



“Something Old, Something New...”

An overview of the process of DNA replication
By: Leila Greene

Focus on Inquiry

The students will be able to describe and model the basic process of DNA replication and how it relates to the transmission and conservation of the genetic information. Students will describe the function of models in science and how they are helpful to the study of DNA.

Lesson Content Overview

Students will reflect on prior knowledge, record their understanding of DNA replication based on a 3D computer model, and will then create a model demonstrating the process of DNA replication. Students will investigate where DNA replication occurs in the human body and why it occurs there. Finally, students will summarize what they learned by collaborating with other classmates.

Duration 140 minutes	Setting Classroom	Grouping Groups of 2 to 4 students	PTI Inquiry Subskills 1.3, 3.3, 3.6, 3.7, 5.2, 5.7, 5.8, 5.9, 6.1, 7.2, 7.3
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Lesson Components	Estimated Time	Inquiry Subskills Used	Technology Used	Level of Student Engagement	Brief Description
Engage	5 min	3.3, 3.6, 3.7, 5.2	Internet and Video	2	Students will watch a video and storyboard their understanding of the process of DNA replication. Students will work collaboratively to share their understanding using small groups and a whiteboard.
Explore	80 min	5.7, 5.8, 5.9	None	3	Students will work in groups of 2 or 4 to create a model of DNA and the process of DNA replication. They will investigate where replication occurs in the human body.
Explain	20 min	3.6, 5.2, 7.2, 7.3	None	2	Students will in groups of 2-4 to explain why DNA replication occurs in certain places in the human body. Students will reflect on the importance of models to the study of DNA.
Expand/Elaborate	30 min	1.3, 5.2, 6.1	Computer	3	Students will work in groups of 2 or 4 to investigate different forms of mutations and what DNA does in order to proofread and correct any errors that may result during the process of DNA replication. Students will reflect on possible outcomes of DNA mutation.
Evaluate	5 min	7.3	None	1	Students will complete a summative assessment on DNA replication.

Level of Student Engagement

1	Low	Listen to lecture, observe the teacher, individual reading, teacher demonstration, teacher-centered instruction
2	Moderate	Raise questions, lecture with discussion, record data, make predictions, technology interaction with assistance
3	High	Hands-on activity or inquiry; critique others, draw conclusions, make connections, problem-solve, student-centered

Next Generation Science Standards – Inquiry

- NGSS Practice 1: Asking Questions and Defining Problems
- NGSS Practice 2: Developing and Using Models
- NGSS Practice 3: Planning and Carrying Out Investigations
- NGSS Practice 6: Constructing explanations
- NGSS Practice 7: Engaging in arguments from evidence
- NGSS Practice 8: Obtaining, Evaluating and Communicating Information



Next Generation Science Standards – Life Science

HS-LS1-2 Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.



Florida Science Standards – Nature of Science

SC.912.N.3.5 - Describe the function of models in science, and identify the wide range of models used in science.



Florida Science Standards – Life Science

SC.912.L.16.3 - Describe the basic process of DNA replication and how it relates to the transmission and conservation of the genetic information.

SC.912.L.16.4 - Explain how mutations in the DNA sequence may or may not result in phenotypic change. Explain how mutations in gametes may result in phenotypic changes in offspring.



Materials and Advance Preparation

Materials List

Class set:

- 1 pack of jumbo craft sticks
- 1 pack of white pipe cleaners
- 1 pack of colored beads (need red, blue, yellow, and green)
- Scissors (20-24)
- Tweezers/Forceps (20-24)
- Markers (Black, Purple , Light Blue, and Orange)
- Whiteboards and dry erase markers

Student materials (groups of 2-4 students):

- 4 jumbo craft sticks
- 6 pipe cleaners (to be cut in half)
- 12 Beads:
 - red
 - yellow
 - blue
 - green
- 1 black marker, purple marker, light blue /teal marker, orange marker
- 1 scissor
- 1 tweezer/forceps
- 1 Whiteboard and 1 Dry Erase Marker

Blackline Masters

1. **Blackline Master # 1 - Guide to Creating Models- Teacher handout**
2. **Blackline Master # 2 - “Something Old, Something New...”- Student Handout**
3. **Blackline Master # 3- DNA Sequences**
4. **Blackline Master # 4 - DNA Replication Cards**
5. **Blackline Master #5 – DNA Mutation Simulation Activity Sheet**
6. **Blackline Master #6 - DNA Replication Assessment**
7. **Blackline Master #7 – Answer Keys**

Advance Preparation

1. Purchase a pack of Jumbo Craft Sticks (1 bag contains approx. 40 pcs – enough for 10, 2 person groups or 20 groups of 4)
2. Purchase a pack of White Pipe Cleaners (1 bag contains approx.100 pcs)
3. Purchase Markers (pack of 10)
4. Purchase colored beads (1 pack contains approx.1,000 beads)
5. Print Blackline Master # 2, #5, and #6 for each student
6. Print Blackline Master #3 & #4 for each group or pair of students

Lesson Information

Learning Objectives

1. Students will be able to describe the overall process of DNA replication and explain how genetic information is conserved.
2. Students will be able to describe reasons why DNA replication occurs in the human body for the purpose of regrowth, regeneration and development.
3. Students will be able to explain how mutations are formed, the mechanisms DNA has in place to “proofread” and correct these mistakes in the DNA sequence, and the genotypic and phenotypic consequences when DNA mutations are not corrected.
4. Students will be able to describe why models are useful to the study of DNA and DNA replication.

Prior Knowledge Needed by the Students

- Students should already know the overall structure of DNA including the nitrogenous bases and sugar/phosphate backbone.
- Students should understand base pairs and base pairing rules.

Background Information

After Watson and Crick discovered that DNA contains the genetic information to life, they developed a proposal to explain how DNA copied itself during the cell cycle in a process known as **DNA replication**. During this process, several enzymes such as **Helicase** and **DNA Polymerase** work together to unzip the double helix, bond new nucleotides to the existing DNA strands in order to create an exact copy of the original DNA strand. The replication process can be summarized into four steps including: 1) Unzipping of the DNA double strand with the help of Helicase. 2) Free-floating nucleotides pair one-by-one with the bases on the template strand. 3) DNA Polymerase bonds the nucleotides together to form new strands that are complementary to each template strand. 4) Two identical molecules of DNA result. Each of which contains the original DNA strand and a new strand. **Mutations** are described as an alternation in the DNA sequence. During replication, it is possible for a nucleotide to be mismatched with the exposed base on the template strand. If this occurs unnoticed, and replication proceeds, the DNA will become damaged leading to bulks or breaks in the growing DNA strand. Luckily DNA has a proof-reading mechanism where it recognizes these errors in the DNA strand, removes the incorrect base, and attempt to add the correct base again. (SparkNotes Editors, n.d.)

Lesson Procedure

Engage

1. To introduce the lesson, choose from the following questions to activate prior knowledge:
 - a. What molecule contains the genetic information of life? [*DNA*]
 - b. Describe the structure of DNA. What do the letters DNA stand for? [*double helix, deoxyribonucleic acid*]
 - c. Where in the cell do we find DNA? [*nucleus*]
 - d. Why is it important for DNA replication to occur? [*In order for cells to divide and multiply, DNA must be duplicated. This passes on the specific instructions for each part of the organism.*]

2. Watch a short video (3:27) on DNA replication - “DNA replication- 3D”

<https://www.youtube.com/watch?v=TNKWgcFPHqw>

NOTE: If there is an advertisement at the beginning of the video, please fast forward or “Skip” through the ad if available. Make sure to display the video full screen (arrows to the right of video time bar at the bottom of the screen) so that the web page advertisements and other suggested videos are not seen. Watch for and close any pop-up ads that may occur during the video.

3. After the video, ask students to take turns answering the following questions, one at a time, around their group of 4. This will serve as a collaborative review of the contents of the video clip. Each of the questions should circle around the group before a new question is asked.

- How would you describe the overall process of DNA replication? [*A DNA strand is unzipped, and an exact copy of each strand of DNA is made with the help of different enzymes.*]

- Which enzyme begins the process of DNA replication? [*Helicase*]
 - Which enzyme(s) and/or structure(s) play main roles during DNA replication? Describe their roles. [*Primase- makes primer; DNA Polymerase- binds to primer and makes new strand of DNA; Okazaki Fragments- occur in lagging strand only; Exonuclease- remove RNA primers; Ligase- seals the fragments of DNA*]
 - Why is one strand called “leading” and one strand called “lagging?” [*In the “leading strand,” DNA polymerase replicates the nucleotides in order moving in one direction. In the “lagging strand,” a primer is created and then the DNA polymerase has to work backward in small sections (Okazaki fragments) to build small sections of the DNA at a time. This is more time consuming and it “lags” behind the development of the other strand.*]
 - Why do they call DNA replication the “semi-conservative model?” [*Because each strand of DNA contains one old “conserved” strand of DNA and one new one*]
4. Still working in groups of 4, ask students to grab a whiteboard and draw a 4 box grid. Then ask students to write #1 in the upper left hand corner, #2 in the upper right hand corner, #3, in the lower left hand corner, and #4 in the lower right hand corner. Students will take turns storyboarding the process of DNA replication.
- Give each student approximately 30 seconds to draw or write down a part of the DNA replication process in a storyboard format.
 - After each 30 second interval, say “switch” and the next person in the group will have 30 seconds to add the next steps in the process of DNA replication.
 - Continue this cycle until all students have completed their storyboard of DNA replication.
7. Allow groups to walk around and observe the storyboards of the other groups.

Explore

1. In this activity, students will become molecular biologists who will be creating a model to represent the process of DNA replication and investigate where it takes place in the human body.
2. Distribute **Blackline Master # 2 – Modeling DNA and DNA Replication** (one per student). Students will work in groups of 2 or 4.
3. Working in their groups, students will follow the directions on **Blackline Master # 2** to create a model of DNA and DNA replication. The teacher can follow **Blackline Master #1** for the Model Guide.
4. Distribute **Blackline Master # 3 - DNA Sequence Cards** to students when they are ready for them.
 - a. Students will need their DNA sequence to create their model.
 - b. *Once students have completed part 1, Construction of the DNA model, please collect the DNA Sequence Cards from each group.*
5. Make modeling supplies accessible to the students so that they can get the materials that they need, when they need them.
6. Distribute **Blackline Master # 4 - DNA Replication Cards** to students when they are ready for them.

Explain

1. Students will complete the reflective questions on their handout.
2. Some questions you might ask students within their groups or as a whole class include:
 - What enzyme do the scissors represent? What is the function of this enzyme? [*helicase; split the DNA*]
 - What enzyme do the forceps represent? What is the function of this enzyme? [*ligase; seal the strands*]
 - Which craft stick represents the old DNA strand? [*blue*]
 - Which craft stick represents the new DNA strand? [*orange*]
 - Why did we draw circles and pentagons on our stick? What does this represent? [*The circles and pentagons represent the sugar/phosphate backbone of the DNA*].
 - How did the free floating nucleotides bind to the template or original strand? [*DNA polymerase*]

- How was the genetic information conserved during this process? *[Because each strand of DNA contains one old conserved strand of DNA and one new one]*
 - Where does DNA replication occur in the body? Why? *[nucleus where DNA is stored]*
 - Why do you think it is important to match the bases appropriately? *[Base Pairing Rules: A → T, C → G; if not an error /mutations will occur]*
 - Predict what will DNA do if there is a mismatch in the pairing of the bases? *[DNA Polymerase will proofread and correct any mis-paired bases, if proofreading misses the mismatch, a mutation will occur]*
 - Was there anything that surprised you about DNA replication? Explain. *[Student answers will vary]*
3. Review of the correct process of DNA replication including the major enzymes and proteins that contribute. This process is necessary so that students do not have misconceptions about the formation of the new strand from the template or original strand.

Expand

1. Ask students the following questions:
 - Can an error occur during DNA replication? If so, what will DNA do to prevent or stop this from happening? *[Yes, errors can occur. DNA polymerase moves backwards by one base pair, performs base excision, and then re-inserts the correct base to continue to replication]*
 - What might happen if the DNA polymerase does not catch the error in DNA replication? *[A mutation will occur and the DNA will continue to be copied inaccurately.]*
2. Have students watch the YouTube video, “Mutations” (7:02) <https://www.youtube.com/watch?v=eDbK0cxKKsk>. Which explains mutations and the different types of mutations.
NOTE: *If there is an advertisement at the beginning of the video, please fast forward or “Skip” through the ad if available. Make sure to display the video full screen (arrows to the right of video time bar at the bottom of the screen) so that the web page advertisements and other suggested videos are not seen. Watch for and close any pop-up ads that may occur during the video.*
3. Explain to students that they are now going to use their knowledge of DNA replication and mutation to simulate situations in which mutations have occurred.
4. Distribute **Blackline Master #5** – DNA Mutation Activity to each student.
5. Allow students time to model the different type of mutations on their activity.
6. Allow students time to answer the questions that accompany the activity.
7. Review the correct formations of the different mutations once all students are finished to ensure that students have the accurate understanding of each mutation.

Evaluate

Informal/Formative Evaluation

1. Observation of students’ progress and understanding throughout Explore & Elaborate activity.
2. Responses to probing questions to small groups.

Formal/Summative Evaluation

1. Final project and completed worksheet (**Blackline Master # 2 & #5**) can be graded and based on the following components:
 - a. Accuracy of structure of model in showing the process of DNA replication
 - b. Accuracy of explanation of why DNA replication occurs in specific places in the body including the skin, hair, heart, and liver.
 - c. Accuracy of creation of mutations and explanation of impact of mutations.
2. 8 Question Summative Quiz (**Blackline Master #7**)

WRAP UP.

Bring the lesson to a conclusion by asking students to stand up and pair up with someone in the room other than in their group. Once in pairs, ask each student to explain to their new partner what they learned with regards to DNA replication and mutations. Give each student approximately 30 seconds

to speak and share their learning with their partner. Students could also ask their partners to clarify parts of the lesson that they didn't fully understand.

Supplementary Resources

Teachers

GeneEd. (2012). *DNA, Genes, Chromosomes- Replication*. Retrieved from http://geneed.nlm.nih.gov/topic_subtopic.php?tid=15&sid=21

Students

Learn Genetics. (2016). *Build a DNA Molecule*. Retrieved from <http://learn.genetics.utah.edu/content/molecules/builddna/>

CITATION OF SOURCES.

123FreeVectors. (N.D.). Hand picture. Retrieved from <http://www.123freevectors.com/free-vector-hands/>

Bozeman Science. (2012). Video: Mutations. Retrieved from <https://www.youtube.com/watch?v=eDbK0cxKKsk>

GDJ. (2016) Hair picture. Retrieved from <https://openclipart.org/detail/241260/woman-with-long-hair-line-art>

Gustavorezende. (2013). Heart picture. Retrieved from <https://openclipart.org/detail/181644/anatomical-heart>

Maritacovarrubias. (2010). Liver picture. Retrieved from <https://openclipart.org/detail/37315/liver>

McDougal, H. a. (2012). *Biology*. Canada: Houghton Mifflin Harcourt Publishing Company.

SparkNotes Editors. (n.d.). SparkNote on DNA Replication and Repair. Retrieved November 24, 2015, from <http://www.sparknotes.com/biology/molecular/dnareplicationandrepair/>

Spletstoeser, T. (2015) RNA Codons Picture. Retrieved from <https://commons.wikimedia.org/wiki/File%3ARNA-codons-aminoacids.svg>

Sprouse, E. (2010). What causes DNA mutation? Retrieved from <http://science.howstuffworks.com/life/genetic/dna-mutation.htm>

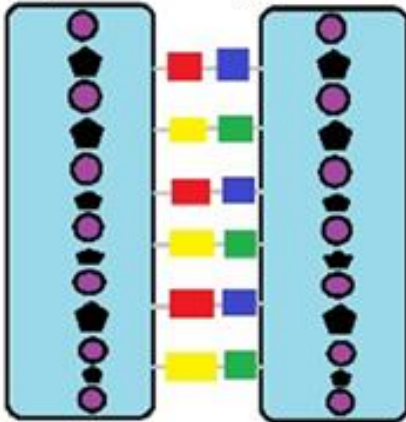
Yes, I cited all materials and resources used in this lesson.

Leila Greene
Lesson Author

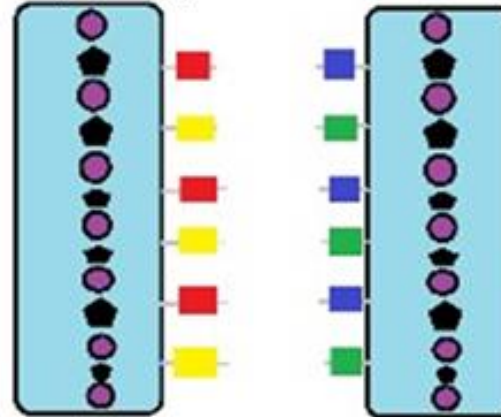
Blackline Master # 1

Guide to Creating Models- Teacher Handout

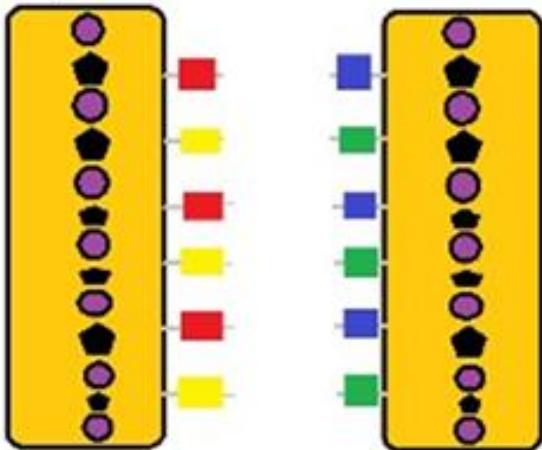
Step 1: The original DNA strand is made



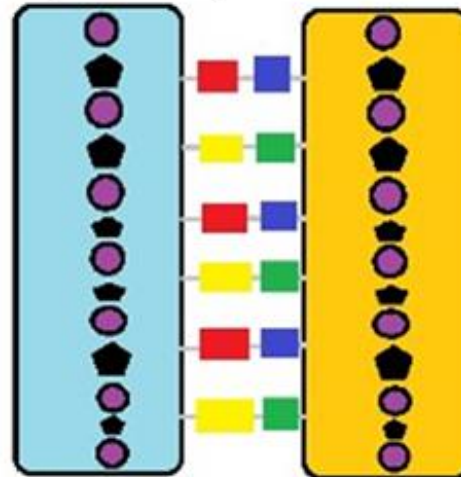
Step 2: Separation of DNA Strands



Step 3: Formation of New DNA Strands



Step 4: Binding of new and old DNA strands



Blackline Master # 2

Name _____ Period _____ Date _____

Something Old, Something New...

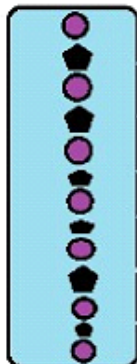
You are a Molecular Biologist who is studying the process of DNA replication. Your task is to build a model that represents this process. Next you will investigate where DNA replication took place in the human body and explain why it occurred. This activity is divided up into three parts.

Part 1: Modeling DNA

Materials:

- 2 jumbo sticks
- Markers, sharpie
- 6 pipe cleaners
- 12 colored beads

1. Obtain a DNA sequence strip from your teacher.
2. Working in groups of two or four, create a model of DNA by following the steps below.
 - a. To make the backbone of DNA, take two jumbo craft sticks and color them with a blue marker.
 - b. Next, with a sharpie marker, draw 7 alternating circles and 6 pentagons as seen in the picture below. Repeat the same for the second craft stick.



- c. What does the series of circles and pentagons on our craft sticks model? _____

What does the circle represent? _____

What does the pentagon represent? _____

- d. Determine what color beads you will need to complete your DNA model by reading the DNA sequence on your DNA Sequence Card.
 - Adenine (A) = Red
 - Thymine (T) = Blue
 - Cytosine (C) = Yellow
 - Guanine (G) = Green

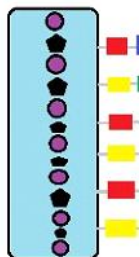
You should also determine the complementary strand sequence by matching the base pairs following base pairing rules. When you are finished matching your base pairs, you should have 12 beads total.

What part of the DNA strand do the colored beads model? _____

- e. Next, take a pipe cleaner and wrap it around your jumbo stick on each pentagon and twist the two ends of the pipe cleaner together so the pipe cleaner is attached to the stick. Repeat five more times.

What part of DNA do the pipe cleaners model? _____

- f. Following your DNA sequence on your paper, insert your beads in order onto each pipe cleaner. See image below for an example.

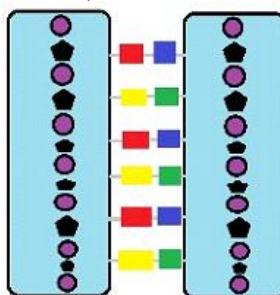


- g. Next, insert your matching base pairs onto the pipe cleaner.
 h. Finally wrap the remaining amount of pipe cleaner around the second craft stick and twist to attach it to the stick. Repeat five more times.

What does attaching the pipe cleaners to the other stick model? _____

Describe the shape of your DNA model? What does it look like to you?

- i. You have now completed your DNA model. Your model should look similar to the image below (*colors of beads should be different*).



- Why might it be IMPORTANT to model DNA?

- Why would it be NECESSARY to model DNA?

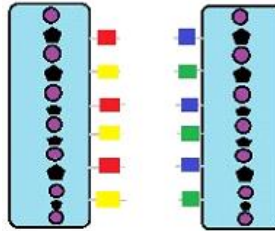
- What are the LIMITATIONS of your DNA model? In other words, what can real DNA show or do that your model cannot show or do?

Part 2: Modeling DNA Replication

Materials:

- DNA model
- Scissors
- 2 jumbo sticks
- 6 pipe cleaners
- 12 colored beads
- forceps

1. Now you are ready to model the process of DNA replication.
2. Working in your same groups, complete the steps below.
 - a. Take a pair of scissors and cut along the middle of the pipe cleaner in between your beads. See image below.



What is happening in your DNA model? _____

What are the scissors modeling? _____

- b. Next, take two craft sticks and color them using an orange marker.

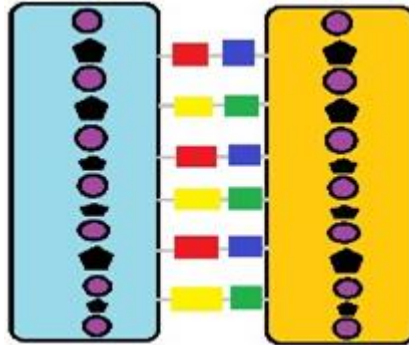
What do you think the orange craft stick might be modeling? _____

- c. With a sharpie marker, draw an alternating series of 7 circles and 6 pentagons as seen in the picture below. Repeat the same for the second craft stick.



- d. Next, wrap a pipe cleaner around your jumbo stick on each pentagon. Twist the pipe cleaner together so that it is attached to the stick. Repeat five more times.
- e. Repeat the above step with the second orange craft stick.
- f. Then, align your original DNA strand (blue craft stick with half of the beads) with the new orange craft stick.
- g. Using base pairing rules, insert a matching bead along the pipe cleaner attached to the orange craft stick.
- h. Continue to insert your matching beads until you reach the end of the DNA Sequence.

- i. Finally, take the loose end of the pipe cleaner from the orange stick and twist it to the pipe cleaner attached to the original DNA strand (blue stick) using the forceps. Your DNA model should look similar to the image below (*colored beads may be different*).



- What enzyme was modeled by the forceps used to seal the pipe cleaners together?

- Explain why the process of DNA replication is described as “semi-conservative?”

- Why might it be IMPORTANT to model DNA replication?

- Why would it be NECESSARY to model DNA replication?

- What are the LIMITATIONS of your DNA replication model? In other words, what can real DNA replication show or do that your model cannot show or do?

Part 3: Investigating DNA Replication in the Human Body

Materials:

- Newly synthesized DNA model
- DNA replication cards

1. After completing your newly synthesized DNA through DNA replication, obtain the DNA replication cards from your teacher and do the following:
 - a. Match the DNA Replication Card to your DNA sequence to find out where your model of DNA replication occurred in the human body.
 - b. Next, answer the questions below.

Where did your process of DNA replication occur in the human body? How do you know?

Explain why it is important for that area of the body to undergo DNA replication?

Explain what structure(s) and action(s) DNA takes in order to prevent mismatches and mistakes from occurring during the process of DNA replication? _____

Predict what might happen (to genotype and phenotype) if there was a mismatch in base pairing during the process of DNA replication? _____

Blackline Master # 3

DNA Sequences

Choose ONE of the following samples to create your model.

<p>DNA Sample 1: T – A – G – C – T – A –</p>	<p>DNA Sample 2: G – A – C – T – G – A –</p>
<p>DNA Sample 3: C – A – T – T – C – A –</p>	<p>DNA Sample 4: G – A – C – C – G – A –</p>




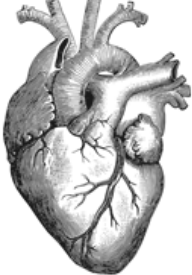
DNA Sequences




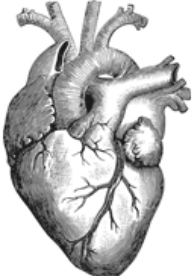
Choose ONE of the following samples to create your model.

<p>DNA Sample 1: T – A – G – C – T – A –</p>	<p>DNA Sample 2: G – A – C – T – G – A –</p>
<p>DNA Sample 3: C – A – T – T – C – A –</p>	<p>DNA Sample 4: G – A – C – C – G – A –</p>

Blackline Master # 4

DNA Replication Cards

<p>C-G A-T T-A T-A C-G A-T</p> 	<p>T-A A-T G-C C-G T-A A-T</p> 
<p>G-C A-T C-G C-G G-C A-T</p> 	<p>G-C A-T C-G T-A G-C A-T</p> 

<p>C-G A-T T-A T-A C-G A-T</p> 	<p>T-A A-T G-C C-G T-A A-T</p> 
<p>G-C A-T C-G C-G G-C A-T</p> 	<p>G-C A-T C-G T-A G-C A-T</p> 

Blackline Master #5

DNA Mutation Simulation Activity

You will be using the given base pairs to model how each mutation affects the DNA sequence. Write the new DNA sequence in the square boxes to show how the DNA is altered in each mutation.

Point Mutation: change in one base

Original Strand:



DNA Sequence after Point Mutation:

--	--	--	--	--	--	--	--	--	--	--	--	--

What are the possible consequences of a point mutation?

Insertion Mutation: add in one additional base

Original Strand:



DNA Sequence after Insertion Mutation:

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What are the possible consequences of an insertion mutation?

Deletion Mutation: remove one base

Original Strand:



DNA Sequence after Deletion Mutation:

--	--	--	--	--	--	--	--	--	--	--

What are the possible consequences of a deletion mutation?

Inversion Mutation: reverse one section of bases (a whole gene)

Original Strand:



DNA Sequence after Inversion Mutation:

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What are the possible consequences of an inversion mutation?

1. You are visiting a local lake when you notice a sign that says, "WARNING: This area contains chemicals known by the State of Florida to cause cancer and birth defects." How is it possible for the chemicals in the lake to have this sort of effect?

2. Make and defend a claim based on evidence from this activity that 1) mutations in the DNA sequence may or may not result in phenotypic change, 2) mutations in gametes may result in phenotypic changes in offspring, and 3) mutations may be the result of environmental factors or inherited traits.

Claim: _____

Evidence supporting #1: _____

Evidence supporting #2: _____

Evidence supporting #3: _____

Blackline Master #6

DNA Replication Assessment

1. Which of the following accurately reflects the correct order of DNA replication?
 - a. Primase creates an RNA primer, helicase unzips the DNA, DNA polymerase adds nucleotides and creates new DNA, DNA polymerase fills in the gaps, DNA ligase seals the fragments of DNA, exonuclease removes the primers.
 - b. Helicase unzips the DNA, primase creates an RNA primer, DNA polymerase adds nucleotides and creates new DNA, exonuclease removes the primers, DNA polymerase fills in the gaps, DNA ligase seals the fragments of DNA.
 - c. DNA polymerase adds nucleotides and creates new DNA, helicase unzips the DNA, primase creates an RNA primer, exonuclease removes the primers, DNA polymerase fills in the gaps, DNA ligase seals the fragments of DNA.
 - d. DNA ligase seals the fragments of DNA, DNA polymerase fills in the gaps, DNA polymerase fills in the gaps, exonuclease removes the primers, DNA polymerase adds nucleotides and creates new DNA, primase creates an RNA primer, helicase unzips the DNA.

2. How is DNA polymerase related to the reduction of genetic mutations?
 - a. It seals up the DNA strands to ensure that mutations cannot occur.
 - b. It signals the helicase to unzip the DNA strand and fix mutations to the DNA nucleotides.
 - c. It proofreads the DNA nucleotides, deletes errors, and replaces errors with the correct nucleotides.
 - d. It creates primers that are able to proofread the DNA and delete, reverse, and translocate mutations.

3. Why is DNA replication often referred to as the “semi-conservative” model?
 - a. Because one strand contains mutations and the other strand does not.
 - b. Because one strand has more base pairs and the other strand has less base pairs.
 - c. Because one strand comes from the mother and the other strand comes from the father.
 - d. Because one strand is the original strand and the other strand is the newly synthesized one.

4. Why is it important for DNA replication to continuously occur in integumentary system (skin)?
 - a. To constrict the amount of blood flow to the skin
 - b. To decrease the amount of melanin or the pigmentation of one's skin color
 - c. To regenerate the amount of keratinocytes and promote healing faster
 - d. To decrease the amount of sweat being released from the sudoriferous glands.

5. According to base pairing rules, complete the complementary DNA sequence below:

A - T - G - T - C - G

 - a. C - G - A - C - A - U
 - b. G - C - A - C - T - A
 - c. T - A - C - A - G - C
 - d. U - A - C - A - G - C

6. How could a DNA mutation lead to changes in the organism?
 - a. A mutation could occur in sex cells and result in a phenotypic change.
 - b. A mutation could occur in somatic cells and be passed on to offspring.
 - c. A mutation could occur in somatic cells and result in a phenotypic change.
 - d. A mutation could occur in sex cells that result in changes to the sex organs.

7. Why might it be important to model DNA and DNA replication?
 - a. DNA and DNA replication is a long process that would take too long to observe.
 - b. DNA and DNA replication observation creates a dangerous situation for scientists.
 - c. DNA and DNA replication is so small that it cannot be observed except with an electron microscope.
 - d. DNA and DNA replication can only be simulated under very specific conditions that are difficult to observe.

8. Which of the following would not be an appropriate way to model DNA and DNA replication?
 - a. A 3-D video simulation
 - b. A mathematical model
 - c. A physical model
 - d. A sketch or drawing

Blackline Master #7– Answer Keys

Something Old, Something New...

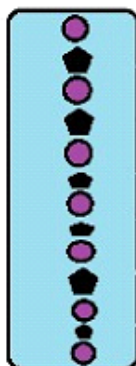
You are a Molecular Biologist who is studying the process of DNA replication. Your task is to build a model that represents this process. Next you will investigate where DNA replication took place in the human body and explain why it occurred. This activity is divided up into three parts.

Part 1: Modeling DNA

Materials:

- 2 jumbo sticks
- Markers, sharpie
- 6 pipe cleaners
- 12 colored beads

3. Obtain a DNA sequence strip from your teacher.
4. Working in groups of four, create a model of DNA by following the steps below.
 - a. To make the backbone of DNA, take two jumbo craft sticks and color them with a blue marker.
 - b. Next, with a sharpie marker, draw 7 alternating circles and 6 pentagons as seen in the picture below. Repeat the same for the second craft stick.



- c. What does the series of circles and pentagons on our craft sticks model? *The sugar phosphate backbone of DNA*

What does the circle represent? _____ *phosphate* _____

What does the pentagon represent? _____ *sugar* _____

- d. Determine what color beads you will need to complete your DNA model by reading the DNA sequence on your DNA Sequence Card.
 - Adenine (A) = Red
 - Thymine (T) = Blue
 - Cytosine (C) = Yellow
 - Guanine (G) = Green

You should also determine the complementary strand sequence by matching the base pairs following base pairing rules. When you are finished matching your base pairs, you should have 12 beads total.

What part of the DNA strand do the colored beads model? _____ *the DNA bases* _____

Part 2: Modeling DNA Replication

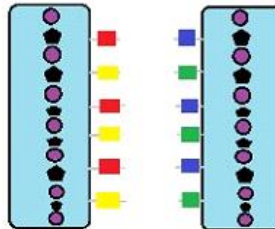
Materials:

- DNA model
- Scissors
- 2 jumbo sticks
- 6 pipe cleaners
- 12 colored beads
- forceps

3. Now you are ready to model the process of DNA replication.

4. Working in your same groups, complete the steps below.

- a. Take a pair of scissors and cut along the middle of the pipe cleaner in between your beads. See image below.



What is happening in your DNA model? *The DNA is unzipping. Students may mention helicase.*

What are the scissors modeling? *The scissors are modeling the helicase unzipping the double helix into two separate strands of DNA.*

- b. Next, take two craft sticks and color them using an orange marker.

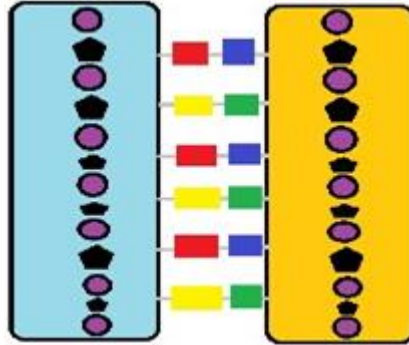
What do you think the orange craft stick might be modeling? *The orange sticks will be modeling the new strands of DNA.*

- c. With a sharpie marker, draw an alternating series of 7 circles and 6 pentagons as seen in the picture below. Repeat the same for the second craft stick.



- d. Next, wrap a pipe cleaner around your jumbo stick on each pentagon. Twist the pipe cleaner together so that it is attached to the stick. Repeat five more times.
- e. Repeat the above step with the second orange craft stick.
- f. Then, align your original DNA strand (blue craft stick with half of the beads) with the new orange craft stick.
- g. Using base pairing rules, insert a matching bead along the pipe cleaner attached to the orange craft stick.

- h. Continue to insert your matching beads until you reach the end of the DNA Sequence.
- i. Finally, take the loose end of the pipe cleaner from the orange stick and twist it to the pipe cleaner attached to the original DNA strand (blue stick) using the forceps. Your DNA model should look similar to the image below (*colored beads may be different*).



- What enzyme was modeled by the forceps used to seal the pipe cleaners together? *The forceps are modeling the DNA ligase that seals the old and new DNA strands together.*
- Explain why the process of DNA replication is described as “semi-conservative?” *DNA replication is called “semi-conservative” because one strand is old DNA which is conserved and one strand is new DNA.*
- Why might it be IMPORTANT to model DNA replication?
Student responses may vary but could include that DNA replication is an important process to understand and using a model would allow you to manipulate the process and understand how it works.
- Why would it be NECESSARY to model DNA replication?
Student responses may vary but could include that DNA replication is too small and too fast to observe.
- What are the LIMITATIONS of your DNA replication model? In other words, what can real DNA replication show or do that your model cannot show or do? *Student responses may vary but could include that their model doesn't generate new DNA like the real DNA does.*

Part 3: Investigating DNA Replication in the Human Body

Materials:

- Newly synthesized DNA model
 - DNA replication cards
2. After completing your newly synthesized DNA through DNA replication, obtain the DNA replication cards from your teacher and do the following:
- a. Match the DNA Replication Card to your DNA sequence to find out where your model of DNA replication occurred in the human body.
 - b. Next, answer the questions below.

Where did your process of DNA replication occur in the human body? How do you know? *Student responses may vary depending on what sequence they received. They will know because they were able to successfully follow base pairing rules.*

Explain why it is important for that area of the body to undergo DNA replication?

Student responses may vary but could include that each part of the body needs to replace dead cells, repair injuries or disease, and grow.

Explain what structure(s) and action(s) DNA takes in order to prevent mismatches and mistakes from occurring during the process of DNA replication? *DNA polymerase proofreads the DNA sequence and deletes and replaces mis-written DNA code.*

Predict what might happen (to genotype and phenotype) if there was a mismatch in base pairing during the process of DNA replication? *If there was a mismatch in base pairing, this would code for a different amino acid. This could result in a genotype change and thus, a phenotype change. This could also result in no changes. If the changes occur in the sex cells, this could result in a new, mutated trait being passed on to offspring.*

DNA Mutation Simulation Activity

You will be using the given base pairs to model how each mutation affects the DNA sequence. Write the new DNA sequence in the square boxes to show how the DNA is altered in each mutation.

*****These are possible answers. Students may come up with other, also accurate responses.*****

Point Mutation: change in one base

Original Strand:



DNA Sequence after Point Mutation:

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

What are the possible consequences of a point mutation?

A point mutation could cause a change in the protein that is synthesized, it could get corrected by DNA polymerase, or it could be in an inactive area and nothing could happen.

Insertion Mutation: add in one additional base

Original Strand:



DNA Sequence after Insertion Mutation:

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

What are the possible consequences of an insertion mutation?

An insertion mutation could cause a frameshift or "slippage" which would change the proteins that are synthesized and alter the function of the gene, it could get corrected by DNA polymerase, or it could be in an inactive area and nothing could happen.

Deletion Mutation: remove one base

Original Strand:



DNA Sequence after Deletion Mutation:

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

What are the possible consequences of a deletion mutation?

A deletion mutation could cause a change in the protein that is synthesized, it could get corrected by DNA polymerase, or it could be in an inactive area and nothing could happen.

Inversion Mutation: reverse one section of bases (a whole gene)

Original Strand:



DNA Sequence after Inversion Mutation:

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

What are the possible consequences of an inversion mutation?

An inversion mutation could cause a change in the protein that is synthesized, it could have major effects on the function of the gene, or it could be in an inactive area and nothing could happen.

1. You are visiting a local lake when you notice a sign that says, “WARNING: This area contains chemicals known by the State of Florida to cause cancer and birth defects.”

How is it possible for the chemicals in the lake to have this sort of effect?

The chemicals in the lake are carcinogens and can damage the chemicals that make up DNA (cytosine, guanine, thymine and adenine). These chemicals can be swapped out or disguised for one another. This would result in insertion, deletion or substitution mutation. When the DNA then duplicates, it writes the code incorrectly. Proteins that were previously created from the original DNA sequence can potentially be altered.

2. Make and defend a claim based on evidence from this activity that 1) mutations in the DNA sequence may or may not result in phenotypic change, 2) mutations in gametes may result in phenotypic changes in offspring, and 3) mutations may be the result of environmental factors or inherited traits.

Claim: Example: DNA mutations may or may not result in phenotypic changes due to mutations in somatic cells, mutations in offspring due to mutations in the parents’ sex cells, or mutations caused by environmental factors.

Evidence supporting #1: A mutation could occur and then be corrected by the DNA polymerase. A mutation could occur in an area of the DNA that does not code for anything that is visible.

Evidence supporting #2: A mutation in the sex cells could be passed on to the offspring and could show phenotypic changes in the offspring. When DNA is replicated, it is replicated with the incorrect code.

Evidence supporting #3: Carcinogens and other stressful conditions in the environment can result in weakening the DNA or miscoding of the DNA which would result in mutations. Mutations occurring in the sex cells would be passed on to offspring.

DNA Replication Assessment

1. Which of the following accurately reflects the correct order of DNA replication?
 - a. Primase creates an RNA primer, helicase unzips the DNA, DNA polymerase adds nucleotides and creates new DNA, DNA polymerase fills in the gaps, DNA ligase seals the fragments of DNA, exonuclease removes the primers.
 - b. Helicase unzips the DNA, primase creates an RNA primer, DNA polymerase adds nucleotides and creates new DNA, exonuclease removes the primers, DNA polymerase fills in the gaps, DNA ligase seals the fragments of DNA.
 - c. DNA polymerase adds nucleotides and creates new DNA, helicase unzips the DNA, primase creates an RNA primer, exonuclease removes the primers, DNA polymerase fills in the gaps, DNA ligase seals the fragments of DNA.
 - d. DNA ligase seals the fragments of DNA, DNA polymerase fills in the gaps, DNA polymerase fills in the gaps, exonuclease removes the primers, DNA polymerase adds nucleotides and creates new DNA, primase creates an RNA primer, helicase unzips the DNA.

2. How is DNA polymerase related to the reduction of genetic mutations?
 - a. It seals up the DNA strands to ensure that mutations cannot occur.
 - b. It signals the helicase to unzip the DNA strand and fix mutations to the DNA nucleotides.
 - c. It proofreads the DNA nucleotides, deletes errors, and replaces errors with the correct nucleotides.
 - d. It creates primers that are able to proofread the DNA and delete, reverse, and translocate mutations.

3. Why is DNA replication often referred to as the “semi-conservative” model?
 - a. Because one strand contains mutations and the other strand does not.
 - b. Because one strand has more base pairs and the other strand has less base pairs.
 - c. Because one strand comes from the mother and the other strand comes from the father.
 - d. Because one strand is the original strand and the other strand is the newly synthesized one.

4. Why is it important for DNA replication to continuously occur in integumentary system (skin)?
- To constrict the amount of blood flow to the skin
 - To decrease the amount of melanin or the pigmentation of one's skin color
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 - A physical model
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