Name: _____ Block: _____ Score: _____

UNIT 6 - The Structure and Function of DNA

Lesson 6.1: DNA Structure and Replication

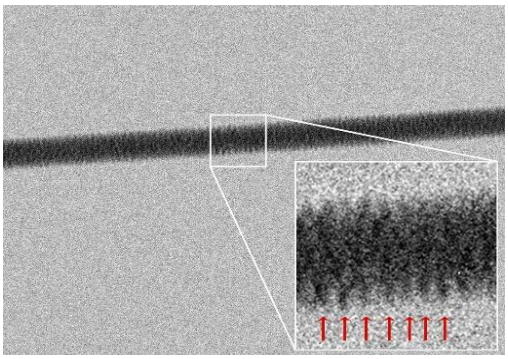
Objective	1. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells. 2. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.

Engage

How can you make conclusions about something you cannot see? This has been a challenge throughout the history of science. Sometimes scientists must use indirect evidence.

A researcher looks at a test tube containing a purified sample of DNA in a solution.

This is a colored transmission electron micrograph (TEM) of bacterial DNA.



This is a transmission electron micrograph (TEM) of the first high-contrast direct image of a bundle (fiber) of strands of DNA. The inset at lower right shows the helical structure. The red arrows are pointing at the edges of the helix.

Understanding the structure and function of DNA is one such case in biology. Early biologists recognized that characteristics were passed from one generation to the next, but the molecules responsible for this phenomenon were too small to be seen using early microscopes. Remarkably, biologists pieced together evidence about the structure of the molecule responsible for the unique characteristics of each organism. Over time, scientists built on the work of others, and, at the same time, technology continued to improve. Today, we have a much clearer understanding about DNA—the molecule that contains the code for life.

Predict: *Based on the images shown of DNA, how would you describe its appearance? How do you think scientists determined the structure and function of DNA?*

_____

_____

_____

_____

_____

_____

Lesson 6 – *Exploration 1 – The Function of DNA*

Codes for Proteins (p. 259)

What is **DNA, or Deoxyribonucleic Acid**?

What does it mean if a trait is inherited, or *heritable*?

Describe the *central dogma* of molecular biology. How does information travel?

What are a few roles of proteins in the body?

Kinesin is a motor protein that transports organelles and proteins around a cell. The structure of kinesin is crucial for its function. What might happen to the structure of kinesin if the DNA code was damaged?

Mechanisms for Heredity (p. 259-262)

What is **genetics**?

Complete the table below with descriptions for each of the experiments that

	Griffith
Summary of Experiment	
Key Data	
Questions at the End	
	Avery

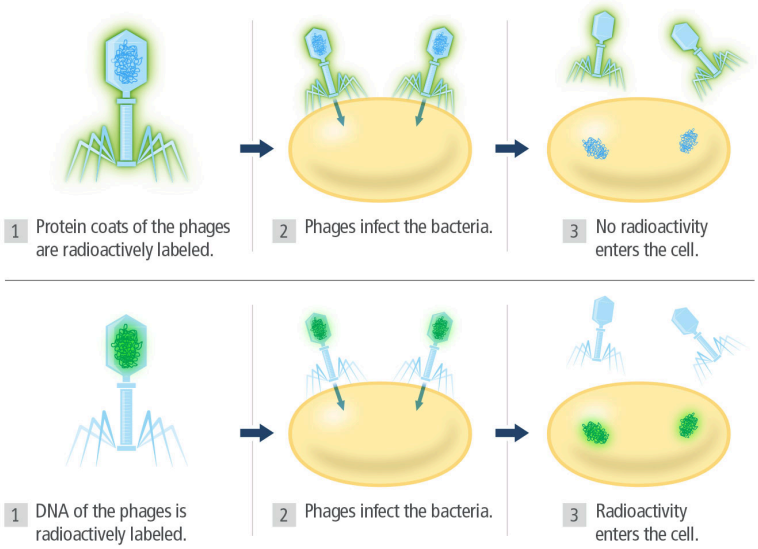
Summary of Experiment	
Key Data	
Questions at the End	
	Hershey & Chase
Summary of Experiment	
Key Data	
Questions at the End	

Avery and his group performed a chemical analysis of the molecule determined to be the "transforming principle." The table shows the percentage of nitrogen and phosphorus and the ratio of nitrogen to phosphorus for four samples.

Chemical analysis of the transforming principle

	% Nitrogen (N)	% Phosphorus (P)	Ratio of N to P
Sample A	14.21	8.57	1.66
Sample B	15.93	9.09	1.75
Sample C	15.36	9.04	1.69
Sample D	13.40	8.45	1.58
Known value for DNA	15.32	9.05	1.69

How does the data in the table support the claim that DNA is the transforming principle?



Develop a conclusion about the results shown in the diagram above by completing the following statements.

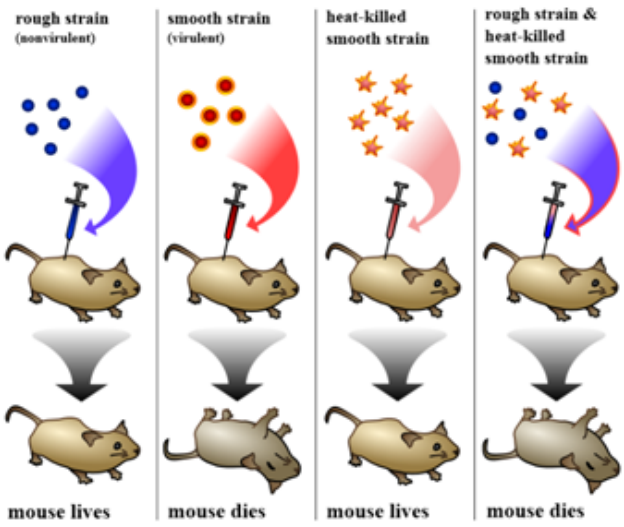
> When bacteriophages with radioactively labeled proteins infected with bacteria, radioactivity (**did**, **did not**) enter the cell. When bacteriophages with radioactively labeled DNA infected the bacteria, radioactivity (**did**, **did not**) enter the cell. Therefore, the material that is being injected into the bacteria is (**proteins**, **DNA**).

Extension 6.1, Exploration 1: The History of DNA

Griffith - 1928

Even though DNA has been known since the mid 1800's, its structure and function weren't discovered until the beginning of the 20th century. Our understanding of what DNA does and what it looked like took a long time to come together, but there were three key experiments that helped scientists learn what DNA does. Those experiments have been summarized for you here. Use the information in the passages and your own critical thinking skills to answer the following questions.

Frederick Griffith wanted to explore the differences between different types of pneumococcus bacteria (a bacteria that causes pneumonia). He did this by injecting mice with two different strains of bacteria. One, the rough strain, doesn't cause disease. The other, the smooth strain, causes the mice to die. He also noticed that when the smooth strain was heated and then injected, the mice lived. But he also noticed that when both the heated smooth strain and the normal rough strain were both injected into the same mouse, the mouse died. The figure below summarizes the findings of his experiment.



1. What is the *independent variable* in Griffith's experiment (what did he change)? What is the dependent variable (what did he record)?

2. The heat-killed bacteria are Griffith's control group. Why did Griffith need to show that the heat-killed bacteria didn't make the mouse die?

3. Why do you think that the mix of heat-killed and rough bacteria killed the fourth mouse?

Griffith's Conclusion

Because the heat-killed bacteria mixed with the rough bacteria were lethal to the mouse, Griffith concluded that **something from the heat-killed bacteria "transformed" the rough bacteria and made them lethal**. But at this time, he had no idea what had caused the transformation. Other scientists picked up where he left off and tried to figure out what was causing the transformation. The first group of scientists to try were Oswald Avery, Colin MacLeod, and Maclyn McCarty.
Avery, MacLeod, and McCarty killed the bacteria in the same way as Griffith, and they then purified the different parts of the bacteria. They showed that when they injected the DNA portion of the bacteria into the mice, the mice died just as they did in Griffith's experiments. This was the first evidence that DNA was the genetic material.

Avery - 1944

In the early 1940s, Oswald Avery and his colleagues set out to test whether the transforming agent in Griffith's experiment was protein, RNA, or DNA. The scientists used enzymes to separately destroy each of the three molecules in heat-killed S cells. They used a protease enzyme to destroy protein in heat-killed cells in the first experiment, an enzyme called RNase to destroy RNA in the second experiment, and an enzyme called DNase to destroy DNA in the third experiment. Then they separately mixed the three experimental batches of heat-killed S cells with live R cells and injected mice with the mixtures. The cells missing protein and RNA were able to transform R cells into S cells and kill the mice. However, cells missing DNA did not transform R cells into S cells, and the mice survived.

1. What enzyme destroys protein?

2. What enzyme destroys DNA?

3. What experimental batch of heat-killed S cells and live R cells resulted in the mice surviving?

4. In Avery's experiment, R cells were transformed into _____.

Hershey and Chase – 1952

Alfred Hershey and Martha Chase took Avery's experiment even further. They wanted to confirm what Avery and his colleagues found, so they studied the effects of a virus called a *bacteriophage* on bacteria cells. Viruses infect cells by injecting their genetic information into a cell to take it over. Then, the cell makes copies of the virus. At the time, many people thought that proteins carried genetic information, so they put radioactive elements on both the proteins and the DNA of the virus. After the virus attached itself to the bacteria, they checked to see if the cell was radioactive. Their results are summarized in the figure below to the left.

1. Based on Hershey and Chase's results, what was the virus injecting into the cells?

2. Based on the results, do you think that DNA or proteins carry genetic information? Why?

Exploration 2 – The Structure of DNA

Objective	1. I can describe the structure of a DNA molecule. 2. I can explain the process of DNA replication

Nucleotides (p. 263)

Define and illustrate the following terms:

monomer -

polymer -

DNA (a nucleic acid) is a polymer - the monomer units are called _____.

A protein is a polymer - the monomer units are called _____.

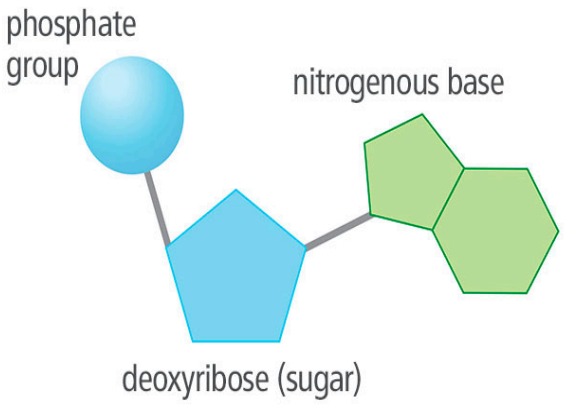
The _____ that make up _____ differ only in their _____-containing bases.

List the four bases of nucleotides below. Include both the full name and their abbreviations.

1. _____ 3. _____

2. _____ 4. _____

Use Figure 7 to answer the following questions.



1. What do the lines between the phosphate group and sugar and between the sugar and the base represent?

2. DNA is a long molecule which can contain billions on nucleotides. What is the term for this type of molecule? What is the term for the subunits that make it up?

_____ bonds are found in the backbone and _____ link the bases together.

The four nucleotides that make up DNA

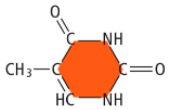
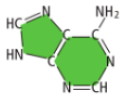
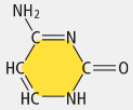
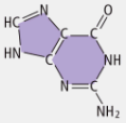
PYRIMIDINES			PURINES		
Name of base	Structural formula	Model	Name of base	Structural formula	Model
thymine			adenine		
cytosine			guanine		

Figure 8: The four nucleotides that make up DNA.

Use the table in Figure 8 to answer the following questions.

1. Which base is most similar to thymine?

2. How do the structures of *purines* differ from the structure of *pyrimidines*?

3. What would the DNA "ladder" look like if *purines* paired with other *purines*?

4. What would the DNA "ladder" look like if *pyrimidines* paired with other *pyrimidines*?

<u>Determining DNA Structure (p. 263-265)</u>

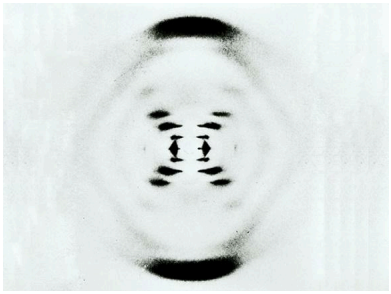
What is ***Chargaff's Rule***?

Chargaff found that the _____ four bases are found in the DNA of all _____, but the

_____ of the four bases _____ from one organism to another.

What technique did Rosalind Franklin use to study DNA?

Figure 0: X-Ray evidence



Describe ***x-ray crystallography***.

What did Franklin's x-ray photographs show?

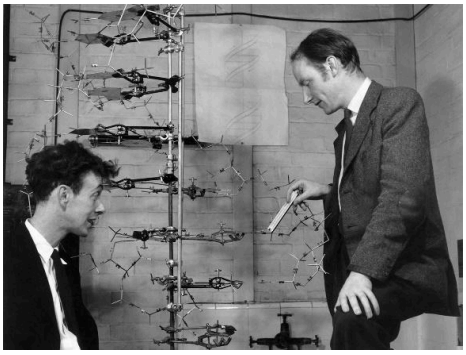
Rosalind Franklin's results made her conclude that the DNA molecule was helical, or spiral-shaped. What questions about the structure of DNA are not answered by her results? Choose all the correct answers:

a) The shape of the DNA molecule
b) The overall structure of the DNA molecule
c) The chemical makeup of the DNA molecule
d) The arrangement of the nitrogenous bases A, T, C, & G

Which scientists provided the background for Watson and Crick's study of DNA structure?

Watson and Crick found that if they paired the _____-ringed _____ with the

_____-ringed _____, the bases fit like a puzzle.



Use Figure 11 to answer the following question.

By building a physical model, Watson and Crick were able to see that adenine fit with thymine and guanine fit with cytosine.

- How do Chargaff's results support Watson and Crick's model?

Watson and Crick built a _____-_____ model, in which two strands were _____—that is, if one strand is ACACAC, the other strand is _____.

If you were looking at a single strand of DNA with a base sequence of GATTACA, what would the *complementary* strand be?

Current DNA Model (p. 265)

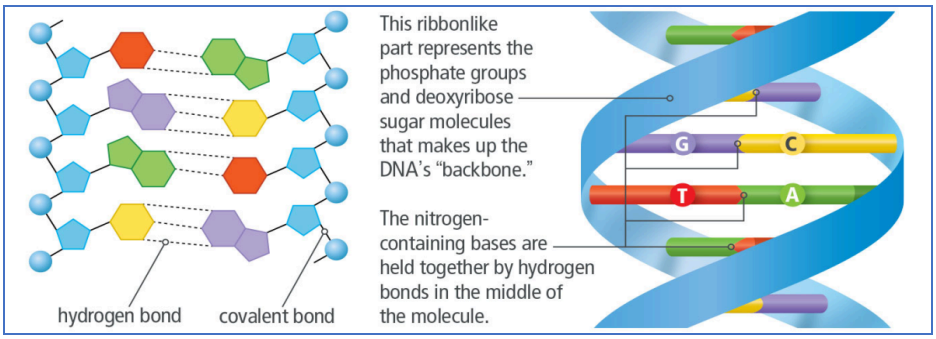


Figure 12: Model of DNA

1. Examine the model of DNA from Figure 12. Explain the structure of the molecule by completing the following statements, by choosing the correct answer.

   The base pairs are found in the (**middle**, **outside**) of the DNA molecule. The base pairs are held together by (**hydrogen**, **covalent**) bonds, which are relatively (**strong**, **weak**). The deoxyribose sugars and phosphates are found in the (**middle**, **outside**) of the DNA molecule. The sugars and phosphates are connected by (**hydrogen**, **covalent**) bonds, which are relatively (**strong**, **weak**).

2. Look at the hydrogen bonds between the base pairs in Figure 12. Which base pairs do you think are held more tightly together? Why?

3. Describe the structure of DNA using a ladder as an analogy.
   - **a.** What makes up the rungs, or steps of the ladder?
   - **b.** What makes up the sides?
   - **c.** How is the ladder shaped?

Extension 6.1, Exploration 2: The Structure of DNA

Label the diagram. Use these choices: deoxyribose, phosphate group, hydrogen bonds, and base pair

DNA (deoxyribonucleic acid) is the building block of the life. DNA is called a **nucleic acid** because it was first found in the nucleus, though it can also be found in organelles such as the chloroplast and the mitochondria. DNA molecules are incredibly long. If all the DNA bases of the human genome were typed as A, C, T and G, the 3 billion letters would fill 4,000 books of 500 pages each!

DNA, in eukaryotes, is organized into individual strands called **chromosomes**. Humans have 46 chromosomes (23 pair), which consist of about 70,000 genes. A **gene** is a segment of DNA that codes for a particular protein, which in turn codes for a trait. Before cell division, chromosomes condense and become visible to the naked eye, though they are not always in this highly condensed form.

DNA controls the production of proteins within the cell. These proteins in turn, form the structural units of cells and control all chemical processes within the cell. Think of proteins as the building blocks for an organism, proteins make up your skin, your hair, and parts of individual cells. How you look is largely determined by the proteins that are made. The proteins that are made is determined by the sequence of DNA in the nucleus.

The DNA helix looks like a spiral ladder. DNA is a polymer made of repeating monomers called **nucleotides**. The combination of a **single base,** a **deoxyribose sugar**, and a **phosphate** make up a **nucleotide** monomer. The sugar and the phosphate form the backbone and are held together by strong covalent bonds. The two sides of the ladder are held together by weak hydrogen bonds between the bases, or the rungs of the ladder. The H-bonds must be weak as DNA can actually "unzip" when it needs to replicate - or make a copy of itself. DNA needs to copy itself when a cell divides, so that the new cells each contain a copy of the DNA. Without these instructions, the new cells wouldn't have the correct information.

The rungs of the ladder are pairs of 4 types of nitrogen bases. Two of the bases are purines- **adenine** and **guanine**. The pyrimidines are **thymine** and **cytosine**. The bases, **A, G, T, C,** always bond in a certain way. **Adenine will only bond to thymine**. **Guanine will only bond with cytosine**. This is known as the "**Base-Pair Rule**".

1. What do the letters DNA stand for?
2. What is a chromosome?
3. What is a gene?
4. DNA is a *polymer*, which means that is made up of many repeating single units (*monomers*). What are the monomers called?
5. The “backbone” of the DNA molecule is made up of two alternating components, what are these?
6. There are four different variations of these monomers(four different bases), what are the names of those bases?
7. The two bases that are purines are:
8. The two bases that are pyrimidines are:
9. The bases are paired by _____ bonds along the axis of the molecule.

Write the complementary sequence to following DNA strand:

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

| | | | | | | | | | | | | | | | | | | | |

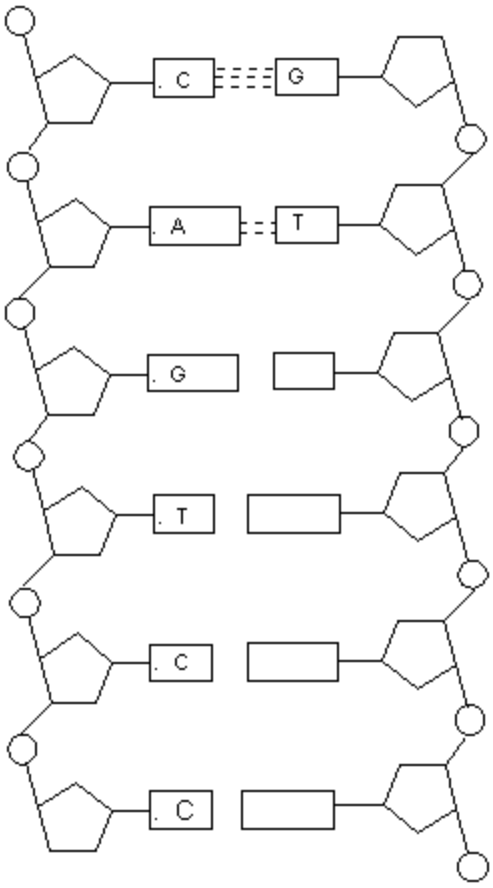
11. Use the image at the right to complete the follow:

a. Circle a nucleotide.

b. Label: a deoxyribose sugar, a phosphate, a nitrogenous base, Adenine, Thymine, Guanine and Cytosine

12. Label the 3 covalent bonds in a nucleotide and a hydrogen bond

13. Add the bases that are not already labeled and the hydrogen bonds that are missing



DNA showing the complementary base pairing between antiparallel strands

Exploration 3 – DNA Replication

<u>DNA Process for Replication (p. 266-267)</u>

What is ***replication***?

When does replication take place?

What does replication ensure?

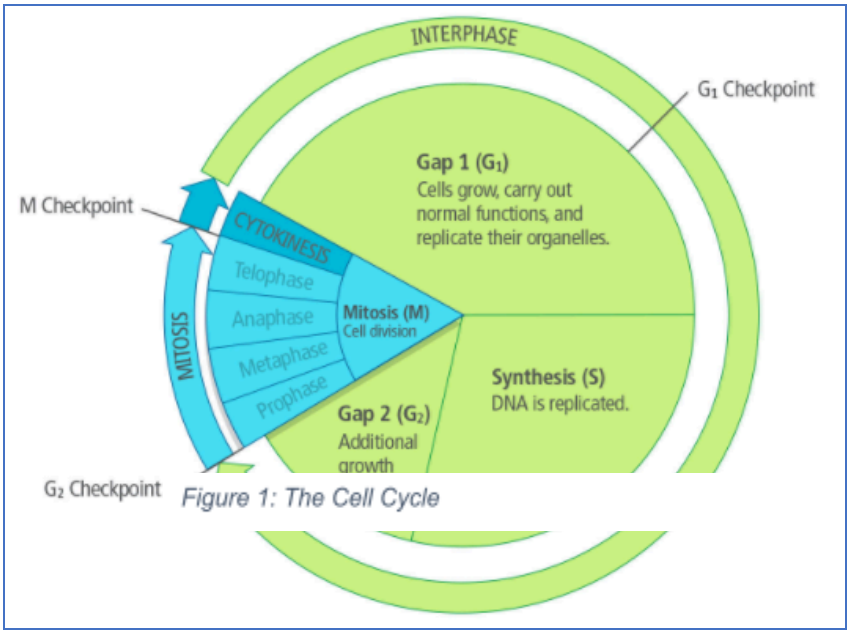


Figure 1: The Cell Cycle

➢ Which of these statements are true of DNA replication during the cell cycle? Select all the correct answers:

- **a)** It occurs during the G_1 phase.
- **b)** It results in double the amount of DNA.
- **c)** DNA replication occurs during the S phase.
- **d)** It results in new combinations of genetic material.
- **e)** It allows each cell to have an identical set of DNA after cell division.

➢ The word *synthesis* comes from a Greek word meaning "to put together, or combine". Why is the S-phase called the *synthesis* phase?

➢ What types of biomolecules do the work of replication?

➢ The name of an enzyme can reveal its function. The suffix, *-ase* indicates that a protein is an enzyme, and the root word before the suffix indicates which molecule is the substrate for this enzyme. One enzyme involved in DNA replication is called *helicase*. Based on the information that you know about enzymes, what do you think the function of helicase is? Choose all correct answers:

- **a)** Breaks bonds to unwind the DNA molecule.
- **b)** Increases the rate of chemical reactions.
- **c)** Prepares nucleotides to reattach to the molecule.
- **d)** Lowers the activation energy of the unzipping process.
- **e)** Adds free-floating nucleotides to the DNA template.

In the table below, describe the function of each type of enzyme involved in DNA replication.

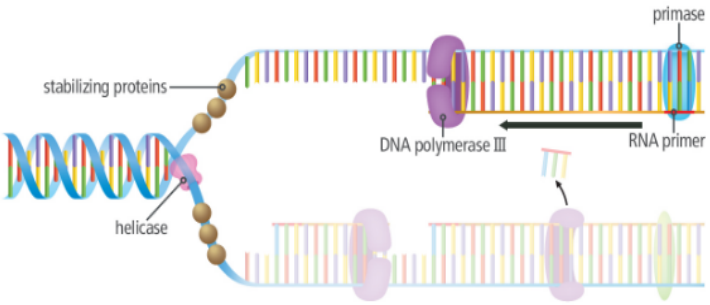
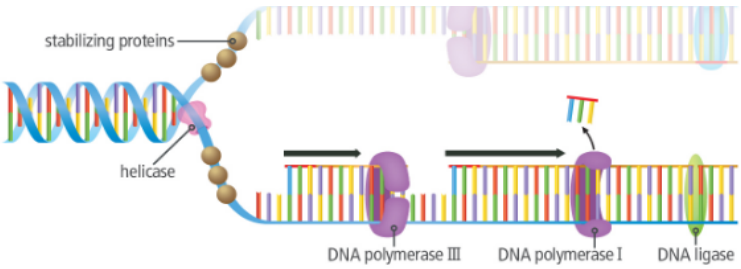
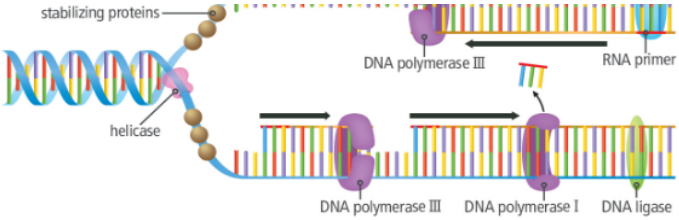
Enzyme	Function
Helicase	
Single-Strand Binding Proteins (SSBs), or Stabilizing Proteins	
Primase	
DNA Polymerase	
Ligase	

Using Figure 14 as reference, answer the following questions.

➢ Why are stabilizing proteins needed to keep the DNA strands separated?

a) Hydrogen bonds normally cause the DNA strands to stick together.
b) The wrong nucleotides can mistakenly pair up on the templates.
c) The sugar-phosphate bonds can coil around each other, preventing replication.
d) Without stabilizing proteins, the DNA strands can fragment.

➢ What is a replication fork, and why do two exist during replication of the molecule in Figure 14?

Stage of Replication	Description
	
	
	

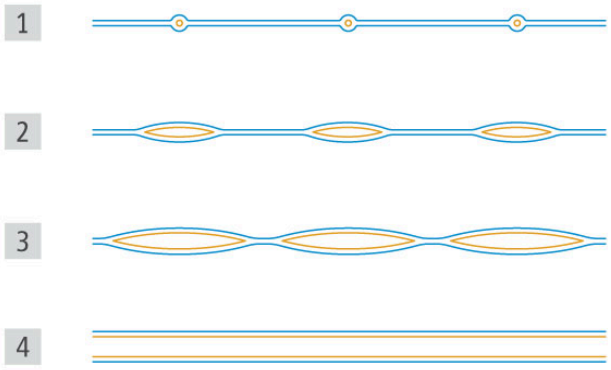
What is the product of replication?

Why is the process of DNA replication considered ***semiconservative***?

Figure 1: The product of replication.

Draw an example of semiconservative replication here:

Fast and Accurate Replication (p. 268)



Why does DNA form multiple origins of replication along the chromosome?

What is a ***base substitution***?

How can DNA polymerase I help fix mistakes in the sequencing of nucleotides?

Why is it important for DNA polymerase I to proofread the new strands of DNA before the cell divides?

Extension 6.1, Exploration 3: DNA Replication

What is the first step in the process of DNA replication?

Which enzyme is responsible for "unzipping" the DNA double helix?

Which enzyme is responsible for facilitating the hydrogen bonding between nucleotides in a new DNA molecule?

Which enzyme is responsible for creating the covalent bonds that connect the sugar-phosphate backbone of the new DNA molecules?

If the sequence of one single strand of DNA is C-A-A-G-T-A-G-G-C-T, what is the sequence of the complementary strand?

Describe the origin of each strand of the new double helices created after DNA replication.

Why is DNA replication important to the growth and development of a multi-cellular organism?

Place the following terms in the correct order from smallest to largest: Nucleosome, supercoils, coils, chromosome, DNA double helix

List the 3 basic steps of DNA replication:

a. _____

b. _____

c. _____

The model of DNA below is ready to be copied. Compared to the original double helix, evaluate the copies made during three attempts of DNA replication. List any errors with the replication if they occurred:

Original

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

Replication #1

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

AND

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

List problems if any:

_____

_____

_____

_____

_____

_____

Replication #2

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

AND

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

List problems if any:

_____

_____

_____

_____

_____

_____

Complete the diagram on the left. Then circle the areas in the diagram on the right that show a genetic mutation.

DNA Correctly Copied

A	
G	
C	
T	
A	
T	
A	

→

DNA Incorrectly Copied

A	
G	
C	
T	
A	
T	
A	

→

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

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