Molecular Biology of the Gene

10

Most biologists would agree that the most significant biological discovery of the twentieth century was the discovery of the structure of the gene. At the beginning of the century Mendel's rules were rediscovered, and genes were traced to the chromosomes. Soon it was possible to map the locations of genes, and scientists started wondering what exactly genes were made of and how they shaped an organism. By mid-century, it was clear that DNA is the genetic material and that genes act by directing the synthesis of proteins. Soon researchers discovered the double helix structure of DNA and deciphered the genetic code by which DNA shapes the body. Then scientists learned how to make genes and move them from one organism to another. As the twenty-first century begins, biologists map entire genomes and use their knowledge of genetics to reshape organisms, fight disease, and trace evolution. This chapter describes the molecular biology of the gene and the discoveries that continue to enlarge our understanding of genes.

Organizing Your Knowledge

Exercise 1 (Modules 10.1 – 10.3)

Web/CD Activity 10A *The Hershey-Chase Experiment*
Web/CD Activity 10B *Phage T2 Reproductive Cycle*
Web/CD Activity 10C *DNA and RNA Structure*
Web/CD Activity 10D *The DNA Double Helix*

Review the discovery that DNA is the genetic material, and the structures of DNA and RNA. Then match each phrase on the right with the correct term(s) on the left. Note that some answers are used more than once, and some questions have multiple answers.

A. Adenine (A)
B. Base
C. Cytosine (C)
D. DNA
E. *E. coli*
F. Double helix
G. Guanine (G)
H. Hydrogen bond
I. Radioactive isotope
J. Covalent bond
K. Bacteriophage
L. Protein
M. Nucleic acid
N. Nucleotide
O. Centrifuge
P. Phosphate
Q. Polynucleotide
R. RNA
S. Sugar
T. Thymine (T)
U. Uracil (U)

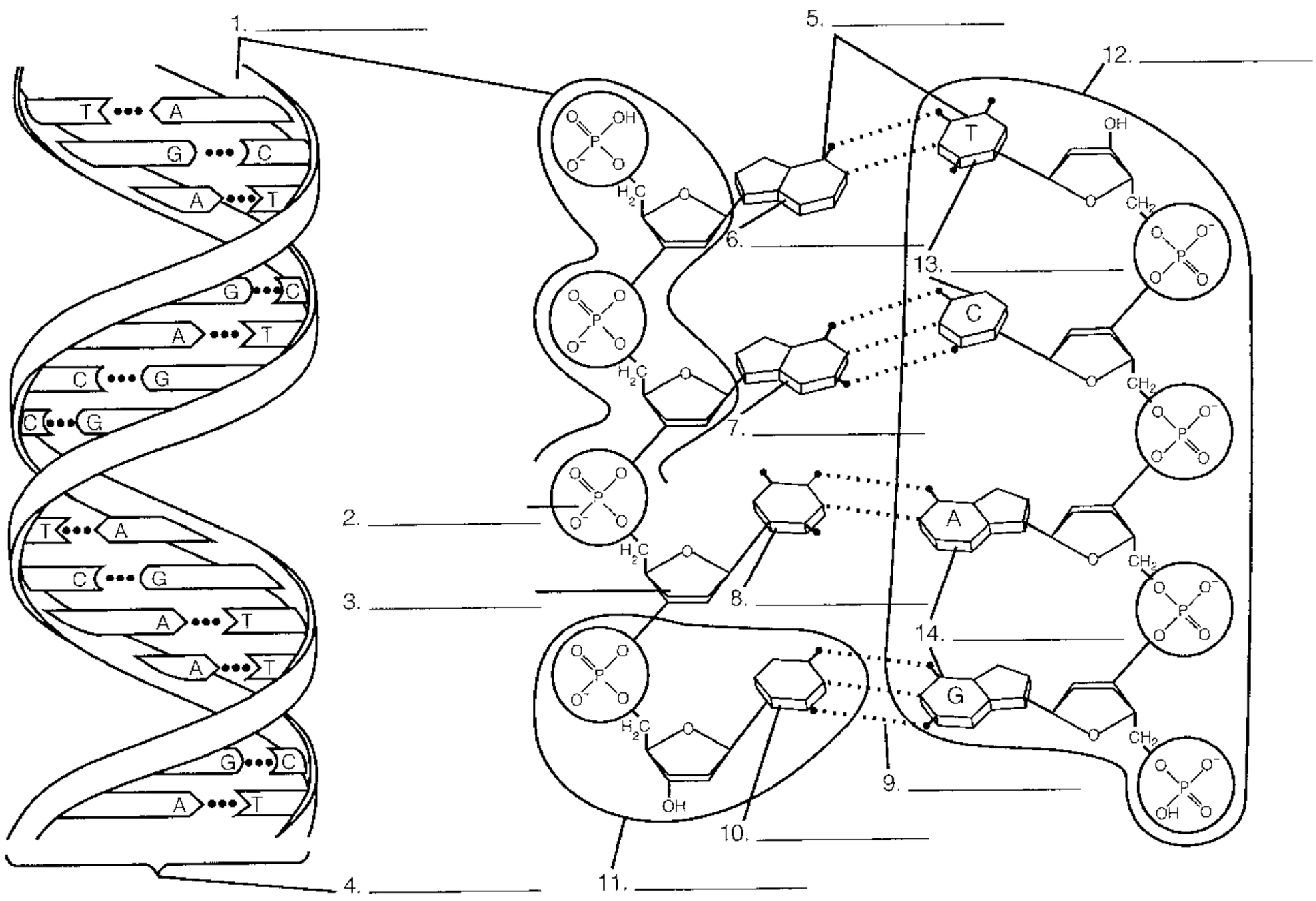
_____ 1. The basic chemical unit of a nucleic acid
_____ 2. The "transforming factor" that alters pneumonia bacteria
_____ 3. The two kinds of nucleic acids
_____ 4. The three parts of every nucleotide
_____ 5. A pair of these forms a "rung" in the DNA ladder
_____ 6. Used to "label" DNA and protein in experiments
_____ 7. The component of a bacteriophage that enters the host cell
_____ 8. Two alternating parts that form the nucleic acid "backbone"
_____ 9. The four bases in DNA
_____ 10. The DNA base complementary to T
_____ 11. A virus that attacks bacteria
_____ 12. The substance a phage leaves outside its host cell
_____ 13. Ribose in RNA and deoxyribose in DNA
_____ 14. Watson and Crick deduced the structure of this molecule
_____ 15. The four bases in RNA
_____ 16. The DNA base complementary to G
_____ 17. A bacterium attacked by T2 and T4 phages
_____ 18. The sequence of these encodes DNA information
_____ 19. Eukaryotic chromosomes consist of this and DNA
_____ 20. The overall shape of a DNA molecule

_____ 21. Links adjacent nucleotides in a polynucleotide chain
_____ 22. Machine used to separate particles of different weights
_____ 23. Links a complementary pair of bases together
_____ 24. A polymer of nucleotides
_____ 25. RNA base that is not in DNA

Exercise 2 (Modules 10.2 – 10.3)

Web/CD Activity 10C *DNA and RNA Structure*
Web/CD Activity 10D *The DNA Double Helix*

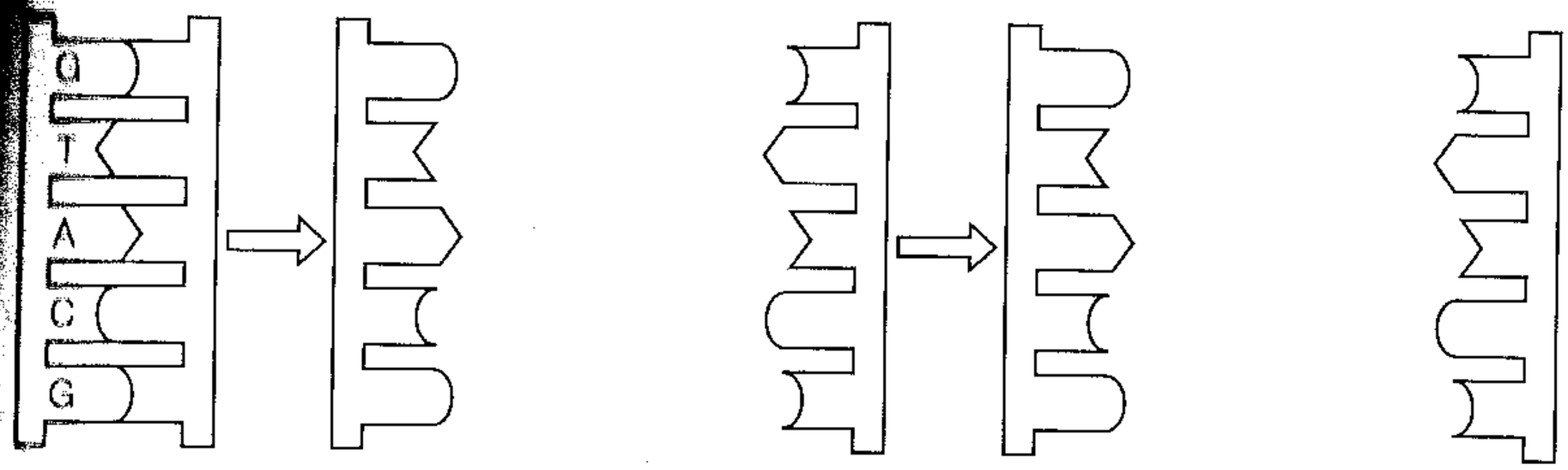
Review the structure of DNA by labeling these diagrams. Include **nucleotide, polynucleotide, sugar (deoxyribose), phosphate group, sugar-phosphate backbone, pyrimidine bases, purine bases, thymine (T), adenine (A), guanine (G), cytosine (C), hydrogen bond, complementary base pair,** and **double helix.**



Exercise 3 (Module 10.4)

Web/CD Activity 10E *DNA Replication: An Overview*

Reproduction and inheritance involve copying DNA instructions, so that they can be passed to the next generation. This process is carried out by DNA polymerases, enzymes that use each strand of the DNA helix as a template on which to build a complementary strand. Review DNA replication by completing the simplified diagrams below. The first diagram shows the parent DNA molecule; label the nucleotides in the right-hand strand. Complete and label the second diagram, so that it shows the parent strands separating and being used as templates. Label the third diagram, so that it shows two completed daughter molecules of DNA. Color the original DNA strands blue and the new strands red.

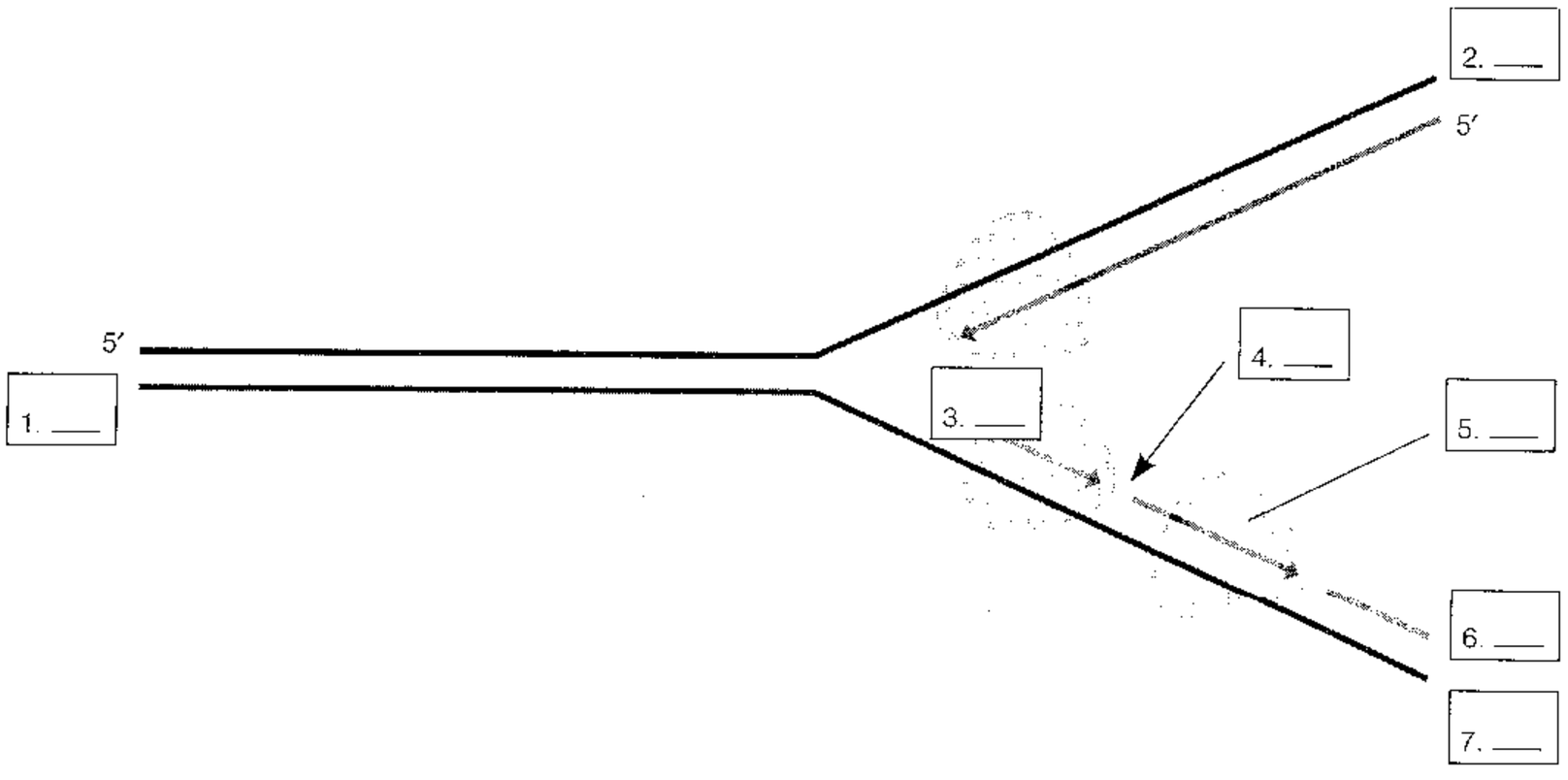


Exercise 4 (Module 10.5)

Web/CD Activity 10F *DNA Replication: A Closer Look*

This module describes some of the ins and outs of DNA replication. Look at the diagrams carefully. Then see if you can match each of the numbers in the boxes on the diagram below with one of the lettered choices. Choices may be used more than once.

A. 5′ end of daughter strand
B. 3′ end of daughter strand
C. 5′ end of parental strand
D. 3′ end of parental strand
E. DNA polymerase
F. where DNA ligase will unite pieces



...ise 6 (Modules 10.7 – 10.14)

...VED Activity 10H *Transcription*
...VED Activity 10I *Translation*

...e modules explain how the information in a gene is used to build a protein. Review the ...ses of transcription and translation by filling in the blanks below.

The first step in making a protein is transcription of a gene. This occurs in the [1]_____ of a eukaryotic cell. An enzyme called [2]_____ carries ...the process of transcribing RNA from the DNA. It starts at a specific nucleotide se...nce called a [3]_____, next to the gene. RNA polymerase attaches, and the ...o DNA strands separate. RNA polymerase moves along one strand, and as it does, RNA _____ take their places one at a time along the DNA template. They hydrogen-...nd with complementary bases, following the same pairing rules as in DNA—C with G, ...d U (replacing T in RNA) with A. As the RNA molecule elongates, it peels away from the ...NA. Finally, the enzyme reaches the [5]_____, a base sequence that signals ...e end of the gene, and the polymerase molecule lets go of the gene and the RNA molecule. ...n a prokaryote, the RNA transcribed from a gene, called [6]_____ (mRNA), ...an be used immediately in polypeptide synthesis. In a eukaryotic cell, the RNA is further ...modified, or [7]_____, before leaving the nucleus as mRNA. Extra nucleotides ...are added to the ends of the transcript, and noncoding regions called [8]_____ ...are removed. The remaining [9]_____ are spliced together to from a continuous ...coding sequence. The finished mRNA leaves the nucleus and enters the [10]_____, ...where translation takes place.

Translation of the "words" of the mRNA message into the [11]_____ se...quence of a protein requires an interpreter—[12]_____ (tRNA)—which links the ...appropriate [13]_____ with each [14]_____ in the mRNA message. ...A tRNA molecule is a folded strand of RNA. At one end, a special [15]_____ at...taches a specific amino acid. The other end of the tRNA molecule bears three bases called the [16]_____, which is complementary to a particular mRNA codon. During the ...translation process, the tRNA matches its amino acid with an mRNA codon.

[17]_____ are the "factories" where the information in mRNA is trans...lated and polypeptide chains are constructed. A ribosome consists of protein and [18]_____(rRNA). Each ribosome has a groove that serves as a binding site for mRNA. There are two binding sites for tRNA: The P site holds the tRNA carrying the grow...ing [19]_____, while the A site holds a tRNA bearing the next amino acid.

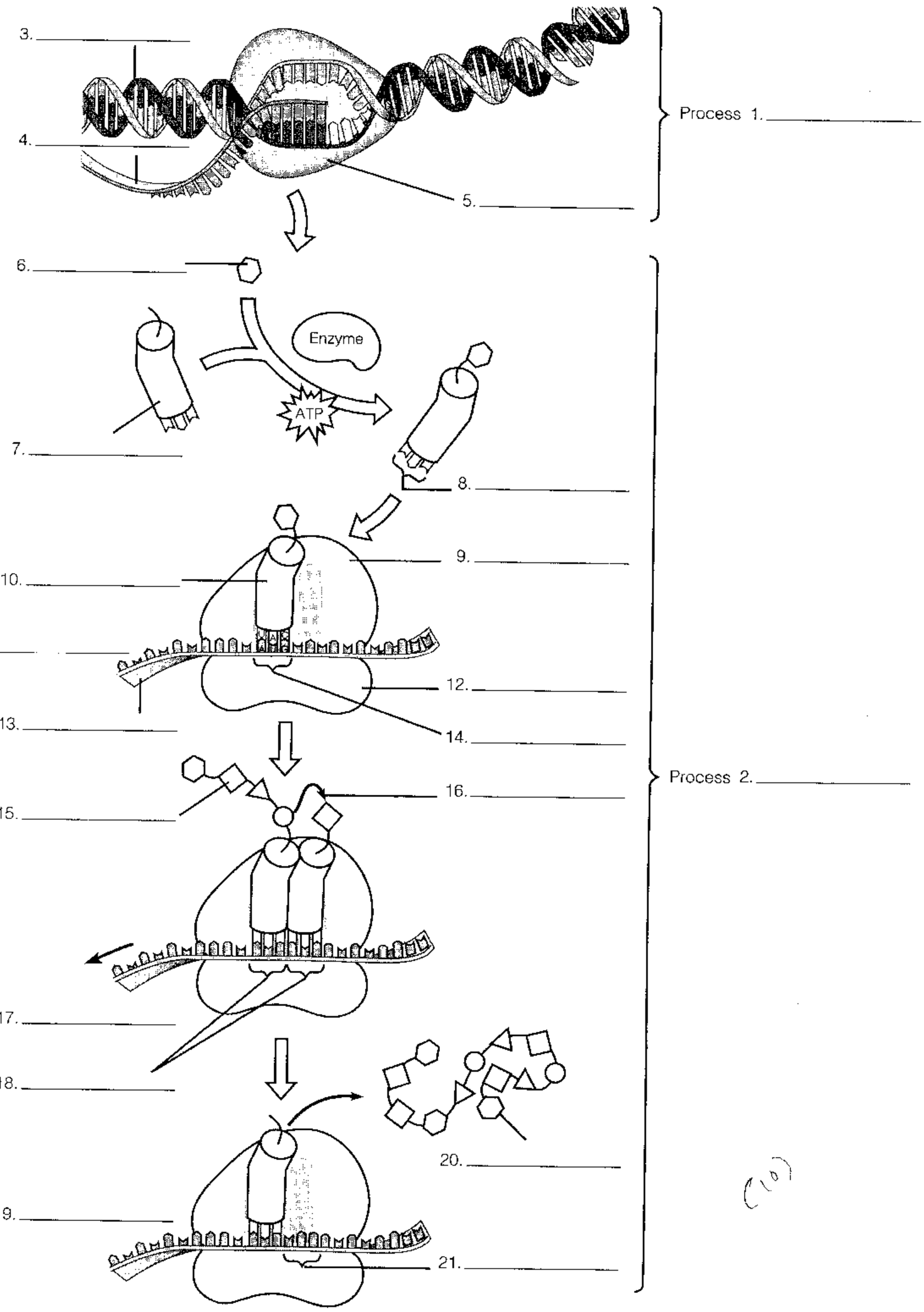
Translation begins with initiation. An mRNA and a special [20]_____ tRNA bind to the ribosome and a specific mRNA codon, the [21]_____, where translation begins. The initiator tRNA generally carries the amino acid methionine (Met). Its anticodon UAC binds to the start codon, AUG. The initiator tRNA fits into the P site on the ribosome.

The next step in [22]_____synthesis is elongation—adding amino acids to the growing chain. The anticodon of an incoming tRNA, carrying its amino acid, pairs with the mRNA codon at the open A site. With help from the ribosome, the polypeptide separates from its tRNA and forms a peptide bond with the [23]_____ attached to the tRNA in the A site. Then the "empty" tRNA in the P site leaves the ribosome, and the tRNA in the A site, with the polypeptide chain, is shifted to the P site. The mRNA and tRNA move as a unit, allowing the next codon to enter the A site. Another tRNA, with a complementary anticodon, brings its amino acid to the A site. Its amino acid is added to the chain, the tRNA leaves, and the complex shifts again. In this way, [24]_____ are added to the chain, one at a time.

Finally, a [25]_____ reaches the A site of the [26]_____, terminating the polypeptide. A stop codon causes the polypeptide to separate from the last tRNA and the [27]_____. The polypeptide folds up, and it may join with other polypeptides to form a larger [28]_____ molecule.

Exercise 7 (Module 10.15)

This module summarizes the key steps in the flow of genetic information from DNA to protein. Study the diagrams carefully, then label the numbered parts and processes.



Exercise 8 (Modules 10.8 and 10.16)

These modules describe the genetic code, how biologists cracked the code, and how mutations change the meaning of the coded genetic message. Use the genetic code chart (Figure 10.8A in the textbook) to translate the following mRNAs into amino acid sequences and answer the questions.

mRNA nucleotide sequence:
(mRNA 1)

1. Amino acid sequence:

Mutation in mRNA:
(mRNA 2)

2. Amino acid sequence:
3. Number of bases changed in mRNA:
4. Type of mutation:
5. Number of amino acids changed:

Mutation in mRNA:
(mRNA 3; compare to 1)

6. Amino acid sequence:
7. Number of bases changed in mRNA (look carefully!):
8. Type of mutation:
9. Number of amino acids changed (compared to mRNA 1):
10. Which mutation had the greatest effect and why?

(10)

Exercise 9 (Modules 10.17 – 10.22)

Web/CD Activity 10J *Phage Lysogenic and Lytic Cycles*
Web/CD Activity 10K *Simplified Reproductive Cycle of a DNA Virus*
Web/CD Activity 10L *Retrovirus (HIV) Reproductive Cycle*

These modules describe the structures and life cycles of viruses. Match each phrase on the right with a term from the left. Some answers are used more than once.

A. RNA viruses
B. Prophage
C. AIDS
D. Glycoprotein spikes
E. Virus
F. DNA
G. Lytic cycle
H. Vaccine
I. Nucleus
J. Membranous envelope
K. Bacteriophage
L. Provirus
M. HIV
N. Reverse transcriptase
O. Lysogenic cycle
P. Retrovirus
Q. White blood cell
R. Prophage genes
S. Tobacco mosaic
T. Plasma membrane
U. RNA
V. Cytoplasm
W. Hantavirus
X. Ebola virus

____ 1. Consists of nucleic acid packaged in protein
____ 2. Leads quickly to breaking open of host cell
____ 3. Phage DNA inserted into bacterial chromosome
____ 4. When virus "hides" as part of bacterial chromosome
____ 5. Responsible for toxins of diphtheria, botulism
____ 6. Rod-shaped plant virus
____ 7. This or DNA may be virus genetic material
____ 8. Cause of flu, colds, polio, mumps, AIDS
____ 9. Helps flu or mumps virus enter and leave host cell
____ 10. Used by mumps virus or HIV to attach to host receptors
____ 11. Mumps virus reproduces here
____ 12. Mumps virus makes this and protein from RNA template
____ 13. Mumps virus gets envelope from this part of host cell
____ 14. Herpesvirus reproduces here
____ 15. Genetic material of herpesvirus
____ 16. DNA of herpesvirus inserted into host cell DNA
____ 17. Can be used to prevent a viral disease
____ 18. Virus that causes AIDS
____ 19. Genetic material of HIV
____ 20. RNA virus that reproduces by means of DNA
____ 21. Enzyme that can make DNA from RNA template
____ 22. Form in which HIV "hides" in host cell
____ 23. Acquired immune deficiency syndrome
____ 24. Kind of cell infected by HIV
____ 25. Causes an African hemorrhagic fever
____ 26. Virus like T2 that infects bacteria
____ 27. An RNA virus carried by rodents