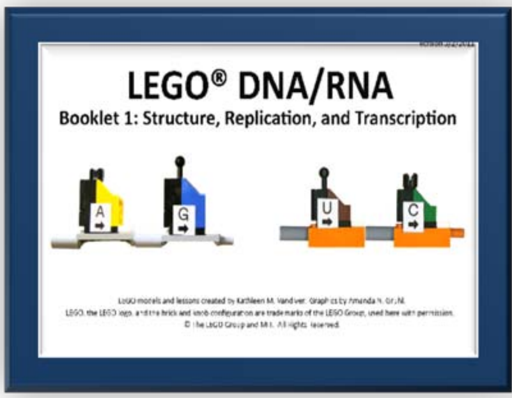
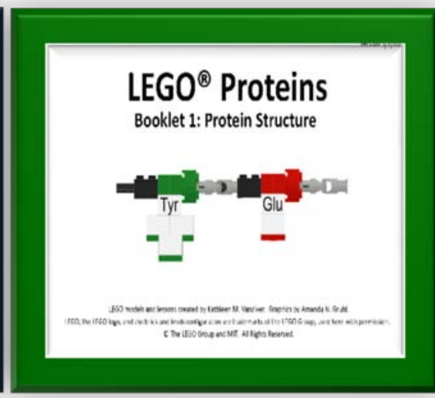
LEGO DNA Learning Center Set

Teacher Guide





Teacher Guide

Draft Version

Provided by Kathleen Vandiver June 19, 2011
MIT Center for Environmental Health Sciences

funded in part by the Arthur Vining Davis Foundations

LEGO® DNA Learning Center Set
Teacher Guide

Credits

Boston Public Schools, Science Department

This Teacher Guide is one of the tangible results of a fruitful collaboration with the Boston Public Schools. We thank Pamela Pelletier, Science Department Senior Program Director and Suzanne Gill, BPS Professional Development Specialist for orchestrating this pilot project with BPS teachers in the system. Their commitment to this new hands-on biology curriculum made possible both the professional development workshops and the follow-on support to the teachers in the classroom. We also thank the nine BPS teachers involved this past year: Art Garcia, Ivyrose Hess, Juliet Parry, Nivia Pina, Sarah Page, Marcy Ostberg, Andrew Rabin, Leilani Roser, for their feedback and enthusiasm. A special thanks to Johanna Waldman for taking the lead.

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Volunteer Support

We wish to thank Lori Tsuruda, MIT Alum and the Director of the non-profit organization, "People Making a Difference." During the months of January to April 201, Lori organized and led hundreds of volunteers who contributed more than 1000 person hours to produce the 10 BPS LEGO DNA Learning Center Sets. Thank you to all the volunteers who contributed to this project.

MIT Support

The program manager of the NASA SOI teacher professional development project in year one was Dr. Kathleen Vandiver, MIT Center for Environmental Health Sciences, Director of Outreach and Education Program. The graphics and editing support for the LEGO Booklets was provided by Dr. Amanda Gruhl, a multi-talented Instructor from MIT Edgerton Center. Staff support from the MIT Center for Environmental Health Sciences and the MIT Edgerton Center played a role in this success as well.

Kathleen M. Vandiver PHD
Teacher Guide author. 6-18-11

LEGO® DNA Learning Center Set
Teacher Guide

Overview

The materials in this Teacher Guide are currently under development, hence the word "Temporary" in the title. We plan to provide updates and animations soon and will make them available on line.

The Teacher Guide provides the following components: 1) a Lesson Plan, 2) a PowerPoint Slide Show, and 3) a Student Worksheet for each of the four sessions.

The session components in the Teacher Guide:

1) **The Lesson Plan** was formatted on each page as a table for quick reading. For each part of session, the column headers for each sub-activity are: the length of time, the pedagogical purpose, and a brief description of the activity. Here are the four lessons each which can be completed in a 55 min. period.

- Session One: Protein Structure and Function
- Session Two: An Introduction to DNA Structure
- Session Three: DNA and Transcription
- Session Four: Protein synthesis and Translation;

Note that our lesson sequence places proteins before DNA. Prior knowledge about protein structure is of great help to students. It is difficult for students to pick up the basics about protein structure at the same time as figuring out the multistep process of DNA directed protein synthesis. Thus our sequence is recommended.

Each session is anticipated to take about 55 minutes. The lesson count can be considered as four sessions which require five days to complete, since Session Four addresses half the class at a time. The teacher repeats the LEGO lesson with the other half of the class the next day. The alternate activity TBD is to be engaging and self-directed.

2) **PowerPoint Slides** provided follow the lesson plan and are designed to support a teacher teaching the material for the first time. Pages from the LEGO student booklet were placed in the PPT whenever the students need to transition to doing a LEGO activity. This is also useful both for students as well as the teacher, as the students can check that they are have the correct page. Unfortunately, the booklet images may look sketchy in this draft PPT version. Remind students to work from their actual booklets (not the slides) for the details.

3) **Student Worksheets** accompany each lesson as a summary. When should they be used? From our pilot work with BPS teachers in the spring of 2011, we learned that it is very challenging to have the students shifting back and forth between LEGO work and paper work, and thus it was not practical to create a student paper that contained everything.

Thus we now suggest that teachers use the worksheets as a summary paper at the end of class, or as a review paper for yesterday's lesson at the beginning of the class the next day. These draft worksheets contain only "level one" questions, just to be sure that all students have the facts for studying. More stimulating higher level questions developed in collaborations with BPS Biology teacher Johanna Waldman will be included later. We wanted to complete the basic knowledge level information first.

An omission on the worksheets that a teacher could rectify easily is a vocabulary list. This could be added on the back of the page of each worksheet.

Suggested approach for teachers starting out:

1) Find and take home the LEGO Teacher Box. This file-sized box has all the materials needed to try out all the LEGO exercises. The box includes the LEGO model kits and the student booklets.

2) Read and complete all the LEGO activities found in the student booklets, **LEGO Protein Booklet 1, & 3**; **LEGO DNA/RNA Booklet 1**, to prepare yourself. You need to become familiar with the student materials anyway and doing the exercises in the booklet will be a good content review. The booklets can be shared with special needs instructors to help them learn more biology as well; now you can recommend this approach from personal experience.

Note: Both **Protein Booklet 2** and **DNA Booklet 2 are missing** because have not been published yet. These are the booklets for the more advanced students, which will include hydrogen bonding in protein helices and leading & lagging strands in DNA replication, for example.

Materials List

The material list is on a separate, two- sided page. It may be found in a pocket on the outside of each Storage Box. A general outline is below.

There are three large storage boxes:

1) LEGO DNA/ RNA
2) LEGO Proteins
3) LEGO tRNA

There are two small storage boxes:

1) LEGO Teacher Box
2) LEGO Accessory Box

There are two posters showing important molecules inside cells:

1) "Tour of a Cell," a cut through a B lymphocyte showing all the molecules. David Goodsell
2) Muscle Cell poster from the Exploratorium. David Goodsell

Content List Document for the LEGO® DNA Learning Center Set

As of 5-12-11 K Vandiver

The 3 large boxes – page 1

DNA/RNA Storage Box

1 **12 DNA/RNA kits Numbered 1-12**

2 **36 layout mats Numbered 1-12 on the back**

12 layout mats are A & T nucleotides of DNA: the yellow and red bases on gray sugars
12 layout mats are G & C nucleotides of DNA: the blue and green bases on gray sugars
12 layout mats are RNA nucleotides: the blue, green, yellow, brown (U)bases on Orange sugar.

3 **12 DNA/RNA booklets These are labeled " DNA/RNA Booklet 1" Numbered 1-12**

Protein Storage Box

1 **12 Protein kits Numbered 1-12**

2 **24 Layout mats Numbered 1-12 on the back**

12 layout mats are Hydrophobic amino acids: the yellow amino acids
12 layout mats are Hydrophilic amino acids: the red, blue, and green amino acids

3 **12 Protein booklets These are titled "Protein Booklet 1" Numbered 1-12**

4 **Cell Membrane Mats Each model has 5 parts. These are designed to be taped around a cardboard box the size of a Photocopier box for paper.**

- **2 top views WITH THE PORE** Note: the 3rd top view is located in the Teacher Box
- **2 side view A** short piece
- **2 side view B** long piece
- **2 side view C** short piece
- **2 side view D** long piece

tRNA Storage Box

1. **8 tRNA kits Numbered 1-8**
2. **8 "layout mats" keep inside each kit because they are not the same.**

   The kits are different: 1 alpha, 2 alpha mutated, 3 beta, 4 beta mutated,
   5 alpha, 6 alpha mutated, 7 beta, 8 beta mutated
3. **8 tRNA booklets This is called tRNA Booklet 1 Numbered 1-8**
4. **8 Ribosome Mats numbered 1-8 on the back so you don't have to hand them out with the matching set.**

   NOTE : The #9 tRNA kit is in the teacher box: The #9 tRNA kit is exceptional – anticodons can be rearranged. Should not be given to students. Also the #9 booklet and ribosome is in the teacher box

Content List for Each LEGO® Storage Box

As of 5-12-11 K Vandiver The 2 smaller boxes – page 2

Teacher Box

This teacher box was designed to function as a sampler for the LEGO Set

It contains what you need to try out the activities for yourself.

"Gene strips" and "Amino acid cards" are not in the box and may be found in the teacher accessory box.

1 **There are 3 LEGO kits in the teacher box:**

- **2 DNA / RNA kits Number 13 is Extra and Number 14 is the Teacher Kit**
- **2 Protein kits Number 13 is Extra and Number 14 is the Teacher Kit**
  Note: To demonstrate the full 4 chain channel protein, two protein kits are necessary. One protein kit can make 1 beta chain and 1 alpha chain.
- **1 tRNA kit Number 9** Note: #9 tRNA kit is not glued. The anticodons can be prepared individually. The original tRNA kit came prepared with the anticodons for translating the alpha chain.
  - Inside this tRNA kit there are 4 different Layout Mats, one for each channel protein. All can be prepared from the contents of this kit.

2 **Layout mats for each kit are here:**

2 layout mats are A & T nucleotides of DNA: the yellow and red bases on gray sugars
2 layout mats are G & C nucleotides of DNA: the blue and green bases on gray sugars
2 layout mats are RNA nucleotides: the blue, green, yellow, brown (U)bases on orange sugars
2 layout mats are Hydrophobic amino acids: the yellow amino acids
2 layout mats are Hydrophilic amino acids: the red, blue, and green amino acids

3 **Other mats:**

1 Ribosome Mat marked "Teacher" #9
1 Cell Membrane Mat (top view with the pore) marked "Teacher" #9

4. **Teacher Guide Book Including:**

"Molecular Workbench" DVD
Flash drive with Power Points, Animations, Word doc Files of Student Classwork papers.

Teacher Accessory Box

1 **1 Plastic box labeled " Lost & Found"**

2 **1 Plastic box labeled " Fix-it Box"**

3 **8 "Gene Strips" These show a double stranded DNA nucleotide sequence for the following proteins:**
1 alpha, 2 alpha mutated, 3 beta, 4 beta mutated
5 alpha, 6 alpha mutated, 7 beta, 8 beta mutated

4 **8 packets of "Amino Cards" in re-closable plastic bags:**
1 alpha, 2 alpha mutated, 3 beta, 4 beta mutated
5 alpha, 6 alpha mutated, 7 beta, 8 beta mutated

POSTERS

1 **One Poster by David Goodsell Cell Panorama – Eleven foot long. Source: 3D molecular Designs**
2 **One Poster by David Goodsll Poster of Muscle --std size. Source: Exlporatorium Store**

☐ DNA/RNA
☐ Protein
☐ tRNA Kit #_______

Team Kit Care Record

Date	Team members	Name and # of pieces missing, broken or extra (write "OK" if kit is complete)	Teacher's initials

Date	Team members	Name and # of pieces missing, broken or extra (write "OK" if kit is complete)	Teacher's initials

Teacher Guide: LEGO Lesson One
Protein Structure and Function

K Vandiver Draft 4-25-11

Goals:

1) The student will be able to describe a protein molecule as a flexible chain made up of smaller molecules, amino acids.
2) The student will be able to demonstrate basic hydrophilic and hydrophobic protein folding rules, to demonstrate that the 3-dimensional shape of a protein depends upon the order of the amino acids in the chain.
3) The student will be able to construct a helix from a chain of amino acids.
4) The student will be able to describe how the shape of the protein is important to its function. A channel protein is the example which the student can use.

Prior to the lesson, complete this set up work:
(You will need to obtain 2 photocopier paper cartons to fabricate the cell membrane model.)

1) Create a chain of LEGO amino acids as a model protein for the first activity. **(Required.)**
   Remember: Keep the amino ends (black) on the left as you build. The #1 amino acid is always the one with the free <u>amino</u> group. So Arg (#14) will have its acid group free.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Met	Phe	Gly	Val	Ser	Tyr	Ser	Pro	Cys	Glu	Ser	His	Asp	Arg

   Additionally it is good to create an exciting LEGO DNA molecule to display as the double helix when students enter the room. (However, this is optional day, but required for the next lesson.) This molecule is something students will recognize and because it is made from LEGO, they may be interested in seeing other LEGO molecules.

2) Plan to arrange students in teams of two. Seat them next to each other, not across. They will need to share booklets and other materials, and they need have clear table space for building with the LEGO.

3) Set up a place in the room for the "LEGO Lost and Found Box" and the "LEGO Fix-it Box"

4) Plan a place in the room to store the materials, ready to hand out. Teams will be two students per kit and need:
   - 1 LEGO Protein kit
   - 2 LEGO Layout mats (one yellow , one other colors)
   - 1 LEGO Protein Booklet

5) Construct the model of a cell membrane from the laminated bilipid membrane sheets. The set comes with laminated membrane sheets to construct two complete 3 –D cell membrane models. Note there is a third (top-down view) laminated membrane sheet (located in the Teacher Box) if you have a large class.
   - Find 2 photocopier paper cartons for the box structure, if you haven't already.
   - Tape the four side sheets onto the box, leaving the round phospholipid heads sticking up above the top flat surface. Use the sheets labeled : "Side view A,B,C,D "
   - Place the sheet labeled "top view "flat on the top of the box.

LESSON One Summary of the LEGO activities in order

Sequence	Time	[Slides] booklet	Purpose of each activity	Brief Description
1) the hook activity to gain interest of all	5 min	[Slides] [2-3] Booklet Page 3	LEGO is used to focus attention. This introduction is designed as a "hook"; the activity relies not on prior knowledge but on observational skills.	Students make observations about a model LEGO protein chain. The collective observations made about the model will summarize protein structure. Use the PPT to help you summarize how the LEGO model looks like a protein.
2) recall prior knowledge	5 min	[Slides] [4-6] Booklet Page 5,6	Help your students relate to prior knowledge about proteins in the body, and in cells. Help them recognize the size relationships of cell to molecule.	The teacher helps students connect the new protein structure information with prior knowledge about proteins in the body and proteins in the cell. Slides help to show getting smaller to the size of molecules. Teacher tells a story and acts out the story with the LEGO proteins: eating protein like egg protein, breaking it down to individual amino acids, amino acids traveling in the blood to the muscle, the muscle cell DNA directing the amino acids to be placed in a different order to become muscle proteins.
3) training for LEGO kit care.	5 min	[Slides] [7-8] Booklet Page 2	Train your students to take care of the LEGO kit by following the directions for good LEGO Kit care.	The kits are handed out, student teams check kits with the Protein Layout Mats, students sign record papers, teacher initials the paper.
4) basic amino acid structure	5 min	[Slides] [9-10] Booklet Page 8	Get a LEGO piece into their hands! Learn the three parts an amino acid with tactile reinforcement. Learn how to make and undo peptide bonds with the model. BE SURE to demonstrate the correct way to pull apart the chains.	Students choose an amino acid to hold, learn 3 parts of an amino acid. (acid group, amino group and side chain) The teacher demonstrates connecting and disconnecting the peptide bonds.
5) demo of great protein variety; learning which amino acid is #1	5 min	[Slides] [11] Booklet Page 11	Students experience the amazing variety of proteins, get a chance make their own chain, and they learn how to recognize which end of the chain is #1. This will become <u>very important</u> when you give them building instructions and they need to build amino acid chains in order!	Each student builds their own short protein chain, 4 amino acids long to answer a class question, "Can millions of different proteins be made from only 20 amino acids?" Students hold up their chains to compare. Even with 4 amino acids long, there is low likelihood of the same sequence being built. Proteins are hundreds of amino acids long, lots more opportunity for variety. Students learn how to figure out how amino acids are counted put in order (1-2-3-4) in the chain. This is very important. The first amino acid #1 has its black end (amino group) is free. The last amino acid in the chain has the grey part (acid group) free.

6) protein folding rule about hydrophilic and hydrophobic amino acids	7 min	[Slides] [13-14] Booklet Page 13-15	Students learn one basic rule about protein folding: if there is water on the outside of the protein, the hydrophilic amino acids will orient themselves to the outside, and the hydrophobic amino acids will be folded towards the inside of the protein.	The teams will build a 12 amino acid long protein. The teacher asks the teams to fold it according to hydrophilic and hydrophobic rules and to show their answer. The teacher circulates among the teams, asking them to explain their solutions that are demonstrated.
7) Structure and function relationships with molecules Students get a feel for the importance of the order of the amino acids	10 min	[Slides] [15-21] Booklet Page 25-31	Students learn about the importance of the order of the amino acids. The order allows the protein channel to create the watery passageway in the middle, the pore opening. Students see the pattern, two hydrophobic, two hydrophilic, two hydrophobic, two hydrophilic, continuing to wrap around. This alternating pattern creates a working protein pore. They will build the same protein from a gene later in the week and can see that DNA message contains a code for the <u>order</u> of the amino acids. Mutations can cause havoc with protein function.	The second big project the teams do is to build a part of a channel protein and insert it into a model cell membrane. After the chains are built, ask the 4 students to come forward to show how it will fit into the cell membrane. Gather students around to talk about the results. If you have a large class and gathering them around won't work, you can lead the discussion using the booklet page or PPT where the LEGO protein chains are shown INCORRECTLY with the hydrophobics towards the middle. This discussion will help students note that the hydrophobic yellow amino acids should be oriented NOT towards the middle this time. (Instead-- the side chains would be buried towards the hydrophobic tails of the lipids surrounding them on the outside.) At the end, the instructor helps students to see how the function of the channel protein is directly related to the order of the amino acids in its protein chain. The teacher holds up one chain in a linear form. Asks "Do you see a pattern here in the chain? " Students recognize alternating color pattern of hydrophobic and hydrophilic by groups of two that would continue if the protein model were longer. Helps to make one side of the helix hydrophobic and the other hydrophilic.
8) clean up	3 min		Good LEGO kit care	Clean up – Put away all LEGO amino acids and LEGO materials.

The total time is 45 minutes here. If you have a 50-55 min block, there would be time for students to complete the one page class work sheet summarizing the lesson.

LEGO® DNA Learning Center Set Name ____________________
Lesson 1 Proteins Class Work Class/date_________________
V5/5/11b

Directions: Answer the questions. Use "LEGO® Proteins Booklet 1: Protein Structure."

1. What are the subunits of proteins called? _____________________________
   They are small molecules. Proteins are flexible chains made from these subunits.

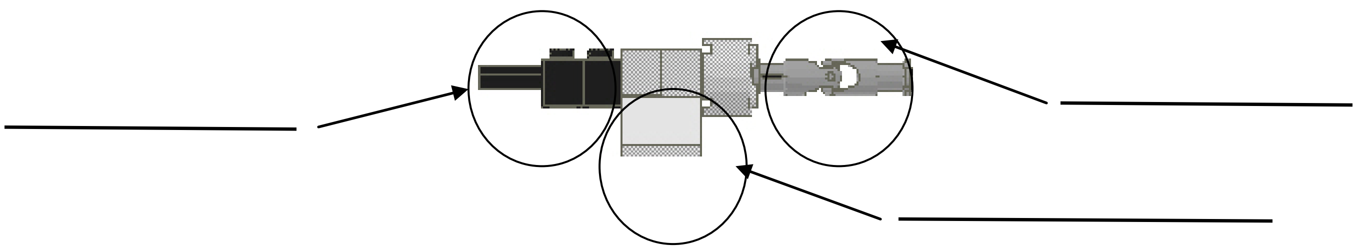
2. Explain how a person gets these subunits into their cells to make new proteins.

____

____

3. How many different amino acids are there? ____

4. Here is an amino acid represented in LEGO. Label the 3 major parts of the molecule.



5. If the LEGO is red, what is this amino acid's full name? ______________________
Look it up in the back of the booklet

6. Write the abbreviation for the amino acid on the model above.

7. Is this amino acid ***hydrophobic*** or ***hydrophilic***?

____

8. If a protein chain was surrounded by water, would you expect to find the **Asp** amino acid in the middle of the folded protein or on the outside surface of the protein?

____

Explain your thinking _____________________________

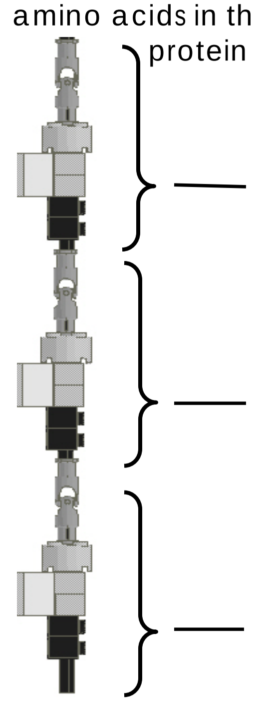
____

9. Give 3 examples of ***hydrophobic*** amino acids:

____
Find the amino acids listed in the back of the booklet

10. Complete the diagram on the right.
    Number the amino acids in the chain correctly.

Label the order of the amino acids in this short protein 1,2 or 3.



LEGO®DNA Learning Center Set
Lesson 1 Proteins Class Work

Name ______________________
Class/date___________________

KEY *answers V5/5/11b*

Directions: Answer the questions. Use "LEGO® Proteins Booklet 1: Protein Structure."

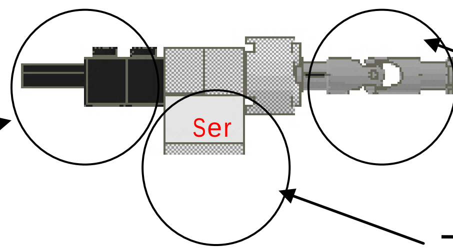
1. What are the subunits of proteins called? _the subunits are called amino acids_
   They are small molecules. Proteins are flexible chains made from these subunits.

2. Explain how a person gets these subunits into their cells to make new proteins. *People eat protein in their food. That protein whether it is from plants or animals, contains amino acids. In the stomach, The protein is broken down into its amino acids. Next it is carried away to other parts of the body by the blood. Another cell in the body, like a muscle cell, takes up the amino acids and puts the amino acids together in a different order. This makes a new and different protein.*

3. How many different amino acids are there? __about 20___

4. Here is an amino acid represented in LEGO. Label the 3 major parts of the molecule.

amino group ______________



Acid group ______________

Side Chain ______________

5. If the LEGO is green, what is this amino acid's full name? ___ Serine______________
Look it up in the back of the booklet

6. Write the abbreviation for the amino acid on the model above.

7. Is this amino acid ***hydrophobic*** or ***hydrophilic***?
____This amino acid is a hydrophilic one_____________________

8. If a protein chain was surrounded by water, would you expect to find the **Ser** amino acid… in the middle of the folded protein or on the outside surface of the protein?

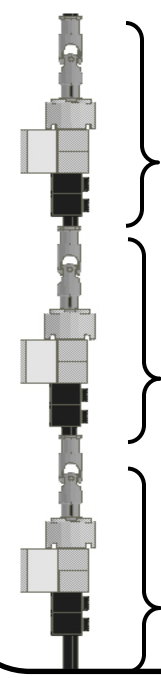
Serine is more likely to be found on the outside surface of a protein

Explain your thinking: Serine, being hydrophilic, has charges which _attract water molecules. (Water also has + and – charges.)___

9. Give 3 examples of ***hydrophobic*** amino acids:
_*answers will vary. (Any 3 of the yellow LEGO amino acids)*
____
Find the amino acids listed in the back of the booklet

10. Complete the diagram on the right.
    Number the amino acids in the chain correctly.

Label the order of the amino acids in this short protein 1,2 or 3.



3 ___

2 ___

1 ___

Teacher Guide: LEGO Lesson Two
DNA Structure and Replication

K Vandiver Draft 4-25-11

Goals:

1) The student will be able to describe DNA as a molecule comprised of four different kinds of smaller molecules, nucleotides which bond together in pairs, abbreviated as AT and CG.
2) The student will be able to describe the overall shape of the molecule as being of a twisted ladder with the two sides of the ladder having opposite directionalities.
3) The student will be to demonstrate the most fundamental concept in DNA replication, that replication is semi-conservative. The student will demonstrate the double stranded structure separating, and new nucleotides pairing, and the completed result: that one of the original strands of the DNA molecule will be conserved in each of the two new DNA molecules.

Prior to the lesson, complete this set up work:

1) Create an exciting LEGO DNA molecule to display as a double helix when students enter the room. (This DNA model is needed for today's lesson.) This molecule is something students will recognize and it helps to motivate them.

2) Arrange students in teams of two. Seat them next to each other, not across. They need to share booklets, and other materials, as before.

3) Set up a place in the room for the LEGO "Lost and Found Box" and the "LEGO Fix-it Box." Today make sure to announce to the students where these boxes are located. DNA nucleotides are the LEGO pieces most frequently misplaced.

4) Plan a place in the room to store the LEGO supplies, ready to hand out. Teams will be two students per kit:
   - 1 LEGO DNA / RNA kit
   - 3 LEGO Layout mats (2 DNA , one RNA orange) This is a good time to explain the DNA vs. RNA abbreviation (DNA =deoxyribonucleic acid and RNA =ribonucleic acid)
   - 1 LEGO DNA / RNA Booklet

Lesson Two Summary of the LEGO activities in order

Lesson Sequence	**Time**	**[Slides] booklet**	**Purpose of the mini -lesson**	**Brief Description**
As the "DO NOW" activity	7 min	NONE	Get closure on the amino acid lesson and a review.	Have student complete the paper in class on the amino acids from yesterday about proteins, if you have not done so.
1) "the hook" an activity to gain interest and participation of all	5 min	[Slides] [1-4]	LEGO DNA is used to focus attention. Make sure to twist and pop open This initial LEGO DNA activity relies both on prior knowledge and on observational skills. Opportunity to demonstrate how to unzip DNA. PINCH	Students make observations about a model LEGO DNA double helix. The collective observations made about the model will help summarize DNA structure and connect to prior knowledge. 1)Show off LEGO DNA twist " double helix means 2) Show off the backbone- LEGO looks like this. 3) Show how it opens in the middle. Demonstrate! It will be helpful when they do their own first activity. See if you can get them asking questions.

2) recall prior knowledge	3 min	[Slides] [5] Booklet Page 3	Cell diagram. Help your students relate to prior knowledge about DNA in the cells. Help them recognize the size relationships of cell to molecule.	Put the nucleotides and DNA into context. They are in the nucleus, inside the cell. Discuss the broader concept of biology, many macromolecules are made from smaller molecules, like proteins are.
3) LEGO kit care.	7 min	[Slides] [6] Booklet Page 2	Continue to ask that they check carefully, sign off and get a teacher signature.	The kits are handed out, student teams check kits with the DNA/RNA Layout Mats, students sign record papers, teacher initials the paper. This can be the time to repeat the distinction DNA vs RNA The abbreviations. LEGO DNA =gray RNA =orange.
4) basic nucleotide structure and the discover your base pairs + unzip	10min	[Slides] [7-11] Booklet Page 8	Get LEGO into their hands! Learn the three parts a nucleotide with tactile reinforcement. BE SURE to remind them about the correct way to unzip the 2 DNA strands.	Students learn 3 parts of nucleotide (base, sugar, side chain.) The students discover the directionally and the base pairing rules. Students practice opening the DNA.
5) define the difficult terms by building them: Gene , DNA Chromosome	5 min	[Slides] [12] Booklet Page 8	Make tactile models. Begin to define genes as sections of the chromosome.	Have 4 students join their DNA segments to a longer ladder to make a chromosome. Their segments are the genes. Take apart and put back in the box at the end.
6) replication	10min	[Slides] [13-16] Booklet Page 9-12	Have student experience the copying procedure, replication They need practice base pairing.	The teams will build a 12 nucleotide section of DNA. Follow directions in the book for replication. Mark the original two strand and notice where they end up. Get the idea of semi-conservation replication. Also how this works to make perfect copies. You can bring in Chargaff's rules.
7) connect replication with mitosis and cell division			Connect DNA replication to mitosis. Refer back to any of your previous teaching materials about cell division.	Please review the connection between replication and mitosis. The cell needs enough DNA for 2 cells before it splits into two cells. DNA replication occurs long before mitosis happens. Review the cell cycle.
8) clean up	3 min		Good LEGO kit care	Clean up – Put away all LEGO nucleotides and LEGO materials.

The total time is 50 minutes here. Utilize the class work paper for a summary at the end of the lesson, or a homework paper, or as the review at the beginning of the next class period.

LEGO® DNA Learning Center Set

Lesson 2 DNA Class Work

Name ________________________

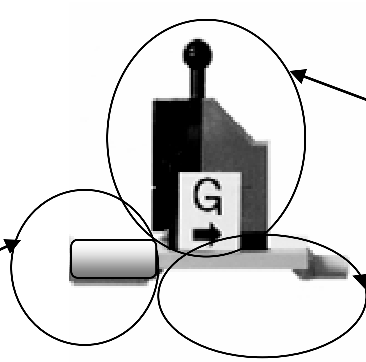
Class/date____________________

Directions: Answer the questions. Use "LEGO® DNA/RNA Booklet 1

1. What are the subunits of DNA called? ________________________________
   They are small molecules.

2. Where these small molecules found in the cell? ______________________________

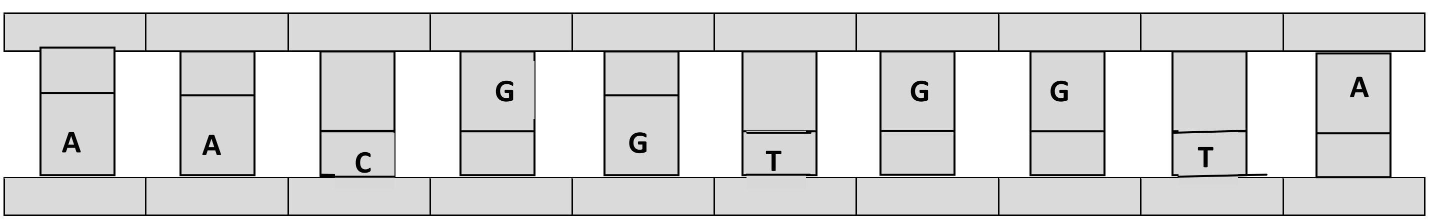
3. Here is a nucleotide represented in LEGO. Label the three major parts.



4. The letter "G" on the nucleotide above is an abbreviation for its chemical name.
Write out the 4 chemical names for the DNA bases:

__________________ __________________ __________________ __________________

6. Complete the missing nucleotides for DNA molecule.
   How many nucleotides are represented in this molecule? ____________



7. If the DNA shown here is replicated, how many nucleotides will there be each new molecule? _____
Explain your thinking. ____

____

____

LEGO® DNA Learning Center Set
Lesson 2 DNA Class Work

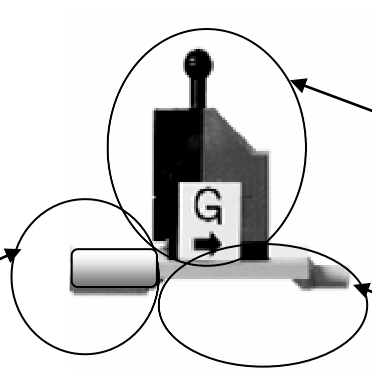
Name ___________________________
Class/date______________________
Key 4-25-11

Directions: Answer the questions. Use "LEGO® DNA/RNA Booklet 1

1. What are the subunits of DNA called? The subunits are called nucleotides (or DNA nucleotides)
   They are small molecules.

2. Where these small molecules found in the cell? ____These molecules are found inside the nucleus.

3. Here is a nucleotide represented in LEGO. Label the three major parts.



Base

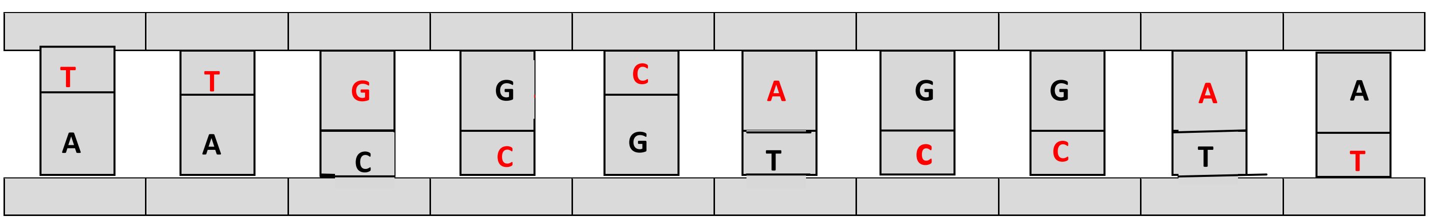
Phosphate group

Sugar

4. The letter "G" on the nucleotide above is an abbreviation for its chemical name.
Write out the 4 chemical names for the DNA bases:

Guanine ______ Cytosine ______ Adenine ______ Thymine ______

6. Complete the missing nucleotides for DNA molecule.
   How many nucleotides are represented in this molecule? _____10_________



7. If the DNA shown here is replicated, how many nucleotides will there be each new molecule? _10____

Explain your thinking. ___Replication produces an exact copy. If DNA starts out with 10 nucleotides, it will produce 10 nucleotides. This is because DNA opens up down the middle and each side helps to create a new side. So it will be the same number of nucleotides for each molecule. Over all, duplication occurs.

____

Teacher Guide: LEGO Lesson Three
The Codon Concept and Transcription

K Vandiver Draft 4-26-11

Goals:

1) The student will be able to decipher a LEGO DNA gene with a simple 3 letter look-up list written in DNA codes, the listing the amino acids in order.
2) The student will be able to use a LEGO DNA molecule to produce a correct mRNA copy of a gene.
3) The student will be able to use the mRNA sequence and the Genetic Code to predict the sequence of amino acids in the protein.
3) The student will be able to describe the process of transcription (above) and that the mRNA exits the nucleus through a pore.

Prior to the lesson complete this set up work:

1) Hope you have saved your LEGO DNA molecule to display again! If any student was absent for the previous lesson, it will be good for them to observe the DNA model and you may want to refer to it in today's lesson.

2) The maximum number of student teams is 8, because there are 8 DNA gene strips. You will probably need to regroup your class to have a total of 8 teams; some teams of 3 students per kit instead of 2 students may be required.

3) Set up the "LEGO Lost & Found Box" and the "LEGO Fix-it Box" in their usual places.

4) Plan a place in the room to store the materials, ready to hand out. Teams will be two or three students per kit:
   - 1 LEGO DNA / RNA kit
   - 3 LEGO Layout mats (2 DNA , one RNA orange)
     Ok to explain DNA abbreviation at this time (DNA deoxyribonucleic acid and RNA ribonucleic acid)
   - 1 LEGO DNA / RNA Booklet

5) Have available the 8 Packs of Amino Acid Cards for the 8 Gene Strips. Note: You may need to unwind /reverse fold the laminated Gene Strips to get the strips to lay flat. Try to do this a day ahead if possible.

Lesson Three Summary of the LEGO activities in order

Lesson Sequence	Time	[Slides] booklet	Purpose of each activity	Brief Description
1) DO NOW It's possible to use this activity as a do now	5 min	NONE	Get closure on the DNA lesson and a review.	Have students complete the paper in class on the DNA from yesterday, if they have not done it. If they have it completed, they should compare answers.
2) LEGO kit care.	7 min	[Slides 2] booklet p.2	Continue to ask that they check carefully, sign off and get a teacher signature.	Hand out kits. Student teams check kits with the DNA/RNA Layout Mats; students sign record papers; teacher initials the paper. Quick introduction to the RNA vs. DNA. The difference is the sugar (color and shape in LEGO)

3) Preview how DNA works with codes. 3 letter code = amino acid.	10 min	[Slides 3,4,5,7,] **booklet** p. 14 [Slides] **booklet** p.15, 16, 17	Students will build and decipher a LEGO DNA gene with a simple 3 letter look-up list that is written in DNA. This will help them understand the concept of how the codons work before getting bogged down in the multiple steps cells take to make proteins.	We are going to use the gene strips in order to build some genes correctly and swiftly. The strips are great because they have the codons marked on them. • Pull out the 8 DNA strips. (Max 8 teams in this class) Students build the LEGO on top of the strips so there are no mistakes. • Four genes have been created; 2 of each the protein Alpha and alpha mutated, + beta and beta mutated. So the kit has 2 complete sets total. Let the students know that they are going to work on decoding the secret DNA messages. • Students use the look up table in the booklet to figure which amino acid card to slide under each codon. • This activity can introduce them to a mutant. We have a normal and a mutated alpha (an allele) and the same with beta. Some altered genes will produce a defective protein. The order of the amino acid will be different. The students will remember the pattern of 2 hydrophilic , 2 hydro phobic, 2 hydrophilic to create the working pore. • Students can look at each other's work with the amino acid cards. • Collect CARDS AND STRIPS at the end. • **Do NOT take apart the GENE –need it next**
4) students connect prior cell knowledge current cell information	5 min	[Slides 8] **booklet** p. 3 for cell	Cell diagram. Help your students relate to prior knowledge about DNA in the cells. Use the Goodsell poster to help students understand the molecular nature of the cell.	Quickly Review the cell diagram in PowerPoint. • Stress that the DNA can't leave the nucleus, • but the ribosomes out in the cytoplasm are the protein factories. • Point out the orange strand coming out of the nucleus. Creating a temporary copy of the code to carry the message out the ribosome is the solution. Next, look at the David Goodsell poster: Locate nuclear pore (has strands in the pore opening) DNA (yellow), mRNA (pink), and ribosome (purple) Again make it clear why mRNA has a job to do. Message needs to get to the ribosome.
5) Watch transcription in an animation.	5 min	CD with the LEGO Set	Begin to learn more details about transcription to introduce the new content.	Show the **Molecular Workbench** on the CD to the whole class with a projector. Start with Unit 3 called "Transcription - copying a gene to mRNA" (The animation has no sound. You can describe what you want them to know in your own words.)

				Show it twice. Ask questions on the second time through. For example, "Where is the copy of the gene going to when it leaves the nucleus? "
6) Learn how to transcribe by hand.	15 min	[Slides1 10,11,1 2,13,14] **booklet** p.18 p. (last page) On last page in booklet we added a RNA chem. diagram	Learn the three parts a RNA nucleotide, including the type of sugar and what's different between U and T. Students learn to transcribe. They use a LEGO DNA template to make a LEGO mRNA copy. The mRNA is released and leaves the nucleus.	• Students practice opening the DNA. • >>>PINCH < < • Introduce the RNA nucleotides, and the lack of a " t" You may want to point out the page in the booklet where the RNA chemistry is shown. (Added now as the last page in the booklet) Compare DNA and RNA and compare "T" with "U" as a base. mRNA is created by base-pairing (The size and shape of the molecule is what determines which nucleotide can pair. (Don't let students just read the letters.) Which side should the student base-pair with? NOTE : The mRNA and the gene should be the same sequence (except U and T). Also the mRNA should start with AUG. Remember, if the students <u>pair with the ATG side</u> of the DNA, this <u>won't work to give AUG!</u> The rule is that the gene (the coding strand) and mRNA will always be the same sequence. EMPHASIZE this? You may want to show the gene located on the top strand sometimes, and other times sometimes on the bottom. ATG becomes AUG. • Students practice opening the DNA/mRNA • >>>PINCH << < To release the mRNA!! Off to the ribosomes.
8) clean up	3 min		<u>**SAVE 4 mRNA transcripts FROM THE LAST CLASS of the day for the next lesson!**</u> Purpose: It is easier to start from the mRNA to do the translation.	<u>**Last Class of the day — Special instructions:**</u> Save the 4 mRNA LEGO transcripts. How to know which is which? You lay each mRNA on top of its DNA gene strip. Clean up – Put away all the other LEGO nucleotides and LEGO materials.

Total time is 50 minutes. Student can do the class work paper if there is time.

LEGO® DNA Learning Center Set Name ______________________
Lesson 3 Transcription Class Work Class/date__________________
V 5/5/11b

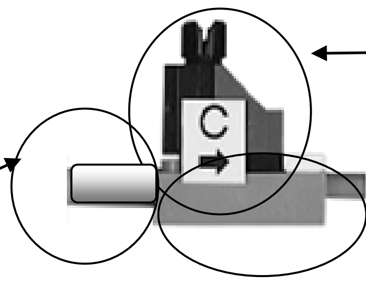
Directions: Answer the questions. Use "LEGO® DNA/RNA Booklet 1"

In transcription, mRNA is produced. The mRNA molecule is a copy of one side of the DNA.

1. Where does the process of transcription take place in the cell? ______________________________

2. What are the subunits of mRNA called? ________________________

3. Here is one mRNA nucleotide. Label the three major parts.
Which one of the circled parts is different in RNA compared to DNA? ____________________



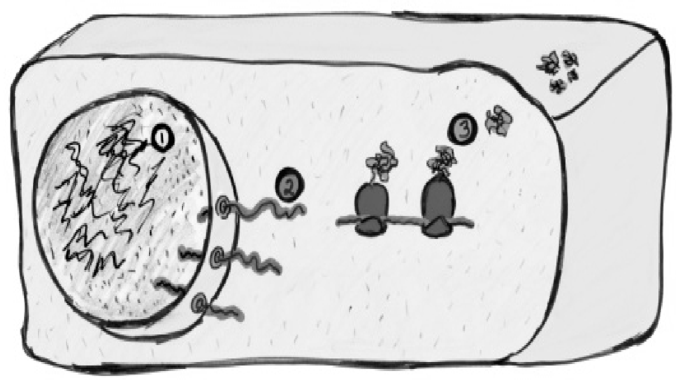
This diagram shows a cell.

4. DNA is locked up inside which cell part?

____

5. What molecule is leaving the nucleus in this diagram? (It is labeled #2)

____



6. Here is DNA molecule with a short gene
The gene (coding strand) is on bottom. → **Gene**
The mRNA for this gene is **AUG CCC UUU AAA AUC**

TAC GGG AAA T T T ATC
ATG CCC T T T AAA TAG (Gene)

The rule is: mRNA has the same letters as the gene. (Except the T becomes a U.)

Gene **TAC GGG AAA T T T ATC**
ATG CCC T T T AAA TAG

Here the gene is the top strand!
Transcription occurs.
Write the mRNA letters here: __ __ __ __ __ __ __ __ __ __ __ __ __ __ __

LEGO® DNA Learning Center Set
Lesson 3 Transcription Class Work

Name ______________________
Class/date__________________
KEY V 5/5/11b

Directions: Answer the questions. Use "LEGO® DNA/RNA Booklet 1"

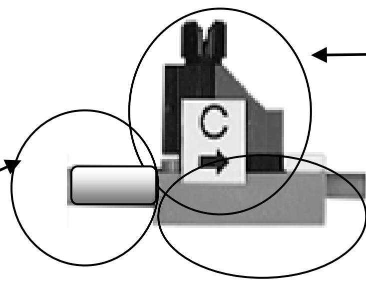
In transcription, mRNA is produced. The mRNA molecule is a copy of one side of the DNA.

1. Where does the process of transcription take place in the cell? _*This process takes place in the nucleus.*_

2. What are the subunits of mRNA called? ____ *The subunits are called nucleotides (or RNA nucleotides)*

3. Here is one mRNA nucleotide. Label the three major parts.
Which one of the circled parts is different in RNA compared to DNA? *The sugar is different.*___

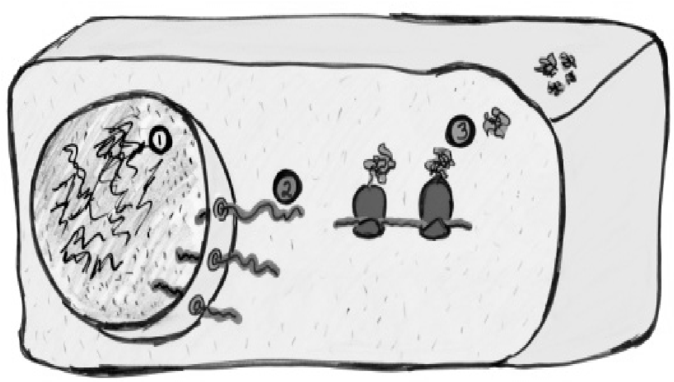
Base



Phosphate group

Sugar
(ribose sugar not deoxyribose)

This diagram shows a cell.



4. DNA is locked up inside which cell part?

The DNA is locked up inside the nucleus.

5. Which molecule is leaving the nucleus in this diagram? (It is labeled #2)

A molecule called mRNA is leaving the nucleus (through a nuclear pore).

6. Here is DNA molecule with a short gene
The gene (coding strand) is on bottom. → **Gene**
The mRNA for this gene is **AUG CCC UUU AAA AUC**

TAC GGG AAA T T T ATC
ATG CCC T T T AAA TAG

The rule is: mRNA has the same letters as the gene. (Except the T becomes a U.)

Gene
TAC GGG AAA T T T ATC
ATG CCC T T T AAA TAG

Here the gene is the top strand!
Transcription occurs.
Write the mRNA letters here: **U A C G G G A A A U U U A U G**

Teacher Guide: LEGO Lesson Four
The Process of Translation

K Vandiver Draft 4-27-11

Discussion of which version of the Translation Lesson Plan to provide:

Developer's Experience

The lesson management issues for translation are complicated because there are: 1) multiple steps in the cell process, 2) mutations that are included with the 2 different genes, and 3) multiple sets of LEGO molecules that are required. However, the instructors at the MIT Museum have very successfully and easily taught this lesson for years. (2008-2011) The instructors can do it well because the class has been divided in half and we typically are working with 8- 14 students at a time, not the full 24-28. The rest of the class at the MIT Museum is working on the computers. The groups swap after an hour.

For the teaching of the translation steps on the ribosome, the MIT instructors typically have the students gather around just one ribosome where we translate one mRNA. We pick the mutated beta channel protein gene to show how a mutation can affect protein function. Student involvement is accomplished in the following way. The instructor asks different students to participate in the different steps such as in selecting the tRNA, removing the amino acid, and sliding over the mRNA, and so the activity becomes a shared experience. Also working together in this circle around the ribosome table creates an atmosphere that encourages questioning. Lots of good discussions occur spontaneously at this point.

BPS Teacher 's Pilot

During the BPS pilot testing in spring of 2011, most of the teachers wanted the students to get the same maximal hands-on experience with the LEGO translation steps as with the other LEGO lessons. Therefore the pilot teachers designed several different variations on the MIT Museum plan. Two lesson variations with full classes of 28 students will be described. 1) Beginning with the class together, dividing the class in half, and swapping the two groups on and off of the four ribosome tables during the 55 min period. This class did produce eight proteins and the chains were saved for a follow-up discussion about the mutations the next day. (This classroom had the benefit of 4 teachers present at the time. 2) Another teacher with 28 students in her classroom arranged the room to have 8 ribosomes, 4 on each side of the room. The students also successfully managed to produce proteins simultaneously. (Two teachers present at the time.) What made this possible was that the teacher led the students through the initial steps on the ribosome using a video camera and a projector.

BPS Teachers recognize validity of MIT technique, we look forward trying new method

Both of the pilot teachers in the lessons described above, managed well planned and executed lessons, but they were not certain they would do it this way again. Basically, the mechanical logistics of translation didn't allow enough time for mental processing. Vandiver has a solution in mind. A student training video or animation of translation with the new LEGO molecules could be provided. It would be created with built-in pauses, where the teacher would ask, "what happens next?" to give the students with practice with the decision -making steps and an opportunity to ask questions. This video-questioning a technique has already been tested at two teacher workshops using an older version of LEGO molecules. This technique was observed to improve the translation accuracy as well as overall comprehension of the process.

But for now, the following lesson plan is recommended, that the class be split into half and that this lesson take 2 days in a classroom. This version provides the least stress on the teacher. After you are more experienced, you might consider other more complex variation. A paper and pencil task is recommended for the alternate activity, something that doesn't require too much direction, but is engaging. Teachers probably have their favorite exercises available.

Goals:

1) The student will be able to describe the process of translation to include:
- the mRNA attaching to a ribosome which is located in the cytoplasm;
- the tRNA molecules, working like taxis, each carrying an amino acid to the ribosome;
- the tRNA selectively binding by base pairing in groups of 3 to the mRNA; and
- the amino acids joining together in a sequence to form a chain which is a protein.

2) The student will be able to decipher a genetic code (RNA nucleotide look up table) for the amino acids.
3) The student will be able to describe the function of DNA as being the stored information for creating proteins, and that the order of the nucleotides dictates the order of the amino acids in the protein chain.
4) The student will be able to describe a mutation as a change in the DNA which can lead to a change in the protein structure. This change in turn can affect how well the protein will work, for better or worse.

Prior to the lesson complete this set up work:

1) You will have saved 4 mRNA transcripts. Be sure you know which genes they are from: alpha, alpha mutated, beta, beta mutated.
2) You will need the cell membrane model (lipid bilayer laminates taped on the photocopier box from lesson 1)
3) This lesson requires some additional space planning if you would like to recreate parts of the cell in the classroom. This is highly recommended because if the cell nucleus and ribosome are designated in the room, then the students can simulate carrying the LEGO mRNA out of the nucleus to the ribosome for translation.
    - Suggestion. Use the head table or the side table/counter as the nucleus. Place all the gene strips there, as well as the mRNA transcripts. Create 1-4 tables for the ribosomes, so that the mRNA can be carried out there. Alternatively, you can use masking tape to outline/ designate parts of the lab benches as ribosomes and the nucleus. Add the green ribosome mats as well.
    - The rest of the room can be left as usual, as the other half of the class will be doing the paper exercise.
4) Translation on the ribosome. This is process is complicated because there are multiple steps and because translation requires the use of many LEGO kits at the same time. Adaptations for working with different numbers of students are currently being piloted. The following instructions have been written for a class of about 24 students.
5) Background information about the kits and gene strips:
    - <u>Gene strips.</u> There are 4 different gene strips: alpha, alpha mutated, beta and beta mutated. Note that the maximum number of teams is 8. There are 8 gene strips.
    - <u>DNA/RNA kits.</u> The class needs messenger RNA strands to begin the lesson. Transcription has been completed. (These could be saved from last classes. Note that the kit and the strand need labels for kit number and for what it is, alpha, beta, etc.)
    - <u>Protein kits.</u> Note that one LEGO protein kit can make at total of 1 alpha chain and 1 beta chain.
    - <u>tRNA kits</u>—Each kit contains the tRNA molecules for a particular gene, like an alpha or a alpha mutated. Remember there are 4 different gene strips: alpha, alpha mutated, beta, and beta mutated. Thus tRNA kits #1-4 are all four different ones, and then the numbers #5-8 repeat the sequence of the four genes so that there are 2 of every kind of gene and tRNA boxes for them.
    - The teacher tRNA kit, #9 is different. It can do any of these four genes. The nucleotides can be rearranged for the anticodons. Be careful. The default setting on the #9 Teacher tRNA kit is an alpha channel protein.
6) Plan what to emphasize in the lesson. You have the opportunity to discuss many ideas beside the steps of translation. For example,
    - <u>Mutations</u> ---opportunity to show how one change in a DNA nucleotide can produce a shape change in a protein.
    - <u>Genetic diseases.</u> Some people inherit and are born with a genetic disease. The Channel protein gene in this lesson models cystic fibrosis. The protein is the genetic trait. How the dominant and recessive genes work in this case, is that the recessive gene codes for the non-functional protein.

- Connections with Mendelian genetics. The beta mutated gene will give you a detrimental mutation. The one base pair change in position 13 nucleotide and (position 1 of 3 in codon) in Beta mutated changes a hydrophobic amino acid to a hydrophilic one. The chain pattern is no longer the necessary 2 phobic, 2 philic, 2 phobic to make the sides of the helices one type or the other. The Beta mutated protein chain now has too many hydrophilic amino acids and the pore doesn't work.
- Code redundancy-- Both CCC and CCU both code for Proline. This mutation may not matter much for the protein.

7) Maintain the place in the room for the LEGO "Lost and Found Box" and the "LEGO Fix-it Box"
8) Have the following ready
   - Gene strips
   - LEGO Protein kits
   - LEGO tRNA sets
   - Ribosome mats.

9) If you plan for students to repeat translation with other mRNA transcripts after the group demonstration, for each ribosome station, the station should have matching materials (e.g. Alpha or alpha mutated gene components all the way through.)
   - 1 protein kit
   - 1 tRNA box
   - 1 green ribosome mat

IMPORTANT TIP for LEGO Management in Translation

1) If you plan on translating more than one gene in a class period … OR
2) If your ribosome space is very crowded…

Remove the following 10 amino acids each protein kit and put them inside the 8 (or 9 teacher) tRNA kits. These 10 amino acids include all the amino acids necessary to build any channel protein. The rationale is that all the protein kits will be missing the same 10 amino acids. Therefore you can return the amino acids without having to figure out which # kit they came from.

Amino acid list:

1 **Met**
2 **Pro**
3 **Arg**
4 **Glu**
5 **Ser**
6 **Ala**
7 **Cys**
8 **Val**
9 **Leu**
10 **Thr**

However within one class period, you will still need to be sure you know which tRNA box (#1-4) to place the disassembled the protein chain back into for the next class. Having tRNA kits (#5-8) prepared with these 10 amino acids inside may help as a back-up. This is in case you don't have time to reset the materials and have an incoming class, you use the (#5-8) sets which are ready.

Lesson Four Summary of LEGO Translation

Lesson Sequence	Time	[Slides] booklet	Purpose of the mini -lesson	Brief Description of the experience
1) DO NOW Students are divided into groups: LEGO Group and Paper Group- to swap next time.	7 min	NONE	Review previous lesson molecules Divide the class and explain the seating and lesson format.	Have students complete the paper from yesterday, if they have not done it yet. If they have it completed, they should compare answers.
2) LEGO kit care.	7 min	**[Slides 2]** **Booklet: See table of contents for tRNA structure**	Do the kit check of the tRNA boxes #1-4 first. The purpose of doing this early in the lesson is to get the students engaged early. Also then when the animations are shown, the students will better understand what they are looking at if they can recognize a tRNA molecule.	Introduce tRNA molecules. They are the last new LEGO molecule. This may seem out of order, but I think it could be useful early in the lesson to have a hands-on, active experience. All student teams can check kits with the tRNA Layout Mats; students sign record papers; teacher initials the paper as usual. Two parts of the tRNA : 1) amino acid attachment site 2) The anti- codon--- binds to the mRNA
3) Students connect prior cell knowledge to current cell information Preview how protein synthesis works.	13 min	**[Slides 3, 4 , 5 6]** **Booklet: See table of contents for the specific genes**	Orientation to the cell for the process of translation. Review about molecules and organelles in the cell. Depends on your students: Maybe--Introduce the genetic code here. Students need coaching to interpret the table. We have PPT slides courtesy of Johanna Waldman, BPS lead biology teacher, for coaching how to read the genetic code as a table.	Make a story about the cell. Start by explaining that the cell is growing bigger and so it needs more cell membrane proteins. Ask them to tell you the steps completed so far, 1. DNA opens up down the middle (pinch) 2. mRNA pairs to the side opposite the gene (the side opposite the coding strand.) 3. mRNA forms, leaves the nucleus. 4 Goes to ribosomes. Next, look at the David Goodsell poster: Locate nuclear pore (strands in the opening) DNA (yellow), mRNA (pink), and ribosome (purple) Again make it clear why mRNA has a job to do. Message needs to get to the ribosome. <u>Vocabulary words make clear their origins</u> Transcription (old days scribes copied) Translation (changing language). Language change here too: <u>Nucleotides in order</u> >>becomes>> <u>amino acids in order.</u>

				Animations to use in order of use today Molecular workbench transcription #3 Molecular workbench TRANSLATION. #4 Optional --Dr. V made animation with the older LEGO of translation. Ok to play this. -- on MIT tech TV website. Search LEGO. Find Translation
4) Students learn how translation Works	7 min	**[Slides-none]** **Booklet: See table of contents for the specific genes**	Teacher reviews transcription to get to the mRNA. Then demonstrates how to do translation with the LEGO transcript *with the students helping with the steps. ***If this is the only translation that students will do, then select the beta mutated gene. This defective protein will give you a lot to talk about.** * If this is just the first demo and students will be doing more, then use the alpha transcript.	TEACHER REVIEW IN THE NUCLEUS Go to the nucleus. In the nucleus will be 3 mRNA strands (alpha mutated, beta mutated and beta) and all the DNA genes as paper strips . Review the **chromosome** vocabulary word. Teacher may show how joining the DNA Gene Strips end-to-end makes a chromosome. (1000s of genes joined end to end= chromosome.) Verbally review transcription, so everyone remembers. TEACHER DEMONSTRATION TRANSLATION (with participation by students) Have the students carry out the mRNA to the ribosome o Do translation. o Produce protein o Put protein in the model cell membrane. o Discuss the effect of changing one nucleotide
5) The LEGO group continues to either build another protein chain or discuss the results further .	10 min	**[Slides none]** **Booklet: See table of contents for the specific genes booklet**	Repetition and practice at doing translation Or Discuss genes and traits, how the protein is the trait.	If there is time, you can have the LEGO teams go back to the nucleus. They take another mRNA out to the ribosome. One approach is to get second chain built in every class. After the beta mutated chain, have students do the one alpha mutated transcript together. Discuss why the alpha mutated gene product isn't different from the alpha gene. (Both CCC and CCU both code for Proline.) -- OPTION if you have much longer class period: have 4 teams do all 4 genes on 4 ribosomes and put them in them into membrane for a discussion.
	3 min		Good LEGO kit care	Clean up – Put away all LEGO nucleotides and LEGO materials. The amino acids need to be returned to the tRNA set if you have another class coming in.

Total time is 47 minutes. Students can do the class work paper if there is time.

Also you have some time to address the needs of the rest of the class.

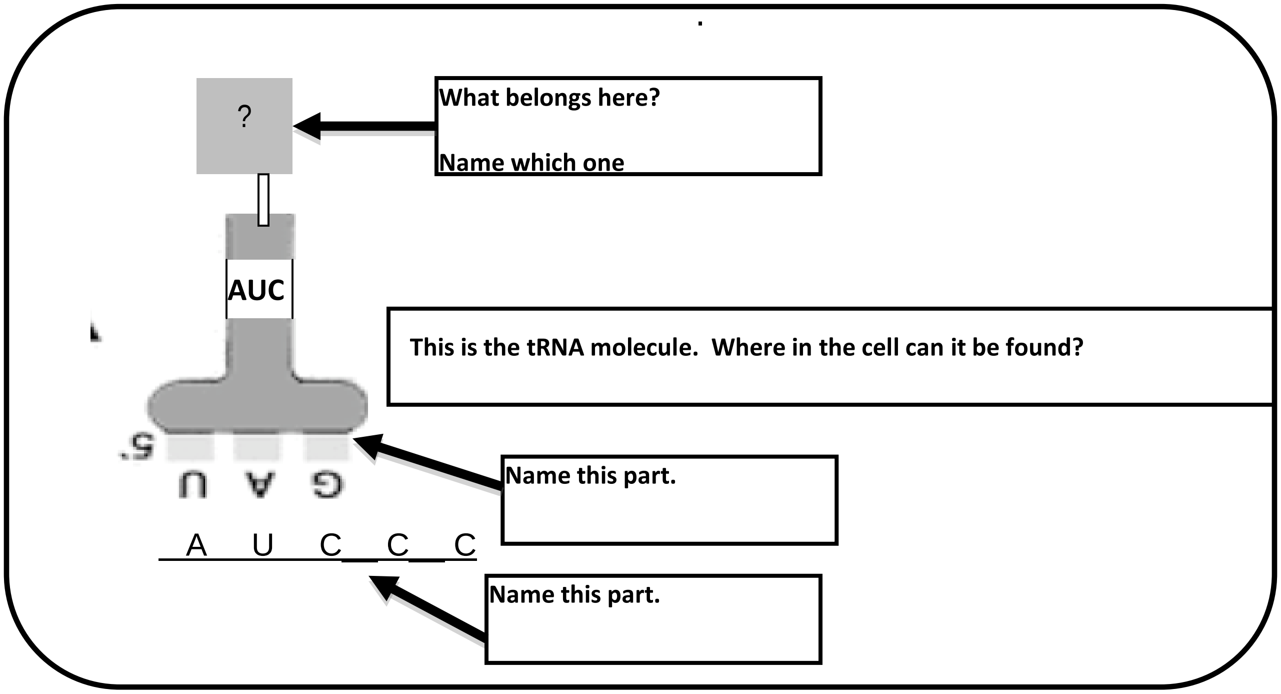
LEGO® DNA Learning Center Set
Lesson 4 Translation Class Work

Name ________________________
Class/date____________________

Directions: Answer the questions. Use Student Booklets "Proteins" or "Protein Synthesis" for reference

1. The process by which a protein chain is built from the messenger RNA (mRNA) is

   ___________________________.



2. What part of the tRNA must interact with the mRNA to complete translation?________________________

   ____

3. How does the ribosome know when to stop translating? ____

   ____

4. Code your own protein!
   - Select any four amino acids that you like. Put them in the top row.
   - Write in the codons underneath. You will need to look them up in a booklet. Lastly, change the code to the anticodons that would be on the tRNA molecules to match up with your RNA.

Amino acid >>				
Codons in RNA >>	____ ____ ____	____ ____ ____	____ ____ ____	____ ____ ____
Anticodon on the tRNA would be:	____ ____ ____	____ ____ ____	____ ____ ____	____ ____ ____

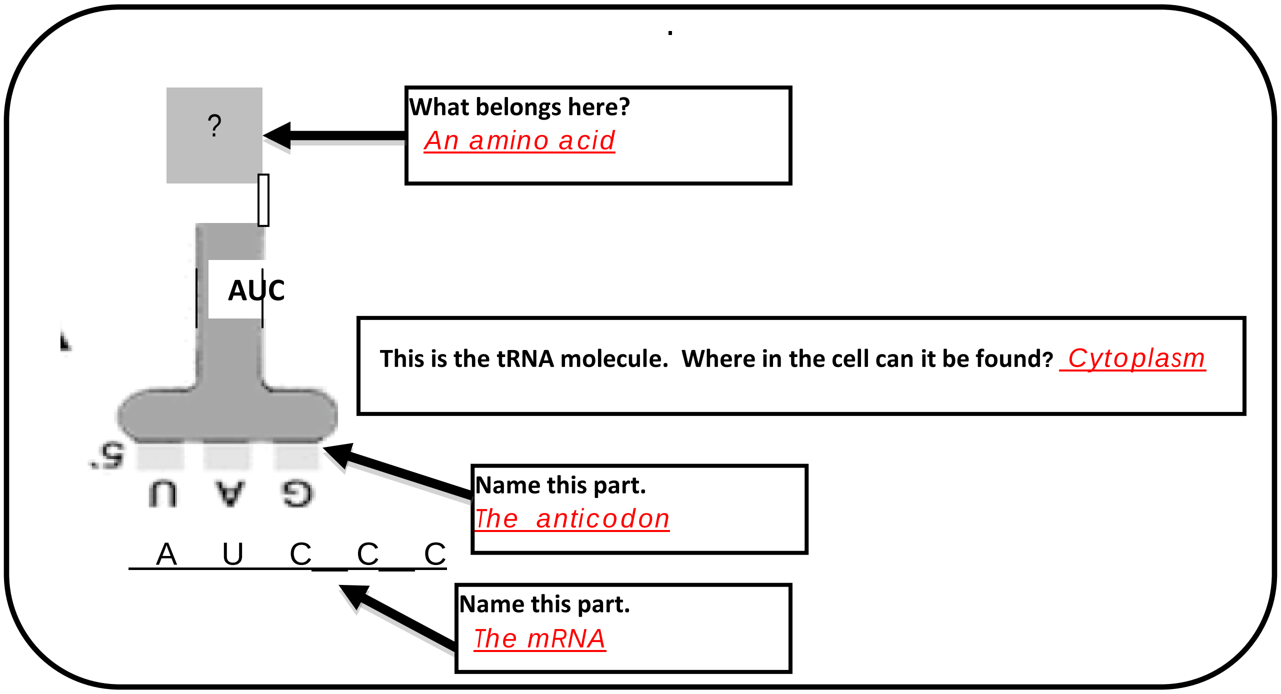
LEGO® DNA Learning Center Set
Lesson 4 Translation Class Work

Name ___________________________
Class/date______________________

Directions: Answer the questions. Use Student Booklets "Proteins" or "Protein Synthesis" for reference

1. The process by which a protein chain is built from the messenger RNA (mRNA) is

   The process is called translation .



2. What part of the tRNA must interact with the mRNA to complete translation _The anticodons bases must pair with the bases in the mRNA, three at a time._

3. How does the ribosome know when to stop translating? ______ _The mRNA contains stop codons. A stop codon (like UAG) causes the mRNA to fall off of the ribosome._

4. Code your own protein! _Answers will vary . One example is done_
   - Select any four amino acids that you like. Put them in the top row.
   - Write in the codons underneath. You will need to look them up in a booklet. Lastly, change the code to the anticodons that would be on the tRNA molecules to match up with your RNA.

Amino acid >>	Met			
Codons in RNA >>	_A_ _U_ _G_	____ ____ ____	____ ____ ____	____ ____ ____
Anticodon on the tRNA would be:	_U_ _A_ _C_	____ ____ ____	____ ____ ____	____ ____ ____