9 DNA and Its Role in Heredity

Chapter Outline

In this chapter we examine the structure and function of another macromolecule, DNA. DNA is a nucleic acid that is responsible for transmitting heredity from one generation to another. It occurs as a double-stranded helix, typically packaged in the form of a chromosome. DNA replication occurs in a semiconservative fashion, meaning that each of the two "new" DNA copies have one strand of the original DNA and one strand that is newly synthesized. Although the vast majority of DNA copying is exact and precise, changes in DNA, *mutations*, frequently occur. Some mutations are small and inconsequential, while others change the organism and can result in the complete rearrangement of a chromosome.

As you read this chapter, pay particular attention to the experimental evidence presented. This evidence reveals how we know what we know about DNA. Many of the DNA research experiments were "wet lab" procedures, like those of Rosalind Franklin, Maurice Wilkins, Hershey and Chase, and Meselson and Stahl. Some scientists, including Watson and Crick, did little to no experimentation but rather built models based on the work of numerous experiments by others. Both experimentation and modeling are important scientific practices.

Chapter 9 emphasizes **Big Idea 3**, but it also considers the idea of emergent properties in **Big Idea 4**.

Big Idea 3 states that living systems store, retrieve, transmit, and respond to information essential to life processes. Chapter 9 lays the groundwork for heredity with its discussion of the structure and function of DNA. Specific parts of the AP Biology curriculum that are covered in Chapter 9 include:

- **3.A.1:** DNA, and in some cases RNA, is the primary source of heritable information.
- **3.A.4:** The inheritance pattern of many traits cannot be explained by simple Mendelian genetics.
- **3.C.1:** Changes in genotype can result in changes in phenotype.
- **3.C.2:** Biological systems have multiple processes that increase genetic variation.
- **3.C.3:** Viral replication results in genetic variation, and viral infection can introduce genetic variation into the hosts.
- **3.D.1:** Cell communication processes share common features that reflect a shared evolutionary history.

Big Idea 4 states that biological systems interact in complex ways. Specifically, Chapter 9 includes:

- **4.A.1:** The subcomponents of biological molecules and their sequence determine the properties of that molecule.

Chapter Review

Concept 9.1 *explains how DNA structure reflects its role as the genetic material. DNA is found in chromosomes as a double-stranded helix. It is a nucleic acid, containing the nucleotides adenine (A) paired with thymine (T), and cytosine (C) paired with guanine (G). The two strands of DNA are antiparallel, meaning that the code of each strand is "read" in the direction opposite that of the other strand. The complementary pairing arrangement (A with T; C with G) stabilizes the double helix.*

1. Describe the major contributions to the discovery of the specific structure of DNA by the following scientists:

a. Hershey and Chase: _____

b. Erwin Chargaff: _____

c. Rosalind Franklin: _____

d. Watson and Crick: _____

2. Define bacterial transformation, and discuss how studies of this phenomenon influenced DNA research.

3. In living organisms, the amount of adenine is equal to the amount of thymine, and the amount of cytosine is equal to that of guanine. A researcher measured the amount of adenine in a cell and found it to be 15 percent of the DNA. Calculate the amounts of the other nucleotides, and report the percent of each.

4. Explain why the molecular ratio of A+T to C+G is always the same within a single species, yet differs across species.

5. Explain how the double helical structure of DNA allows for each of the following:

a. Storage of genetic information: _____

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b. Precise replication during the cell division cycle: _____

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c. Susceptibility to mutations: _____

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d. Expression of the coded information as phenotypes: _____

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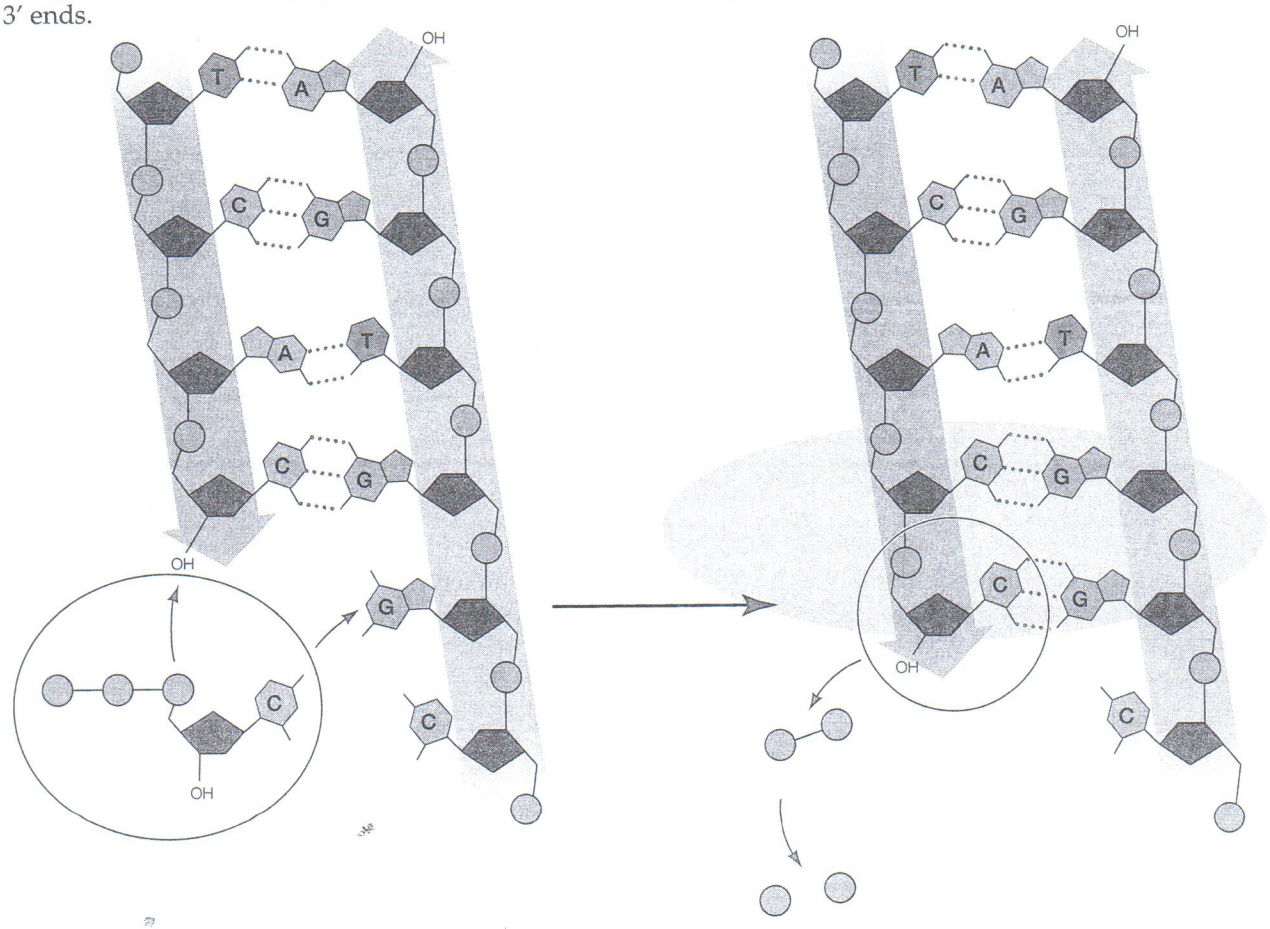
Concept 9.2 *explains that DNA replicates semiconservatively. The two antiparallel strands of DNA are held together by weak hydrogen bonds. During DNA replication, these bonds are pulled apart as DNA polymerase assembles complementary base pairs to form a new double strand of DNA.*

6. The diagram below shows a strand of DNA being replicated. Label the following: a phosphate, sugar, nitrogenous base, DNA polymerase, growing strand, and template strand. For each strand, label the 5′ and 3′ ends.



7. In the diagram for Question 6, the strand on the left shows the impending addition of a cytosine with three phosphates attached. Two of the phosphates will ultimately become detached. What result is achieved by the departure of the two phosphate groups?

8. Briefly describe the function of each of these enzymes in DNA replication.

a. Primase:

b. DNA polymerase:

c. Ligase:

9. Discuss continuous and discontinuous replication, using the terms *leading strand* and *lagging strand*.

10. Compare the point of origin of DNA replication in prokaryotes with that of eukaryotes, and explain how this difference serves an important function.

11. Explain how adjacent Okazaki fragments of DNA become linked together to form a longer and more continuous stretch of DNA.

12. Describe how the telomeres, the ends of chromosomes, are shortened each time a chromosome replicates.

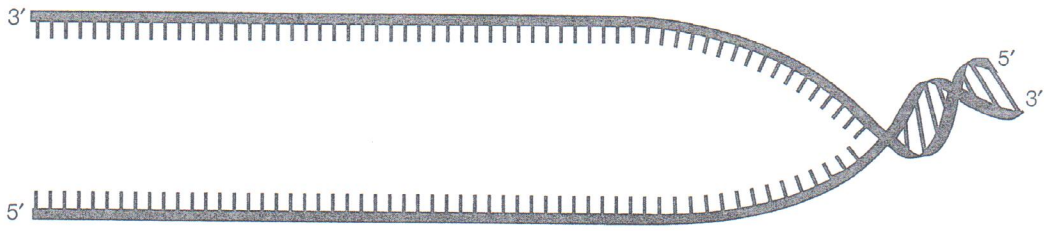
13. Explain how telomeres help prevent the loss of genetic material during replication.

14. Define the function of telomerase, and describe what types of cells are particularly dependent on its continual function.

15. Describe the mechanism by which PCR proceeds, and discuss one example of PCR's use.

16. Imagine that you need to amplify (copy) a single gene from a eukaryotic organism with eight chromosomes. Describe the materials you will need, and state the function of each.

17. The diagram below shows two strands of DNA ready for replication.



a. Draw in the DNA on the continuous side being formed by DNA polymerase.

b. Draw in two Okazaki fragments on the discontinuous side, one that is formed and a second that is still being formed by DNA polymerase. Label the spot to be filled in by ligase.

Concept 9.3 *describes how mutations are heritable changes in DNA. Mutations can occur by the substitution of single nucleotides or by rearrangement of large segments of chromosomes.*

18. Discuss whether adult-onset skin cancer in a tanning-bed fanatic is caused by a somatic mutation or by germline mutation.

19. Explain the difference between silent mutations and loss-of-function mutations. Which type is more common?

20. Describe and discuss the differences between point mutations and chromosomal mutations.

21. Identify five different mutagens that are in your everyday environment, and indicate how you might avoid each.

a. _____

b. _____

c. _____

d. _____

e. _____

22. Describe the type of mutations that provide the raw material for natural selection. Explain your answer.

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23. Discuss how PCR was used to examine the DNA of Neanderthal people.

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24. If you search the Internet for images of Neanderthals, you will find many older images that depict them as dumb, ape-like, inferior human beings. This more recent drawing depicts Neanderthals as more like modern humans. Explain why this newer image is likely to be more accurate.

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Science Practices & Inquiry

In the AP Biology Curriculum Framework, there are seven **Science Practices**. In this chapter, we focus on **Science Practice 2:** The student can use mathematics appropriately, and **Science Practice 6:** The student can work with scientific explanations and theories. This exercise is based more specifically on **Science Practice 2.2:** The student can apply mathematical routines to quantities that describe natural phenomena; and **Science Practice 6.4:** The student can make claims and predictions about natural phenomena based on scientific theories and models.

Question 25 asks you to use a mutation rate to perform a calculation and then generate a scientific explanation on this topic using your knowledge of genetics. Scientists frequently draw on their knowledge to explain phenomena in our world. In this case, you are asked to explain a mutation rate, based on your knowledge of the human genome (**Learning Objective 3.6**).

25. In the April 30, 2010, issue of *Science*, J. C. Roach, *et al.*, reported that the mutation rate for humans is approximately 1.1×10^{-8} mutations per base pair in the haploid genome. Humans have a diploid genome of 6×10^{9} base pairs.

a. Calculate the number of mutations in each new child. Show your work.

b. Explain why the majority of these spontaneous mutations have no effect on most children.