CHAPTER 10

Molecular Biology of the Gene

Objectives

Introduction Explain how a herpesvirus invades a cell and forces the cell to reproduce the virus.

The Structure of the Genetic Material

10.1 Describe the experiments of Griffith and Hershey and Chase which demonstrated that DNA is the genetic material.
10.2–10.3 Compare the structure of DNA and RNA.

DNA Replication

10.4 Explain how the structure of DNA facilitates its replication.
10.5 Describe the process of DNA replication.

The Flow of Genetic Information from DNA to RNA to Protein

10.6 Describe the locations, reactants, and products of transcription and translation.
10.7–10.8 Explain the "languages" of DNA and RNA that are used to produce polypeptides.
10.9 Explain how RNA is produced.
10.10 Explain how eukaryotic RNA is processed before leaving the nucleus.
10.11 Explain how tRNA functions in the process of translation.
10.12 Describe the structure and function of ribosomes.
10.13 Explain how translation begins.
10.14 Describe the step-by-step process by which amino acids are added to a growing polypeptide chain.
10.15 Diagram the overall process of transcription and translation.
10.16 Describe the major types of mutations and their possible consequences.

Viruses: Genes in Packages

10.17 Compare the lytic and lysogenic reproductive cycles of a phage.
10.18 Describe the reproductive cycle of an enveloped virus. Explain how the herpes virus is different from this cycle.
10.19 Describe the most common characteristics of plant viruses.
10.20 Explain how new viruses evolve and why certain viruses emerge as major threats.
10.21 Explain how the AIDS virus enters a host cell and reproduces.
10.22 Explain what the authors mean when they say that molecular geneticists have "a love-hate relationship" with viruses.

Key Terms

molecular biology
bacteriophage (phage)
nucleotide
polynucleotide
sugar-phosphate backbone
thymine (T)
cytosine (C)
adenine (A)
guanine (G)
uracil (U)
double helix
DNA polymerase
DNA ligase
transcription
translation
triplet code
codon
RNA polymerase
promoter
terminator
messenger RNA (mRNA)
intron
exon
RNA splicing
transfer RNA (tRNA)
anticodon
ribosomal RNA (rRNA)
start codon
stop codon
translocation
mutation
reading frame
mutagenesis
mutagen
lytic cycle
lysogenic cycle
prophage
retrovirus
reverse transcriptase
AIDS
HIV

Word Roots

liga- = bound or tied (*DNA ligase:* a linking enzyme for DNA replication)

Lecture Outline

Introduction *Saboteurs Inside Our Cells*

A. The chromosome theory of inheritance set the historical and structural stage for the development of a molecular understanding of the gene.

B. Many of the basics of **molecular biology** began to be understood by studying viruses and the mechanism used by viruses to gain control over DNA replication and the transcriptional and translational machinery of a cell (Figure 10.0).

1. *Review:* Are viruses living things? Recall some of the characteristics of life that viruses do not exhibit, particularly cellular structure and metabolism.
2. Viruses are composed of a protein coat and internal DNA (or RNA), and they depend on the metabolism of their host to make more viral particles (Figure 10.1C).
3. Viruses infect all living things.
4. Experimental systems using phages were a logical choice for early experiments on the molecular biology of the gene. Phages are simple, with simple genes infecting relatively simple and easily manipulated bacteria.

C. This chapter focuses on the structure of DNA, how it is replicated, and the process of protein synthesis through transcription and translation.

I. The Structure of the Genetic Material

Module 10.1 Experiments showed that DNA is the genetic material.

A. In 1928, Griffith showed that some substance (he did not know what) conveyed traits (pathogenicity) from heat-killed bacteria to living bacteria without the trait.

B. Evidence gathered during the 1930s and 1940s showed it was DNA rather than protein (both complex macromolecules found in chromosomes) that was the genetic material.

C. In 1952, Hershey and Chase, using a virus called T2, showed that it was the DNA in the virus that infected the bacterial cell. Viruses of this type are called **bacteriophages** (**phages** for short).

D. The structure of a T2 phage is very simple, consisting of a protein coat and a DNA core (Figure 10.1A).

E. Hershey and Chase devised a simple experiment using T2 phage and demonstrated that the radioactive isotope of sulfur (found only in proteins) was not transferred into new viral particles, whereas the radioactive isotope of phosphorus (found only in DNA) was transferred (Figure 10.1B).

F. The life cycle of a T2 phage results in the production of multiple copies of the T2 phage and the death of the infected bacterial cell (Figure 10.1C).

Module 10.2 DNA and RNA are polymers of **nucleotides.**

A. *Review:* The polymeric nature of DNA and RNA **polynucleotides** (Module 3.20, Figure 3.20A, B, C).

B. Focus on the chemical structure of the three components of each monomer nucleotide: a phosphate group, acidic; deoxyribose, a five-carbon sugar; and nitrogenous bases (Figure 10.2A).

C. Mention the presence of a ribose sugar, rather than a deoxyribose sugar, in RNA (Figure 10.2C).

D. Briefly discuss the structural similarities and differences between the four nitrogenous bases **(thymine, cytosine, adenine, and guanine)** that occur in DNA and the one, **uracil,** that occurs instead of thymine in RNA, noting their commonly used abbreviations (Figure 10.2B, C).

E. Note the structural similarities between DNA and RNA molecules. The only differences are the ribose sugar and the use of uracil in RNA (Figure 10.2D).

Module 10.3 DNA is a double-stranded helix.

A. Some of the data that went into the Watson-Crick model: the chemical structure of DNA, including that of the component structures; Wilkins and Franklin's X-ray crystallographs (from which one can deduce helical form and width and repeating length of the helix); Chargaff's chemical analysis showing that the amounts of A and T, and G and C, were always equal, and previous knowledge that the ratios of A + T to G + C varied from species to species.

B. The model that fit all the observations was a **double helix** (a twisted rope ladder) with sugar backbones on the outside and hydrogen-bonded nitrogenous bases on the inside (Figure 10.3C, D).

C. G always bonds with C and A always bonds with T, but there are no restrictions on the linear sequence of nucleotides along the length of the helix.
NOTE: While not overtly stated in the accompanying text, Figure 10.3D illustrates that it is the combination of one purine and one pyrimidine that accounts for the known width of the double helix. This figure also illustrates that adenine and thymine are joined by two hydrogen bonds and guanine and cytosine are joined by three hydrogen bonds.

D. Two strands of the double helix run in opposite directions.
NOTE: The strands are *antiparallel.*

E. The Watson-Crick model was proposed in a short paper in 1953 and almost immediately led to proposed mechanisms about DNA function.
NOTE: The story of American James Watson's and his English colleague Francis Crick's discovery of the structure of DNA includes many aspects of great scientific discoveries: making the necessary observations, careful thought as to what the observations mean, insightful formulation of a hypothesis (model) based on the analysis of the observations, and being in the right place at the right time. There is also some controversy about the manner in which some of the story unfolded.

II. DNA Replication

Module 10.4 DNA replication depends on specific base pairing.

A. The nature of the reproductive process, and of the cell cycle involved in it, requires that complete and faithful copies of DNA be produced (replicated).

B. Watson and Crick stated that their model suggested a copying mechanism.

C. The mechanism proposed and confirmed by the end of the 1950s involved each half of the double helix functioning as a template upon which a new, missing half is built (Figure 10.4A).
NOTE: Each new double helix consists of one old and one new strand; thus the mechanism of replication is *semiconservative.*

D. The actual mechanism involves a complex arrangement of molecular players, the help of enzymes, particularly DNA polymerases, and some geometric contortions including untwisting of the parent helix and retwisting the daughter helices (Figure 10.4B).

E. Despite its speed (50–500 pairs per second), replication is very accurate, with approximately one mistaken nucleotide pair in a billion.
NOTE: Ask your students what life would be like on Earth (if any) if DNA replication were mistake free.

Module 10.5 DNA replication: A closer look.

A. Replication occurs simultaneously at many sites (replication bubbles) on a double helix. This allows DNA replication to occur in a shorter period of time than replication from a single origin would allow (Figure 10.5A).

B. **DNA polymerases** can only attach nucleotides to the 3' end of a growing daughter strand. Thus, replication always proceeds in the 5' to 3' direction.

C. Within the replication bubbles, one daughter strand is synthesized continuously while the other daughter stand must be synthesized in short pieces, which are then joined together by **DNA ligase** (Figure 10.5C).
NOTE: These short pieces of DNA are called *Okazaki fragments.*

D. DNA polymerases also proofread the new daughter strands.

E. This replication process assures that daughter cells will carry the same genetic information as each other and as the parental cell.

III. The Flow of Genetic Information from DNA to RNA to Protein

Module 10.6 The DNA genotype is expressed as proteins, which provide the molecular basis for phenotypic traits.

A. *Review:* The roles that proteins play in organisms (Module 3.11).

B. The molecular basis of phenotypic traits are the proteins an organism can make (with a variety of functions).

C. The molecular basis of genotype is now recognized to be DNA.

D. The one gene–one enzyme hypothesis was formulated in the 1940s by Beadle and Tatum, who were studying nutritional mutants of the mold *Neurospora.* They found that genetic mutants lacked single enzymes needed to complete metabolic pathways (Figure 10.6B).

E. This idea was soon extended to include all proteins (adding a variety of structural types) and later restricted to individual polypeptides (because some proteins are composed of several distinct polypeptide chains).

F. This flow is now known to occur in two stages: **transcription** of the genetic code in the nucleus to a messenger RNA (mRNA) molecule, and **translation** of the mRNA message in the cytoplasm (Figure 10.6A).

Module 10.7 Genetic information written in codons is translated into amino acid sequences.

A. The nucleotide monomers represent letters in an alphabet that can form words in a language. Each word codes for one amino acid in a polypeptide.

B. There are four letters (A, T, G, and C) and 20 amino acids. One-letter words would create 4 distinct words. Two-letter words would create a vocabulary of 16 words (4×4). Three-letter words would create a vocabulary of 64 words ($4 \times 4 \times 4$).
Review: Recall the discussion of probability in Module 9.7.

C. Triplets of bases are the smallest words of uniform length that can specify all the amino acids. These triplets are known as **codons.**

Module 10.8 The genetic code is the Rosetta stone of life.

A. The first codon was deciphered by Nirenberg in 1961.

B. Nirenberg added polyuracil (an artificially made RNA polynucleotide) to a mixture containing ribosomes and other cell fractions required for translation. The polypeptide polyphenylalanine was produced, which indicated UUU was the codon for phenylalanine.

C. The code was completely known by the end of the 1960s. It shows redundancy but no ambiguity (Figure 10.8A).

D. Make a polypeptide using an arbitrary sequence of bases (Figure 10.8B).

E. The code is virtually the same for all organisms. Thus, bacterial cells can translate the genetic messages of human cells, and vice versa. This gives evidence of the relatedness of all life and suggests that the genetic code was established early in the history of life.
Preview: Recombinant DNA techniques enable biologists to transfer genes of one organism to another and have them expressed (Chapter 12).

Module 10.9 Transcription produces genetic messages in the form of RNA.

A. In transcription, one strand of DNA serves as a template for the new RNA strand.

B. **RNA polymerase** constructs the RNA strand (Figure 10.9A).

C. Transcription is initiated from one strand of the DNA, as indicated by a **promoter** region (the site at which RNA polymerase attaches); the DNA unwinds; and RNA polymerization and elongation occur. Finally, the mRNA sequence is terminated when the process reaches a special **terminator** region of the DNA (Figure 10.9B).
NOTE: Transcription means copying a message into a new medium.
Preview: The regulation of this process is discussed in Chapter 11.

D. Two other types of RNA (ribosomal RNA or rRNA and transfer RNA or tRNA) play a role in translation and are transcribed by this process.

Module 10.10 Eukaryotic RNA is processed before leaving the nucleus.

A. RNA that encodes an amino acid sequence is called **messenger RNA (mRNA).**

B. In prokaryotes, transcription and translation both occur in the cytoplasm.

C. In eukaryotes, a completed mRNA molecule leaves the nucleus and the message is translated in the cytoplasm. Review Module 10.6 (Figure 10.6A).

D. Prior to leaving the nucleus, however, RNA is modified in a process called **RNA splicing.** The regions of DNA that are not used in the production of protein (introns) must be removed, leaving only the exons. Exons are ligated and the ends of the modified RNA molecule have additional nucleotides added in an effort to reduce enzymatic attack (Figure 10.10).

E. The players in the translation process include ribosomes, tRNA molecules, enzymes and protein factors, and sources of cellular energy.
NOTE: Translation means rewording a message into a new language. The new language in this case is the linear sequence of amino acids in polypeptides.

Module 10.11 Transfer RNA molecules serve as interpreters during translation.

A. Amino acids that are to be joined in correct sequence cannot recognize the codons on the mRNA.

B. **Transfer RNA** molecules (Figure 10.11A, B), one or more for each type of amino acid, match the right amino acid to the right codon.

C. Each tRNA contains a region (the **anticodon**) that recognizes and binds to the correct codon for its amino acid on the mRNA.

D. The right tRNA for each amino acid and its codon are temporarily joined by the aid of a specific enzyme (at least one for each tRN–amino acid complex) and the expenditure of one ATP molecule (Figure 10.11C).

Module 10.12 Ribosomes build polypeptides.

A. Ribosomes are composed of **ribosomal RNA (rRNA)** and protein, arranged in two subunits (Figure 10.12A).

B. The shape of ribosomes provides a platform on which protein synthesis can take place. There are locations for the mRNA, and two tRNA–amino acid complex binding sites (an A site and a P site) (Figure 10.12B, C).

Module 10.13 An initiation codon marks the start of an mRNA message.

A. Translation can be divided into the same three phases as transcription: initiation, elongation, and termination.

B. An mRNA molecule is longer than the genetic message it contains. It contains a starting nucleotide sequence that helps in the initiation phase and an ending sequence that helps in the termination phase (Figure 10.13A, B part 1, and Figure 10.15 part 5).

C. Initiation is a two-step process.

1. The initial sequence helps bind the mRNA to the small ribosomal subunit; a specific **start codon** binds with an initiator tRNA anticodon carrying the amino acid methionine (Figure 10.13B part 1).
2. The large ribosome binds to the small subunit as the initiator tRNA fits into the P site on the large subunit (Figure 10.13B part 2).

Module 10.14 Elongation adds amino acids to the polypeptide chain until a stop codon terminates translation.

A. Elongation involves three steps (Figure 10.14).
   1. Codon recognition: The anticodon of an incoming tRN–amino acid complex binds with the codon at the ribosome's A site.
   2. Peptide bond formation: A polypeptide bond is formed between the growing polypeptide (attached to the tRNA at the P site) and the new amino acid.
   3. Translocation: The P-site tRNA leaves the complex, and the A-site tRNA–polypeptide chain complex moves to the P site.

B. An enzyme within the ribosome structure catalyzes the formation of the polypeptide bond.

C. Elongation continues until a special **stop codon** (UAA, UAG, or UGA) causes termination of the process. The finished polypeptide is released, and the ribosome splits into its two subunits.

D. A polypeptide develops its tertiary structure both during and after translation.

Module 10.15 Review: The flow of genetic information in the cell is DNA → RNA → protein.

A. Figure 10.15 is a summary of the five stages of transcription and translation.

B. The synthesis of a strand of mRNA complementary to a DNA template is transcription (stage 1).

C. The conversion of the information encoded within a strand of mRNA into a polypeptide is translation (stages 2 through 5).

D. *Review:* Following their synthesis, several polypeptides may come together to form a protein with quaternary structure. Levels of protein structure are discussed in Modules 3.1–3.18.

Module 10.16 Mutations can change the meaning of genes.

A. Many differences in inherited traits in humans have been traced to their molecular deviation.

B. A change in the nucleotide sequence of DNA is known as a **mutation.**

C. Certain substitutions of one nucleotide base for another will lead to mutations, resulting in the replacement of one amino acid for another in a polypeptide sequence (Figure 10.16A). Base substitutions usually cause a gene to produce an abnormal product, or they result in no change if the new codon still codes for the same amino acid.

D. A base substitution is known to account for the type of hemoglobin produced by the sickle-cell allele (Module 9.14).

E. Base substitutions rarely lead to improved or changed genes that may enhance the success of the individual in which it occurs. These types of mutations provide the genetic variability that may lead to the evolution of new species (Chapter 13) (Figure 10.16B).

F. The addition or subtraction of nucleotides may result in a shift of the three-base **reading frame;** all codons past the affected one are likely to code for different amino acids (Figure 10.16B). The profound differences that are produced will almost always result in a nonfunctional polypeptide.

G. **Mutagenesis** can occur spontaneously or because of physical (radiation) or chemical **mutagens.**
   Preview: Such mutagenesis may result in cancer (Modules 11.15–11.19).

IV. Viruses: Genes in Packages

Module 10.17 Viral DNA may become part of the host chromosome.

A. Viruses depend on their host cells for the replication, transcription, and translation of their nucleic acid.

B. Some bacteriophages are known to reproduce in two ways (Figure 10.17).

C. In the **lytic cycle,** a phage immediately directs the host cell to replicate the viral nucleic acid, transcribes and translates its protein-coding genes, assembles new viruses, and causes host cell lysis, releasing the reproduced phages.

D. In the **lysogenic cycle,** a phage's DNA is inserted into the host cell DNA by recombination and becomes a **prophage.** This DNA sequence is replicated with the host cell's DNA over many generations. Finally, some environmental cue directs the prophage to switch to the lytic cycle. Such prophages may cause the host cell to act differently than if the prophage were not there.

Module 10.18 Connection: Many viruses cause disease in animals.

A. Viruses have a great variety of infectious cycles in eukaryotes. Those that infect plants or animals can cause disease.
NOTE: Organisms from all kingdoms have viruses that infect their cells.

B. In one type (enveloped RNA virus, such as the virus that causes mumps), the viral genes are in the form of RNA, which functions as a template to make complementary RNA. Complementary RNA functions either as mRNA to direct virus protein synthesis directly or as a template from which more viral RNA is made. Newly assembled viral particles leave the cell by enveloping themselves in host plasma membrane (Figure 10.18B).

C. Other viruses of eukaryotes, such as the herpesviruses that cause chickenpox, shingles, mononucleosis, cold sores, and genital herpes, reproduce inside the host cell's nucleus and can insert as a provirus in the host DNA, much like a prophage in the lysogenic cycle.
NOTE: Viruses that cause cold sores and genital herpes are different strains.

D. *Preview:* Animals defend against viruses through their immune systems. Vaccines, which induce the immune system's delayed responses to viral coat molecules, offer a possible defense against future viral infection (Chapter 24).

E. Antibiotic drugs used to treat bacterial infections cannot be used to treat viral infections.

Module 10.19 Connection: Plant viruses are serious agricultural pests.

A. Most plant viruses are RNA viruses (Figure 10.19).

B. Insects, farmers, and gardeners may all spread plant viruses.

C. Infected plants may pass viruses to their offspring.

D. The are no cures for most viral diseases of plants. Research has focused on prevention and the selective breeding of resistant varieties.

Module 10.20 Connection: Emerging viruses threaten human health.

A. HIV, the virus that causes AIDS, is an example of an emerging virus, as are Ebola (Figure 10.20A) and hantavirus (Figure 10.20B).

B. Viruses are thought to have arisen from cellular nucleic acid fragments. Support for this comes from viral nucleic acid being more similar to its host DNA than to the nucleic acid of viruses that infect different hosts.

C. Mutation of existing viruses is the major source of new viral diseases. High rates of mutation, particularly of RNA viruses, also accounts for the difficulty the immune system has in dealing with viruses.
Preview: This high mutation rate plays a major role in the difficulty of developing treatments and vaccines for HIV (Module 24.18).

Module 10.21 The AIDS virus makes DNA on an RNA template.

A. The virus that causes **AIDS** is human immunodeficiency virus, or HIV (Figure 10.21A).

B. HIV particles are enveloped, like those that cause mumps. Although they carry genes in the form of RNA, these genes are expressed by being first transcribed back to DNA (reverse transcription), at which time they enter the host cell's chromosomes as a provirus and remain unexpressed for several years. HIV finally becomes active by using the host cell's machinery to reassemble new viruses, much like a DNA virus (Figure 10.21B).
Preview: **Reverse transcriptase** as a tool of biotechnology is discussed in Module 12.7.

C. *Preview:* HIV infects cells involved in the human immune system and is discussed in greater detail in Module 24.18.

Module 10.22 Virus research and molecular genetics are intertwined.

A. On the one hand, virus research played an important early role in experiments on the molecular structure and activity of genes, and continues to do so.

B. On the other hand, viruses cause some of the worst diseases we are dealing with today (Figure 10.22).

Class Activities

1. Initiate a class discussion of how human behaviors have promoted the spread of emerging viruses. Be sure that your students understand how the spread of emerging viruses, bacteria, and parasites can be related to global climatic patterns.

Transparency Acetates

Figure 10.1A	Phage T2
Figure 10.1B	The Hershey-Chase experiment
Figure 10.1C	Phage reproductive cycle
Figure 10.2A	DNA polynucleotide
Figure 10.2B	Nitrogenous bases of DNA
Figure 10.2C	Part of an RNA nucleotide
Figure 10.3C	A rope-ladder model for the double helix
Figure 10.3D	Three representations of DNA
Figure 10.4A	A template model for DNA replication

Figure 10.4B	Untwisting and replication of DNA
Figure 10.5A	Multiple "bubbles" in replicating DNA
Figure 10.5B	The opposite orientations of DNA strands
Figure 10.5C	How daughter DNA strands are synthesized
Figure 10.6A	The flow of genetic information in a eukaryotic cell
Figure 10.7	Transcription and translation of codons
Figure 10.8A	Dictionary of the genetic code (RNA codons)
Figure 10.8B	Deciphering the genetic information in DNA
Figure 10.9A	A close-up view of transcription
Figure 10.9B	Transcription of a gene
Figure 10.10	The production of eukaryotic mRNA
Figure 10.11A	The structure of tRNA
Figure 10.11B	The symbol for tRNA used in this book
Figure 10.12A	The true shape of a functioning ribosome
Figure 10.12B	Binding sites of a ribosome
Figure 10.12C	A ribosome with occupied binding sites
Figure 10.13A	A molecule of mRNA
Figure 10.13B	The initiation of translation
Figure 10.14	Polypeptide elongation
Figure 10.15	Summary of transcription and translation
Figure 10.16A	The molecular basis of sickle-cell disease
Figure 10.16B	Types of mutations and their effects
Figure 10.17	Two types of phage reproductive cycles (Layer 1)
Figure 10.17	Two types of phage reproductive cycles (Layer 2)
Figure 10.18A	An influenza virus
Figure 10.18B	The reproductive cycle of an enveloped virus
Figure 10.19	Tobacco mosaic disease (mottling of leaves) and the structure of the virus (right)
Figure 10.21A	A model of HIV structure
Figure 10.21B	The behavior of HIV nucleic acid in a host cell

Media

See the beginning of this book for a complete description of all media available for instructors and students. Animations and videos are available in the Campbell Image Presentation Library. Media Activities and Thinking as a Scientist investigations are available on the student CD-ROM and web site.

Animations and Videos	File Name
Phage T2 Reproductive Cycle Animation	10-01B-PhageT2ReproAnim.mov
DNA Structure Animation (no narration)	10-03D-DNAstructAnim-B.mov
DNA Structure Animation	10-03D-DNAstructAnim-S.mov
DNA Replication Animation (no narration)	10-05A-DNArepliAnim-B.mov
DNA Replication Animation	10-05A-DNArepliAnim-S.mov

DNA Replication Overview Animation	10-05A-DNArepOverviewAnim.mov
Leading Strand Animation (no narration)	10-05C1-LeadingStrandAnim-B.mov
Leading Strand Animation	10-05C1-LeadingStrandAnim-S.mov
Lagging Strand Animation (no narration)	10-05C2-LaggingStrandAnim-B.mov
Lagging Strand Animation	10-05C2-LaggingStrandAnim-S.mov
DNA Replication Review Animation (no narration)	10-05C3-DNArepliRevAnim-B.mov
DNA Replication Review Animation	10-05C3-DNArepliRevAnim-S.mov
Transcription Animation	10-09B-TranscriptionAnim.mov
RNA Processing Animation	10-10-RNAprocessingAnim.mov
Translation Animation	10-13B-TranslationAnim.mov
Phage Lambda Reproductive Cycle Animation	10-17-PhageReproAnim.mov
HIV Reproduction Animation	10-21B-HIVreproductionAnim.mov

Activities and Thinking as a Scientist	**Module Number**
Web/CD Activity 10A: *The Hershey-Chase Experiment*	10.1
Web/CD Activity 10B: *Phage T2 Reproductive Cycle*	10.1
Web/CD Activity 10C: *DNA and RNA Structure*	10.
Web/CD Activity 10D: *DNA Double Helix*	10.3
Web/CD Activity 10E: *DNA Replication: An Overview*	10.4
Web/CD Thinking as a Scientist: *What Is the Correct Model for DNA Replication?*	10.4
Web/CD Activity 10F: *DNA Replication: A Closer Look*	10.5
Web/CD Activity 10G: *Overview of Protein Synthesis*	10.6
Web/CD Thinking as a Scientist: *How Are Nutritional Mutations Identified?*	10.6
Web/CD Activity 10H: *Transcription*	10.9
Web/CD Activity 10I: *Translation*	10.14
Biology Labs On-Line: *TranslationLab*	10.15
Web/CD Thinking as a Scientist: *Connection: How Do You Diagnose a Genetic Disorder?*	10.16
Web/CD Activity 10J: *Phage Lysogenic and Lytic Cycles*	10.17
Web/CD Activity 10K: *Simplified Reproductive Cycle of a DNA Virus*	10.18
Web/CD Thinking as a Scientist: *Connection: Why Do AIDS Rates Differ Across the U.S.?*	10.20
Web/CD Activity 10L: *Retrovirus (HIV) Reproductive Cycle*	10.21
Web/CD Thinking as a Scientist: *Connection: What Causes Infections in AIDS Patients?*	10.21