Chapter 1: Overview of Genetics

Student Learning Objectives

Upon completion of this chapter you should be able to:

1. Understand the key biological molecules that are associated with the study of genetics.
2. Understand the relationships between genes and traits and the types of traits that are studied by geneticists.
3. Understand the four principle levels of genetic study: molecular, cellular, organism, and population.
4. Recognize the three major fields of genetics (transmission, molecular, and population) and the general characteristics of each field.

1.1 The Molecular Expression of Genes

Overview

The study of genetics involves a fundamental understanding of both organic molecules and cellular processes. For most students, these concepts were first introduced in their introductory biology classes. The text sections on biochemicals (page 4), proteins and enzymes (pages 4-5), and DNA (pages 5-6) provide a quick refresher of this material. If a more comprehensive review is needed, you should consult an introductory text book.

Outline of Key Terms

<table>
<thead>
<tr>
<th>Term</th>
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<tbody>
<tr>
<td>Genome</td>
<td>Genetic code</td>
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<td>Chromosomes</td>
<td>Gene expression</td>
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<td>Gene</td>
<td>Transcription</td>
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<td>Macromolecules</td>
<td>Messenger RNA (mRNA)</td>
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<tr>
<td>Carbohydrates</td>
<td>Translation</td>
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<tr>
<td>Lipids</td>
<td>Polypeptides</td>
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<tr>
<td>Nucleic Acids</td>
<td>Traits</td>
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<tr>
<td>Nucleotides</td>
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<tr>
<td>Deoxyribonucleic acid (DNA)</td>
<td></td>
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<tr>
<td>Ribonucleic acid (RNA)</td>
<td></td>
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<tr>
<td>Proteins</td>
<td></td>
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<tr>
<td>Amino acids</td>
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<tr>
<td>Enzymes</td>
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<tr>
<td>Proteome</td>
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Focal Points

- The Human Genome Project (Figure 1.1)
- Molecular organization of a living cell (Figure 1.4)
- Gene expression at the molecular level (Figure 1.6)
Exercises

For questions 1 to 5, refer to the labels on the diagram below.

1. The process by which genetic information is converted into a functioning protein.
2. The functional protein responsible for the observed traits.
3. The label that indicates messenger RNA.
4. The label that indicates the source of the information for producing a trait.
5. The process by which the genetic information is copied in RNA.

For questions 6 to 8, complete the sentence with the most appropriate term(s):

6. _______ are the only types of macromolecules that do not comprise polymers.
7. All of the proteins that a cell makes at a given time is called its _________.
8. Building blocks of nucleic acids and proteins are termed ______ and ______, respectively.

1.2 The Relationship Between Genes and Traits

Overview

While many students can provide a definition of the terms genes and traits, the relationship is frequently not understood. Figure 1.6 in the first section provides a visual link between the genetic information (DNA) and the functional protein that is at the core of the expression of traits. While educational materials frequently focus on morphological traits,
primarily due to the fact that they are easier to describe, visualize, and illustrate, physiological
traits, and to a certain extent, behavioral traits, are also controlled by the expression of genes.
The section begins with the four principle levels of genetic study: molecular, cellular, organism, and population (page 7, and Figure 1.7). It then proceeds to examine how genetic variation underlies differences in inherited traits (Figures 1.8 and 1.9), and how traits can be controlled by genes and influenced by the environment (Figure 1.10). The section ends with a discussion of genetics and reproduction, and genetics and evolution (pages 9-10).

**Outline of Key Terms**

<table>
<thead>
<tr>
<th>Traits</th>
<th>Genes variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physiological traits</td>
<td>Genetic mutations</td>
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<tr>
<td>Morphological traits</td>
<td>Morphs</td>
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<tr>
<td>Behavioral traits</td>
<td>Environmental influence</td>
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<tr>
<td>Levels of genetic study</td>
<td>Norm of reaction</td>
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<tr>
<td>Molecular level</td>
<td>Phenylketonuria (PKU)</td>
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<tr>
<td>Alleles</td>
<td>Types of cells</td>
</tr>
<tr>
<td>Cellular level</td>
<td>Somatic cells</td>
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<tr>
<td>Organism level</td>
<td>Diploid</td>
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<tr>
<td>Population level</td>
<td>Homologs</td>
</tr>
<tr>
<td>Species</td>
<td>Gametes</td>
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<tr>
<td></td>
<td>Haploid</td>
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<tr>
<td></td>
<td>Biological evolution</td>
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<tr>
<td></td>
<td>Natural selection</td>
</tr>
</tbody>
</table>

**Focal Points**

- The relationship between genes and traits (Figure 1.7)
- The complement of human chromosomes in somatic cells and gametes (Figure 1.11)
- Genetics and evolution (pages 10-11)

**Exercises**

For questions 1 to 6, choose from one of the following levels of genetic study:
- a. population level
- b. molecular level
- c. cellular level
- d. organism level

- 1. The action of proteins, such as enzymes, occurs at this level of organization.
- 2. Regulation of transcription and translation occurs at this level of organization.
- 3. An analysis of the prevalence of a trait in a given population.
- 4. It is at this level that the traits are most notably detectable for geneticists.
- 5. An allele is due to a change in the genetic material at this level.
- 6. This level examines how the occurrence of a trait influences habitat or survival.
For questions 7 to 12, choose from the following:

a. example of a physiological trait
b. example of a morphological trait
c. example of a behavioral trait

_____ 7. The flower colors and seed shapes of pea plants studied by Gregor Mendel in the 19th century.
_____ 8. Trunk length in elephants.
_____ 9. Metabolic efficiency of an organism under anaerobic conditions.
_____ 11. Mating call of birds.
_____ 12. Wing size in insects.

1.3 Fields of Genetics

Overview

As is the case with any of the scientific disciplines, geneticists specialize in areas of study. Although these genetic specialists may differ in the level at which they study genetic principles, they frequently use similar methods. This section first distinguishes between the three traditional areas of genetics: transmission, molecular, and population. It then describes hypothesis testing and discovery-based science, which are the two general types of scientific approaches used in the study of genetics.

Outline of Key Terms

Model organisms                     Loss-of-function mutation
Fields of genetics                  Loss-of-function allele
    Transmission genetics            Scientific approaches
    Molecular genetics               Hypothesis testing
    Population genetics              Scientific method
Genetic cross                       Discovery-based science

Focal Points

- Model genetic organisms (Figure 1.13)
- The three areas of genetics (pages 13-14)
- Genetics is an experimental science (page 15)
Exercises

For questions 1 to 6, indicate whether the research is in the (a) transmission, (b) molecular, or (c) population field of genetic study. Some questions may have more than one answer.

1. An assessment of a loss-of-function allele on an organism’s physiology.
2. Patterns of inheritance of a disease in a family.
3. The relationship between genetic variation and the environment.
4. Studies of the variations in DNA between species.
5. The movement of traits from parents to offspring.
6. An examination of how a group of animals is adapting to a new environment.

Match the model organism in questions 7 to 12 to their correct scientific names.

_____ 7. A bacterium
_____ 8. A yeast
_____ 9. A fruit fly
_____ 10. A nematode worm
_____ 11. A mouse
_____ 12. A flowering plant

a. Arabidopsis thaliana
b. Mus musculus
c. Escherichia coli
d. Saccharomyces cerevisiae
e. Caenorhabditis elegans
f. Drosophila melanogaster

Chapter Quiz

1. The primary advantage of sexual reproduction is:
   a. it maintains the chromosome number for the species.
   b. it is necessary to protect against the effects of natural selection.
   c. it creates diploid gametes that are clones of the parents.
   d. it enhances genetic variation for the species.
   e. none of the above are correct.
2. Patterns of inheritance within a family would most likely be associated with which of the following?
   a. transmission genetics.
   b. population genetics.
   c. molecular genetics.
   d. none of the above.

3. Which of the following best describes the term genetic variation?
   a. differences in inherited traits within individuals of a population
   b. the changing of the genetic makeup of a population over time
   c. the basic unit of heredity
   d. the characteristics of an organism
   e. the effect of the environment on the expression of a trait

4. Contrasting forms within a single species are best described as
   a. alleles.
   b. genes.
   c. morphs.
   d. traits.

5. Enzymes belong to what class of macromolecules?
   a. lipids
   b. nucleic acids
   c. proteins
   d. carbohydrates

6. In humans, gametes are _______, and somatic cells are _______.
   a. diploid ; haploid
   b. haploid ; diploid
   c. diploid ; diploid
   d. haploid ; haploid

7. Which of the following types of scientific approaches involves collection and analysis of data without the need for a preconceived hypothesis?
   a. scientific method
   b. discovery science
   c. both A and B
   d. neither A nor B

8. A protein biochemist works primarily at the ________ level of genetic analysis.
   a. population
   b. molecular
   c. organism
   d. cellular

9. The basic unit of heredity is called the ________
   a. protein
   b. trait
   c. gene
   d. enzyme
   e. morph
10. Phenylketonuria (PKU) is an example of __________.
   a. natural selection
   b. biological evolution
   c. genetic cross
   d. transcription
   e. environmental influence

Answer Key for Study Guide Questions

This answer key provides the answers to the exercises and chapter quiz for this chapter. Answers in parentheses ( ) represent possible alternate answers to a problem, while answers marked with an asterisk (*) indicate that the response to the question may vary.

1.1  1. d  4. a  7. proteome
     2. e  5. b  8. nucleotides; amino acids
     3. c  6. lipids

1.2  1. c  6. a  11. c
     2. b  7. b  12. b
     3. a  8. b
     4. d  9. a
     5. b  10. a

1.3  1. b  6. c  11. b
     2. a  7. c  12. a
     3. c  8. d
     4. b  9. f
     5. a  10. e

Quiz

1. d  5. c  9. c
2. a  6. b  10. e
3. a  7. b
4. c  8. b