DNA Structure & Replication
How is the genetic information stored and copied?

Why?
DNA is the molecule of heredity. It contains the genetic blueprint for life. For organisms to grow and repair damaged cells, each cell must be capable of accurately copying itself. So how does the structure of DNA allow it to copy itself so accurately that cells can then replicate during cell division?

Model 1: The Structure of DNA

1. What are the 3 parts of a nucleotide?

2. What kind of sugar is found in a nucleotide?

3. Which nucleotide component contains nitrogen?
4. How many different nitrogen bases are there? Name them.

5. Circle a single nucleotide on each side of the ladder model of DNA.

6. In the ladder model of DNA, how are the nucleotides arranged?

7. Which components of the nucleotides pair together to form the “rungs” of the ladder?

8. On the ladder model of DNA label each of the bases with the letter A, T, C or G.

9. Which components of the nucleotides form the sides (backbone) of the ladder?

10. When one nucleotide contains adenine, to what type of base will the adenine attach on the opposite nucleotide strand?

11. How many hydrogen bonds (lines) connect these two bases?

12. When one nucleotide contains cytosine, to what type of base will the cytosine attach on the opposite nucleotide strand?

13. How many hydrogen bonds connect these two bases?

14. Using complete sentences, with your group write a rule for how the bases are arranged in the ladder model of DNA.

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**Read This!**

Erwin Chargaff investigated the ratio of nucleotide bases found in the DNA from a variety of organisms. From his research, as well as research by Rosalind Franklin and Maurice Wilkins, Watson and Crick developed the **base-pair rule** during their race to discover the structure of DNA.
15. The ladder model of DNA is a simplified representation of the actual structure and shape of a DNA molecule. According to the final diagram in Model 1, what is the actual shape of the DNA molecule?

16. The DNA molecule is usually referred to as a double helix. Explain why.

**Model 2: DNA Replication**

17. What molecule is attached to the left-hand portion of the DNA molecule?

18. What type of biological molecule is this?

19. Looking at the diagram, what do you think is the function of this molecule?

20. What will need to be broken in order to separate the strands of DNA?
21. What rule is used to join the free nucleotides to the exposed bases of the DNA?

22. This type of replication is called **semi-conservative** replication. Considering the meaning of these words (semi – half; conserve – to keep), explain why DNA replication is called semi conservative.

23. DNA molecules can be tens of thousands of base pairs in length. Mistakes in DNA replication lead to mutations, which may or may not be harmful to an organism. How does semi-conservative replication help prevent mutations during DNA replication?

24. The proportions of the bases are consistent within a species; however they do vary between species. Using the base pair rules complete the following table to show the percentage of each type of base in the five different organisms.

<table>
<thead>
<tr>
<th>Organism</th>
<th>Adenine</th>
<th>Guanine</th>
<th>Cytosine</th>
<th>Thymine</th>
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<tbody>
<tr>
<td>Human</td>
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</table>
25. In the Meselson & Stahl experiment, how is the DNA in the first test tube described?

26. What is the atomic mass of the N in this DNA?

27. During the first replication, what is the atomic mass of the N in the bases that are added?

28. How is the DNA in the second test tube (after replication) described? Discuss with your group what this term means and why it is used to describe the DNA.

29. The lines in the test tubes represent the DNA after it has been centrifuged (spun at high speeds to separate molecules by weight). What is different about the position of the DNA band in the first test tube compared to the band in the second test tube?
30. In the third test tube the DNA has been allowed to replicate again, using $^{14}$N free nucleotides. Using all the diagrams in the model, explain why there are now two bands showing in the third test tube and explain why they are positioned the way they are.

31. With your group draw what you would expect to see if the DNA in the third test tube were to replicate again, using $^{14}$N free nucleotides. Draw the DNA bands in the test tube as well as the DNA molecules. Use solid lines to represent the $^{15}$N DNA and dashed lines to represent the $^{14}$N DNA.
Teacher’s Guide & Answer Key

Learning Objectives:
After completing the activity the students should be able to:

1. Draw a simple representation of a nucleotide and name each of the three components.
2. Apply the base pair rule to show how the two strands of a DNA molecule are joined and how a DNA model replicates.
3. [With the Extension Questions] Explain how the Meselson and Stahl experiment supports the semi-conservative model of DNA replication.

Prerequisites:
Students should have a basic knowledge of atomic mass, bonding, and biological molecules, including the fact that most enzymes end in –ase.

Assessment Questions:

1. In a DNA molecule, a sugar, phosphate and nitrogenous base are collectively referred to as:
   a. DNA
   b. RNA
   c. Nucleotide
   d. Codon
2. Explain what is meant by semi-conservative replication and why it helps ensure faithful replication of the DNA molecule.
   It is called semi-conservative replication because half of the original molecule is kept and the other half is synthesized from free nucleotides. Because new nucleotides are brought in according to the base pair rule, it lessens the likelihood that the wrong nucleotide sequence is created during replication.
3. Use the base-pair rule to show the corresponding nucleotide sequence that would create a DNA molecule:

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

Teacher Tips:
Question 6 can be used to introduce the concept of antiparallel strands where appropriate. Additional enzymes involved in replication such as RNA primase and DNA polymerase are not shown, in order to keep the model simplified. These can be introduced later of through animations such as http://www.johnkyrk.com/DNAreplication.html
Target Responses:

1. What are the 3 parts of a nucleotide? Deoxyribose sugar; phosphate; N-containing base

2. What kind of sugar is found in a nucleotide? deoxyribose

3. Which nucleotide component contains nitrogen? Base

4. How many different nitrogen bases are there? Name them. FOUR (adenine, thymine, cytosine & guanine)

5. Circle a single nucleotide on each side of the ladder model of DNA. Two complete nucleotides should be circled (each containing the base, and sugar and phosphate groups)

6. In the ladder model of DNA, how are the nucleotides arranged? In two [anti-parallel] strands.

7. Which components of the nucleotides pair together to form the “rungs” of the ladder? Nitrogenous bases

8. On the ladder model of DNA label each of the bases with the letter A, T, C or G. All bases should be labeled appropriately.

9. Which components of the nucleotides form the sides (backbone) of the ladder? Sugars & phosphates

10. When one nucleotide contains adenine, to what type of base will the adenine attach on the opposite nucleotide strand? Thymine

11. How many hydrogen bonds (lines) connect these two bases? 2

12. When one nucleotide contains cytosine, to what type of base will the cytosine attach on the opposite nucleotide strand? Guanine

13. How many hydrogen bonds connect these two bases? 3

14. Using complete sentences, with your group write a rule for how the bases are arranged in the ladder model of DNA. A pairs with T and C pairs with G

15. The ladder model of DNA is a simplified representation of the actual structure and shape of a DNA molecule. According to the final diagram in Model 1, what is the actual shape of the DNA molecule? Helix

16. The DNA molecule is usually referred to as a double helix. Explain why. The helix refers to the coiled shape, but as there are two strands coiled around each other, it is a double helix.
17. What molecule is attached to the unbroken portion of the DNA molecule? **DNA helicase**

18. What type of biological molecule is this? **An enzyme**

19. Looking at the diagram, what do you think is the function of this molecule? **To [unwind and] separate the DNA strands.**

20. What will need to be broken in order to separate the strands of DNA? **The hydrogen bonds holding the base pairs together.**

21. What rule is used to join the free nucleotides to the exposed bases of the DNA? **The base-pair rule: A-T & C-G**

22. This type of replication is called **semi-conservative** replication. Considering the meaning of these words (semi – half; conserve – to keep), explain why DNA replication is called semi conservative. **Because during replication, half of the original molecule is kept and the other half is synthesized from free nucleotides.**

23. DNA molecules can be tens of thousands of base pairs in length. Mistakes in DNA replication lead to mutations, which may or may not be harmful to an organism. How does semi-conservative replication help prevent mutations during DNA replication? **One half of the original molecule is kept and the new strand is made from free nucleotides, which can only join according to the base pair rule, so it lessens the likelihood that the wrong nucleotide sequence is created.**

24. The proportions of the bases are consistent within a species; however they do vary between species. Using the base pair rules complete the following table to show the percentage of each type of base in the five different organisms.

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25. In the Meselson & Stahl experiment, how is the DNA in the first test tube described? **Heavy**

26. What is the atomic mass of the N in this DNA? **15**

27. During the first replication, what is the atomic mass of the N in the bases that are added? **14N bases are added.**

28. How is the DNA in the second test tube (after replication) described? Discuss with your group what this term means and why it is used to describe the DNA. **Hybrid DNA (15N/14N). It means a mix or combination of two things and the DNA is now a combination of 15N and 14N nucleotides.**
29. The lines in the test tubes represent the DNA after it has been centrifuged (spun at high speeds to separate molecules by weight). What is different about the position of the DNA band in the first test tube compared to the band in the second test tube? **In the first tube the band is lower down, closer to the bottom of the tube, compared to the band in the second test tube.**

30. In the third test tube the DNA has been allowed to replicate again, using $^{14}$N free nucleotides. Using all the diagrams in the model, explain why there are now two bands showing in the third test tube and explain why they are positioned the way they are. Each hybrid DNA separated and using the free $^{14}$N nucleotides four molecules of DNA were made. Two contain only $^{14}$N nucleotides, so they are light, and the other two still contain a mix of $^{14}$N and $^{15}$N so they are hybrid. **This creates two bands as shown in the diagram.**

31. With your group draw what you would expect to see if the DNA in the third test tube were to replicate again, using $^{14}$N free nucleotides. Draw the DNA bands in the test tube as well as the DNA molecules. Use solid lines to represent the $^{15}$N DNA and dashed lines to represent the $^{14}$N DNA.

*Should have two hybrid strands and six light strands. The light band in the test tube should now be drawn thicker to represent the fact that there is substantially more light DNA compared to hybrid DNA.*