DNA Structure and Replication

How is genetic information stored and copied?

Why?

Deoxyribonucleic acid or 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?

Model 1 – The Structure of DNA

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1. Refer to the diagram in Model 1.
   a. What are the three parts of a nucleotide?
      *Deoxyribose sugar, phosphate, and nitrogen-containing base.*
   b. What kind of sugar is found in a nucleotide?
      *Deoxyribose.*
   c. Which nucleotide component contains nitrogen?
      *The base.*
   d. Name the four nitrogen bases shown in Model 1.
      *Adenine, thymine, guanine, and cytosine.*

2. DNA is often drawn in a “ladder model.” Locate this drawing in Model 1.
   a. Circle a single nucleotide on each side of the ladder model of DNA.
      *Two complete nucleotides should be circled, each containing the base, sugar, and phosphate groups.*
b. What part(s) of the nucleotides make up the rungs of the “ladder”?
Nitrogen bases.
c. What parts of the nucleotides make up the sides (backbone) of the “ladder”?
Sugar and phosphate.
d. Look at the bottom and top of the “ladder” in Model 1. Are the rungs parallel (the ends of the strands match) or antiparallel (the ends of the strands are opposites)?
The strands are antiparallel.

3. 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. See Model 1.

4. Refer to Model 1. When one nucleotide contains adenine, what type of base is the adenine attached to on the opposite nucleotide strand?
Thymine.

5. The two strands of DNA are held together with hydrogen bonds between the nitrogen bases. These are weak bonds between polar molecules. How many hydrogen bonds connect the two bases from Question 4?
Two.

6. Refer to Model 1. When one nucleotide contains cytosine, what type of base is the cytosine attached to on the opposite nucleotide strand?
Guanine.

7. How many hydrogen bonds connect the two bases from Question 6?
Three.

8. With your group, use a complete sentence to write a rule for how the bases are arranged in the ladder model of DNA.
A pairs with T and C pairs with G.

**Read This!**

Erwin Chargaff (1905–2002), an Austrian-American biochemist, 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 complementary base-pair rule during their race to discover the structure of DNA. The complementary base-pair rule states that adenine and thymine form pairs across two strands, and guanine and cytosine form pairs across two strands.

9. Fill in the complementary bases on the strand below according to the base-pair rule.

\[
\begin{array}{cccc}
A & T & C & C \\
T & A & G & G \\
\end{array}
\]

10. The ladder model of DNA is a simplified representation of the actual structure and shape of a DNA molecule. In reality, the strands of DNA form a double helix. Refer to the double helix diagram in Model 1 and describe its shape using a complete sentence.

* A double helix has two strands coiled around each other.
11. Examine Model 2. Number the steps below in order to describe the replication of DNA in a cell.

   4. Hydrogen bonds between nucleotides form.
   1. Hydrogen bonds between nucleotides break.
   2. Strands of DNA separate.
   3. Free nucleotides are attracted to exposed bases on the loose strands of DNA.

12. Locate the DNA helicase on Model 2.

   a. What type of biological molecule is DNA helicase?
      *An enzyme.*

   b. What is the role of DNA helicase in the replication of DNA?
      *To (unwind and) separate the DNA strands.*

13. What rule is used to join the free nucleotides to the exposed bases of the DNA?

   *The complementary base-pair rule (A-T; C-G).*

14. 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.

   *During replication, half the original molecule is kept and the other half is synthesized from free nucleotides.*
15. 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 complementary base-pair rule, so it lessens the likelihood that the wrong nucleotide sequence is created.

16. 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>
</tr>
</thead>
<tbody>
<tr>
<td>Human</td>
<td>31</td>
<td>19</td>
<td>19</td>
<td>31</td>
</tr>
<tr>
<td>Cow</td>
<td>28</td>
<td>22</td>
<td>22</td>
<td>28</td>
</tr>
<tr>
<td>Salmon</td>
<td>29</td>
<td>21</td>
<td>21</td>
<td>29</td>
</tr>
<tr>
<td>Wheat</td>
<td>27</td>
<td>23</td>
<td>23</td>
<td>27</td>
</tr>
<tr>
<td>Yeast</td>
<td>31</td>
<td>19</td>
<td>19</td>
<td>31</td>
</tr>
</tbody>
</table>
17. According to Model 3, what term refers to loose DNA inside of a nucleus?

*Chromatin.*

18. During what part of the cell cycle is the DNA in a cell's nucleus replicated?

*DNA is replicated during synthesis.*

19. During what part of the cell cycle is the DNA in a cell condensed into chromosomes?

*The beginning of mitosis.*

20. Replicated chromosomes are often illustrated as an X shape to match how they look in real life just before cell division.

   a. According to Model 3, which of the following diagrams correctly show an original set of homologous chromosomes (grey) and their sister chromatids (black)—the replicated portion?

   b. What structure holds the two sister chromatids together as they prepare for cell division?

   *Centromere.*
Teacher Resources – DNA Structure and Replication

Learning Objectives

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 molecule replicates.
3. Describe the steps to DNA replication in the semi-conservative model.

Prerequisites

1. Students should have a basic knowledge of bonding, including hydrogen bonds.
2. Students should have a basic knowledge of 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. a nucleotide.  
   d. a codon.
2. Explain what is meant by semi-conservative replication and why it helps ensure accurate replication of the DNA molecule.
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 G T

Assessment Target Responses

1. c.

2. 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. T A A G C G A A T T C C G G C A

Teacher Tip

- 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 through animations such as this website (accessed January 2012). http://www.johnkyrk.com/DNAreplication.html