11 Regulation of Gene Expression

Chapter Outline

The DNA code is the transcription template for making RNA, which is then processed to make mRNA. The mRNA code is translated at the ribosomes to guide the synthesis of a polypeptide or a protein. Most of the cells of an organism carry the full set of that organism's DNA code.

The expression of different genes is what leads to the specialization of the thousands of kinds of cells in the human body (e.g., liver cells, skin cells, bone cells). In addition to encoding cell types, DNA encodes the messages necessary to repair cells, maintain homeostasis, regulate cell death, and address a host of other activities. Inducible genes, operons, transcription factors, posttranscriptional factors, and the cell's environment all work together in a dynamic fashion to maintain homeostasis and maximize the cell's functions.

Chapter 11's coverage of the AP Biology Curriculum Framework encompasses three of the **Big Ideas**.

Big Idea 2 states that the utilization of free energy and the use of molecular building blocks are characteristic of processes fundamental to life. Chapter 11 looks at regulation of DNA and gene expression. Specifically, Chapter 11 addresses:

- **2.C.1:** Organisms use negative feedback mechanisms to maintain their internal environments and respond to external environmental changes.

Big Idea 3 states that living systems store, retrieve, transmit and respond to information essential to life processes. Chapter 11 continues discussing DNA and includes the regulation of DNA. Chapter 11 includes:

- **3.B.1:** Gene regulation results in differential gene expression, leading to cell specialization.

Big Idea 4 states that biological systems interact in complex ways. Continuing with the theme of regulation, Chapter 11 considers the effects of the environment as well. Specifically, Chapter 11 addresses:

- **4.C.2:** Environmental factors influence the expression of the genotype in an organism.

Chapter Review

Concept 11.1 *examines how gene regulation can involve positive and/or negative regulation. The general label "transcription factor" is given to a regulatory protein that binds to DNA and activates or prevents transcription. Operons serve in transcriptional regulation for prokaryotes. They allow prokaryotes to conserve energy and resources by expressing genes only when their protein products are needed. Viruses, particularly bacteriophages, provide a convenient model to study transcription regulation. Viruses infect bacteria and turn them into virus factories by shutting down bacterial gene transcription and rapidly stimulating genome replication.*

1. It has long been suspected that alcoholism in some families includes a genetic influence. Briefly describe the recent discovery of the genetic underpinnings of alcoholism in studies of lab rats.

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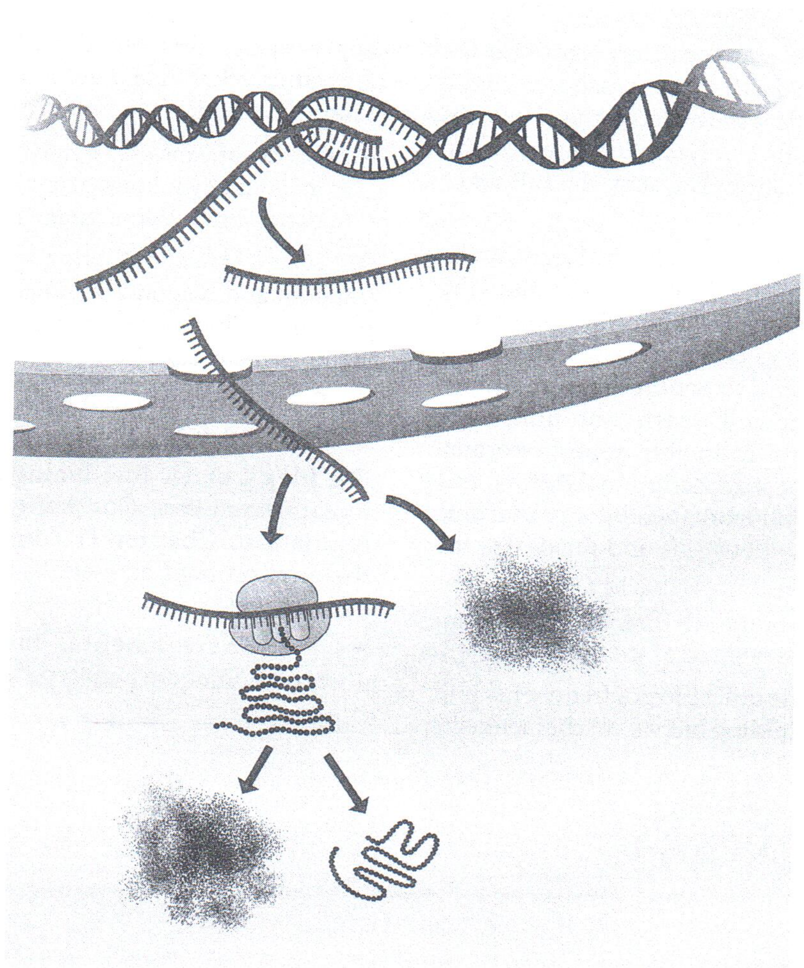
2. In the diagram below, label and identify the five potential points (shown as arrows) for the regulation of gene expression.



3. Explain the primary difference between a constitutive gene and an inducible gene, and provide an example of each.

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4. Describe the three primary parts of the *lac* operon.

a. ____

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b. ____

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c. ____

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5. Explain why the *trp* operon is described as a repressible operon, and discuss how this regulatory function is important to a bacterial cell.

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6. Describe two features of bacteria that make them especially useful for studying the mechanisms of gene regulation.

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7. Explain why viruses are not considered cellular organisms.

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8. Explain how the four types of viruses are distinguished by differences in their genetic material.

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9. Describe the lytic and lysogenic phases of viral reproduction.

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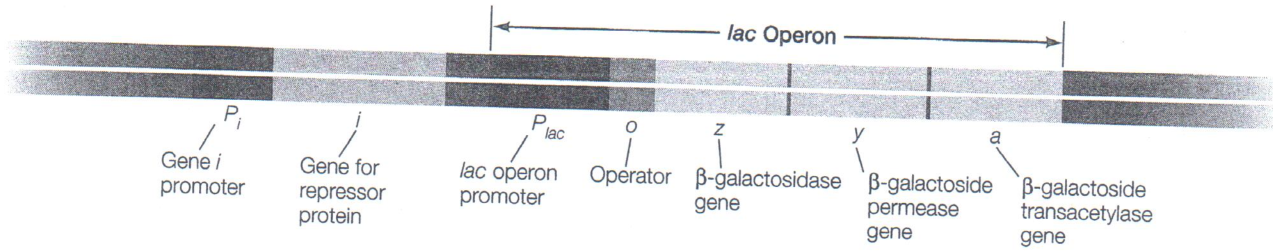
10. Genetic mutations are useful in analyzing the control of gene expression. In the *lac* operon of *E. coli*, gene *i* codes for the repressor protein, P_{lac} is the promoter, *o* is the operator, and *z* is the first structural gene; (+) means wild type/normal; (−) means mutant/nonfunctional. Using the diagram below for reference, fill in the table by writing "YES" or "NO" to describe the presence of transcription in different genetic and environmental conditions.



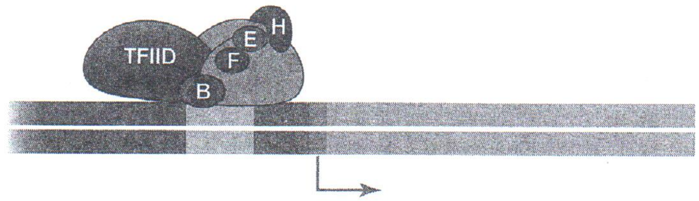
Genotype	*z* Transcription level: Lactose present	Lactose absent
$i^- P_{lac}^+ o^+ z^+$		
$i^+ P_{lac}^+ o^+ z^-$		
$i^+ P_{lac}^- o^+ z^+$		
$i^+ P_{lac}^+ o^- z^+$		

Concept 11.2 *explains how eukaryotic gene regulation can be even more complex than operon control of prokaryotic gene regulation. While operons are sometimes found in eukaryotes, genes are regulated at several other points as they are transcribed to RNA.*

11. Explain why transcription factors are found more commonly in eukaryotes than in prokaryotes.

12. Describe all the necessary components that must be present before RNA polymerase II can transcribe a segment of eukaryotic DNA.

13. In the diagram below, label the following: DNA, TATA box, transcription initiation site, promoter, transcription factors, and RNA polymerase II.



14. Describe the chemical matching between a transcription factor and the specific DNA sequence to which it binds.

15. Discuss the concept of "induced fit" as it applies to a transcription factor binding to DNA.

16. Discuss the importance of precision in the coordination of gene expression.

17. Explain how HIV uses RNA as its genetic material but still uses DNA for insertion as a provirus.

Concept 11.3 *explains how epigenetics and the environment also regulate genes. These influences can be passed down through multiple generations.*

18. Describe two ways that epigenetic changes to DNA can alter gene expression, and describe how these changes can be inherited despite the lack of changes in the parent's DNA sequence.

a. ______________________________

b. ______________________________

19. Early in life, identical twins behave very similarly and are often difficult to tell apart. As they age, subtle differences appear, and as they reach middle age, the differences become more distinct. Explain how this can occur at a molecular level with reference to their shared DNA.

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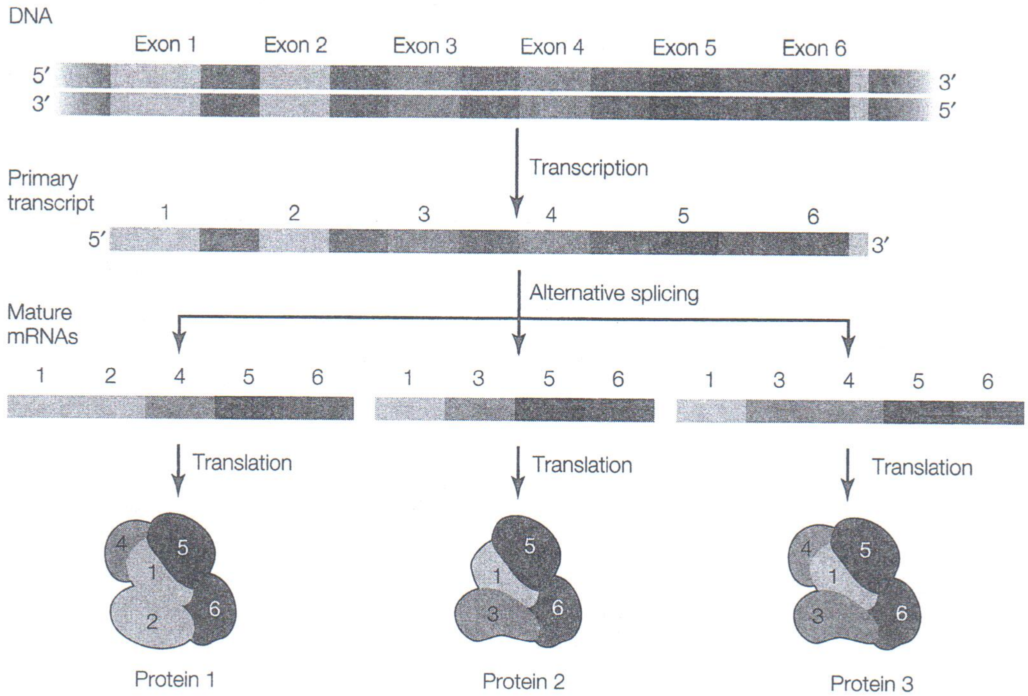
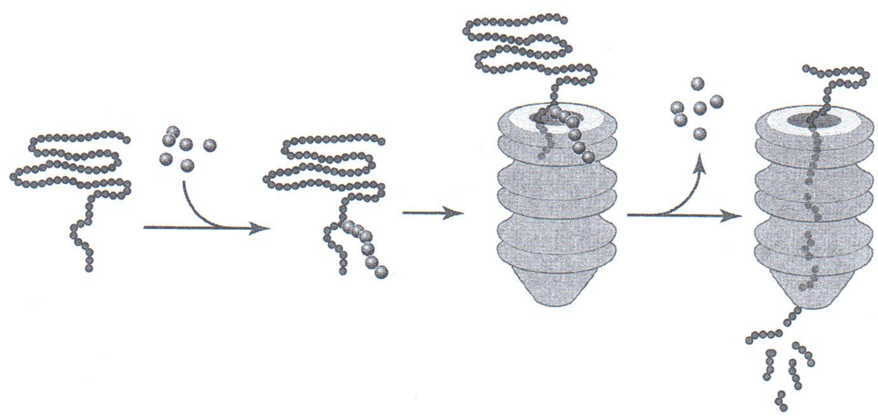
Concept 11.4 *examines regulation of gene expression in the steps that follow transcription, including alternative RNA splicing and the control of mRNA translation. Farther along the sequence, the longevity of a protein product in the cell is also regulated by proteasomes, which degrade proteins when they are no longer useful to a cell.*

20. In *Drosophila*, sex is determined by a gene that has four exons, which we will designate 1, 2, 3, and 4. In the female embryo, splicing generates two active forms of the protein, one containing information from exons 1 and 2 and one containing information from exons 1, 2, and 4. In the male embryo, the protein contains information from all four exons (1, 2, 3, and 4), but the protein is inactive. Draw a diagram that represents this process, using the one below as a model.



21. Explain how it is that humans have only about 24,000 genes but at least 85,000 different mRNA sequences.

22. In the figure below, label targeted protein, ubiquitin, and proteasome.



23. Explain the role of ubiquitin as shown in the figure for Question 22.

24. Explain how microRNA (miRNA) can act in gene silencing.

25. Complete the table below for the different types of gene regulation.

	Location in cell	**Molecule(s) acted on**	**Example**
Operons			
Transcription factors			
Translational			
Epigenetics			
Chromatin remodeling			
miRNA			
Alternative splicing			

Science Practices & Inquiry

In the AP Biology Curriculum Framework, there are seven **Science Practices**. In this chapter, we focus on **Science Practice 7:** The student is able to connect and relate knowledge across various scales, concepts, and representations in and across domains. More specifically, we focus on **Science Practice 7.1:** The student can connect phenomena and models across spatial and temporal scales.

Question 26 asks you to describe the connection between the regulation of gene expression and observed differences between individuals in a population (**Learning Objective 3.19**).

26. In a breeding experiment, fruit flies showed unusual growths on their eyes. This trait lasted for eleven to thirteen generations before breeding resulted in normal fruit flies.

a. Could this change have occurred due to a mutation or change in the DNA sequence? Why or why not?

b. Explain how this change could continue for generations and then disappear.