Name_____ Biol 211 - Group Number_____

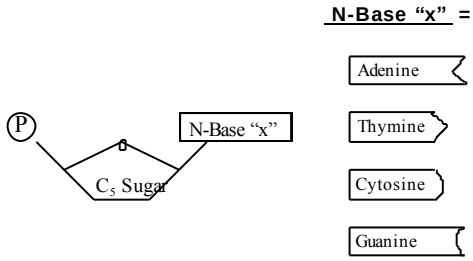
Active Learning Exercise 9. The Hereditary Material: DNA

Reference: Chapter 16 (*Biology* by Campbell/Reece, 8th ed.)

1. a.) What is a ***nucleotide***?

   b.) What is a ***nitrogen base***? List those found in ***DNA*** and those in ***RNA***.

2. Make a diagram of a ***double stranded DNA*** molecule that contains *nine nucleotides in each strand*—any sequence is fine, however, draw each nucleotide as shown below. Label where the covalent and hydrogen bonds are, and label the three parts of one nucleotide. Don't worry about showing the helical nature of DNA in your diagram!!!

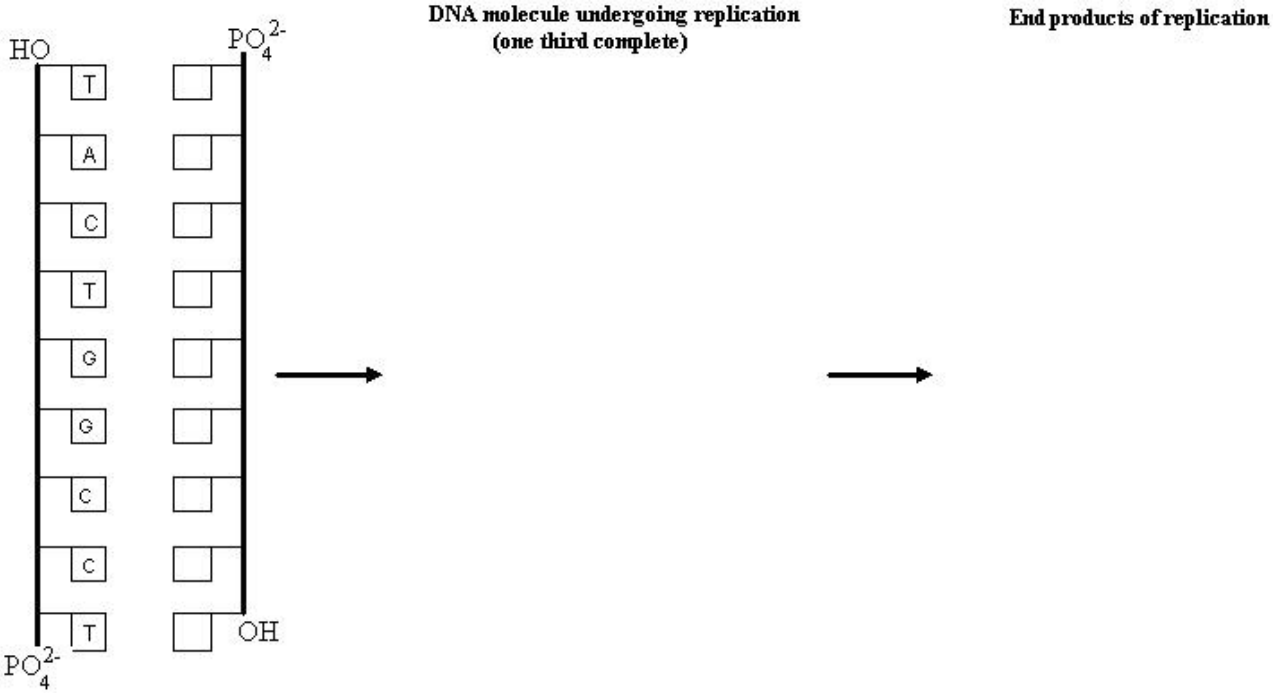


3. a.) How can you distinguish between the two ends of a sugar-phosphate chain in DNA (or RNA)?

   b.) **Label** the ends of *each* strand in your diagram on page 1. (**Hint**: What is the difference between the 5' and 3' ends?)**.**

4. a.) Complete the base sequence of the ***complementary strand*** of the hypothetical DNA segment diagrammed below. Use dashed lines to indicate hydrogen bonding between paired bases. Now show *how* this molecule would be replicated:

   b.) Draw the molecule partially "unzipped" while undergoing replication (*one-third complete*), followed by the resulting daughter molecules with their correct nucleotide sequences and base pairing. Use *two colors*, one for the template (or parent) strands, and another for the newly synthesized daughter strands. *Label the 3' and 5' ends of all strands*.



5. Explain why the process of DNA replication had to evolve 3.5 to 4.0 billion years ago. Why is it necessary for all reproducing organisms on earth today to be able to do this?

6. When during the cell cycle does DNA replication occur?

7. Describe the process of ***DNA replication***, and explain the role of ***helicase***, ***topoisomerase***, ***single strand binding protein*** (SSBP), ***DNA polymerases I and III***, ***DNA ligase***, ***RNA primer*** and ***primase***. *Make a labeled diagram to help clarify your description*.

8. What are ***Okazaki fragments***? Why do they exist? Which enzyme eventually links these fragments together?

9. Once replication is complete the process of ***"proofreading"*** occurs. What is it, why is it important, and what enzyme does it?

10. What are ***telomeres*** and why are they essential for the survival of our species and all other eukaryotic species

11. Most somatic cells in the human body can divide about 40-60 times before they ultimately stop dividing. On the other hand, cancerous cells, stem cells (undifferentiated cells that divide to give rise to other cell types; e.g. stem cells in the bone marrow give rise to the various types of blood cells, including RBC's and WBC's), and the stem cells of the germ line (those that produce the gametes) are *not* limited in the number of times they can divide. *Explain why stem cells and cancerous cells have unlimited reproductive capability, while somatic cells can divide only a finite number of times. What role does* ***telomerase*** *play? Explain and illustrate with a diagram how telomerase functions.*

Something you may find interesting.....

The number of times a cell is capable of dividing is called the ***Hayflick limit***. It's intriguing to note that the cells of longer-lived species of animals have a larger Hayflick limit (e.g. Human fibroblast cells have a Hayflick limit of 40-60), while those of short -lived species have smaller Hayflick limit (e.g. mice live 2-3 years and have a Hayflick limit of about 10). Although cells continue living when they reach the Hayflick limit, they often become senescent. ***Senescent cells*** are ***dedifferentiated***, appear structurally abnormal under the microscope, and gradually lose their ability to function properly. On the other hand, many cells cease to divide after they are formed (e.g. most neurons in the brain), yet they do not normally become senescent. Although the exact relationship between the Hayflick limit and longevity is still unclear, it is a hot area of current research.

12. What we know about DNA and how it controls the activities of an organism is the result of thousands of scientists scattered around the world. The biologists indicated in the questions below are among the groundbreakers. Briefly indicate their contributions to molecular genetics by summarizing their experiments, their conclusions, and how they reached their conclusions.

    a.) What experiments would you perform to test whether DNA is the hereditary material of organisms? Begin by discussing the transformation experiments of ***Griffith***, then those of ***Avery***, ***McCarty*** and ***MacLeod***, and finally those by ***Hershey and Chase***.

b.) In a one-page paper published in the British journal *Nature,* ***James Watson*** and ***Francis Crick*** revolutionized biology forever by proposing the double helical structure of DNA. The strength of a theory is in its powers of prediction. Watson and Crick's proposed structure of DNA had enormous implications since it suggested how DNA might replicate, and how it might control cellular activities. Upon reading Watson and Crick's one page paper, other biologists hypothesized that DNA might control the production of proteins via an intermediate messenger, perhaps RNA. Recall that enzymes, which are made of protein, control the metabolic activities of cells. It was only a matter of time before theses predictions were actually confirmed. *Explain* how the work of ***Edwin Chargaff*** and that of ***Rosalind Franklin*** and ***Maurice Wilkins*** led to Watson and Crick's determination of the structure of DNA.

c.) Bacterial cells were fed with labeled nitrogen-containing food (i.e. with the heavy isotope of nitrogen, ^{15}N). After several generations, the DNA strands of the bacterial chromosomes were found to contain labeled nitrogen, ^{15}N. The bacteria were then fed on normal food (all nitrogen present was the lighter isotope, ^{14}N) and when they, in turn, divided, it was found that the cells produced contained DNA in which only one of the two strands contained labeled nitrogen atoms. How can this be explained? Make a simple labeled diagram to illustrate your response and name the biologists who first performed these experiments.

13. If the result of the ***Hershey and Chase experiment*** had been that radioactive sulfur (^{35}S) was found inside the cells instead of radioactive phosphorous (^{32}P), what could have been concluded?

14. In what order do the following enzymes and polypeptides function during replication? Record the appropriate letters in the spaces provided below.
    a.) single-strand binding proteins
    b.) DNA polymerase III
    c.) helicase
    d.) primase
    e.) DNA polymerase I
    f.) DNA ligase
    g.) topoisomerase

    _____ → _____ → _____ → _____ → _____ → _____ → _____

15. What enzyme does a gamete-producing cell include that compensates for replication-associated shortening?
    a.) DNA polymerase II b.) DNA ligase c.) telomerase d.) DNA nuclease e.) helicase

16. DNA has two functions: It can ***self-replicate***, and it acts as a template for the ***transcription*** of DNA into RNA. DNA is capable of these functions because…
    a.) Its two strands are held together by easily broken covalent bonds.
    b.) Its nucleotides can base-pair with both ribose and deoxyribose nucleotides.
    c.) Its replication is semiconservative.
    d.) Replication and transcription are thermodynamically spontaneous and require no enzymes.

17. During DNA replication, the leading strand is synthesized continuously, while the lagging strand is synthesized as ***Okazaki fragments***. This is because…
    a.) DNA synthesis can take place only in the 5′→3′ direction.
    b.) DNA polymerases can bind to only one strand at a time.
    c.) Two different DNA polymerases are involved in replication (DNA polymerase I and III).
    d.) There are thousands of origins of replication on the lagging strand.

18. Werner's syndrome is a rare inherited disorder that results in premature aging with death often happening at an age of 30 to 40 years. The physical consequences of Werner's syndrome begin to appear in adolescence where growth stops, hair turns gray, and arteriosclerosis and wrinkling of the skin begin. It is believed that a mutation in the gene responsible for the production of the enzyme helicase is primarily responsible for Werner's syndrome. Hypothesize why an individual with a poorly functioning helicase enzyme would have such severe problems.

19. Most nerve cells do not replicate their DNA upon reaching maturity. Suppose that a cell biologist measured the amount of DNA in several different types of human cells:
    1) Nerve cells
    2) Sperm cells
    3) Bone cells just starting interphase
    4) Skin cells in the S phase
    5) Intestinal cells just beginning mitosis

    She found x amount of DNA in the nerve cells. Use this fact and the information in the table below to identify Cells A - D. Note: If the cell cycle and mitosis are a bit rusty, review chapter 12.

Cell Type	Amount of DNA in Cell	Identity of Cell
Nerve Cell	x	Nerve Cell
Cell A	2x	
Cell B	1.6x	
Cell C	0.5x	
Cell D	x	