13.4 Gene Regulation and Expression

Lesson Objectives

- Describe gene regulation in prokaryotes.
- Explain how most eukaryotic genes are regulated.
- Relate gene regulation to development in multicellular organisms.

Lesson Summary

Prokaryotic Gene Regulation Prokaryotes do not need to transcribe all of their genes at the same time. They can conserve energy and resources by regulating their activities, producing only those genes necessary for the cell to function. In prokaryotes, DNA-binding proteins regulate genes by controlling transcription. An **operon** is a group of genes that are regulated together. An example is the *lac* operon in the bacterium *E. coli*:

- This group of three genes must be turned on together before the bacterium can use lactose as food.
- When lactose is not present, the DNA-binding protein called *lac* repressor binds to a region called the **operator**, which switches the *lac* operon off.
- When lactose binds to the repressor, it causes the repressor to fall off the operator, turning the operon on.

Eukaryotic Gene Regulation Transcription factors are DNA-binding proteins. They control the expression of genes in eukaryotes by binding DNA sequences in the regulatory regions. Gene promoters have multiple binding sites for transcription factors, each of which can influence transcription.

- Complex gene regulation in eukaryotes makes cell specialization possible.
- The process by which microRNA (miRNA) molecules stop mRNA molecules from passing on their protein-making instructions is **RNA interference (RNAi)**.
- RNAi technology holds the promise of allowing scientists to turn off the expression of genes from viruses and cancer cells, and it may provide new ways to treat and perhaps even cure diseases.

Genetic Control of Development Regulating gene expression is especially important in shaping the way a multicellular organism develops. Gene regulation helps cells undergo **differentiation**, becoming specialized in structure and function. Master control genes are like switches that trigger particular patterns of development and differentiation in cells and tissues.

- **Homeotic genes** are master control genes that regulate organs that develop in specific parts of the body.
- **Homeobox genes** share a similar 130-base DNA sequence called homeobox. They code for transcription factors that activate other genes that are important in cell development and differentiation in certain regions of the body.
- **Hox genes** are a group of homeobox genes that tell the cells of the body how to differentiate as the body grows.

Environmental factors can also affect gene expression.

Prokaryotic Gene Regulation

1. How do prokaryotes conserve energy?

2. How do DNA-binding proteins in prokaryotes regulate genes?

3. What is an operon?

4. What is in the *lac* operon in *E. coli*?

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

6. What turns the *lac* operon off?

7. How does a repressor protein turn off the *lac* operon?

8. How does lactose turn on the *lac* operon?

9. Complete the table to describe the role of each regulatory region or molecule in the operation of the *lac* operon.

Regulatory Region or Molecule	What It Does
Repressor protein	
Operator	
RNA polymerase	
Lactose	

Eukaryotic Gene Regulation

10. In what two ways is gene regulation in eukaryotes different from gene regulation in prokaryotes?

a. _____

b. _____

11. What is a TATA box? What does a TATA box do?

_____

12. What are transcription factors and what do they do?

_____

13. Explain how gene regulation makes cell specialization possible.

_____

14. What is microRNA and how is it related to mRNA?

_____

15. Explain how the process of RNA interference works.

_____

Genetic Control of Development

For Questions 16–23, write the letter of the correct answer on the line at the left.

_____ **16.** As an embryo develops, different sets of genes are regulated by

A. mRNA and *lac* repressors.
B. operons and operators.
C. transcription factors and repressors.
D. promoters and operators.

_____ **17.** The process through which cells become specialized in structure and function is

A. transcription.
B. gene expression.
C. differentiation.
D. RNA interference.

_____ **18.** Homeotic genes are

A. regulator genes that bind to operons in prokaryotes.
B. master control genes that regulate organs that develop in specific parts of the body.
C. parts of the silencing complex that regulates gene action through RNA interference.
D. base sequences complementary to sequences in microRNA.

_____ **19.** What role do homeobox genes play in cell differentiation?

A. They code for transcription factors that activate other genes important in cell development and differentiation.
B. They block certain gene expression.
C. They cut double-stranded loops into microRNA.
D. They attach to a cluster of proteins to form a silencing complex, which binds to and destroys certain RNA.

_____ **20.** In flies, the group of homeobox genes that determines the identities of each segment of a fly's body is the group known as

A. silencing complexes.
B. promoters.
C. operators.
D. Hox genes.

_____ **21.** Clusters of Hox genes are found in

A. flies only.
B. flies and frogs only.
C. plants only.
D. nearly all animals.

_____ **22.** The "switches" that trigger particular patterns of development and differentiation in cells and tissues are

A. mRNA molecules.
B. master control genes.
C. silencing complexes.
D. Dicer enzymes.

_____ **23.** Metamorphosis is

A. a series of transformations from one life stage to another.
B. the master switch that triggers development and differentiation.
C. the product of interactions among homeotic genes.
D. the process by which genetic information is passed from one generation to the next.

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24. Environmental factors can influence gene expression. Fill in the table below to show how organisms respond to conditions in their environment.

	Environmental Factor Influencing Gene Expression	How the Organism Responds
E. coli with limited food supply	nutrient availability	
A tadpole in a drying pond		

Apply the Big Idea

25. Many research studies have shown that different species may possess some of the exact same genes but show vastly different traits. How can that happen?

Chapter Vocabulary Review

For Questions 1–7, write True if the statement is true. If the statement is false, change the underlined word or words to make the statement true.

_____ **1.** DNA contains the sugar ribose.

_____ **2.** Messenger RNA carries copies of the instructions for making proteins from DNA to other parts of the cell.

_____ **3.** RNA polymerase transfers amino acids to ribosomes.

_____ **4.** The process of transcription produces a complementary strand of RNA on a DNA template.

_____ **5.** The enzyme that assembles a complementary strand of RNA on a DNA template is RNA polymerase.

_____ **6.** The region of DNA where the production of an RNA strand begins is called the intron.

_____ **7.** Exons are spliced together in forming messenger RNA.

For Questions 8–16, match the term with its definition.

Definition

_____ **8.** The sequence of bases that serves as the "language" of life

_____ **9.** A sequence of three bases on a tRNA molecule that is complementary to a sequence of bases on an mRNA molecule

_____ **10.** How genetic information is put into action in a living cell

_____ **11.** Having extra sets of chromosomes

_____ **12.** The decoding of an mRNA message into a protein

_____ **13.** A heritable change in genetic information

_____ **14.** A chain of amino acids

_____ **15.** The three consecutive bases that specify a single amino acid to be added to the polypeptide chain

_____ **16.** A chemical or physical agent that causes a change in a gene

Term

A. polypeptide
B. genetic code
C. codon
D. translation
E. anticodon
F. gene expression
G. mutation
H. mutagen
I. polyploidy

For Questions 17–19, complete each statement by writing the correct word or words.

17. A group of genes that are regulated together is called a(n) _____.

18. A region of DNA where a repressor can bind is a(n) _____.

19. Master control genes, called _____ genes, regulate organs that develop in specific parts of the body.

