Chapter 17: Gene Expression: From Gene to Protein

17.1 Describe evidence that helped us understand the process of gene expression, and describe the process.

17.2 Explain transcription, including a description of important molecules involved in the process.

17.3 Trace the steps involved in eukaryotic RNA processing.

17.4 List the cellular components and molecules involved in translation, and describe the process, then describe how multiple polypeptides are made in bacteria and eukaryotes.

17.5 Identify different types of mutations and how they can affect protein structure and function, and then discuss the concept of a gene

This important chapter may be a very long journey, but it is crucial to your understanding of biology. Work on this chapter a single concept at a time and allow plenty of time to truly master the material. It is likely that you are familiar with the basics of protein synthesis from an earlier biology class, but now we will add details to help you understand the larger picture. Many important ideas are found in this chapter, which explains how the genetic code is translated to proteins, and ways that process is regulated. Good luck and take your time.

Study Tip: Recreate the diagram under "Make a visual study guide" on p.335 and label at the arrows the following: transcription, RNA processing, and translation. Know these terms. Be sure to separate these terms from replication, studied in the last chapter. Together, the four terms represent the core of molecular biology.

_____ are the link between genotype and phenotype.

Concept 17.1 Genes specify proteins via transcription and translation

LO 17.1: Describe evidence that helped us understand the process of gene expression, and describe the process.

1. What is *gene expression*?

2. What situation did Archibald Garrod suggest caused "inborn errors of metabolism"?

3. Describe one example Garrod used to illustrate his hypothesis.

4. State the hypothesis formulated by George Beadle while studying eye color mutations in *Drosophila*.

5. What strategy did Beadle and Tatum adopt to test this hypothesis?

6. Which organism did Beadle and Tatum use in their research? _____. How did this organism's nutritional requirements facilitate this research?

7. How were *Neurospora* spores treated to increase the mutation rate?

8. Study Figure 17.3 in your text carefully until the technique used to identify and isolate mutant fungi, the results of the experiment, and the conclusion that was drawn are clear to you. Using the Results Table for Class II mutants, explain why two test tubes show no growth and two test tubes show growth.

9. What significant findings from the research of Beadle and Tatum resulted in their receiving the Nobel Prize in 1958?

10. What revision of detail (but not of basic principle) did this hypothesis undergo as more information was gained? Write this restatement and then box or highlight it. This is an important concept!

Basic Principles of Transcription and Translation

This section will introduce you to the processes and associated terminology needed in the form of an overview. Once you have the big picture, you will take a closer look in the next few concepts. It is not uncommon for students to confuse the terms replication, transcription, and translation. Please take an extra second to make sure you understand the differences and your thinking is on the correct topic!

11. From the first paragraph in this section, find three ways in which RNA differs from DNA.

12. What are the monomers of DNA and RNA? _____Of proteins? _____

13. Describe each of these processes that are essential to the formation of a protein:

transcription

translation

14. Complete the following table to summarize each process.

Process	Template	Product Synthesized	Location in Eukaryotic Cell
Transcription			
Translation			

15. In eukaryotes, what is the *pre-mRNA* called?

16. Write the *central dogma* of molecular genetics, as proclaimed by Francis Crick in the boxes below. This is the essential direction of flow of genetic information. Memorize and understand the central dogma.

17. How many nucleotide bases are there? _____ How many amino acids? _____

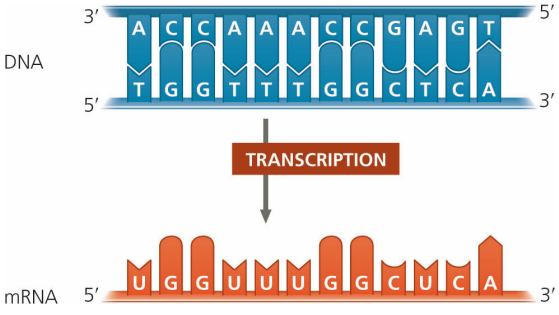
18. How many nucleotides are required to have a unique code for each of these 20 amino acids?

_____

19. The language of DNA is a *triplet code*. How many unique triplets exist? _____

20. DNA is double-stranded; however, for each protein, only one of these two strands is used to produce an mRNA transcript. What is the strand called?

21. Your answer to question 20 should have been *template*. Here is an area where students sometimes become confused: The other strand of DNA is called the *coding strand* because if you substitute U's where T's appear, you will have the mRNA sequence or code. Study Figure17.5, Transcription, in your text to understand this. Label the *template* and *coding* or *non-template* strand.



22. Here is a short DNA *template*. Below it, assemble the complementary mRNA strand. Recall that DNA-to-DNA, DNA-to-RNA, and RNA-to-RNA strand interactions are antiparallel. This means your mRNA strand will run 5′ to 3′.

3′ A C G A C C A G T A A A **5′**

23. How many *codons* are there? _____ Identify one codon using a bracket, and label it.

24. Describe *Marshall Nirenberg's* experiment in which he identified the first codon. What codon/amino acid pair did he identify?

25. Of the 64 possible codons, how many code for amino acids? _____

26. What event is coded for by the codons UAA, UAG, and UGA? _____

27. What is the *start codon*? _____

28. Why is the genetic code said to be *redundant* but not *ambiguous*?

29. Explain the concept of *reading frame* in the context of red dogs eating bugs.

30. Now here is an important idea: **DNA is DNA is DNA**. By this we mean that the code is nearly universal. Because of this, fluorescent green jellyfish genes can be inserted into mosquito larvae, or firefly genes can make a tobacco plant glow. Enjoy a look at Figure 17.7 in your text.

Concept 17.2 Transcription is the DNA-directed synthesis of RNA: A Closer Look

LO 17.2: Explain transcription, including a description of important molecules involved in the process.

31. Name the enzyme that uses the DNA template strand to transcribe a new mRNA strand.

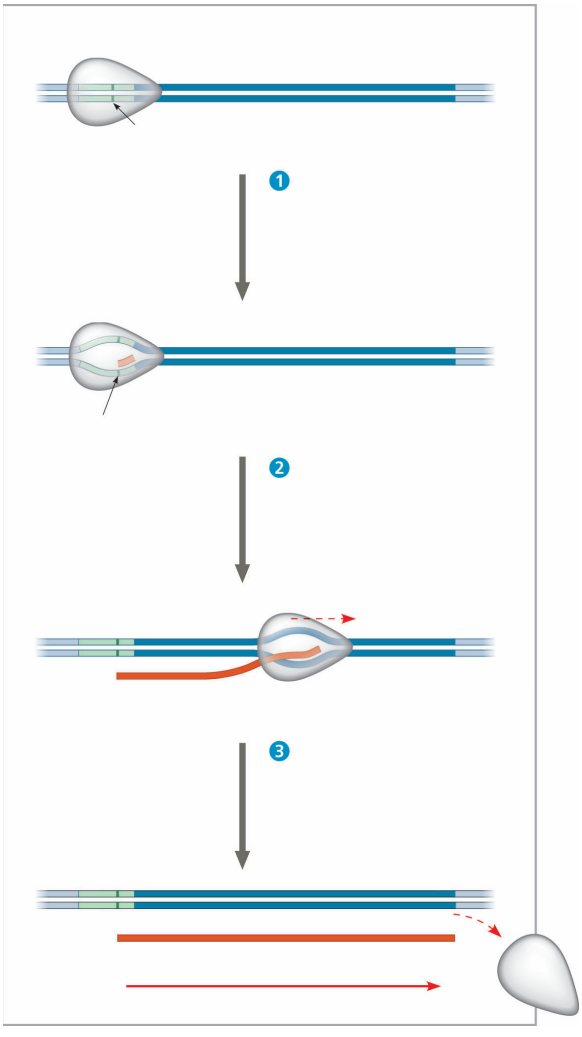
32. Recall from Chapter 16 that *DNA polymerase III* adds new nucleotides to the template DNA strand to assemble each new strand of DNA. Both enzymes can assemble a new polynucleotide only in the 5′ → 3′ direction. Which enzyme, *DNA polymerase III* or *RNA polymerase*, does **not** require a primer to begin synthesis?

33. Why is the *promoter* area important in beginning transcription?

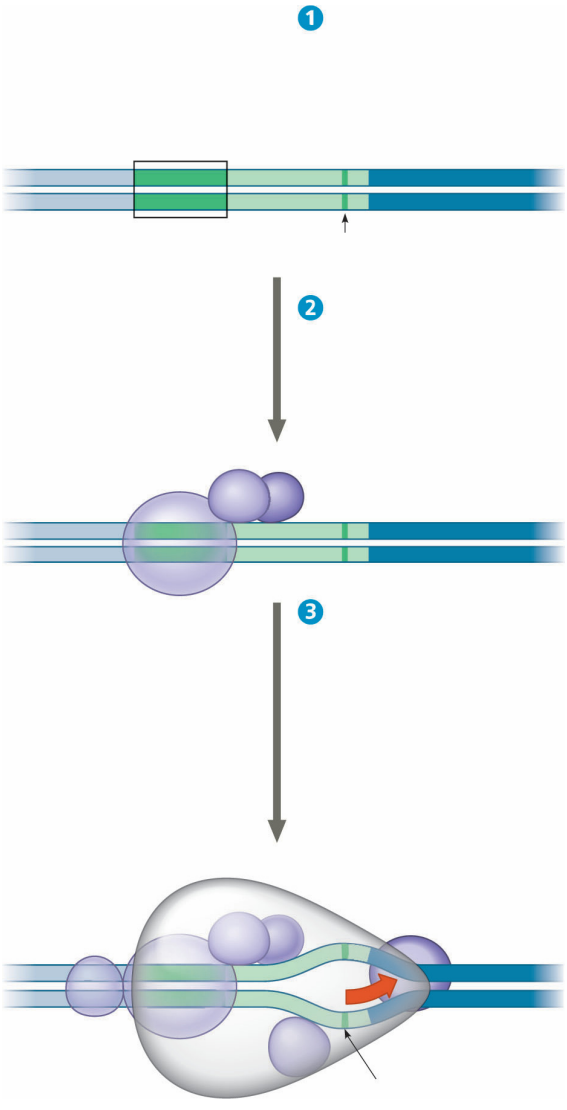
    What region signals the end of transcription?

34. What is a *transcription unit*?

35. Figure 17.8 in your text will require a bit of study. Use it to label these elements on the following figure: *promoter, RNA polymerase, start point, transcription unit, DNA template, nontemplate DNA, 5′ and 3′ ends* of all strands, and *RNA transcript*. Then, to the right of the figure, name the three stages of transcription and briefly describe each stage.



36. Use Figure 17.9 in your text to label these elements of the following figure: *promoter, TATA box, RNA polymerase II, transcription factors, template DNA strand, start point, 5′ and 3′, transcription initiation complex,* and *mRNA transcript.* To the right of the figure, explain the three stages of initiation in a eukaryotic promoter.



37. What is the *TATA* box? How do you think it got this name?

38. In *elongation* of the RNA strand how is the DNA unwound? What happens to the growing RNA strand?

39. How does the *termination* of transcription occur in bacteria?

    What is the signal sequence in eukaryotes that ultimately ends transcription?

Concept 17.3 Eukaryotic cells modify RNA after transcription

LO 17.3: Trace the steps involved in eukaryotic RNA processing.

40. *RNA processing,* sometimes also called *mRNA editing*, occurs only in eukaryotic cells. Prokaryotic cells lack the enzymes to edit mRNA. The primary transcript is altered at both ends, and sections in the middle are removed.

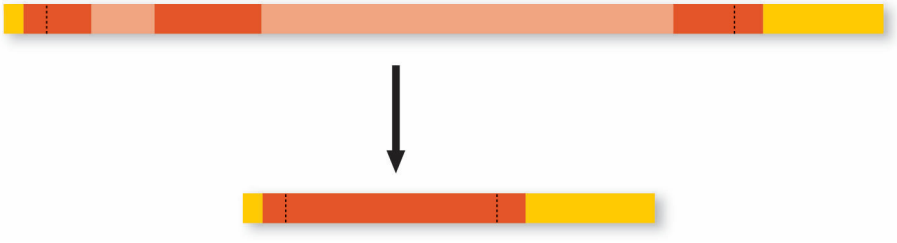
    a. What happens at the 5′ end?

    b. What happens at the 3′ end?

41. What are three important functions of the *5′ cap* and *poly-A tail*?

42. Use the following figure to label all the sections of the RNA molecule including the 5′ cap and the poly-A tail. This RNA molecule is still in the nucleus but has not yet undergone RNA splicing.

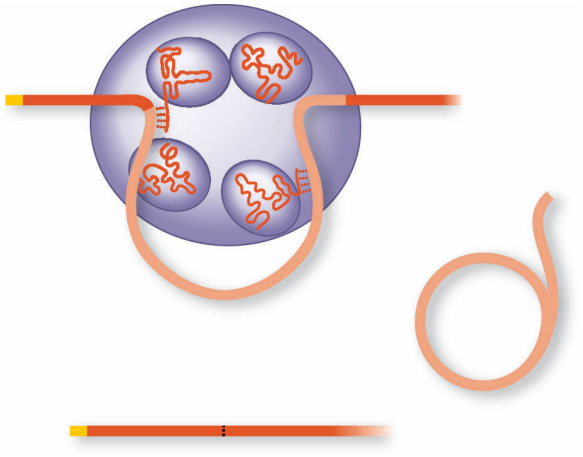
43. The following figure is the next step in preparing the RNA transcript to leave the nucleus: *RNA splicing*. Completely label both the pre-mRNA and the mRNA strand.



44. Distinguish between *introns* and *exons.* Perhaps it will help to remember this: *Exons* are *expressed*.

45. What are the two components of *spliceosomes?* How do spliceosomes work?

46. On the following figure, completely label the spliceosome editing out introns in the pre-mRNA and the resulting mRNA strand.



47. Study the figure and text carefully to explain how the splice sites are recognized.

48. What is a *ribozyme*?

49. What commonly held idea was rendered obsolete by the discovery of ribozymes?

50. What are three properties of RNA that allow it to function as an enzyme?

    a.

    b.

    c.

51. What is the consequence of *alternative splicing* of identical mRNA transcripts?

52. Label the figure and then describe the correspondence between exons and protein domains.

Concept 17.4 Translation is the RNA-directed synthesis of a polypeptide: A Closer Look

LO 17.4: List the cellular components and molecules involved in translation, and describe the process, then describe how multiple polypeptides are made in bacteria and eukaryotes.

53. You may need to read on in this section in order to answer this question, as well as think back to earlier information about mRNA. Come back to this question later if you wish. Three types of RNA are needed for protein synthesis. Figure 17.15 in your text is an overview of translation and will remind and expand the functions of the different types of RNA. Study this figure then complete the following chart.

Type of RNA	Description	Function
mRNA		
tRNA		
rRNA		

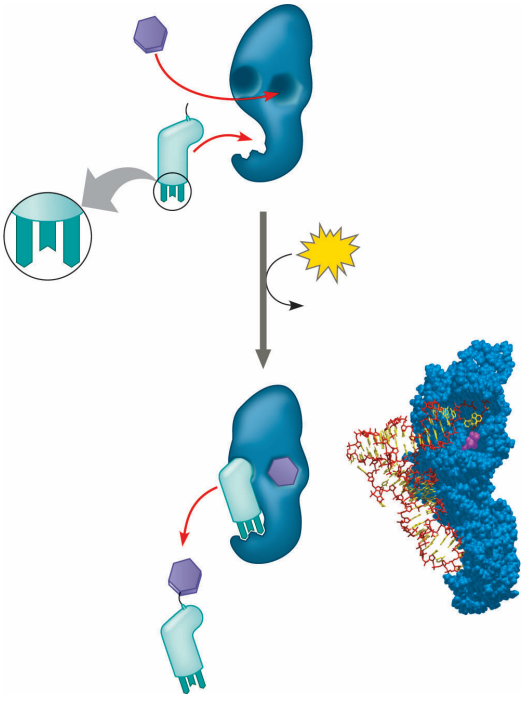
54. What is an *anticodon*?

55. *Transfer RNA* has two attachment sites. What binds at each site? Sketch tRNA to indicate the two attachment sites and note where complementary base pairing and hydrogen bonding occur to give it shape. Figure 17.16 in your text will be helpful.

56. What is the function of *aminoacyl-tRNA synthetases?* How many different *aminoacyl-tRNA synthetases* are there?

57. Scientists expected to find one aminoacyl-tRNA synthetase per codon, but far fewer have been discovered. How does *wobble* explain this?

58. Use the following figure to explain the process of a specific amino acid being joined to a tRNA. Label all parts of the figure. What are the three key points in matching the correct amino acid with the proper tRNA?



59. Describe the structure of a eukaryotic *ribosome*.

60. How does a prokaryotic ribosome differ from a eukaryotic ribosome? What is the medical significance of this difference?

61. On the following figure, label the *large subunit; small subunit; A, P,* and *E sites;* and *mRNA binding site.* To the right of the figure, explain the functions of the A, P, and E sites.

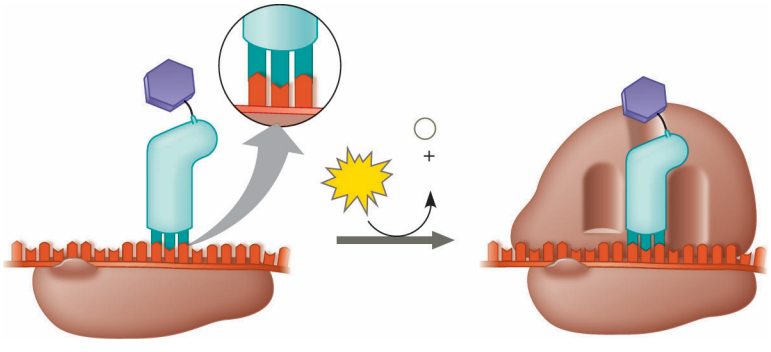
62. Much as with transcription, we can divide translation into three stages. List them. You will find these described in Figures 17.19, 17.20, and 17.21 in your text.

    a.

    b.

    c.

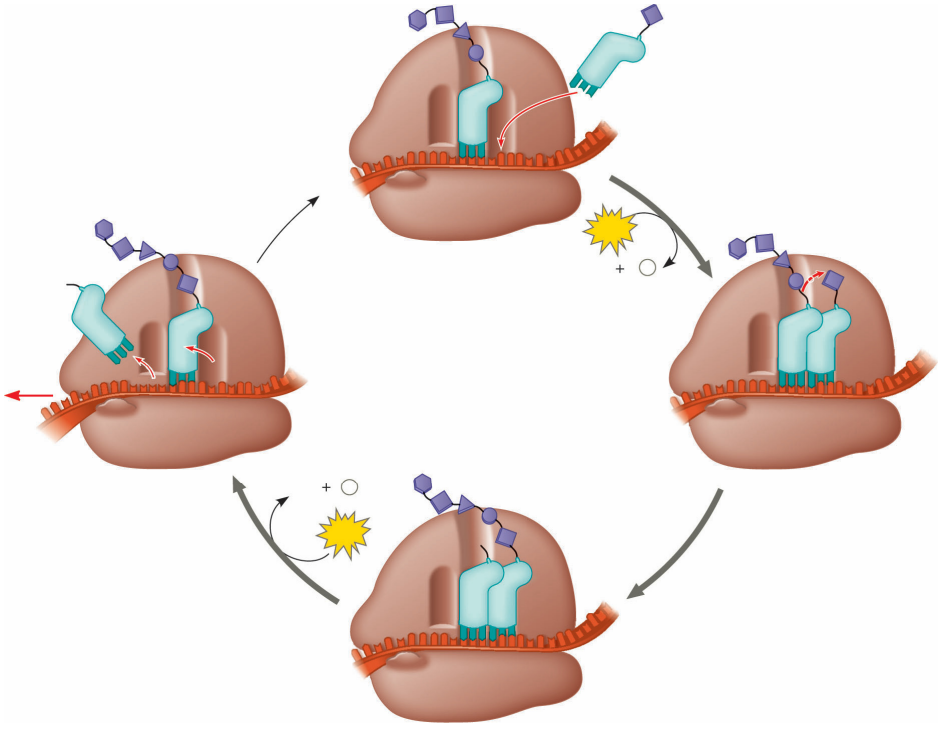
63. Label the events of *initiation*, including these components: *small ribosomal subunit, large ribosomal subunit, mRNA, start codon, initiator tRNA, Met, translation initiation complex, P site,* and *GTP.*



64. Summarize the two key events in forming the translation initiation complex.

65. What is always the first amino acid in the new polypeptide?

66. Now, summarize the events of *elongation*. Include these components on the figure: *mRNA, A site, tRNA, codon, anticodon, ribozyme, P site,* and *E site, codon recognition, peptide bond formation, translocation, 3′ and 5′, polypeptide chain.*



67. Three key events occur in elongation. Explain the important features of each event.

    a. Codon recognition

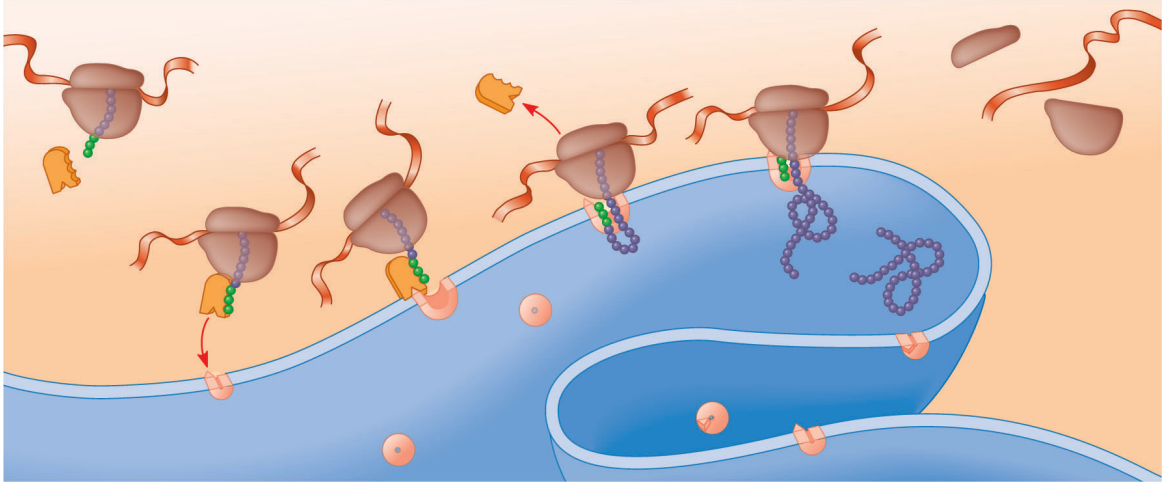
    b. Peptide bond formation

    c. Translocation

68. What is a *release factor*? By what mechanism is termination accomplished?

69. Describe at least three types of *post-translational modifications*.

70. Label the following figure then below the figure explain the six steps that show how proteins are targeted for the endoplasmic reticulum (ER). Also, place the six numbers in their correct location on the figure.



1.

2.

3.

4.

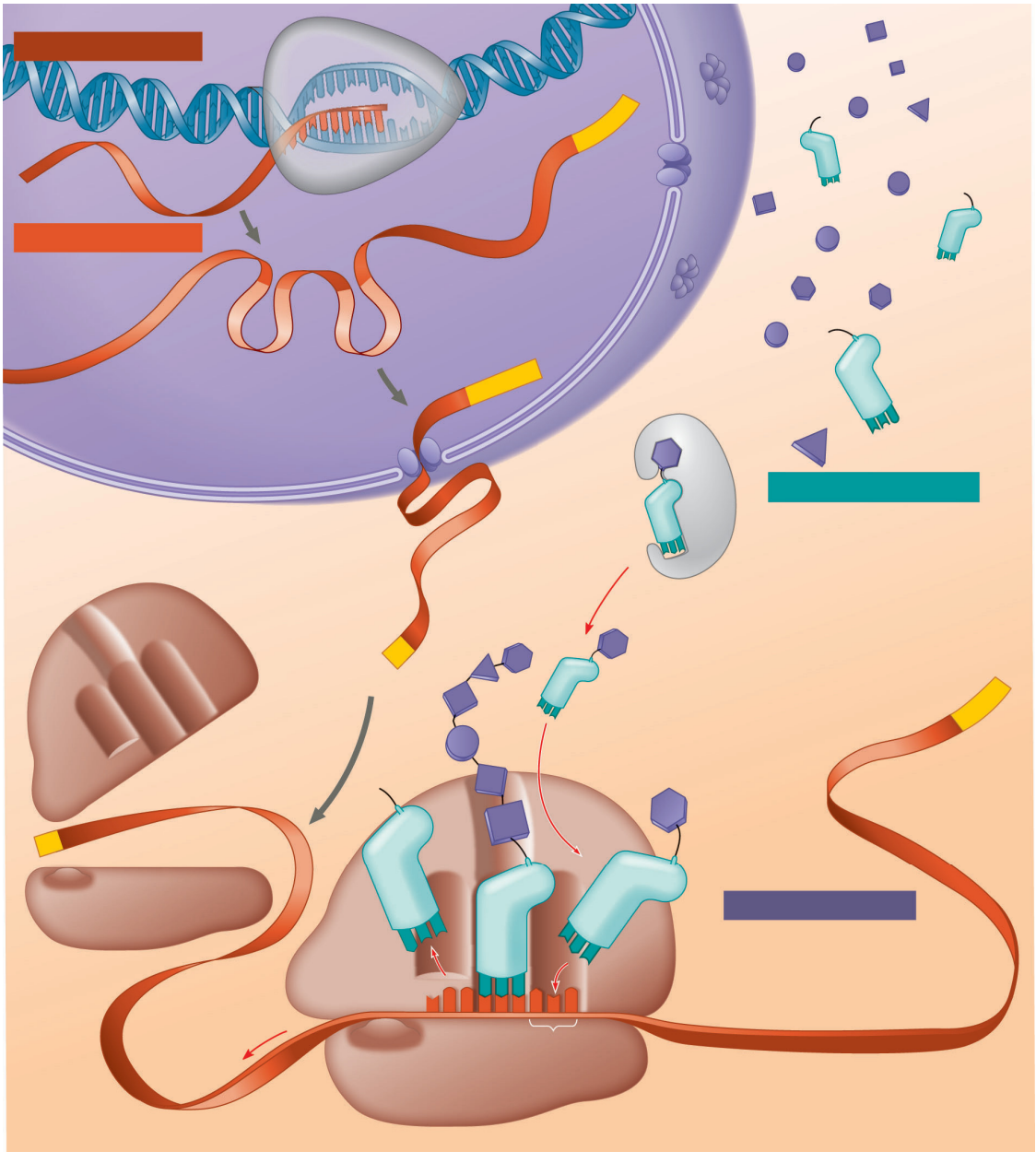
5.

6.

71. What is a *polyribosome*?

72. Besides lacking enzymes for RNA editing, describe how the lack of compartments in a prokaryotic cell results in a difference in gene expression from what was described in eukaryotic cells.

73. Use this summary figure to explain the five major events in transcription and translation. If you have the big picture mastered, the details will fall into place under each of the five major steps .



Concept 17.5 Mutations of one or a few nucleotides can affect protein structure and function

LO 17.5: Identify different types of mutations and how they can affect protein structure and function, then discuss the concept of a gene.

74. Mutations provide the raw material of evolution. Define a *mutation* in terms of molecular genetics.

75. Chromosomal rearrangements are considered large-scale mutations. *Point mutations* are considered small-scale mutations and are of two general types. The first is a *single nucleotide-pair substitution.* What occurs here?

76. How can a *nucleotide-pair substitution* result in a *silent mutation*?

77. What is the difference between a *nonsense* and *missense mutation*?

78. The second category of point mutations includes nucleotide-pair insertions or deletions. These can result in *frameshift mutations*. What does this mean?

79. Use Figure 17.27 in your text to review the types of mutations termed nucleotide-pair substitutions and nucleotide-pair insertion or deletion as explained at the nucleotide level.

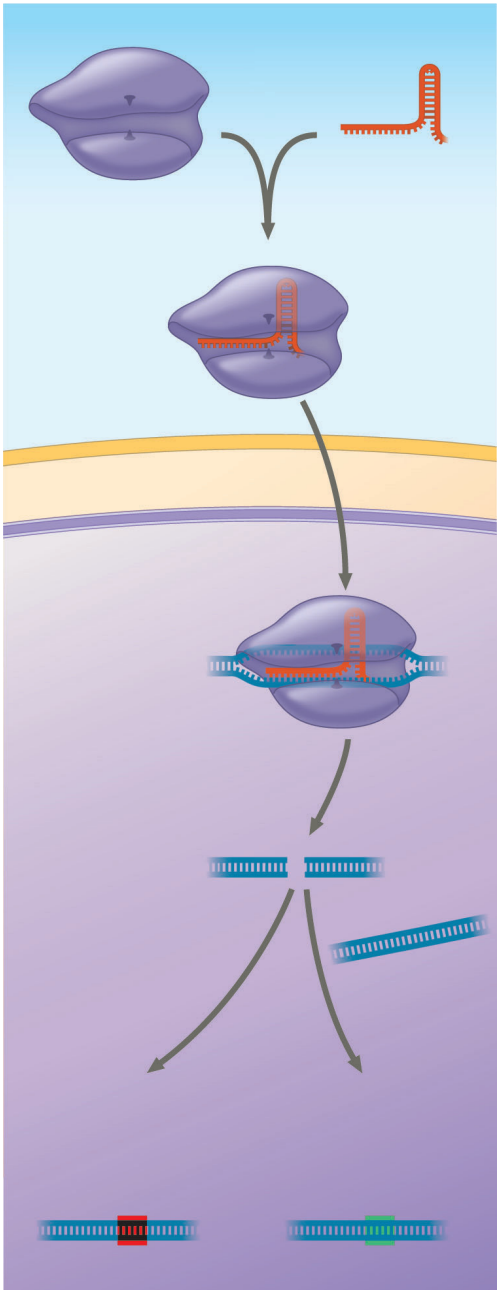
80. What are the two categories of *mutagens*?

81. A powerful new technique for gene editing is the CRISPR-Cas9 system.

    a. What is Cas9?

    b. What is the role of the guide RNA made from the CRISPR region of the bacterial genome?

82. Following Figure 17.28 in your text, label and explain the three major events in gene editing using the CRISPR-Cas9 system.



83. What are the key ethical issues associated with using CRISPR-Cas9 in humans? How do you feel about the use of this system in humans?

84. What is a gene? It used to be simply stated that *one gene codes for one polypeptide*. That definition has now been modified. Write in the following space the broader molecular definition in use today.

Test Your Understanding, p. 363

Now you should be ready to test your knowledge. Place your answers here:

1. _____ 2. _____ 3. _____ 4. _____ 5. _____ 6. _____ 7. _____