11.3 Other Patterns of Inheritance

SC.912.L.16.2 Discuss observed inheritance patterns caused by various modes of inheritance, including dominant, recessive, codominant, sex-linked, polygenic, and multiple alleles. Also covered: SC.912.N.1.1, SC.912.N.1.6, SC.912.L.14.6, SC.912.L.16.1, MA.912.S.3.2

THINK ABOUT IT Mendel's principles offer a tidy set of rules with which to predict various patterns of inheritance. Unfortunately, biology is not a tidy science. There are exceptions to every rule, and exceptions to the exceptions. What happens if one allele is not completely dominant over another? What if a gene has several alleles?

Key Questions

What are some exceptions to Mendel's principles?

Does the environment have a role in how genes determine traits?

Vocabulary

incomplete dominance • codominance • multiple allele • polygenic trait

Taking Notes

Outline Make an outline using the green and blue headings. As you read, write bulleted notes below each heading to summarize its topic.

Beyond Dominant and Recessive Alleles

What are some exceptions to Mendel's principles?

Despite the importance of Mendel's work, there are important exceptions to most of his principles. For example, not all genes show simple patterns of inheritance. In most organisms, genetics is more complicated, because the majority of genes have more than two alleles. Also, many important traits are controlled by more than one gene. Understanding these exceptions allows geneticists to predict the ways in which more complex traits are inherited.

Incomplete Dominance A cross between two four o'clock (*Mirabilis jalapa*) plants shows a common exception to Mendel's principles. **Some alleles are neither dominant nor recessive.** As shown in **Figure 11–12,** the F_1 generation produced by a cross between red-flowered (*RR*) and white-flowered (*WW*) *Mirabilis* plants consists of pink-colored flowers (*RW*). Which allele is dominant in this case? Neither one. Cases in which one allele is not completely dominant over another are called **incomplete dominance.** In incomplete dominance, the heterozygous phenotype lies somewhere between the two homozygous phenotypes.

Codominance A similar situation arises from **codominance,** in which the phenotypes produced by both alleles are clearly expressed. For example, in certain varieties of chicken, the allele for black feathers is codominant with the allele for white feathers. Heterozygous chickens have a color described as "erminette," speckled with black and white feathers. Unlike the blending of red and white colors in heterozygous four o'clocks, black and white colors appear separately in chickens. Many human genes, including one for a protein that controls cholesterol levels in the blood, show codominance, too. People with the heterozygous form of this gene produce two different forms of the protein, each with a different effect on cholesterol levels.

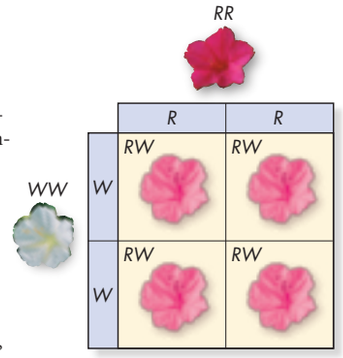


FIGURE 11–12 Incomplete Dominance In four o'clock plants, the alleles for red and white flowers show incomplete dominance. Heterozygous (*RW*) plants have pink flowers—a mix of red and white coloring.

Teach for Understanding

ENDURING UNDERSTANDING DNA is the universal code for life; it enables an organism to transmit hereditary information and, along with the environment, determines an organism's characteristics.

GUIDING QUESTION How can interactions between alleles, genes, and the environment affect an organism's traits?

EVIDENCE OF UNDERSTANDING *After completing the lesson, give students the following assessment to show they understand different patterns of heredity.* Have students write a short poem or rap using the following lesson vocabulary terms: *incomplete dominance, codominance, multiple alleles,* and *polygenic traits.* Tell students their lyrics should show they understand what each term means. Have volunteers share their work with the class.

Getting Started

Objectives

11.3.1 Describe the other inheritance patterns.

11.3.2 Explain the relationship between genes and the environment.

Student Resources

Study Workbook A and B, 11.3 Worksheets

Spanish Study Workbook, 11.3 Worksheets

Lab Manual B, 11.3 Data Analysis Worksheet

BIOLOGY.com Lesson Overview • Lesson Notes • Activities: Art Review • Assessment: Self-Test, Lesson Assessment

For corresponding lesson in the **Foundation Edition**, see pages 271–274.

Activate Prior Knowledge

Tell students to think about all the different shades of hair color that humans have. Then, ask if they think that hair color is controlled by just one gene. Lead students to conclude that there is likely more than one gene responsible for the color of human hair.

BIOLOGY.com Students can drag and drop labels to correctly finish diagrams of three Punnett squares in the activity **Art Review: Exceptions to Mendel's Principles.**

NEXT GENERATION SUNSHINE STATE STANDARDS

For the full text of all benchmarks, see the Course Overview in the front matter of this book.

Other key benchmarks: **SC.912.L.16.1** Use Mendel's laws of segregation and independent assortment to analyze patterns of inheritance.

Teach continued

Lead a Discussion

Explain that there being more than two alleles for a gene is common in a population. Make sure students understand, though, that any given individual in this population will have only two of those alleles. To illustrate this point, write the symbols for four alleles for rabbit coat color on the board in order from the most dominant to the least dominant: C = full color, C^{ch} = chinchilla color, C^{h} = Himalayan color, c = albino (no color). Have students make up genetic crosses for coat color in rabbits. If desired, have them exchange their proposed crosses with a partner who can then use Punnett squares to solve the problems.

DIFFERENTIATED INSTRUCTION

LPR **Less Proficient Readers** Help struggling students better understand lesson concepts by completing a **Jigsaw Review** activity. Form small learning circles of four students each. Assign each group member a number from 1 to 4. Have students regroup into study groups according to number (for example, all 1s together). Assign each group one of the four sections of text with blue heads under **Beyond Dominant and Recessive Alleles.** Have groups review the topic and create a brief lesson on it. Then, instruct students to re-form their original learning circles, and have each member of a circle teach the other members about his or her topic. If you have more students, add **Genes and the Environment** as a topic.

Study Wkbks A/B, Appendix S7, Jigsaw Review.

MYSTERY CLUE Have students discuss whether they think feather color is polygenic. Lead them to conclude that there are likely two genes controlling feather color, one for each pigment. Students can go online to **Biology.com** to gather their evidence.

Address Misconceptions

Polygenic Traits Many students think that one gene is always responsible for one trait. Explain that such a case is actually rare. Most traits—such as hair and eye color in humans—are influenced by multiple genes.

Answers

IN YOUR NOTEBOOK Students' descriptions should reflect that multiple alleles are more than two forms of the same gene in a population and polygenic traits have more than one gene contributing to the phenotype of an individual.

Analyzing Data

SC.912.N.1.1, SC.912.N.1.6, SC.912.L.16.2, MA.912.S.3.2

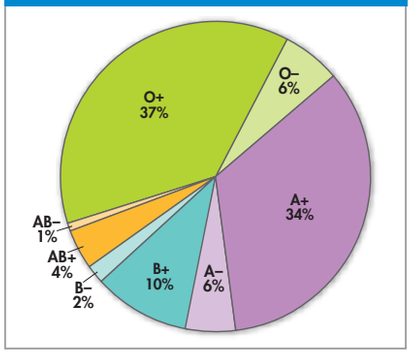
Human Blood Types

Red blood cells carry antigens, molecules that can trigger an immune reaction, on their surfaces. Human blood type A carries an A antigen, type B has a B antigen, type AB has both antigens, and type O carries neither antigen. The gene for these antigens has three alleles; A, B, and O.

For a transfusion to succeed, it must not introduce a new antigen into the body of the recipient. So, a person with type A blood may receive type O, but not vice versa.

Another gene controls a second type of antigen, known as Rh factor. Rh^+ individuals carry this antigen, while Rh^- ones don't. This chart of the U.S. population shows the percentage of each blood type.

Blood Groups in the U.S. Population



1. **Interpret Graphs** Which blood type makes up the greatest percentage of the U.S. population?
2. **Calculate** What percentage of the total U.S. population has a positive Rh factor? What percentage has a negative Rh factor?
3. **Infer** Which blood type can be used for transfusion into the largest percentage of individuals? Which type has the smallest percentage of possible donors available?
4. **Predict** Could a person with O^+ blood have two parents with O^- blood? Could that person have a daughter with AB^+ blood? Explain your answers.

MYSTERY CLUE

Green feathers don't actually contain green pigments. Rather, they contain a mixture of blue and yellow pigments. Could feather color be controlled by more than one gene?

Multiple Alleles So far, our examples have described genes for which there are only two alleles, such as *a* and *A*. In nature, such genes are the exception rather than the rule. **Many genes exist in several different forms and are therefore said to have multiple alleles.** A gene with more than two alleles is said to have **multiple alleles.** An individual, of course, usually has only two copies of each gene, but many different alleles are often found within a population. One of the best-known examples is coat color in rabbits. A rabbit's coat color is determined by a single gene that has at least four different alleles. The four known alleles display a pattern of simple dominance that can produce four coat colors. Many other genes have multiple alleles, including the human genes for blood type.

Polygenic Traits **Many traits are produced by the interaction of several genes.** Traits controlled by two or more genes are said to be **polygenic traits.** *Polygenic* means "many genes." For example, at least three genes are involved in making the reddish-brown pigment in the eyes of fruit flies. Polygenic traits often show a wide range of phenotypes. The variety of skin color in humans comes about partly because more than four different genes probably control this trait.

In Your Notebook *In your own words, describe multiple alleles and polygenic traits. How are they similar? How are they different?*

Analyzing Data

PURPOSE Students will analyze data to make an inference and a prediction about alleles for human blood types.

PLANNING Tell students that the A and B alleles are codominant. A and B are each dominant over O. Explain that the Rh factor is inherited independently of the blood type alleles. Rh^+ is dominant over Rh^-.

ANSWERS

1. O^+
2. 85% are Rh^+; 15% are Rh^-.
3. O^- can be used for 100% of individuals; AB^+ can be used for only 4%.
4. No, because both parents would be homozygous recessive for the Rh factor. They do not have any Rh^+ alleles to pass on. This person could not have an AB^+ daughter, because a person with O^+ blood has only O alleles to pass on.

Genes and the Environment

Does the environment have a role in how genes determine traits?

The characteristics of any organism—whether plant, fruit fly, or human being—are not determined solely by the genes that organism inherits. Genes provide a plan for development, but how that plan unfolds also depends on the environment. In other words, the phenotype of an organism is only partly determined by its genotype.

Consider the western white butterfly, *Pontia occidentalis*. It is found throughout western North America. Butterfly enthusiasts had noted for years that western whites hatching in the summer had different color patterns on their wings than those hatching in the spring. Scientific studies showed the reason—butterflies hatching in the shorter days of springtime had greater levels of pigment in their wings, making their markings appear darker than those hatching in the longer days of summer. In other words, the environment in which the butterflies develop influences the expression of their genes for wing coloration. **Environmental conditions can affect gene expression and influence genetically determined traits.** An individual's actual phenotype is determined by its environment as well as its genes.

In the case of the western white butterfly, these changes in wing pigmentation are particularly important. In order to fly effectively, the body temperature of the butterfly must be 28°C–40°C (about 84°F–104°F) as shown in **Figure 11–13.** Since the spring months are cooler in the west, greater pigmentation helps them reach the body temperature needed for flight. Similarly, in the hot summer months, less pigmentation enables the moths to avoid overheating.

Summer Autumn

Environmental Temperature and Butterfly Needs

Temp. Needed for Flight	Average Spring Temp.	Average Summer Temp.
28–40°C	26.5°C	34.8°C

FIGURE 11–13 Temperature and Wing Color Western white butterflies that hatch in the spring have darker wing patterns than those that hatch in summer. The dark wing color helps increase their body heat. This trait is important because the butterflies need to reach a certain temperature in order to fly. The buckeye butterflies shown above also have different wing patterns at different times of year. These butterflies are darker in the autumn than they are in the summer. **Calculate** *What is the difference between the minimum temperature western white butterflies need to fly and the average spring temperature? Would the same calculation apply to butterflies developing in the summer?* MATH

11.3 Assessment

SC.912.L.14.6, SC.912.L.16.1, SC.912.L.16.2

Review Key Concepts

1. a. Review What does *incomplete dominance* mean? Give an example.

b. Design an Experiment Design an experiment to determine whether the pink flowers of petunia plants result from incomplete dominance.

2. a. Review What is the relationship between the environment and phenotype?

b. Infer What might be the result of an exceptionally hot spring on wing pigmentation in the western white butterfly?

PRACTICE PROBLEM

3. Construct a genetics problem to be given as an assignment to a classmate. The problem must test incomplete dominance, codominance, multiple alleles, or polygenic traits. Your problem must have an answer key that includes all of your work.

BIOLOGY.com Search Lesson 11.3 GO • Self-Test • Lesson Assessment

Lead a Discussion

Point out that "environment" refers to internal factors, too. For example, both men and women can have the genes for male pattern baldness, but baldness shows up more often in men because male hormones trigger the expression of the gene.

DIFFERENTIATED INSTRUCTION

L3 **Advanced Students** Challenge students to design an experiment that shows how environment affects phenotype, using cuttings from a coleus plant.

Assess and Remediate

EVALUATE UNDERSTANDING

Ask volunteers to explain the four patterns of inheritance described in this lesson, as well as how environmental factors can influence phenotypes. Then, have students complete the 11.3 Assessment.

REMEDIATION SUGGESTION

L1 **Struggling Students** If your students have trouble with **Question 1b,** have them work in pairs or small groups to brainstorm possible experiments.

BIOLOGY.com Students can check their understanding of lesson concepts with the **Self-Test** assessment. They can then take an online version of the **Lesson Assessment.**

Answers

FIGURE 11–13 1.5°C; No, because the average summer temperature is greater than the minimum temperature the butterflies need to fly.

Assessment Answers

1a. In incomplete dominance, neither of two alleles is dominant. The phenotype is a blend of the two alleles, such as pink flowers from red and white parents.

1b. Sample answer: Cross two petunia plants with pink flowers. If some of the offspring have red, some have white, and others have pink flowers, the pink color is caused by incomplete dominance.

2a. The environment affects how genes are expressed and therefore influence an organism's phenotype.

2b. The higher temperatures of an unusually hot spring will likely result in lighter wing colors.

PRACTICE PROBLEM

3. Students' problems should follow the rules of genetics and include correct and complete answers.

Teach

Lead a Discussion

Point out that the featured scientist has combined the study of two fields of biology, genetics and immunology. Tell students that population geneticists look at the inheritance of traits in populations rather than in individuals. An immunologist conducts research on the immune system, which is a body system that defends against disease-causing organisms and cancer. Tell students that careers in both areas require advanced degrees with coursework in biology, math, chemistry, computers, and medicine. These careers also require critical thinking skills, complex problem solving, and the ability to communicate orally and in writing.

DIFFERENTIATED INSTRUCTION

L3 **Advanced Students** Suggest interested students find out more about the possible careers that a degree in genetics and immunology might prepare them for. If possible, have them interview a geneticist or immunologist about his or her field of study.

Answers

WRITING Students' explanations might include financial burdens, inadequate health care, and decreased quality of life.

NEXT GENERATION SUNSHINE STATE STANDARDS

For the full text of all benchmarks, see the Course Overview in the front matter of this book.

Careers & BIOLOGY

SC.912.L.14.6 Explain the significance of genetic factors, environmental factors, and pathogenic agents to health from the perspectives of both individual and public health. Also covered: **LA.910.2.2.3**

If you enjoy learning about genetics, you may want to pursue one of the careers listed below.

FORENSIC SCIENTIST

Do you enjoy solving puzzles? That's what forensic scientists do when they solve crimes. Local, state, and federal agencies employ forensic scientists to use scientific approaches that support criminal investigations. Criminalists are forensic scientists who specialize in the analysis of physical evidence, such as hair, fiber, DNA, fingerprints, and weapons. They are often called to testify in trials as expert witnesses.

PLANT BREEDER

Did you ever wonder how seedless watermelons become seedless? They are the product of a plant breeder. Plant breeders use genetic techniques to manipulate crops. Often, the goal is to make a crop more useful by increasing yield or nutritional value. Some breeders introduce new traits, such as pesticide resistance, to the plant's genetic makeup.

POPULATION GENETICIST

Why are certain populations more susceptible to particular diseases? This is the kind of question that population geneticists answer. Their goal is to figure out why specific traits of distinct groups of organisms occur in varying frequencies. The patterns they uncover can lead to an understanding of how gene expression changes as a population evolves.

CAREER CLOSE-UP:

Sophia Cleland, Population Geneticist and Immunologist

Sophia Cleland, a Ph.D. student in immunology at George Washington University, studies the molecular, cellular, and genetic mechanisms that contribute to autoimmune diseases. One of only a few Native Americans with an advanced degree in genetics, Ms. Cleland became interested in autoimmune diseases when she noticed that the frequencies of these illnesses, such as rheumatoid arthritis and lupus, were several times higher among her tribal communities (Lakota-Sioux and California Mission Indian) than among Caucasians. Furthermore, she observed that such diseases progressed more rapidly among these communities than in any other human group in the world. Because of the frequency and severity of these diseases among indigenous tribal groups, Ms. Cleland is spreading the word about the need for focused research in this area.

"A compromise is needed between the world views of indigenous tribal groups and modern scientific approaches to gathering knowledge. We will encounter difficulties, but by working together with an open mind to learn, balanced and just results are possible."

WRITING How do you think a high frequency of genetic illness can affect a population? Explain.

Quick Facts

THE GENETICS OF LUPUS

Lupus presents in different forms, but the most common type damages joints, skin, blood vessels, and organs such as the kidneys and brain. The disease has no cure. Lupus has a complex inheritance pattern. It runs in families but is not solely a genetic disease, leading scientists to think lupus has a genetic susceptibility and is polygenic. The genes involved in lupus vary in populations. The prevalence of lupus is higher in African Americans, Latinos, Asians, and Native Americans. Because lupus is rare in Africa, some scientists think environmental risk factors that are common in the United States and Europe but rare in Africa might trigger the disease.