Summary

12–1 DNA

To understand genetics, biologists had to learn the chemical structure of the gene. Frederick Griffith first learned that some factor from dead, disease-causing bacteria turned harmless bacteria into disease-causing ones. Griffith called this process transformation. Griffith thought that the transforming factor might be a gene. Oswald Avery and his research group later found that DNA was the transforming factor. Alfred Hershey and Martha Chase also showed that genes are made of DNA.

Scientists began studying the structure of DNA to learn how it can carry information, determine an organism's traits, and replicate itself. DNA is a long molecule made up of units called nucleotides. Each nucleotide is made up of a 5-carbon sugar, a phosphate group, and a nitrogen-containing base. There are four kinds of bases: adenine, guanine, cytosine, and thymine.

James Watson and Francis Crick discovered that DNA is shaped like a double helix, or a twisted ladder, in which two strands are wound around each other. The two strands are held together by hydrogen bonds between adenine and thymine and between guanine and cytosine. The sugar phosphate backbone makes up the sides of the ladder.

12–2 Chromosomes and DNA Replication

Single-celled organisms without a nucleus have DNA in the cytoplasm. Most have one circular DNA molecule. In organisms with a nucleus, DNA is in the nucleus. The DNA is organized into different numbers of chromosomes, depending on the organism.

DNA molecules are very long. To fit inside cells, they must be tightly folded. The DNA in a chromosome is wound around proteins, called histones. The DNA and histones wind together to form nucleosomes.

Before a cell divides, it copies its DNA in a process called replication. The DNA molecule separates into two strands. Then, two new strands form, following the rules of base pairing. Each strand of the DNA molecule serves as a template, or model, for the new strand.

Many enzymes carry out DNA replication. One enzyme, called DNA polymerase, joins individual nucleotides to produce the DNA molecule. It also checks that the correct nucleotide is added.

12–3 RNA and Protein Synthesis

In order for a gene to work, the genetic instructions in the DNA molecule must be decoded. The first step is to copy the DNA sequence into RNA. RNA makes it possible for a single gene in a DNA molecule to make hundreds of copies.

RNA has a structure like DNA, except for three differences: (1) The sugar in RNA is ribose instead of deoxyribose; (2) RNA is single-stranded; and (3) RNA has uracil in place of thymine.

Three kinds of RNA molecules work together to make proteins. Messenger RNA has the instructions to put together amino acids to make a protein. Proteins are put together on ribosomes. Ribosomes are made up of proteins and ribosomal RNA. Transfer RNA carries each amino acid to the ribosome according to the coded message in messenger RNA.

Name_____ Class_____ Date _____

RNA is copied from DNA in a process called transcription. The enzyme RNA polymerase binds to DNA and separates the two strands. Then, RNA polymerase builds a strand of RNA using one strand of DNA as the template. The sequence of DNA that signals RNA polymerase where to bind and start making RNA is called the promoter.

The instructions for making proteins are found in the order of the four nitrogenous bases. This code is read three letters, or nucleotides, at a time. Each codon, or group of three nucleotides, specifies a certain amino acid that makes up a protein. In the genetic code, some amino acids are specified by more than one codon. One codon is a start signal for translation. Three codons signal the end of translation.

Translation is the process in which the genetic code in RNA is used to make proteins. Translation takes place on ribosomes. Before translation can begin, messenger RNA is transcribed from DNA. Then, the messenger RNA moves into the cytoplasm and attaches to a ribosome. As each codon of the messenger RNA moves through the ribosome, the proper amino acid is brought into the ribosome by transfer RNA. The ribosome joins together each amino acid. In this way, the protein chain grows. When the ribosome reaches a stop codon, it falls away from the protein chain and the messenger RNA molecule. Transcription has ended.

12–4 Mutations

Mutations are changes in the sequence of DNA. Gene mutations are changes in a single gene. Chromosomal mutations cause changes in whole chromosomes. Gene mutations that occur at a single point in the DNA sequence are called point mutations. When a point mutation causes one base to replace another, only one amino acid is affected. If a nucleotide is added or taken away, it causes a frameshift mutation. All the groupings of three nucleotides, or codons, are changed. This can cause the gene to produce a completely different protein.

In a chromosomal mutation, there is a change in the number or the structure of chromosomes. There are four kinds of chromosomal mutations: deletions, duplications, inversions, and translocations.

12–5 Gene Regulation

Genes can be turned on and off when proteins are needed. In prokaryotes, some genes are turned on and off by a section of a chromosome called an operon. An operon is a group of genes that work together. Two sequences of DNA in the operon that control when genes are turned on and off are the operator and the promoter. When the cell needs a certain protein, RNA polymerase attaches to the promoter and produces a messenger RNA that is translated into the needed protein.

When the cell no longer needs the protein, it makes another special protein called the repressor. The repressor attaches to the operator, blocking the promoter so that RNA polymerase cannot attach to it. This turns the genes of the operon off.

In eukaryotes, there are several ways of turning genes on and off. One system uses a protein that binds directly to DNA. This either starts or increases the transcription of certain genes.

Name _____ Class _____ Date _____

Section 12–1 DNA (pages 287–294)

Key Concepts

- What did scientists discover about the relationship between genes and DNA?
- What is the overall structure of the DNA molecule?

Griffith and Transformation (pages 287–289)

1. What did Frederick Griffith want to learn about bacteria? _____

_____

_____

2. The strain of bacteria that caused pneumonia grew into _____ colonies on culture plates; harmless bacteria produced colonies with _____ edges.
3. Circle the letter of each sentence that is true about Griffith's experiment.
   a. Mice injected with bacteria from smooth colonies died.
   b. Mice injected with bacteria from rough colonies died.
   c. Mice injected with heat-killed bacteria from smooth colonies died.
   d. Mice injected with a mixture of bacteria from heat-killed smooth colonies and live rough colonies died.
4. What result from Griffith's experiment suggested that the cause of pneumonia was not a chemical poison released by the disease-causing bacteria? _____

_____

_____

5. What is transformation? _____

_____

6. What hypothesis did Griffith form from the results of his experiments? _____

_____

_____

Avery and DNA (page 289)

7. Is the following sentence true or false? Avery and his colleagues thought that the molecule required in transformation might also be the molecule of the gene.

_____

8. Briefly describe how Avery and his group determined which molecule was most important for transformation. _____

_____

_____

Name_____ Class_____ Date _____

9. Transformation did not occur when _____ was destroyed.
10. What was the conclusion from Avery's experiments? _____

_____

The Hershey-Chase Experiment (pages 289–290)

11. What is a bacteriophage? _____

_____

12. Circle the letter of each part that makes up a bacteriophage.

a. lipid coat **c.** carbohydrate core

b. protein coat **d.** DNA core

13. What happens when a bacteriophage infects a bacterial cell? _____

_____

_____

14. How would Hershey and Chase learn whether genes were made of protein or DNA?

_____

_____

_____

15. What results did Hershey and Chase observe? _____

_____

_____

16. Hershey and Chase concluded that the genetic material of the bacteriophage was _____.

The Components and Structure of DNA (pages 291–294)

17. List the three critical things that genes were known to do.

a. _____

_____

b. _____

_____

c. _____

_____

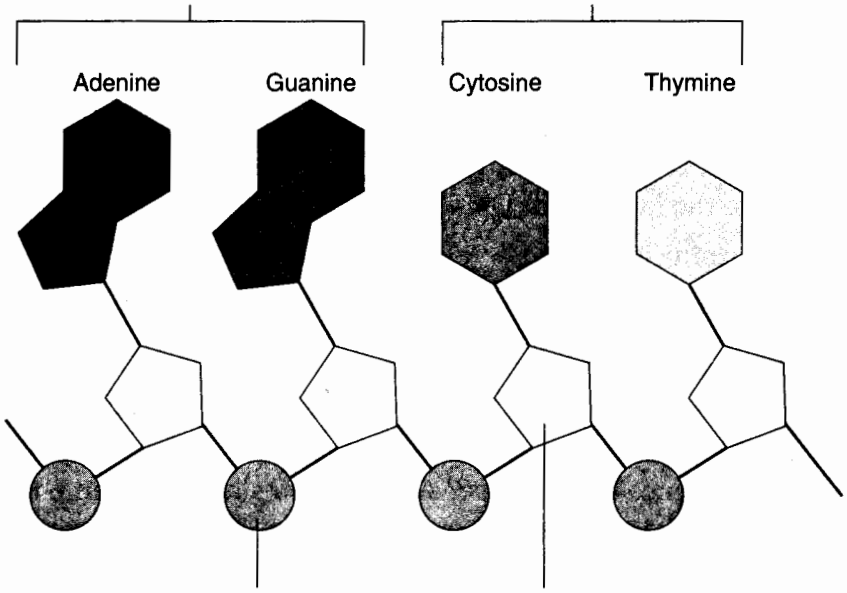
18. What is the makeup of a nucleotide? _____

_____

19. Adenine, guanine, cytosine, and thymine are four kinds of _____ bases in DNA.

Name_____ Class_____ Date _____

20. Identify the components of a nucleotide in the diagram below. Label the bases as purines or pyrimidines.



21. Is the following sentence true or false? Adenine and guanine are larger molecules than cytosine and thymine because they have two rings in their structure. _____

22. What forms the backbone of a DNA chain? _____

_____

23. Is the following sentence true or false? The nucleotides must be joined together in a specific order. _____

24. According to Chargaff's rules, the percentages of _____ are equal to those of thymine and the percentages of _____ are equal to those of guanine in the DNA molecule.

25. Rosalind Franklin's work with X-ray diffraction showed that the DNA molecule is shaped like a(an) _____ and contains _____ strands.

26. How did Francis Crick and James Watson try to understand the structure of DNA?

_____

_____

27. How did Watson and Crick describe the structure of DNA? _____

_____

_____

28. Is the following sentence true or false? According to the principle of base pairing, hydrogen bonds could form only between adenine and cytosine. _____

Name_____ Class_____ Date _____

Section 12–2 Chromosomes and DNA Replication (pages 295–299)

Key Concept

- What happens during DNA replication?

DNA and Chromosomes (pages 295–297)

1. Circle the letter of the location of DNA in prokaryotic cells.
   a. nucleus **b.** mitochondria **c.** cytoplasm **d.** vacuole
2. Is the following sentence true or false? Most prokaryotes contain a single, circular DNA molecule. _____
3. Eukaryotic DNA is generally located in the cell _____ in the form of a number of chromosomes.
4. Is the following sentence true or false? All organisms have the same number of chromosomes. _____
5. Is the following sentence true or false? The *E. coli* chromosome is longer than the diameter of an individual *E. coli* bacterium. _____
6. Circle the letter of each sentence that is true about chromosome structure.
   a. The DNA in eukaryotic cells is very loosely packed.
   b. Prokaryotic cells contain more DNA than eukaryotic cells.
   c. A human cell contains more than 1 meter of DNA.
   d. The DNA of the smallest human chromosome is nearly 10 times as long as many bacterial chromosomes.
7. Eukaryotic chromosomes contain both DNA and protein, packed together to form _____.
8. What are histones? _____
   _____
9. Why are individual chromosomes visible only during mitosis? _____
   _____
   _____
   _____
10. Is the following sentence true or false? Changes in chromatin structure and histone-DNA binding are associated with changes in gene activity. _____
11. What do nucleosomes do? _____
    _____
    _____

Name_____ Class_____ Date _____

DNA Replication (pages 297–299)

12. What occurs during the process of replication? _____

_____

13. Complete the flowchart to describe the process of DNA replication.

The DNA molecule _____, or unzips, into two strands.

↓

Each strand serves as a(an) _____, or model, to produce the new strands.

↓

Two new _____ strands are produced, following the rules of _____.

14. Is the following sentence true or false? In eukaryotic chromosomes, DNA replication begins at a single point in the chromosome and proceeds in two directions.

_____

15. The sites where DNA replication and separation occur are called _____.

16. What occurs when a molecule of DNA is "unzipped"? _____

_____

_____

17. What is the complementary strand of bases for a strand with the bases TACGTT?

_____

18. Is the following sentence true or false? Each DNA molecule resulting from replication has one original strand and one new strand. _____

19. List two major roles of DNA polymerase in the process of DNA replication.

a. _____

b. _____

Reading Skill Practice

The illustrations in textbooks can help you better understand a difficult concept. Look at Figure 12–10 on page 297. List in order, beginning with DNA, the levels of organization of eukaryotic DNA to form chromosomes. Do your work on a separate sheet of paper.

Name_____ Class_____ Date _____

Section 12–3 RNA and Protein Synthesis

(pages 300–306)

Key Concepts

- What are the three main types of RNA?
- What is transcription?
- What is translation?

The Structure of RNA (page 300)

1. List the three main differences between RNA and DNA.

   a. _____

   b. _____

   c. _____

2. What is the importance of the cell's ability to copy a single DNA sequence into RNA?

   _____

   _____

Types of RNA (pages 300–301)

3. What is the one job in which most RNA molecules are involved? _____

   _____

4. Complete the table about the types of RNA.

TYPES OF RNA

Type	Function
	Carries copies of the instructions for assembling amino acids from DNA to the rest of the cell
Ribosomal RNA	
	Transfers each amino acid to the ribosome to help assemble proteins

Transcription (page 301)

5. Circle the letter of each sentence that is true about transcription.

   a. During transcription, DNA polymerase binds to RNA and separates the DNA strands.

   b. RNA polymerase uses one strand of DNA as a template to assemble nucleotides into a strand of RNA.

   c. RNA polymerase binds only to DNA promoters, which have specific base sequences.

   d. Promoters are signals in RNA that indicate to RNA polymerase when to begin transcription.

Name _____ Class _____ Date _____

RNA Editing (page 302)

6. Many RNA molecules from eukaryotic genes have sections, called _____, edited out of them before they become functional. The remaining pieces, called _____, are spliced together.

7. Is the following sentence true or false? RNA editing occurs in the cytoplasm of the cell.

_____

8. What are two explanations for why some RNA molecules are cut and spliced?

a. _____

_____

_____

b. _____

_____

_____

The Genetic Code (pages 302–303)

9. Proteins are made by joining _____ into long chains called polypeptides.

10. How can only four bases in RNA carry instructions for 20 different amino acids?

_____

_____

_____

11. What is a codon? _____

_____

_____

12. Circle the letter of the number of possible three-base codons.

a. 4 **b.** 12 **c.** 64 **d.** 128

13. Is the following sentence true or false? All amino acids are specified by only one codon. _____

14. Circle the letter of the codon that serves as the "start" codon for protein synthesis.

a. UGA **b.** UAA **c.** UAG **d.** AUG

Translation (pages 303–305)

15. What occurs during the process of translation? _____

_____

_____

16. Where does translation take place? _____

_____

Name_____ Class_____ Date _____

17. Circle the letter of each sentence that is true about translation.
    a. Before translation occurs, messenger RNA is transcribed from DNA in the nucleus.
    b. Translation occurs in the nucleus.
    c. It is the job of transfer RNA to bring the proper amino acid into the ribosome to be attached to the growing peptide chain.
    d. When the ribosome reaches a stop codon, it releases the newly formed polypeptide and the mRNA molecule.
18. What is an anticodon? _____

_____

_____

The Roles of RNA and DNA (page 306)

Match the roles with the molecules. Molecules may be used more than once.

Roles	Molecules
_____ 19. Master plan	a. DNA
_____ 20. Goes to the ribosomes in the cytoplasm	b. RNA
_____ 21. Blueprint	
_____ 22. Remains in the nucleus	

Genes and Proteins (page 306)

23. Many proteins are _____, which catalyze and regulate chemical reactions.
24. Is the following sentence true or false? Genes are the keys to almost everything that living cells do. _____

Reading Skill Practice

A flowchart is useful for organizing the steps in a process. Make a flowchart that shows the steps in the process of translation. Look at Figure 12–18 on pages 304–305 for help. For more information about flowcharts, see Appendix A. Do your work on a separate sheet of paper.

Name_____ Class_____ Date _____

Section 12–4 Mutations (pages 307–308)

Key Concept

- What are mutations?

Introduction (page 307)

1. What are mutations? _____

_____

_____

2. Is the following sentence true or false? Chromosomal mutations result from changes in a single gene. _____

Kinds of Mutations (pages 307–308)

3. Mutations that occur at a single point in the DNA sequence are _____ mutations.
4. A mutation involving the insertion or deletion of a nucleotide is a(an) _____ mutation.
5. Complete the table of types of chromosomal mutations.

CHROMOSOMAL MUTATIONS

Type	Description	Examples
		ABC•DEF → AC•DEF
Duplication		
	Part of a chromosome becomes oriented in the reverse of its usual direction	
Translocation		

Name_____ Class_____ Date _____

6. Circle the letter of each sentence that is true about gene mutations.
   a. Point mutations affect just one nucleotide.
   b. The substitution of one nucleotide for another in the gene never affects the function of the protein.
   c. Point mutations that involve the insertion or deletion of a nucleotide change the reading frame of the genetic message.
   d. Frameshift mutations affect every amino acid that follows the point of the mutation.

Significance of Mutations (page 308)

7. Mutations that cause dramatic changes in protein structure are often _____.
8. Mutations are a source of _____ in a species.
9. What is polyploidy? _____

_____

_____

Name_____ Class_____ Date _____

Section 12–5 Gene Regulation (pages 309–312)

Key Concepts

- How are *lac* genes turned off and on?
- How are most eukaryotic genes controlled?

Introduction (page 309)

1. Label the parts of a typical gene in the diagram below.

2. Where does RNA polymerase bind? _____

_____

3. Is the following sentence true or false? The actions of DNA-binding proteins help to determine whether a gene is turned on or turned off. _____

Gene Regulation: An Example (pages 309–310)

4. What is an operon? _____

_____

_____

5. What is the function of the genes in the *lac* operon? _____

_____

_____

6. Circle the letter of each sentence that is true about lactose.
   a. Lactose is a simple sugar.
   b. To use lactose for food, *E. coli* must take lactose across its cell membrane.
   c. The bond between glucose and galactose must be broken in order for *E. coli* to use lactose for food.
   d. Proteins encoded by the genes of the *lac* operon are needed only when *E. coli* is grown on a medium containing glucose.

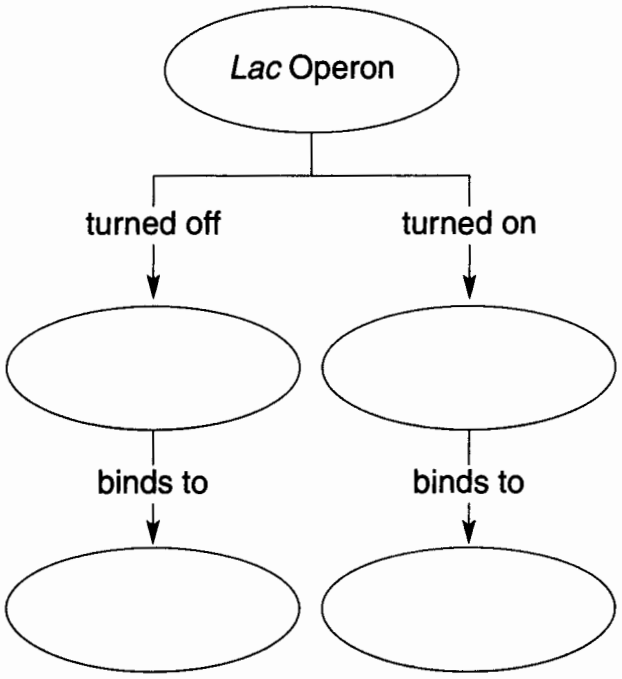
7. What turns the *lac* operon off and on? _____

_____

_____

Name_____ Class_____ Date _____

8. Complete the concept map to show how the *lac* operon is regulated.



9. How does the repressor protein prevent transcription? _____

_____

_____

10. How does lactose cause the *lac* operon to turn on? _____

_____

_____

_____

11. Circle the letter of each sentence that is true about gene regulation in prokaryotic genes.
    a. The *lac* operon is the only example of genes regulated by repressor proteins.
    b. Many other genes are regulated by repressor proteins.
    c. Some genes are regulated by proteins that enhance the rate of transcription.
    d. Cells cannot turn their genes on and off as needed.

Eukaryotic Gene Regulation (page 311)

12. Is the following sentence true or false? Operons are frequently found in eukaryotes.

_____

13. How are eukaryotic genes usually controlled? _____

_____

_____

_____

Name_____ Class_____ Date _____

14. What is the function of the TATA box? _____

_____

_____

15. Eukaryotic promoters are usually found just _____ the TATA box, and they consist of a series of short _____ sequences.

16. List three ways in which proteins that bind to enhancer sequences of a gene can work to regulate gene expression.

    a. _____

    b. _____

    c. _____

17. Why is gene regulation in eukaryotes more complex than in prokaryotes? _____

_____

_____

_____

_____

Development and Differentiation (page 312)

18. What role do the hox genes play in the development of an organism? _____

_____

_____

_____

19. Circle the letter of each sentence that is true about hox genes.

    a. A mutation in a hox gene has no effect on the organs that develop in specific parts of the body.

    b. In fruit flies, a mutation affecting the hox genes can replace a fly's antennae with a pair of legs.

    c. The function of the hox genes in humans seems to be almost the same as it is in fruit flies.

    d. A copy of the gene that controls eye growth in mice does not function in fruit flies.

20. Why do common patterns of genetic control for development exist among animals?

_____

_____

_____

Name_____ Class_____ Date _____

Vocabulary Review

Matching *In the space provided, write the letter of the definition that best matches each term.*

_____ **1.** base pairing
_____ **2.** nucleotide
_____ **3.** histone
_____ **4.** transcription
_____ **5.** intron
_____ **6.** translation
_____ **7.** transfer RNA
_____ **8.** promoter
_____ **9.** mutation
_____ **10.** polyploidy
_____ **11.** operon
_____ **12.** differentiation

a. making a protein using messenger RNA
b. having extra sets of chromosomes
c. hydrogen bonding between adenine and thymine
d. sequence in messenger RNA that is cut out
e. cells specializing in structure and function
f. carries amino acids to the ribosome during protein synthesis
g. unit of DNA
h. copying part of DNA into RNA
i. change in the genetic material
j. group of genes that work together
k. DNA sequence that binds RNA polymerase
l. protein that binds DNA into tight coils

Completion *Fill in the blanks with terms from Chapter 12.*

13. A _____ is a type of virus that infects bacteria.

14. Eukaryotic chromosomes contain both DNA and protein, tightly packed together to form a substance called _____.

15. The duplication of DNA is called _____.

16. The principal enzyme involved in DNA replication is _____ because it joins individual nucleotides to produce a DNA molecule.

17. DNA sequences that code for proteins are called _____.

18. A _____ consists of three consecutive nucleotides that specify a single amino acid.

19. Gene mutations, known as _____, occur at a single point in the DNA sequence.

20. Differentiation of cells and tissues in the embryo is controlled by _____.