What does DNA look like? Name: Date: Per:

Modeling and Simulating DNA Transcription and Translation

3.01 Analyze the molecular basis of heredity

Overview of Activity: This activity allows students to learn about the structure of DNA, DNA replication and how DNA directs the synthesis of proteins. Part One allows students explore the structure of DNA and nitrogenous base pairing. First, students build a model of DNA out of Twizzlers and colored marshmallows so they have a visual experience with DNA structure, nitrogen base pairing and DNA replication. The DNA models are then used to simulate DNA transcription as students use the DNA sequence to build a mRNA molecule. Finally, the students build tRNA molecules with attached amino acids and simulate translation and protein synthesis. Revised from "Have your DNA and Eat it, too"

Materials/resources:

DNA model (per student/group)

- 24 Colored Marshmallows (6 green, 6 pink, 6 orange, 6 yellow per student/group)
- 2 Red Licorice Sticks
- 12 Toothpicks
- 1 Marker or fountain pen (ballpoint will not work)

mRNA and tRNA models for Transcription and Translation Simulation (per student/group)

- 1 pair scissors
- 3 rainbow or black licorice sticks
- 24 Colored Marshmallows (6 green, 6 pink, 6 orange, 6 yellow per student/group)
- 16 toothpicks
- Gummy Candy (4 different kinds or colors of candies per student/group)\
- 1 Marker or fountain pen (ballpoint will not work)

Procedures for the Teacher:

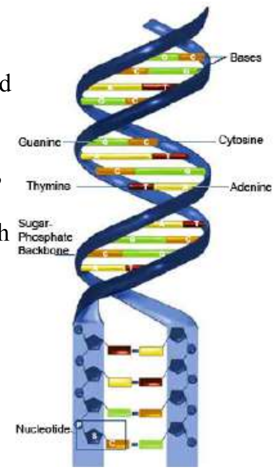
Before Class:

1. Open the bags of marshmallows to allow them to harden as fresh marshmallows are difficult to push onto the toothpicks.
2. Make copies of handout/directions

During Class:

1. Divide class into groups (or students may work individually)
2. Administer the materials.
3. Explain what the different materials represent: licorice is the backbone and marshmallows are the nitrogen bases.
4. Handout Lab Instructions

Making a DNA Model



DNA is a double stranded molecule that directs the processes of all organisms. When **DNA,** is extracted from the nucleus, it looks like a twisted ladder. This shape is called a **double helix**. The sides of the DNA "ladder" are composed of a very strong backbone of 5-carbon sugars and phosphates that protects the inside of the DNA molecule. The rungs of the ladder are made of four **nitrogenous bases**: **adenine (A), thymine (T), cytosine (C), and guanine (G)**. The nitrogen bases pair with one another via **hydrogen bonds** in a certain way: adenine with thymine and guanine with cytosine. Your genetic code is determined by the order of the nitrogenous bases (i.e. CTCGTAGAGATC…but much longer than this!)

Materials for DNA model: 2 Twizzlers®, 6 orange, 6 pink, 6 green and 6 yellow marshmallows, 12 toothpicks, markers.

Step 1: Assemble one side of the DNA Molecule

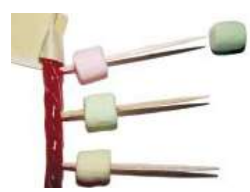
1. Wrap a piece of masking tape around the **end** of **one** Twizzler®
   a. This is your original or "template" strand
2. Using a marker, label each of your marshmallows according to the color key below

Color Key:

A = Adenine = pink marshmallow
T = Thymine = orange marshmallow
C = Cytosine = green marshmallow
G = Guanine = yellow marshmallow

3. The DNA molecule you will be making is made of 12 marshmallow nitrogenous bases with the sequence below. Starting from the top, attach the correct sequence of 12 marshmallow nitrogenous bases to the Twizzler® backbone with **evenly spaced** toothpicks.

C T C G T A G A G A T C



Step 2: Use the first strand of DNA to build the second strand

1.
2.
3.
4. Now that you have your first strand of DNA, you can use it to make your second, complementary strand. Find the complementary marshmallow nitrogenous base for each of your 12 nitrogenous bases and slide them onto the **opposite** end of the toothpick.

As described above, nitrogenous bases **always** pair up in the **same** way:

Adenine (A) with Thymine (T)
Cytosine (C) with Guanine (G)

5. Once you have paired up the marshmallow nitrogenous bases with their partners, attach another Twizzler® backbone to complete the double stranded DNA molecule.

6. Now you can twist the DNA molecule to replicate how real DNA looks.

Let's review. In the DNA model you made:

The whole model represents ___________________
The marshmallows represent ______________________

The toothpicks represent ________________________
You were able to figure out the sequence of the second strand easily because ___________________________________

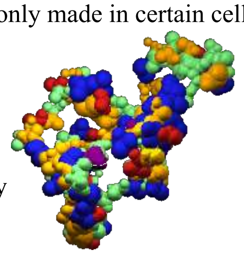
How does DNA direct all the processes of life?

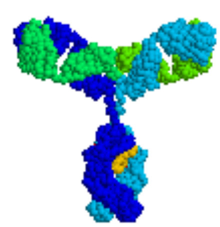
The sequence of the four nitrogen bases in DNA provides a set of instructions for all living organisms, indicating what the organism will be, what it will look like, how big it will be, what things it will be capable of and how long it will live. The DNA is able to orchestrate life by directing the formation of a massive protein workforce. Proteins molecules are like molecular machines or robots that initiate and carry out all the processes needed to sustain life. Proteins are made of long strings of building blocks called amino acids. There are 20 different amino acids found in the human body. Both a protein's ultimate shape and function is determined by both the type of amino acids it is made of and the order in which these amino acids are strung together. Therefore, the DNA code directs the formation of the protein workforce by indicating which amino acids need to be assembled together and in which order.

Since DNA remains protected within the membrane bound nucleus in most organisms, a messenger molecule must relay the DNA code from the nucleus to where the protein-making machinery, the **ribosomes**, are located. The messenger molecule is a molecule that is very similar to a strand of DNA. This molecule, called **messenger RNA or mRNA,** is also made of nitrogen bases attached to a sugar backbone. It is created in the same way as a second strand of DNA is created when DNA is copied, by using the DNA strand as a template and assembling the complementary nitrogen base pairs. Since the mRNA molecule is a complement of the DNA code, it provides a copy of the directions contained in the DNA. The mRNA molecule travels from the nucleus to the ribosome where the mRNA code can be translated into directions for which amino acids need to be assembled. The code is translated via special molecules called **transfer RNA or tRNA**, which carry the amino acid molecules. Every tRNA molecule has a unique set of 3 base pairs at the tip of the molecule that is complementary to three base pairs on the mRNA molecule. Therefore, when the 3 nitrogen bases on the tRNA molecule pairs up with complementary 3 nitrogen bases on the mRNA molecule, the correct amino acid, which is attached to the tRNA molecule is brought to the ribosome. The ribosome then removes the amino acid from the tRNA molecule, which starts a chain of amino acids that will ultimately be a functional protein. Therefore, once the tRNA molecules have translated the mRNA molecul 3 bases at a time, the correct string of amino acids has been assembled. This string of amino acids then folds into a specific shape, making a protein. The **protein** either remains in the cell or is secreted and goes on to carry out the will of the DNA by supporting one of the millions of things that must be done to keep an organism alive.

There are some proteins that are made by all cells such as all the proteins you simulate in this simulation like DNA Polymerase, helicase, RNA polymerase and the many proteins that make up the ribosome. Other proteins found in all cells are the proteins that make up the cytoskeleton, the proteins responsible for breaking down glucose to get energy and membrane proteins that bring materials in and out of cells. Some proteins, however, are only made in specific cells. Therefore, the section of DNA that directs the assembly of these proteins is only converted into mRNA (i.e. transcribed) and translated in these specific cells even though the directions for these proteins exist in every cell. Therefore, cells are unique or specialized by which DNA directions they follow. Some examples of proteins that are only made in certain cells are:

- Insulin made in the Beta cells of the pancreas
- Pepsin made in the alpha cells of the pancreas
- Keratin made in hair, nail and skin cells
- Growth hormone made in the cells of the pituitary
- Hemoglobin made in red blood cells
- Antibodies made in B cells





Insulin Antibody

The balls that make up these proteins are amino acids. The proteins started off as strings of amino acids that folded into these 3-D shapes. In these shapes, the proteins act as molecular machines or robots, and carry out their essential functions in the body.

Simulating how DNA directs the assembly of it's protein workforce: DNA Transcription and Translation

Purpose: Today you will use the DNA molecule you built to simulate how DNA is able to direct the processes of life.

Materials needed to simulate Transcription and Translation:

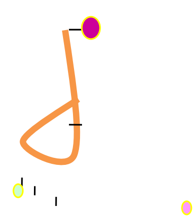
Pre-made edible DNA strand, scissors, 3 pieces of rainbow or black licorice, 6 of each color marshmallow (green, yellow, orange, pink), 12 toothpicks and 4 different gummy candies

Step 1: Make a mRNA molecule from your DNA strand

The mRNA molecule is made in the same way as you made the second, complementary strand of your DNA molecule, by pairing up the complementary nitrogenous bases. First, however, the DNA molecule must be opened up so the nitrogenous bases are accessible to copy. Like nearly all processes in the body, the cutting of the DNA is done by a protein enzyme, called helicase.

1. Using scissors, cut the toothpicks betrween each of the nitrogenous bases. As you do this,the scissors are simulating how the protein, helicase, breaks the weak bonds that hold the base pairs together.
2. The exposed nitrogen bases are then used to make a copy like you did when you built the DNA model, but this time, the complementary strand you make is not another strand of DNA, it is a strand of RNA called messenger or mRNA. Using a rainbow or black licoric as the RNA backbone and the same color pairing as you used for your DNA model, attach the complementary nitrogen bases to the RNA backbone. As you attach the complementary bases to the RNA backbone, your hands are performing the process that is performed in all cells by the enzyme protein, **RNA Polyme**rase.
3. Label the nitrogen bases with the appropriate letters. Note, however, that mRNA molecules do not contain Thymine (T). Instead, they contain a very similar molecules called Uracil (U). Therefore, when making a mRNA molecules Uracil (U) will pair up with an Adenine (A).
4. Once the mRNA molecule is made, it must travel out of the nucleus to the place where in the cell the protein making machinery is, at the ribosome.

Step 4: Create tRNA.



5. Loop the remaining licorice to form a lower-case 'd' shape and secure with a half tooth-pick.
6. Create the **anti codon** sequences UAC, GUA, GUG, AUC on each of the 4 tRNA molecules by attaching the 3 colored marshmallow nitrogen base with a half toothpick

A = Adenine = pink marshmallow

U = Uracil = orange marshmallow

C = Cytosine = green marshmallow

G = Guanine = yellow marshmallow

This is a tRNA with the anti-codon CAC

7. Place the appropriate amino acid candy to the top of the tRNA molecule with a half toothpick as directed by your teacher

UAC codes for ______________(amino acid candy)
GUA codes for ______________ (amino acid candy)
GAG codes for______________ (amino acid candy)
AUC codes for ______________ (amino acid candy)

Step 5: Simulate DNA translation

8. mRNA is read in groups of three nitrogen bases called a codon that lines up with the anticodons on the tRNA molecules
9.

Place the mRNA on the red "Ribosome" labeled paper. Match the mRNA codons with the anti-codons of the tRNA on the red "Ribosome" labeled paper.

Ribsomes are composed of ______________________.

Step 6: Create a Protein.

Remove the Starburst from the tRNA molecules and connect the Starburst in the correct order with toothpicks. Remove the the mRNA, tRNA, and Starburst from the red "Ribosome" labeled paper.

What are the bonds between the Amino Acids (Starburst)? ____________________

The resulting sequence of amino acids are known as a ___________________________.

Using the chart below find the name of each of the amino acids you transcribed above.

________________ ________________ ________________ ________________

First Letter	Second Letter				Third Letter
	U	C	A	G	
U	phenylalanine	serine	tyrosine	Cysteine	U
	phenylalanine	serine	tyrosine	Cysteine	C
	leucine	serine	stop	Stop	A
	leucine	serine	stop	tryptophan	G
C	leucine	proline	histidine	Arginine	U
	leucine	proline	histidine	Arginine	C
	leucine	proline	glutamine	Arginine	A
	leucine	proline	glutamine	Arginine	G
A	isoleucine	threonine	asparagine	Serine	U
	isoleucine	threonine	asparagine	Serine	C
	isoleucine	threonine	lysine	Arginine	A
	methionine	threonine	lysine	Arginine	G
G	valine	alanine	aspartate	Glycine	U
	valine	alanine	aspartate	Glycine	C
	valine	alanine	glutamate	Glycine	A
	valine	alanine	glutamate	Glycine	G