DNA FOR DINNER?

LESSON 4

# Building Blocks to Organisms

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## WHAT WE WILL DO

- Explore the function of common enzymes in food and in humans.
- Learn how DNA provides information to make RNA, from which proteins are made.
- Examine how amino acids are specified in RNA by the specific order of three bases. The order of amino acids determines the particular protein to be made.

## WHAT WE WILL LEARN

- The order of A's, C's, G's and T's in the DNA sequences of genes is the code for specific **amino acids** that result in specific proteins.
- The order of amino acids determines the function of the particular protein.
- Different proteins do different jobs in the organism.
- Some proteins, called **enzymes**, have functions that speed reactions in the cell.
- Certain DNA sequences are "on" switches to start proteins; others are "off" switches to end proteins.

## TABLE OF CONTENTS



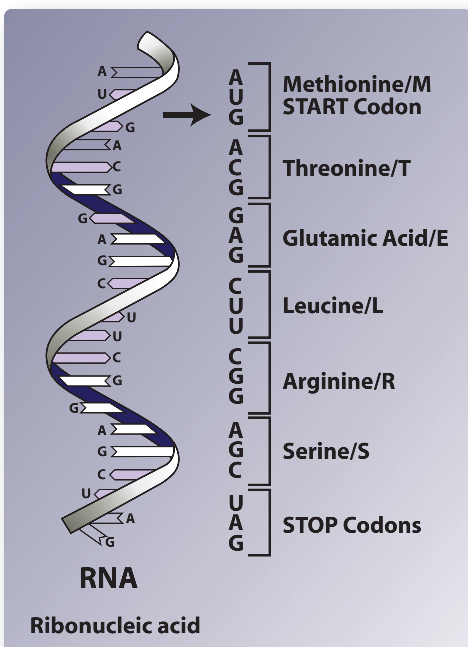
** optional*

*Funding for this project was made available by the American Society of Plant Biologists' Education Foundation.*
*http://aspb.org*

*This curriculum follows 4-H SET guidelines*
*http://www.ca4h.org/SET*



## Appetizer




In a previous lesson participants learned that genes contain coded information. The coded information in a single gene normally provides the organism with the "blueprint" to make a single protein. The information for proteins is contained in DNA in four chemical units or bases, termed A, C, G and T. Information in DNA is copied into the complementary bases A, C, G and U in messenger **RNA** ("U" substitutes for "T" in RNA). The bases in RNA are then read by the cell machinery in sets of three, called a **codon**, that specify one of 20 **amino acids**. Strings of amino acids make proteins and together all proteins give the organism its characteristics.

Proteins are chemicals that each accomplish a task. Certain specialized proteins, called **enzymes**, speed up reactions in the cell - sometimes making them perform a task a million times faster. Some proteins are used to give the organism its shape, while others give it energy to perform work. For example, in plants, some proteins direct the shape and size of leaves; others determine these characteristics for the fruits, flowers and seeds, like their **carbohydrate** and **starch** content. Other proteins help the plant capture energy from the sun and directly turn it into food for the plant and indirectly for humans who eat plants or parts of plants.

# What's in a Word?

**Words**

Amino acids • Carbohydrates • Codon • Enzyme • RNA • Starch

Participants will find new words in this lesson. Some may be similar to words they already know and some may not be.

**Amino acids** are basic building blocks of protein. There are 20 different amino acids: alanine, arginine, asparagine, aspartic acid, cysteine, glutamic acid, glutamine, glycine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, proline, serine, threonine, tryptophan, tyrosine and valine. Each amino acid is specified by different sets of three A's, C's, G's and U's (**Handout 4.1**). The words "amino acid" relates to a 19th century German word meaning "building stones".

**Carbohydrates** are a group of chemicals, containing carbon, hydrogen and oxygen. They include sugars, starches, celluloses, and gums and are a major energy source in our diet. The word comes from *carbo*, meaning carbon, and *hydrate*, meaning water, which contains hydrogen and oxygen.

**Codon** contains three bases of either A's, G's, C's or U's, that code for a specific amino acid. Some amino acids have more than one triplet code. There are also codons that start or stop protein synthesis. Codon has the same origin as a word we learned about in **Lesson 2,** *code*.

**Enzymes** are specialized proteins that speed certain chemical reactions, often millions of times faster than they would occur without enzymes. Most processes in the cell require enzymes. *En* and *zyme*, originally Greek words, mean to leaven, because certain yeast enzymes cause bread to rise or be leavened.

**RNA**, for **r**ibo**n**ucleic **a**cid, is similar to DNA, but contains the sugar, ribose, not deoxyribose as in DNA. Unlike double-stranded DNA, RNA is single-stranded, copied from a single strand of DNA by pairing G with C; C with G; T with A; and A with U, which substitutes for T in RNA. There are three types of RNA: ribosomal, transfer and messenger.

**Starch** is a carbohydrate made of carbon, hydrogen and oxygen and is in the form of sugars linked together. In plants it is mainly in seeds, fruits, tubers, roots and stems. *Starch* comes from the Middle English word, *starche*, a substance used to stiffen cloth.

You may notice other words with these same roots. By finding the root in a word, you may be able to figure out what it means, even if you have never seen the word.

## Remembering the Last Lesson's Important Points

Remember these words?

Cell • Chemicals • Chromosome • Nucleus • Organelle

Ask These Review Questions

- Explain how information in books or flash drives are the same as or different from information in a genome? (Encourage participants to use terms introduced in the last lesson.)
- Describe supercoiling of DNA and explain why it is necessary?
- Give each participant **Handout 4.1**, and ask them to arrange the steps in the order in which they were performed. Then talk about the various steps you performed when you isolated DNA from a tomato (strawberry, kiwi)?
- Tell me what you think might happen if cells did not have DNA.

## Main Course

- Activities will introduce participants to the use of a DNA triplet code that specifies the amino acids in a protein.
- Participants will learn that specific sets of amino acids make particular proteins and that different proteins perform different functions.
- Two activities are offered in this lesson; one is optional. There is also an activity associated with Dessert.
- In these activities participants will learn about RNA and how its bases are arranged in triplets that specify particular amino acids. Amino acids are linked together to form proteins, which perform important functions in the cell.

## ACTIVITY 4.1 Mellow Jell-O® and Spit 'N Crackers

In this activity, participants will learn what kinds of jobs proteins can do. Start with the gelatin and pineapple activity, so the gelatin can set while you do the Spit 'n Crackers activity. Brand names are used as examples and do not constitute product endorsement.

### WHAT TO DO AHEAD OF TIME?

- Purchase fresh pineapple, 1 small can of pineapple, any gelatin flavor and unsalted or matzo crackers.
- Cut fresh pineapple into slices.
- Have boiling water ready.

### WHAT IS NEEDED?

- Boxes of any gelatin flavor.
- Bowls.
- Measuring cups.
- 1 fresh pineapple.
- 1 small can of pineapple drained.
- Unsalted crackers or matzos.
- Napkins.

### HOW MUCH TIME IS NEEDED?

- 15 minutes to set up Mellow Jell-O® Activity.
- 10 minutes for Spit 'N Cracker Activity.
- Additional 5 minutes to observe outcome of Mellow Jell-O® Activity.

## Directions

**Mellow Jell-O®**

Start this activity first to allow gelatin to set up before participants end the activity. Divide participants into groups. Ask half of the groups to make gelatin with fresh pineapple; the other half with canned pineapple. Follow directions on the gelatin box for making the liquid gelatin. Divide the liquid gelatin into enough bowls so that each group has one bowl. Ask some groups to add several chunks of fresh pineapple to their bowl and the other groups to add several chunks of canned pineapple. Thoroughly stir both and refrigerate. Observe results after gelatin sets up.

**Spit 'N Crackers**

After gelatin activity is underway, have participants be seated and give each participant a soda cracker. Have them put it in their mouths and chew. DO NOT SWALLOW. After chewing for 30 seconds, ask participants to describe what taste the crackers have. Then ask them to continue chewing WITHOUT swallowing. After 2 minutes of chewing, ask them again to describe the flavor of the cracker. It is important to use unsalted crackers or matzo because they contain less sugar and salt and thus will have no initial salty or sweet taste.

After the Spit 'N Cracker Activity share with the group the following. Remind them that DNA contains the information that gives an organism its special characteristics, like colors, tastes and smells. The chemical bases in DNA, A,G,C,T, are used to copy another very important informational chemical, called RNA. RNA is complementary to DNA so that every G in the DNA is matched by a C in the RNA copy. Every C is matched by a G; T with an A and every A with a U. The U substitutes for T in RNA. The code in RNA is the information the cell uses to make proteins.

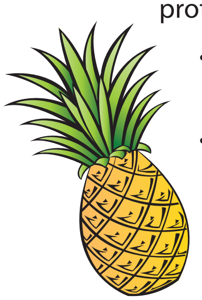
- Describe what kinds of functions proteins might perform?
- Explain why the taste of the cracker changed after you chewed on a cracker for several minute?

  *Hint to Leader: Amylase, an enzyme which degrades starch into sugars, is present in our saliva and changes cracker starch into sugar. Sugars taste sweet; starch doesn't. Breaking down starches to sugars is necessary for the body to use the starch for energy.*

- How do you think the cell is able to make so many different proteins of different functions?

  *Hint to Leader: The number and sequence in which amino acids are hooked together determine a protein's size and its function. Cells hook amino acids together, just like cars in a train are hooked together; the result is called a protein.*


After completing the Spit 'N Cracker activity, have participants check the results from their Mellow Jell-O® Activity. When considering the Mellow Jell-O® Activity, share the following. The ingredient in Jell-O® that makes it wobbly is actually a protein, called gelatin. When it is dissolved in hot water and allowed to cool, the proteins link together like strings in a net to make the mixture solid.



- Explain why you think the gelatin did not solidify when you added fresh pineapple?
- Why do you think canned pineapple did not give the same result?

  *Hint to Leader: The gelatin didn't become wobbly when fresh pineapple was added because there is an enzyme in fresh pineapple that breaks the long protein chains that makes the gelatin strings break into shorter pieces. The heat used to can pineapple destroys the enzyme that breaks down the gelatin.*

## ACTIVITY 4.2 Genetically Modified Hopscotch (optional)

### WHAT TO DO AHEAD OF TIME?

- Choose one of the diagrams in the Leader Supplement for Activity 4.2 to use as your hopscotch court.
- Draw it out with chalk to speed up the game.
- Let the participants add the A's, G's, C's and U's to reinforce learning the chemical units in RNA.
- Copies of **Handout 4.2**.

### WHAT IS NEEDED?

- Cement surface, driveway or sidewalk.
- Sidewalk chalk.
- Unique small markers for each player (stones, plastic yogurt lids, buttons).
- **Handout 4.2** containing the triplet code.
- Paper, pencil to write down amino acid sequences generated.

### HOW MUCH TIME IS NEEDED?

30 - 40 minutes.

## Directions

Remind participants that DNA is written in the chemical bases, A, G, C and T that is translated into RNA. RNA is complementary to the DNA.

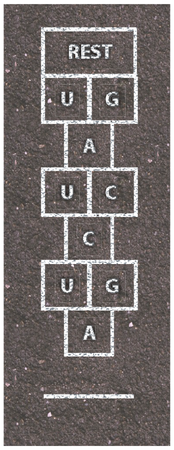
- Explain what it means that RNA is complementary to DNA?

  *Note to leader: Participants will learn more about this in the Dessert activity).*

- Can you discuss why you think it is important that RNA is copied exactly as the DNA is?

The protein synthesizing machinery reads the chemical bases in groups of three, inserting a specific amino acid for each triplet in the RNA using the genetic code (**Handout 4.2**). The amino acids are strung together to make a protein and that protein has a specific function in the cell, just like the enzyme in your spit that broke down the starch in the cracker to make sugar. Today we will create a genetic code with hopscotch and then translate that code into a protein.

## How to Play




Find a level cement surface and draw two identical hopscotch courts with sidewalk chalk following the hopscotch court diagrams shown in the Leader Supplement for Activity 4.2. Each box should be about 18 inches square. Have participants put either an A, G, C or U in each box, as shown. This will help familiarize them with the chemical makeup of RNA. Draw a two-foot line a few feet from the bottom of the diagram where players will stand to toss their markers.

Divide participants into two teams and start each team at the line for one of the hopscotch courts. One player from each team throws their marker. To start their protein, they must get their marker first on an "A". If they do not, the second player tries to land on the "A". Once they get the marker on the "A", they hop on one foot when there is a single square (without a marker) and on two feet when there are two squares across the court. Participants must miss jumping in the square with the marker. They lose their turn if they step on the square with the marker or step on a line. Once the individual reaches the final square, marked REST, he/she turns around and comes back, retracing their steps and stopping at the square with the marker. The participant must then bend down, pick up the marker and return to the beginning line. After the "A", the next player must get a "U" and finally the third player a "G".

Once the team has "AUG", which is the starting codon for almost all proteins, they continue throwing their markers on any square to make a protein of 5 amino acids using sets of 3 bases (for a total of 15 bases). One participant keeps track of each base on the sheet of paper. Each team must end their five-amino acid protein by landing their markers on a stop codon, "UAA, UGA or UAG". If a team gets a stop codon before they have 5 amino acids, they must toss their marker again to get a triplet for an amino acid. Once they have 15 bases, they separate the bases out in the order in which they were generated, into triplets. They then construct their protein by converting the base sequence into an amino acid sequence using **Handout 4.2**.

Once both teams finish, they should check the sequence of the other team to make sure they read the amino acids correctly.

Challenge the players with the following:

- Why do you think you had to land first on the "AUG" before you could start building your protein?
- Explain what you think would happen if you landed on "UAA, UGA or UAG" before the entire protein sequence was completed.

# Final Course

## Discussion with Participants

Proteins are chemicals and our bodies and many foods we eat are made up of proteins. Most proteins are not harmful to our bodies, but some are. Poisonous snakes have many proteins in their saliva. Some are toxic and are called venom. Snake venom is only poisonous when a snake bites you and releases its poisons into your bloodstream. If you drank snake venom or sucked it from a snake bite on your arm, it wouldn't be poisonous.

- Why do you think venom would not be poisonous if you sucked it from a snake bite or drank it?
  *Note to Leader: Humans have enzymes in their digestive systems that break down the venom protein before gets to the bloodstream.*
- How is what happens to venom in your digestive track similar to what happened in the **Spit 'N Cracker Activity**?

# Dessert

## Live and Play DNA

This activity builds on other information that participants has been learned in this lesson. Explain to participants that each of them is going to be one base in a DNA strand that they will form. They will then pair with their complementary base in another DNA strand. They will live and play as DNA!

### WHAT TO DO AHEAD OF TIME?

- Make enough 8.5" x 11" sheets of paper for all participants with equal numbers of A's, C's, G's and T's written in large letters on each sheet.

### WHAT IS NEEDED?

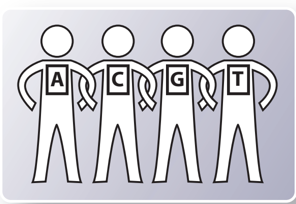
- One sheet of paper with a letter for each participant. Enough sheets of paper so each participant has one.
- Pin or tape paper to attach letters to front of participants' coats or shirts.
- Two 2' long pieces of string or yarn for half of the participants.

### HOW MUCH TIME IS NEEDED?

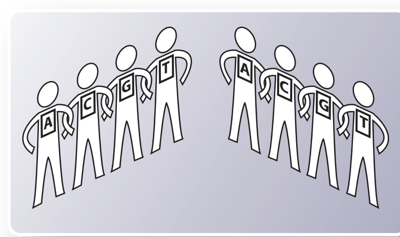
25 - 35 minutes.

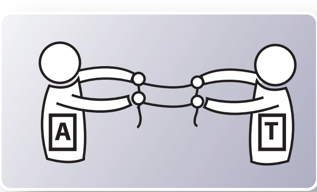
## Directions

Ask each participant to take one letter and either pin or tape it to the front of their coat or shirt. Make sure that there are equal numbers of complimentary bases. That is, the same number of A's and T's and the same numbers of G's and C's so that all participants will be able to pair with their "compliment".




Have participants stand in a long line. The two lines must have equal numbers of A's to match with T's in the other line, G's to match with C's, etc. The leader reminds participants that chromosomes have two complementary strands. The bases in the DNA, A's, T's, G's and C's, link to each other in one strand and then pair with their complementary base in the other strand. Ask half of the participants to line up randomly in a straight line, making sure that there are equal numbers of A's in the first line to match with the same number of T's in the second line; the same number of G's in the first line to match with equal numbers of C's in the second line, etc. To simulate that the bases in each strand link to each other, ask participants in the first line to link elbows tightly with the other "bases" in their line. Once the line is linked, ask the second set of participants to find their complementary base in the first line: "A" finds a "T" and "G" finds a "C". When they find their complementary base, ask them to stand directly across from the base and also link elbows with the other "bases" in their line.






In the two complementary strands that form DNA in an organism, the two complementary bases in the opposite strands pair with each other. To simulate that, hand each participant in the first line 2 pieces of string, one for each hand. Ask participants with complementary bases, standing across from each other, to grab the ends of the two strings being held by their complementary base. Each line should continue to lock elbows.

- Speculate as to which bond in the DNA you think might be stronger – the one linking the backbone (locking elbows) or the pairing between bases (holding the strings)?
- If only one strand of DNA is copied to make RNA, can you guess what must happen to the base pairing in order for copying to occur?

*Special thanks to Jenne Stonaker for providing the idea for the "Live and Play DNA" activity.*

Have everyone take a step to their right. Instruct participants to grasp hands of the person in front of them only if that person is a complementary base.

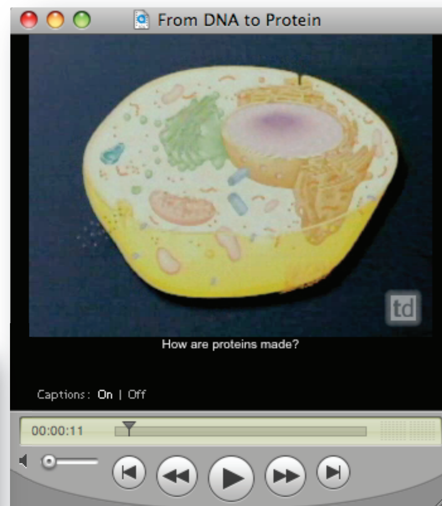
- Describe what you think happened to the strength of the bonding in the backbone when you moved to the right?
- Describe what you think happened to the bonding of the complimentary bases when you moved to the right?

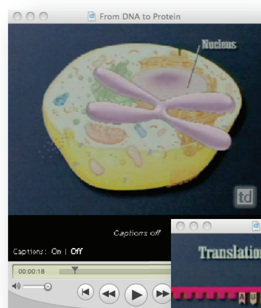
*Tip to Leader: The bonds between the bases in the backbone (elbows linked) are covalent bonds that are stronger than the hydrogen bonding (strings held) that takes place between complimentary bases. Those bases must come apart when DNA is replicated but the bonds in the backbone do not.*

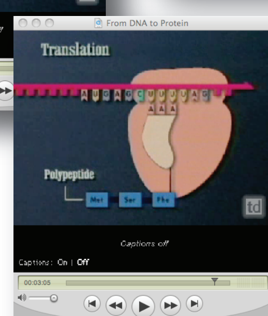
## Stuffed, but Hungry for More?

Watch the animated video, adapted from NOVA's "Secret of Life" http://ucbiotech.org/dnafordinner/lesson4/DNA.html.

This video illustrates the process of protein synthesis, starting with chromosomal DNA inside the cell's nucleus. A gene is transcribed into messenger RNA (mRNA), which leaves the nucleus and binds to the protein synthesizing machinery, called ribosomes, in the cytoplasm. There, other RNAs, called transfer RNAs or tRNAs that attach to the mRNA and build a chain that will fold into a functional protein.




*"From DNA to Protein" video ©1995, 2002 WGBH Educational Foundation. All rights reserved. Adapted from NOVA: "Secret of Life".*

### MATH MENU

1. If there are four different nucleotides and they are used as triplets in the genome to encode amino acids, how many different combinations of triplets can there be?
2. The smallest protein known is believed to be only 20 amino acids long; one of the largest is believed to be 27,000 amino acids. How many times larger is the largest protein?

*See answers in Leader Supplement*

### NEXT TIME WE MEET

In this lesson we learned that genes are coded for in DNA that is made into RNA. The triplet codes in RNA specify amino acids that are linked together to form proteins that serve important functions in the cell. Next time we meet we will see how researchers perform genetic modification of plants by crossing two plants using classical breeding to change traits or by using genetic engineering to locate and move specific genes into other genomes to change traits of the organism that receives the new gene.

### SET CONCEPTS ADDRESSED

Discovery-based research and scientific method

National Science Education Standards in Life Sciences Grades 5-8, addressed: Content Standard C, Structure and function in living organisms; regulation and behavior

SET Process Skills Used: Interpret/analyze/reason/observe; predict; problem solve; question

For more information & additional lessons, please visit
**http://ucbiotech.org/dnafordinner**

# Leader Supplement for Lesson 4

## Supplement for Activity 4.2

**DIAGRAM 1**

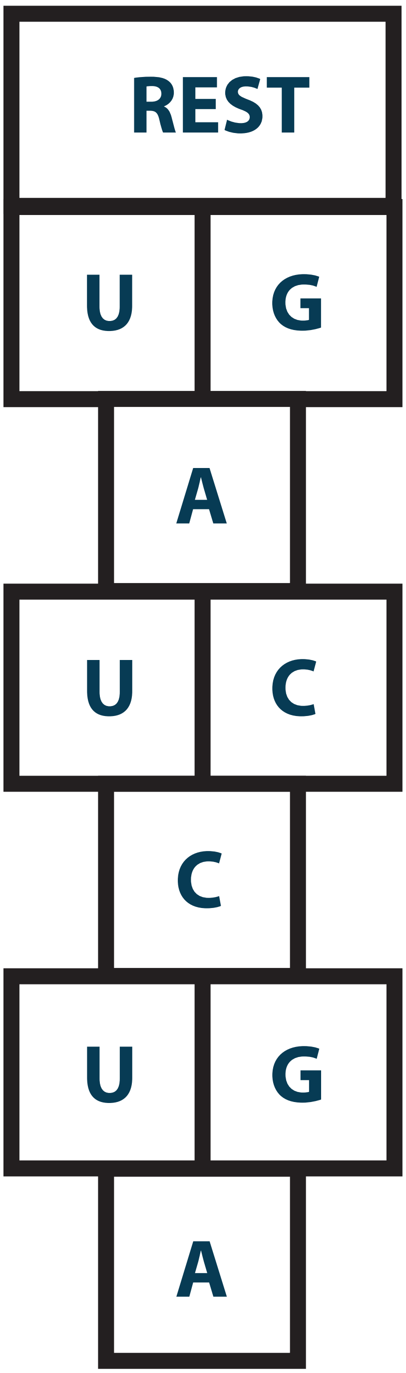
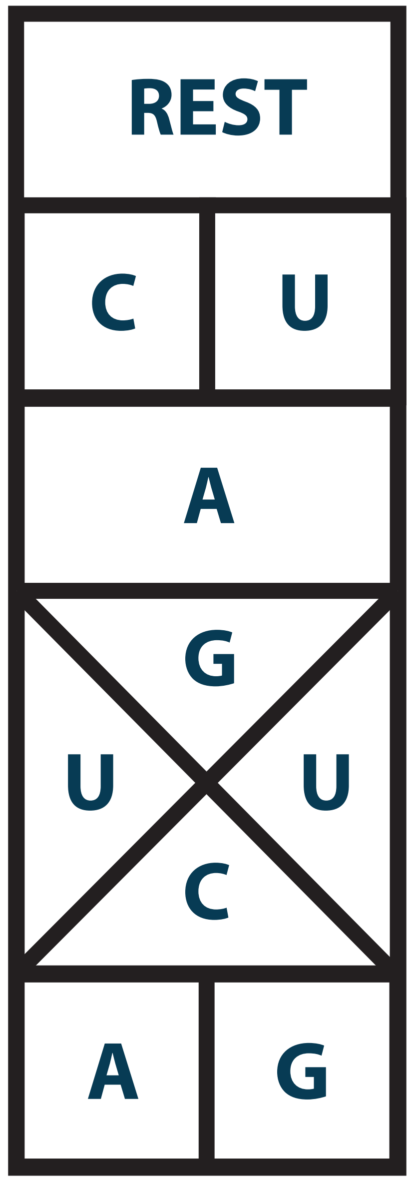



**DIAGRAM 2**




## Answers to Math Menu

1. 64
2. 1350 times

DNA FOR DINNER?

LESSON 4
HANDOUT 4.1

# Juice Bar Jumble

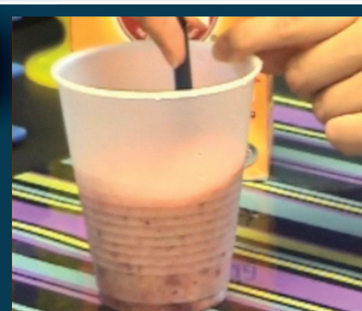
## Instructions

Some of the steps from the DNA isolation activity are pictured. The first and last steps are already numbered and the challenge is to fill in the rest of the numbers in the top left-hand box to create the right sequence of steps. Read the captions to help guide you in the right direction.

1

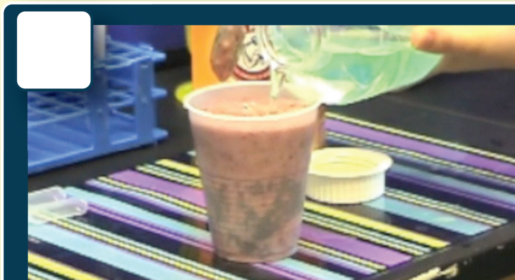
Choose the fruit, put in blender and blend to achieve "pumpkin soup-like" consistency. Add water if necessary; don't overblend.

Add ½ teaspoon (2 milliliters) of mixture to small transparent glass or plastic tube and then add one teaspoon (4 milliliters) of 95% ethanol gently down the side on top of the mixture.



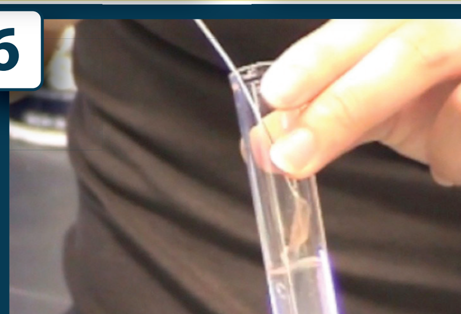
Add blended fruit to plastic cup and add 1 teaspoon baking soda – it will fizz.

Put single layer coffee filter in strainer; filter mixture into glass.



Stir few minutes until fizzing stops. Add equal volume extraction mixture and stir.

6



DNA will appear at the interface. Use a paperclip to pull the gummy mass of DNA out of the solution!

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DNA FOR DINNER?

LESSON 4
HANDOUT 4.2

# Genetically Modified Hopscotch

| Amino Acid/Abbreviation | Triplet Code in RNA |
|---|---|
| Alanine/A | GCU, GCC, GCA, GCG |
| Arginine/R | CGU, CGC, CGA, CGG, AGA, AGG |
| Asparagine/N | AAU, AAC |
| Aspartic Acid/D | GAU, GAC |
| Cysteine/C | UGU, UGC |
| Glutamine/Q | CAA, CAG |
| Glutamic Acid/E | GAA, GAG |
| Glycine/G | GGU, GGC, GGA, GGG |
| Histidine/H | CAU, CAC |
| Isoleucine/I | AUU, AUC, AUA |
| STOP Codons | UAA, UGA, UAG |
| Leucine/L | UUA, UUG, CUU, CUC, CUA, CUG |
| Lysine/K | AAA, AAG |
| Methionine/M START Codon | AUG |
| Phenylalanine/F | UUU, UUC |
| Proline/P | CCU, CCC, CCA, CCG |
| Serine/S | UCU, UCC, UCA, UCG, AGU, AGC |
| Threonine/T | ACU, ACC, ACA, ACG |
| Tryptophan/W | UGG |
| Tyrosine/Y | UAU, UAC |
| Valine/V | GUU, GUC, GUA, GUG |