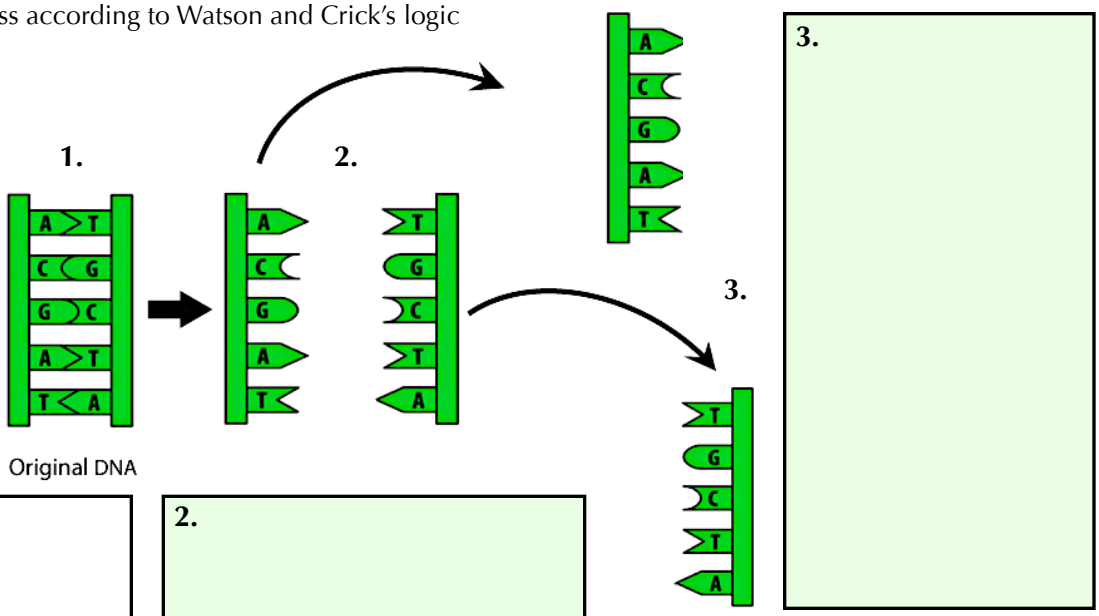
STUDY GUIDE - *Ch. 16.2 - Many Proteins Work in DNA Replication & Repair* **NAME:** _____
- Ch. 16.3 - A Chromosome Consists of a DNA Molecule Packed Together with Proteins

- **PHYSICALLY PRINT OUT this PDF and HANDWRITE (with a black or blue pen) your answers directly on this PDF.** *Typed or digitally-written work is **not** accepted. Do **not** answer questions on separate paper.*
- **Importantly, study guides are NOT GROUP PROJECTS!!!** *You, and you alone, are to answer the questions as you **read** your assigned textbook. You are **not** to share answers with other students. You are **not** to copy any answers from any other source, including the internet.*
- **Get in the habit of writing LEGIBLY, neatly, and in a medium-sized font.** *AP essay readers and I will skip grading anything that cannot be easily read so start perfecting your handwriting, and don't write so large you can't add all the relevant details and key elaborations in the space provided.*
- **SCAN physical documents in color and with good resolution. Then, upload your final work as PDFs to Archie.** *Avoid uploading dark, shaded, washed-out, sideways, or upside-down scans of homework. Keep completed physical study guides organized in your biology binder to use as future study and review tools.*
- **READ FOR UNDERSTANDING and not merely to complete an assignment.** ***First**, read a section quickly to get an overview of the topic covered. Then, read it a **second** time slowly, paraphrasing each paragraph **out loud** and analyzing every figure. Finally, read it a **third** time as you answer the study guide questions if assigned and start building your memory. Try to write answers out in your own words, when possible, and try to purposefully and accurately use all new terminology introduced.*

1. **Watson and Crick,** built a model of the structure of DNA, which they proposed was made up of two parental strands *(two nucleotide polymers)* hydrogen bonded together through the nitrogenous bases that were part of the structure of the two stands' nucleotides. After building their model, they also **proposed a hypothesis about how a cell might copy its DNA molecule(s) soundly**. Study figure 16.10, which is a visual model of the hypothesis Watson and Crick proposed. Complete the visual model below by drawing the missing parts of the model. In the boxes below, explain the stages of the process according to Watson and Crick's logic



1.

2.

3.

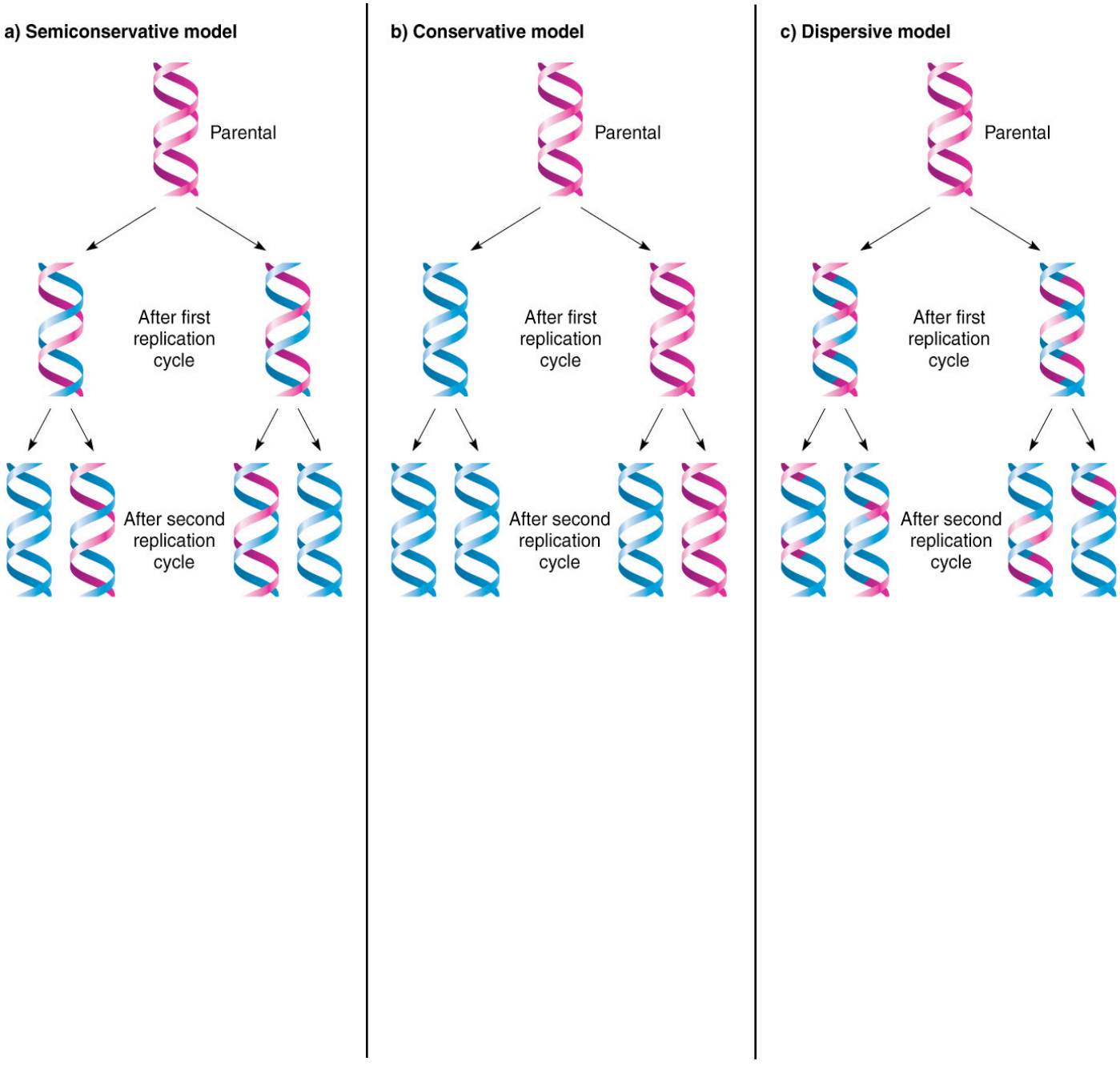
3. a. **Study Figure 16.11.** What is meant by the phrase that **DNA replication is semiconservative**?

b. Alternate models for DNA Replication were referred to as Conservative and as Dispersive. Describe how these two alternative models differ from the Semiconservative Model of DNA Replication.

<u>Conservative Model of DNA Replication</u> =

<u>Dispersive Model of DNA Replication</u> =

c. The illustration below shows the results after two rounds of DNA replication, according to each of the three models of DNA Replication. Using pink/red pen or pencil to indicate the original "parental" DNA an blue pen or pencil to indicate newly synthesized "daughter" DNA, extend this illustration by **<u>drawing all the chromosomes that would result in each of the three models after a THIRD round of DNA replication</u>**.



4. Who performed the **experiments that elucidated the correct mechanism of DNA replication**?

5. a. **Study Figure 16.12 until you fully understand the Meselson Stahl experiment.** How did Meselson and Stahl **create "heavy" DNA** for experiments?

b. 1. After **bacteria were grown for many generations in a culture medium with only heavy ^{15}N isotope available**, what was the **make up of the DNA molecules** in these bacteria? *Circle the correct answers.*

^{15}N -^{15}N ^{15}N -^{14}N $^{15/14}N$ -$^{15/14}N$ ^{14}N -^{14}N

2. When suspending the DNA from these parent cell in a solution and then centrifuging the DNA, **how many bands did researchers EXPECT to see in the test tube**?

3. **How many bands did the researchers actually OBSERVE in the test tube?**

4. Draw the test tube to the right and label the DNA band as ^{15}N -^{15}N.
Since nucleotides of both strands are made with heavier nitrogen isotopes, the band of DNA in solution should be found closer to the bottom of the test tube than the middle or top.

c. *Think:* Bacteria from the heavy-nitrogen-isotope-containing medium were then transferred into a new flask that contained a medium with only light-nitrogen isotope, ^{14}N. After **bacteria were allowed to undergo ONE round of replication** *(perform binary fission once to create daughter bacteria)* **in this new culture medium with only light ^{14}N isotope available**....

1. what was the **EXPECTED make up of the DNA molecules** in the daughter bacteria if **Semiconservative** DNA replication occurred? *Circle the correct answer(s).*

^{15}N -^{15}N ^{15}N -^{14}N $^{15/14}N$ -$^{15/14}N$ ^{14}N -^{14}N

2. what was the **EXPECTED make up of the DNA molecules** in the daughter bacteria if **Conservative** DNA replication occurred? *Circle the correct answer(s).*

^{15}N -^{15}N ^{15}N -^{14}N $^{15/14}N$ -$^{15/14}N$ ^{14}N -^{14}N

3. what was the **EXPECTED make up of the DNA molecules** in the daughter bacteria if **Dispersive** DNA replication occurred? *Circle the correct answer(s).*

^{15}N -^{15}N ^{15}N -^{14}N $^{15/14}N$ -$^{15/14}N$ ^{14}N -^{14}N

d. *Think:* Bacteria from the heavy-nitrogen-isotope-containing medium were then transferred into a new flask that contained a medium with only light-nitrogen isotope, ^{14}N. After **bacteria were allowed to undergo TWO rounds of replication** *(perform binary fission twice to create granddaughter bacteria)* **in this new culture medium with only light ^{14}N isotope available**....

1. what was the **EXPECTED make up of the DNA molecules** in the granddaughter bacteria if **Semiconservative** DNA replication occurred? *Circle the correct answer(s).*

^{15}N -^{15}N ^{15}N -^{14}N $^{15/14}N$ -$^{15/14}N$ ^{14}N -^{14}N

2. what was the **EXPECTED make up of the DNA molecules** in the granddaughter bacteria if **Conservative** DNA replication occurred? *Circle the correct answer(s).*

^{15}N -^{15}N ^{15}N -^{14}N $^{15/14}N$ -$^{15/14}N$ ^{14}N -^{14}N

3. what was the **EXPECTED make up of the DNA molecules** in the granddaughter bacteria if **Dispersive** DNA replication occurred? *Circle the correct answer(s).*

^{15}N -^{15}N ^{15}N -^{14}N $^{15/14}N$ -$^{15/14}N$ ^{14}N -^{14}N

e. 1. Draw the **test tube that Meselson and Stahl OBSERVED after the 1ST round of DNA Replication** was allowed to occur **in bacteria moved from the heavy-nitrogen-containing medium to the light-nitrogen-containing medium**. Label the band(s) of DNA correctly.

2. **Which model(s) of DNA Replication did the results after ONE round of replication disprove** and **WHY**???

f. 1. Draw the **test tube that Meselson and Stahl OBSERVED after the 1ST round of DNA Replication** was allowed to occur **in bacteria moved from the heavy-nitrogen-containing medium to the light-nitrogen-containing medium**. Label the band(s) of DNA correctly.

2. **Which model(s) of DNA Replication did the results after TWO rounds of replication disprove** and **WHY**???

g. Which **model (explanation) of DNA Replication did the results from Meselson and Stahl's experiment support**?

6. *Think:* If Meselson and Stahl had first grown the cells in ^{14}N-containing medium and ***then*** moved them into ^{15}N-containing medium before taking samples, what would have been the result in the test tubes after the first ***and*** then after the second round of replications?

*(Check your answers to **#6** by going to the **Ch.16 Figure Questions** in Appendix A and reviewing the answer for **Figure 16.12**)*

7. a. The Origin of Replication where DNA replication begins. What exactly is this **Original of Replication** though?

b. Explain the **basic steps of all DNA Replication**

1.

2.

3.

c. How does **Eukaryotic DNA differ from Prokaryotic DNA in terms of their Origins of Replication**?

Prokaryotic DNA Replication =

Eukaryotic DNA Replication =

d. Why is it an **ADAPTATION** (a feature that increases the survival and reproductive success of an organism) for Eukaryotes to have multiple Origins of Replication along each linear chromosome?

8. a. What is a **Replication Bubble**?

b. What is s the **Replication Fork**?

b. What is the function of the enzyme **Helicase**?

c. What are the function of the proteins referred to as **Single-Stranded Binding Proteins (SSBPs)**?

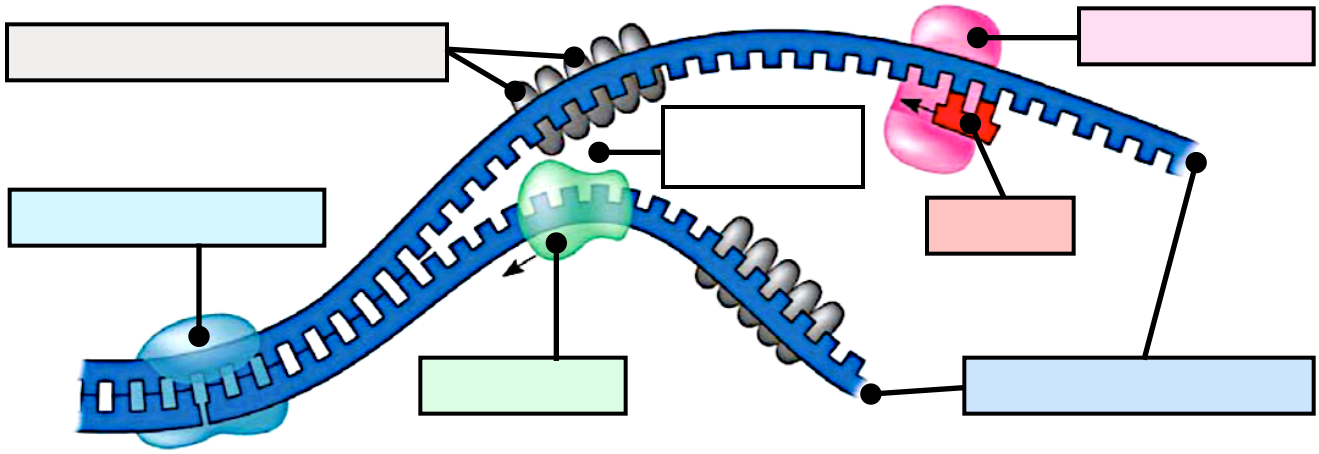
d. Explain the purpose of **Topoisomerase (DNA Gyrase)**.

e. What do **DNA Polymerases** do?

f. What is constructed by the enzyme **Primase** (a type of RNA Polymerase)?

g. During DNA Replication, we want to copy DNA template (parental) strands into daughter stands also made of DNA. **Why is constructing a complimentary primer out of RNA nucleotides by Primase necessary for DNA Replication** if we already have DNA Polymerase that can build daughter strands out of DNA?

9. Take a few minutes to **memorize your answers to #8 and to study Figure 16.4.** Now see if you can label some of the proteins and region as of the initial replication fork that forms right after helicase docs onto an Original of Replication.



10. In eukaryotes there exist at least 11 DNA Polymerases so far discovered. For prokaryotes, the picture is slightly simpler. The two main DNA Polymerases in Bacteria are known as DNA Pol III and DNA Pol I. What is the **function of DNA Pol III**?

11. a. **Though ATP is often used by the cell as a source of energy such as when enzymes catalyze endergonic chemical reactions or when protein pumps actively transport of solutes across a membrane, this ATP is NOT the source of energy DNA Polymerases use to catalyze the dehydration synthesis reactions that covalently bond DNA nucleotides together.**

The **DNA nucleotide**s that are incorporated into the growing daughter DNA strand **arrive at DNA Polymerase as nucleotide triphosphates** *(deoxyATP or dATP, dGTP, dCTP, dTTP)*. What is the purpose of using nucleotide triphosphates for DNA replication when the nucleotides - once incorporated into the DNA strand - will have only one phosphate group attached to the deoxyribose sugar **and** how are they used by DNA Polymerase?

Purpose of Polymerase using Nucleotide Triphosphates for Nucleic Acid Synthesis =

How DNA Polymerase uses Nucleotide Triphosphates during DNA Synthesis =

b. What is the **difference between the ATP used for energy and the ATP *(or technically dATP)* used in replication**?

12. a. What is meant by the statement **"the two strands of DNA in a double helix are antiparallel"**?

b. In what **direction does a daughter DNA strand grow**?

d. What are the **two reasons why DNA strands grow in the direction you stated** above?

1.

2.

13. a. **Study carefully Figure 16.16 and Figure 16.7.** Distinguish between the **leading and the lagging strands** and how they are constructed during DNA replication.

Leading Strand in a Replication Fork =

Lagging Strand in a Replication Fork =

b. What are **Okazaki Fragments**?

c. Remember, that before DNA Pol III can synthesize daughter strand DNA, Primase had to lay down a primer of RNA. This is true when constructing each Okazaki Fragment as well. **How are these RNA nucleotides removed from the Okazaki Fragments and replaced with DNA nucleotides**?

d. Once the sections of RNA have been replaced with DNA, **how are the fragments of daughter DNA strands covalently bonded together to make one long polynucleotide** complimentary to the parent/template DNA strand?

14. Let's see what you have committed to memory about which enzyme (or protein) does which process.

a. **Untwists and separates template strands of DNA =** _____

b. **Holds template DNA strands apart =** _____

c. **Synthesizes short RNA primers complimentary to the DNA template =** _____

d. **Adds DNA nucleotides to new daughter strands =** _____

e. **Relieves the strain ahead of the replication fork caused by the unwinding of the DNA double helix at the replication fork of the replication bubble =** _____

f. **Removes the RNA primer and replaces this section of daughter polymer with DNA nucleotides =**

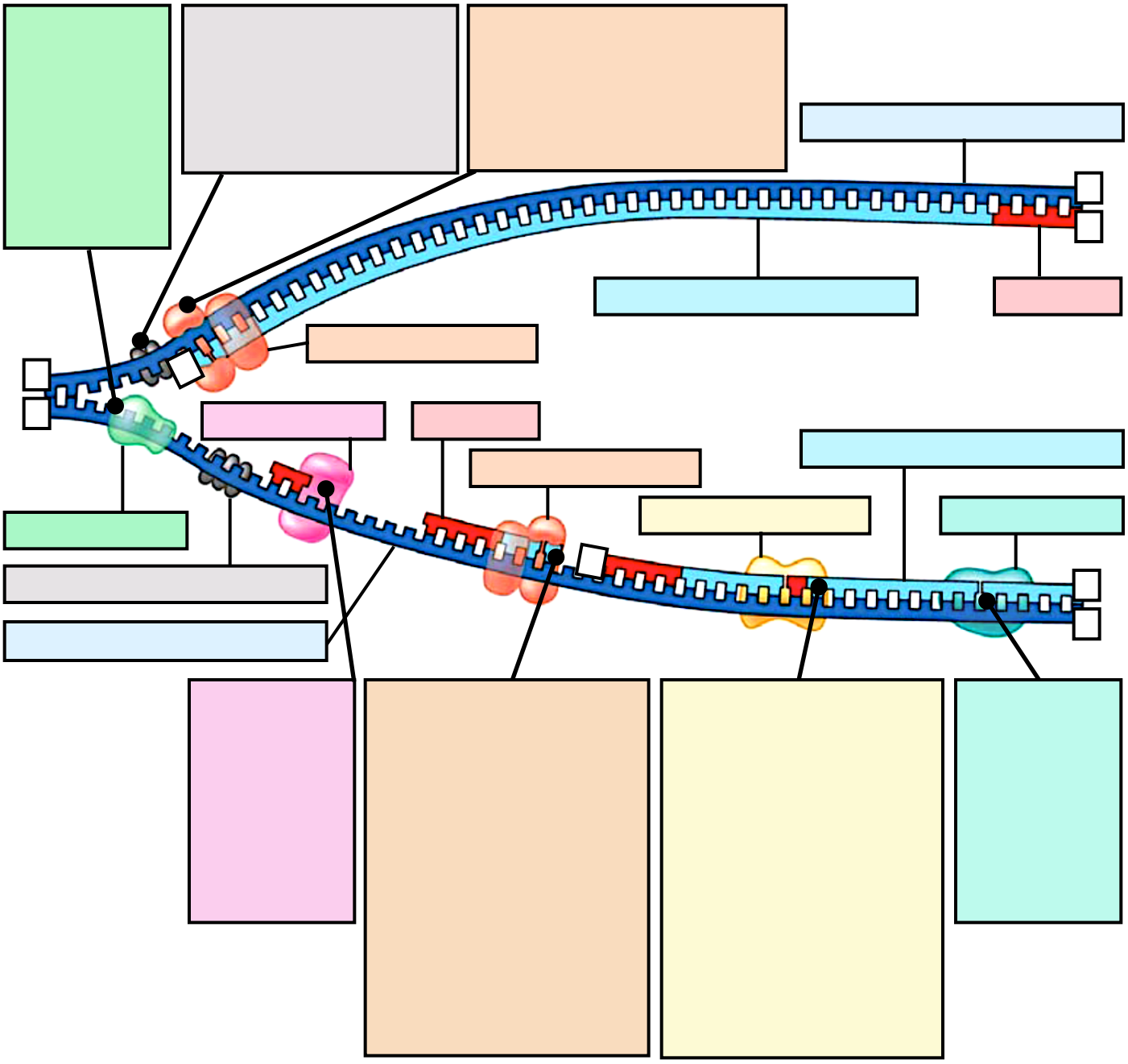
_____

g. **Covalently joins DNA fragments complimentary to the template DNA strand together =**

_____

15. Let's put all the activities that take place at one replication fork in a replication bubble together. **Label** the diagrams below illustrating the synthesis of the leading and lagging strands during DNA replication.

    1. First **label the two template DNA strands** and the **leading daughter strand**, and the **lagging daughter strand**.
    2. Next, add the **3' and 5' ends** of the **template,** the **leading daughter strand**, and the **lagging daughter strand**.
    3. **Label at least two Okazaki Fragments** of the leading daughter strand.
    4. **Circle** the location where one would expect to find the **enzyme Topoisomerase** (DNA Gyrase)
    5. Finally, **explain the steps involved in the copying of a double helix of DNA** by filling in the boxes below.



16. Study Table 16.1. What is the difference in function between **DNA Pol III and DNA Pol I**?

    DNA Pol III =

    DNA Pol I =

17. *Think:* What **role does complementary base pairing play in the replication of DNA**?

*(Check your answers to #17 by going to the **Ch.16.2 Concept Check Question #1** answer in Appendix A)*

18. *Think:* Identify **two major functions of DNA pol III in DNA replication**.

    1.

    2.

*(Check your answers to #18 by going to the **Ch.16.2 Concept Check Question #2** answer in Appendix A)*

19. What is the **relationship between DNA replication and the S phase of the cell cycle**?

*(Check your answers to #19 by going to the **Ch.16.2 Concept Check Question #3** answer in Appendix A)*

20. If the DNA pol I in a given cell were nonfunctional, how would that affect the synthesis of a leading strand?

*(Check your answers to #20 by going to the **Ch.16.2 Concept Check Question #4** answer in Appendix A)*

21. a. What is the error rate of eukaryotic DNA polymerase?

    b. Explain the characteristic of DNA polymerase allows for such a low error rate.

21. What is DNA **mismatch repair**?

22. *Think:* Why is it important that mismatches between nucleotides of opposite strands or alterations to the structure of nucleotides within a strand get repaired when possible? *(Why would DNA repair mechanism be adaptations?)*

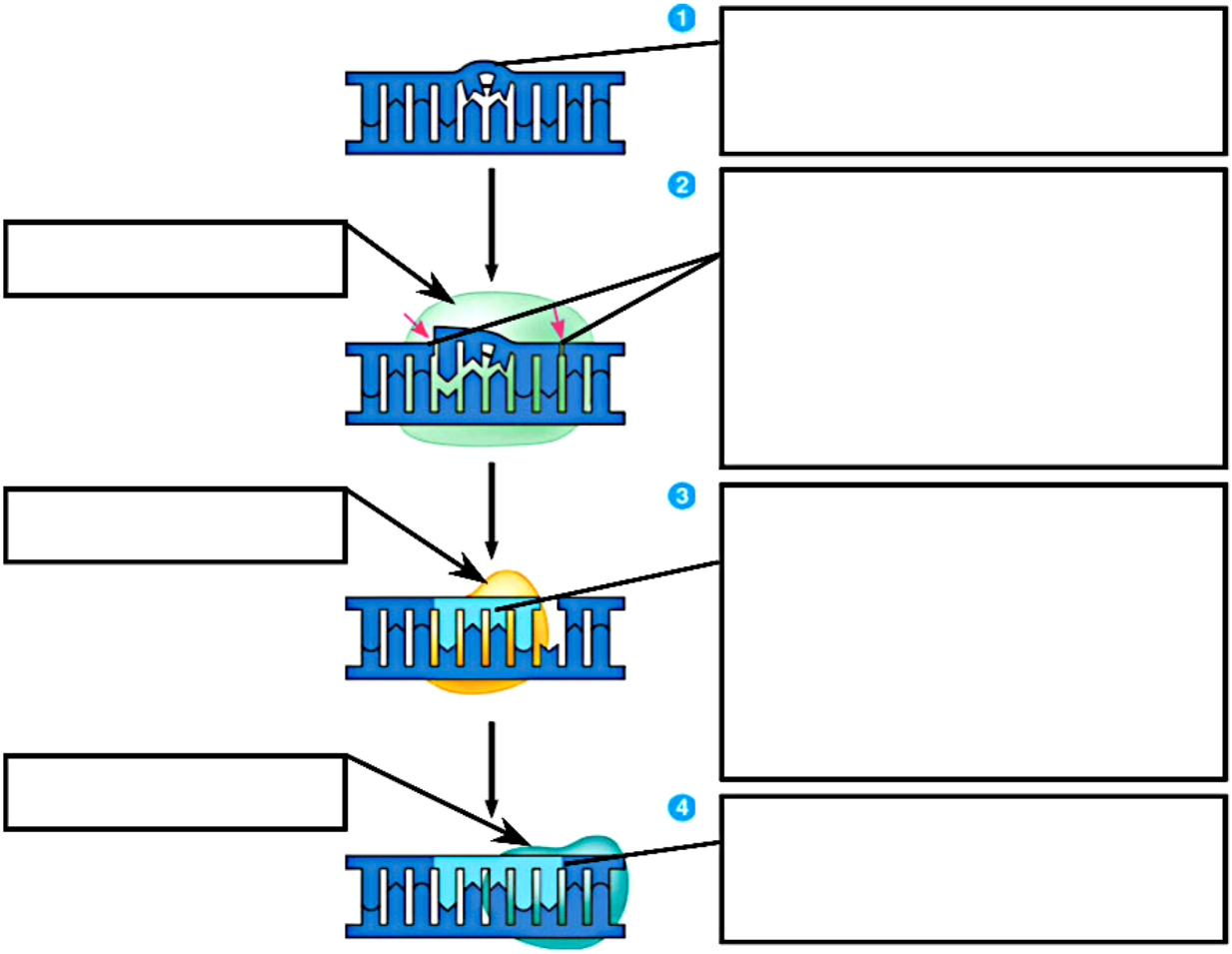
23. a. Though nucleotides can be mismatched during DNA Replication, incorrectly paired nucleotides or changes to the structure of nucleotides can happen outside of the S phase of the cell cycle as well. DNA nucleotides may spontaneous alter their chemical structure or they may get damaged by being exposed to high-energy radiation or harmful chemicals. What change in the DNA is referred to as a **thymine dimer**?

    b. How does the thymine dimer alter the shape of the backbone of the DNA strand it occurs in?

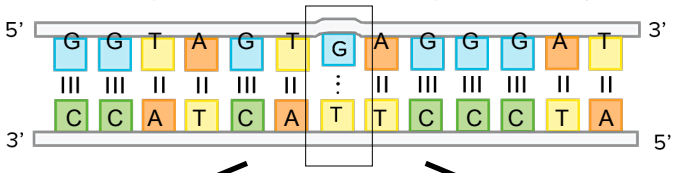
c. What **two enzyme are necessary for conducting nucleotide excision repair**?

1. _____ 2. _____

d. Label the figure below in order to explain the process of **nucleotide excision repair** in order to replace a thymine dimer.



24. Assume that a cell in a gonad inherited DNA with the following base-pair mismatch from its parent cell. The parent cell had undergone DNA replication, when the mismatch occurred, and then completed mitosis to make this daughter cell, but the mismatch in the DNA was never corrected. Assume this daughter cell is a germ line cell in a person's testes, which now has gotten the signal to divide to produce sperm cells. It is now time for this daughter cell to engage in DNA Replication itself before it conducts meiosis to form the gametes that will help make the next generation of offspring. **During S phase, the chromosome with the mismatch will undergo Semiconservative DNA Replication to produce the two double helixes of a duplicated chromosome we call sister chromatids.** Draw the two sister chromatids that result when this original double helix undergoes DNA Replication.



At the end of meiosis, one of these sister chromatids will become a chromosome in one gamete while the other sister chromatid will become a chromosome in a different gamete. **Though the DNA sequences of these chromosomes are now different, neither of the two chromosomes now contain a mismatch!** *Both have perfectly complimentary strands.*

The gamete that inherited the mutant nucleotide pair (or the resulting zygote made from that gamete) will not think to repair the complimentary pair of nucleotides, because the nucleotides are not mismatched anymore.

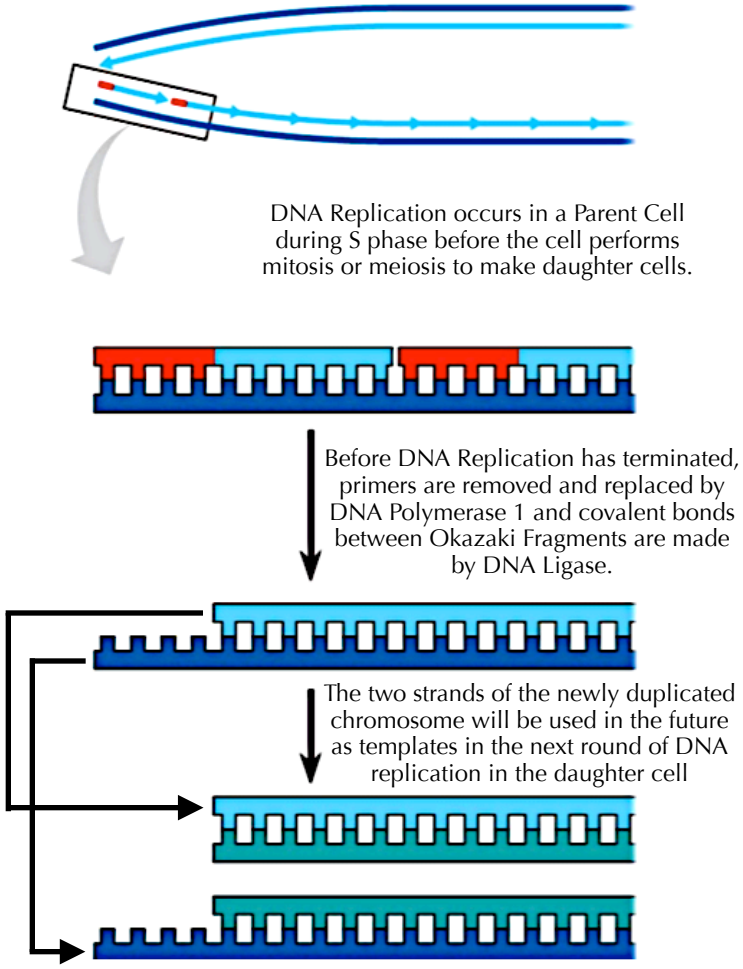
A change in the sequence of nucleotides in DNA is called a _____.

What if the original mismatch was in a gene? Now, there are two versions of this gene in the two gametes that could get passed down to a zygote, and so an offspring, depending on which of these two sperm cell fertilized an egg.

Recall from previous chapters that a new version of a gene is called a _____.

Changes in the DNA sequence of a gene can alter an organism's phenotype.
Natural selection acts on the phenotype of organisms!

25. a. **Describe why the replication machinery cannot replicate the 3′ end of a template strand of a linear chromosome** in Eukaryotes. Reference the figure below in your answer, but be sure to properly **label the 5′ and 3′ ends of all strands** shown, identify **all DNA template strands**, **all daughter strands**, and **all primers** in all molecules shown.



b. What are **telomeres**?

c. In what **two ways are telomeres important**?

1.

2.

d. If the DNA machinery cannot copy the 3′ ends of template strands during DNA Replication, DNA Replication produces progressively shorter and staggered (unevenly-ended) DNA molecules with each successive round of DNA replication. **Why does the DNA inside germ line cells that undergo S phase prior to meiosis and the production of gametes**, which will pass down chromosome copies to offspring, **not get shorter during meiosis with the passing of every subsequent generation of life**?

e. **Explain the details behind why some cancer cells "immortal," but most body cells have limited life span**?

26. a. A **eukaryotic chromosome** consists of a DNA molecule packed together with proteins. What is **chromatin**?

b. **Carefully read Figure 16.23**. What are **histones**?

c. Why do histones bind to well to DNA?

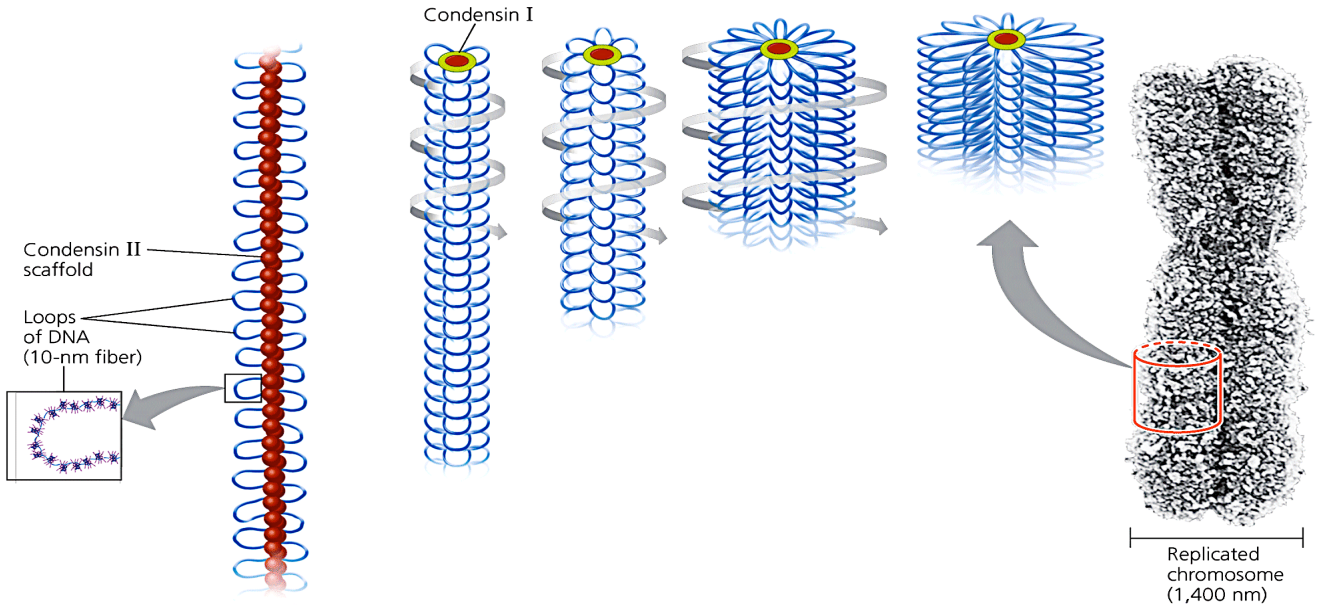
d. What are **nucleosomes**, the basic unit of DNA packing in eukaryotic cells?

e. **Distinguish between Euchromatin and Heterochromatin and gene expression.**

Euchromatin =

Heterochromatin =

f. Outline the **current model for the progressive packaging of DNA starting with the double helix molecule and ending with its coiling and folding into a metaphase chromosome**. Be sure to explain how the DNA exists in each phase and subphase of the cell cycle.



27. Proceed to the TEST YOUR UNDERSTANDING section at the end of the chapter. **Study your chapter sections and all Ch.16 study guides first!** *Then, do your best to try to answer these from memory first in order to test how well you grasped the material before. If you are unsure, return to the relevant section of your chapter and restudy any pertinent material to refresh your memory. (Check some of your answers by going to the **Ch.16 Test Your Understanding** answers in Appendix A)*

1. _____ 2. _____ 3. _____ 4. _____ 5. _____ 6. _____ 7. _____ 8. _____

9.