.)

MEDIA

Demonstration Video
Building the double helix
Video to come

7. CLEAN UP

Minimum time 3min | Total class time spent: 45 minutes

PURPOSE	BOOKLET PAGES	DIRECTIONS	MEDIA
Clean up, return materials, and help others to complete this task on time.	2 	☞ **Students put away all model nucleotides and booklets. Remind students:** » Pinch open the DNA before taking it apart » Lost and Found box for extra or missing pieces. » Shuffle the codon cards when returning them to bags » Collect and return all kits, booklets, gene strips and cards (if you use them).	N/A

8. NEXT STEPS?

In protein synthesis you will need to use the mRNA from these sets. You will also need the Protein Set and tRNA Set to complete translation. If you don't have the Protein Set and the tRNA Set you can continue into translation using animations or other models.

9. HOMEWORK OR REVIEW:

Use questions 9 and 11 on page 28 to check understanding.