

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

transcription.....	P17
central dogma of molecular biology.....	P17
messenger RNA	P17
transfer RNA	P17
translation	P17
amino acid.....	P18

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 vocabulary 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-high-lighted 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.

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
<p>Use the DNA model to focus the students’ attention for a class review at the beginning of the class.</p> <p>This class review helps students who were absent catch up.</p> <p>This class review also helps all students retrieve newly acquired knowledge from lesson 1 & 2 by refreshing student vocabulary and key concepts.</p>	<p>N/A Review by teacher</p>	<p>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.</p> <p>Lesson 1: Begin with a question from Lesson 1 that they will need to know the answer for today:</p> <p>Q: Which nucleotide has the gray sugar? A: DNA</p> <p>Q: Which nucleotide has an orange sugar? A:RNA "R" NA is "R"ange</p> <p>Q: How should we open up the DNA strands with the model? A: with the pinch technique</p> <p>Q: What is the name of weak bond between the bases? A: Hydrogen bond</p> <p>Q: What is the name of the process where DNA opens up and makes more DNA? A: Replication</p> <p>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.)</p>	

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	<p>Lesson 2: In Lesson 2 we learned about hidden codes in the DNA that are needed for making protein molecules.</p> <p>Q: What part of a protein do the DNA nucleotides code for?</p> <p>A: The nucleotides code for specific amino acids</p> <p>Q: How many DNA nucleotides are needed to code for each amino acid?</p> <p>A: 3 nucleotides</p> <p>Q: What is the name of the group of 3 nucleotides that codes for an amino acid?</p> <p>A: Three nucleotides that code for an amino acid are called a codon.</p> <p>Q: What's a gene?</p> <p>A: The length of DNA needed to contain the information for building a protein (or another molecule like RNA)</p> <p>Q: What's a chromosome?</p> <p>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.</p> <p>Optional: Suggest the students look up a favorite plant or animal online. Compare the numbers of chromosomes?</p> <p>Q: What's a genome?</p> <p>A: The amount of DNA needed to build an organism (such as animal, plant or a microorganism.)</p> <p>Note: The genome is considered to be <u>one</u> of every pair of chromosomes since the second chromosome is redundant information.</p>	

1. REVIEW OF PREVIOUS LESSONS (CONT'D)



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

PURPOSE	PAGES	DIRECTIONS CONT'D	MEDIA
<p>Introduction to Lesson 3.</p> <p>Hand out only the booklets first. Open to P 16-17 to see the cell diagram.</p> <p>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:</p> <ol style="list-style-type: none"> 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. 	<p>N/A</p> <p>Review by teacher</p>	<p>Begin Lesson 3</p> <p>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.”</p> <ul style="list-style-type: none"> » 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. <ol style="list-style-type: none"> 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. 	<p>None</p> <p>Suggest for High School and above</p> <div data-bbox="1698 586 2003 878" style="border: 1px solid red; padding: 10px; text-align: center;"> <p><i>Video DNA Video Transcription Video to come</i></p> </div>

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

Using Your Booklet and Kit

Kit type - required kit for all teams

Kit contents - see materials list

1. Open the kit. Count the gray DNA pieces in the small bags (100). Do a comparison check with a partner. Check that the colors are in the correct places. There are:

- 10 green (G)
- 10 blue (C)
- 10 red (A)
- 10 yellow (U)

2. Count the orange RNA pieces in the large compartments. Count that the colors are in the correct places. There are:

- 4 brown (5')
- 4 yellow (3')
- 4 green (2')
- 4 blue (1')

3. Identify and count the pieces in the last compartments. There are:

- 4 pink caps (5' cap)
- 4 red caps (3' cap)
- 4 pink nucleotides
- 4 red nucleotides
- 4 black cap (5' cap)
- 4 black cap (3' cap)

Page 2

PART I: STRUCTURE

Introducing the Nucleotides

DNA is the abbreviation for **deoxyribonucleic acid**. RNA is the abbreviation for **ribonucleic acid**. The pieces shown below are the building blocks of DNA and RNA. These small molecules are **nucleotides**.

Look at the photos and the figures. There are 2 kinds of nucleotides.

DNA Nucleotide **RNA Nucleotide**

Which nucleotides are gray?

Page 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	BOOKLET PAGES	DIRECTIONS	MEDIA
<p>Assembling the DNA model right on top of the full-sized gene strip minimizes student errors.</p> <p>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.</p>	<p>N/A</p>	<p>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.</p> <ul style="list-style-type: none"> » 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! <p>Collect the gene strips!</p> <p>The strips will not be needed for the rest of the lesson. Removing the strips clears the visual clutter – helps with focus.</p>	<div style="border: 1px solid red; padding: 10px;"> <p><i>Teacher Training Video #2 Video to come.</i></p> </div>

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

Differences Between DNA and RNA

You developed the genes directly, the proteins with the other cells. Your cells copy the information into RNA nucleotides for the RNA to then be used to make proteins.

Remember the central dogma of molecular biology:
DNA → RNA → Protein

Let's examine RNA. There are some major differences between DNA and RNA structures.

- DNA and RNA have different sugars. This is why the DNA sugar is gray and the RNA sugar is orange.

Adenine (A) Guanine (G)

Page 22

- DNA is usually double-stranded. RNA is usually single-stranded.

- DNA has Thymine, but RNA has Uracil instead. In RNA, uracil pairs with Adenine.

Uracil (U) Cytosine (C)

Page 23

Knowing Your Nucleotides

- Take out 1 of each color DNA nucleotide. Hold it up to your hand and use the picture to identify the parts.
 - phosphate (light gray cylinder)
 - sugar (dark gray block)
 - base (colorful shape with letters)
- Look at the chemical diagrams below each base. The red arrows show the atoms in each nucleotide.

Adenine (A) Guanine (G)

Page 4

- Find the letters on the models. This is part of the chemical notation of the bases.
 - Adenine (A)
 - Guanine (G)
 - Thymine (T)
 - Cytosine (C)
- Compare the sizes of all 4 bases.
- Which bases are larger?
- Find the arrows on each model nucleotide. Find the T and mark it on the sugar. The arrow points toward the 3' end. Arrows are important when building DNA strands.
- Build a small DNA molecule with just 4 nucleotides: A, T, G, and C. Your DNA should look like a ladder, with 2 nucleotides on each side of the ladder.

Thymine (T) Cytosine (C)

Page 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.

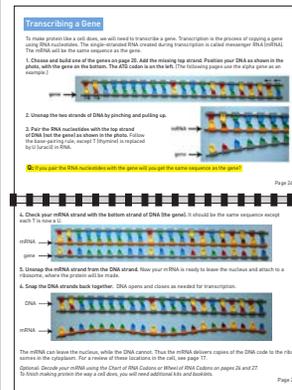
Key points the models can teach us about transcription:

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



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.
<https://www.youtube.com/watch?v=AWjRcNSqJ6w&t=2s>.

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

Transcribing a Gene

To make proteins like a cell does, we will need to transcribe a gene. Transcription is the process of copying a gene onto RNA molecules. 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 label one of the genes on page 23. Add the missing top strand. Practice your DNA as shown in the diagram with the gene on the bottom. The 3' end is on the left. The following paper can be used as an example.
2. Unzip the two strands of DNA by pinching and pulling up.
3. Pair the RNA nucleotides with the top strand of DNA from the gene as shown in the diagram. Follow the base pairing rule, except T (thymine) is replaced by U (uracil) in RNA.

Now you are the RNA nucleotides with the gene and you get the mRNA sequence from the gene.

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

5. Unzip 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.

The mRNA can leave the nucleus, while the DNA cannot. Thus the mRNA delivers copies of the DNA code to the ribosome for the cell to use. For a review of these activities in the cell, see page 27.

Optional: Show the gene pairing using the Chart of DNA Codes or show all the Codes on pages 26 and 27. To finish making protein the way a cell does, you will need additional kits and booklets.

Page 24

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 polymerase 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

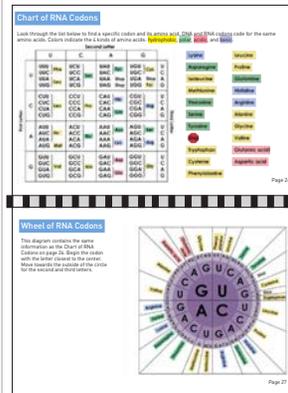
This activity gives students more practice with various Charts for the Genetic Code.

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



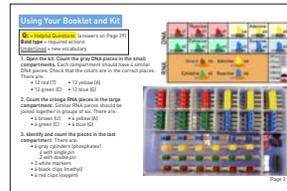
Minimum time 3min | Total class time spent: 45 minutes

PURPOSE

Clean up, return materials, and help others to complete this task on time.

BOOKLET PAGES

2



DIRECTIONS

- 🗉 **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).

MEDIA

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.