Chapter 12 Organizer

Refer to pages 4T-5T of the Teacher Guide for an explanation of the National Science Education Standards correlations.

Section	Objectives	Activities/Features
Section 12.1 **Mendelian Inheritance of Human Traits** National Science Education Standards UCP.2, UCP.3; A.1, A.2; C.2; F.1; G.1, G.2 (1 session, 1/2 block)	1. **Interpret** a pedigree. 2. **Determine** human genetic disorders that are caused by inheritance of recessive alleles. 3. **Predict** how a human disorder can be determined by a simple dominant allele.	**MiniLab 12-1:** Illustrating a Pedigree, p. 316 **Problem-Solving Lab 12-1,** p. 317
Section 12.2 **When Heredity Follows Different Rules** National Science Education Standards UCP.2, UCP.3; A.1, A.2; C.2; F.4; G.1-3 (3 sessions, 2 1/2 blocks)	4. **Distinguish** between incompletely dominant and codominant alleles. 5. **Compare** multiple allelic and polygenic inheritance. 6. **Analyze** the pattern of sex-linked inheritance. 7. **Summarize** how internal and external environments affect gene expression.	**Problem-Solving Lab 12-2,** p. 324 **Design Your Own BioLab:** What is the pattern of cytoplasmic inheritance? p. 336
Section 12.3 **Complex Inheritance of Human Traits** National Science Education Standards UCP.2, UCP.3, UCP.5; A.1, A.2; C.2; F.1; G.1-3 (2 sessions, 1 1/2 blocks)	8. **Compare** codominance, multiple allelic, sex-linked, and polygenic patterns of inheritance in humans. 9. **Distinguish** among conditions in which extra autosomal or sex chromosomes exist.	**Inside Story:** The ABO Blood Group, p. 331 **Problem-Solving Lab 12-3,** p. 332 **MiniLab 12-2:** Detecting Colors and Patterns in Eyes, p. 333 **Social Studies Connection:** Queen Victoria and Royal Hemophilia, p. 338

Need Materials? Contact Carolina Biological Supply Company at 1-800-334-5551 or at **http://www.carolina.com**

MATERIALS LIST

BioLab

p. 336 *Brassica* rapa seeds (normal and variegated), potting soil, potting trays, paintbrushes, forceps, single-edge razor blade, light source, labels

MiniLabs

p. 316 pencil, paper
p. 333 hand lens, colored pencils, paper

Alternative Lab

p. 322 petri dish, label, paper towels, scissors, tobacco seeds
p. 332 microscope, prepared slides of male and female human cheek cells

Quick Demos

p. 318 none
p. 323 none
p. 334 none

Key to Teaching Strategies

- L1 Level 1 activities should be appropriate for students with learning difficulties.
- L2 Level 2 activities should be within the ability range of all students.
- L3 Level 3 activities are designed for above-average students.
- ELL ELL activities should be within the ability range of English Language Learners.
- COOP LEARN Cooperative Learning activities are designed for small group work.
- P These strategies represent student products that can be placed into a best-work portfolio.
- These strategies are useful in a block scheduling format.

Patterns of Heredity and Human Genetics

Teacher Classroom Resources

Section	Reproducible Masters	Transparencies
Section 12.1 **Mendelian Inheritance of Human Traits**	Reinforcement and Study Guide, p. 51 L2 Critical Thinking/Problem Solving, p. 12 L3 BioLab and MiniLab Worksheets, p. 57 L2 Tech Prep Applications, pp. 19-20 L2 Content Mastery, pp. 57-58, 60 L1	Section Focus Transparency 29 L1 ELL Reteaching Skills Transparency 20 L1 ELL
Section 12.2 **When Heredity Follows Different Rules**	Reinforcement and Study Guide, pp. 52-53 L2 Concept Mapping, p. 12 L3 ELL Laboratory Manual, pp. 83-86 L2 Content Mastery, pp. 57, 59-60 L1	Section Focus Transparency 30 L1 ELL Reteaching Skills Transparency 21 L1 ELL
Section 12.3 **Complex Inheritance of Human Traits**	Reinforcement and Study Guide, p. 54 L2 BioLab and MiniLab Worksheets, pp. 58-60 L2 Laboratory Manual, pp. 87-90 L2 Content Mastery, pp. 57, 60 L1	Section Focus Transparency 31 L1 ELL

Assessment Resources

Chapter Assessment, pp. 67-72
MindJogger Videoquizzes
Performance Assessment in the Biology Classroom
Alternate Assessment in the Science Classroom
Computer Test Bank
BDOL Interactive CD-ROM, Chapter 12 quiz

Additional Resources

Spanish Resources ELL
English/Spanish Audiocassettes ELL
Cooperative Learning in the Science Classroom COOP LEARN
Lesson Plans/Block Scheduling

NATIONAL GEOGRAPHIC Teacher's Corner

Index to National Geographic Magazine

The following articles may be used for research relating to this chapter:

"The Family Line: The Human-Cat Connection," by Stephen J. O'Brien, June 1997.

GLENCOE TECHNOLOGY

The following multimedia resources are available from Glencoe.

Biology: The Dynamics of Life

CD-ROM ELL
Exploration: *Trait Inheritance*
Video: *Fruit Fly Genetics*
Animation: *Sex-linked Traits*
Exploration: *Blood Types*

Videodisc Program
Sex-linked Traits

The Infinite Voyage
A Taste of Health
The Geometry of Life

Chapter 12

Getting Started Demo

Many genes are needed to code for all the traits shown by the family in the photo. Demonstrate how this large amount of DNA can fit into the small volume of a chromosome by coiling a long piece of wire. First, coil the wire so that it looks like a telephone cord, then coil the coiled wire to make it even more compact.

Theme Development

The main theme of the chapter is **homeostasis**, which is normally maintained during the transmission of genetic material but is disrupted by the inheritance of particular alleles that result in genetic disorders. The **nature of science** is illustrated by the concepts developed by Morgan as he worked with and interpreted data from sex-linked traits.

0:00 Out of Time?

If time does not permit teaching the entire chapter, use the BioDigest at the end of the unit as an overview.

Chapter 12

Patterns of Heredity and Human Genetics

What You'll Learn

- You will compare the inheritance of recessive and dominant traits in humans.
- You will analyze the inheritance of incompletely dominant and codominant traits.
- You will determine the inheritance of sex-linked traits.

Why It's Important

The transmission of traits from generation to generation affects your appearance, your behavior, and your health. Understanding how these traits are inherited is important in understanding the traits you may pass on to a future generation.

Getting Started

All in a Family

Examine the family photo on this page. Notice the physical traits of each family member, how they are similar, and how they are different. *How do genes make these people look like they do?*

interNET CONNECTION To find out more about human genetics, visit the Glencoe Science Web Site. **www.glencoe.com/sec/science**

Magnification: 4500×

It is difficult to imagine how the information for such varied traits as eye or hair color and athletic talent could be contained in the nucleic acids composing this chromosome.

Section 12.1

Section 12.1 Mendelian Inheritance of Human Traits

SECTION PREVIEW

Objectives

Interpret a pedigree.

Determine human genetic disorders that are caused by inheritance of recessive alleles.

Predict how a human trait can be determined by a simple dominant allele.

Vocabulary

pedigree
carrier
fetus

As you learn about traits, you will see that some, such as tongue rolling or a widow's peak hairline, are relatively harmless. Other traits produce devastating disorders and even death. All of these traits demonstrate how genes are inherited, and this is what you need to learn. The disorders caused by genetic transmission of traits are the motivation that drives scientists to do research to discover treatments and cures.

Tongue rolling (above) and widow's peak hairline (inset)

Making a Pedigree

At some point, you have probably seen a family tree, either for your family or for someone else's. A family tree traces a family name and various family members through successive generations. Through a family tree, you can trace your cousins, aunts, uncles, grandparents, and great-grandparents.

Pedigrees illustrate inheritance

Geneticists often need to map the inheritance of genetic traits from generation to generation. A **pedigree** is a graphic representation of genetic inheritance. At a glance, it looks very similar to any family tree.

A pedigree is made up of a set of symbols that identify males and females, individuals affected by the trait being studied, and family relationships. Some commonly used symbols are shown in ***Figure 12.1.*** A circle represents a female; a square

Figure 12.1 **Geneticists use these symbols to make and analyze a pedigree.**

Multiple Learning Styles

Look for the following logos for strategies that emphasize different learning modalities.

Kinesthetic Meeting Individual Needs, pp. 324, 326; Project, p. 327

Visual-Spatial Quick Demo, pp. 318, 334; Reteach, pp. 320, 335; Portfolio, p. 325; Meeting Individual Needs, p. 326; Microscope Activity, p. 330

Intrapersonal Meeting Individual Needs, p. 317; Extension, p. 327

Linguistic Portfolio, pp. 316, 330; Biology Journal, pp. 319, 331; Check for Understanding, p. 335

Logical-Mathematical Activity, p. 328

Assessment Planner

Portfolio Assessment
- **Portfolio, TWE,** pp. 316, 321, 325, 330
- **Problem-Solving Lab, TWE,** p. 324
- **Assessment, TWE,** p. 330

Performance Assessment
- **Problem-Solving Lab, TWE,** p. 317
- **Assessment, TWE,** pp. 318, 323, 328, 334
- **Alternative Lab, TWE,** p. 332-333
- **MiniLab, SE,** pp. 316, 333
- **BioLab, SE,** pp. 336-337

Skill Assessment
- **Assessment, TWE,** pp. 320, 335
- **Alternative Lab, TWE,** pp. 322-323
- **BioLab, TWE,** pp. 336-337

Knowledge Assessment
- **MiniLab, TWE,** pp. 316, 333
- **Problem-Solving Lab, TWE,** p. 332
- **Section Assessment, SE,** pp. 320, 328, 335
- **Chapter Assessment, SE,** pp. 339-341

Section 12.1

Prepare

Key Concepts

The section begins with a discussion of pedigrees and their interpretation. Then the inheritance of autosomal recessive disorders such as cystic fibrosis, phenylketonuria, and Tay-Sachs disease is described. The section closes with a discussion of autosomal traits such as tongue rolling, widow's peak, and Huntington's disease.

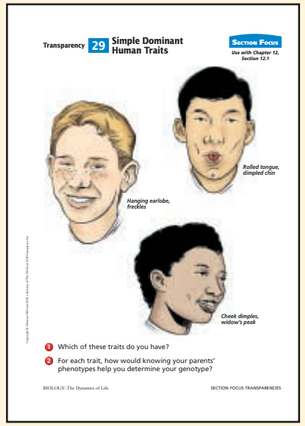
Planning

- Obtain a long piece of wire for the Getting Started Demo.

1 Focus

Bellringer

Before presenting the lesson, display **Section Focus Transparency 29** on the overhead projector and have students answer the accompanying questions. L1 ELL



2 Teach

MiniLab 12-1

Purpose
Students will observe a specific human trait and prepare a pedigree.

Process Skills
observe and infer, interpret scientific illustrations

Teaching Strategies
- If any of your students are adopted, be sure he or she is paired with a student who is not adopted and can contribute family information to the pair's pedigree.
- Provide students with information about various human traits that are inherited in a simple Mendelian pattern.

Expected Results
Students will construct pedigrees of a human trait.

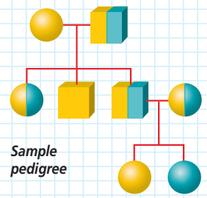
Analysis
1. Answers may include earlobe shape, widow's peak, tongue rolling, or ability to taste PTC paper.
2. The number of individuals may be too small to determine the inheritance pattern.

Assessment
Knowledge Provide a pedigree that consists of only a few individuals and has enough information so that students can determine genotypes for the given phenotypes. Use the Performance Task Assessment List for Analyzing the Data in **PASC,** p. 27. L1

Resource Manager
BioLab and MiniLab Worksheets, p. 57 L2
Section Focus Transparency 29 and Master L1 ELL

MiniLab 12-1 Analyzing Information

Illustrating a Pedigree The pedigree method of studying a trait in a family uses records of phenotypes extending for two or more generations. Studies of pedigrees can be used to yield a great deal of genetic information about a related group.


Sample pedigree

Procedure
1. Working with a partner, choose one human trait, such as attached and free-hanging earlobes or tongue rolling, that interests both of you.
2. Using either your or your partner's family, collect information about your chosen trait. Include whether each individual is male or female, does or does not have the trait, and the relationship of the individual to others in the family.
3. Use your information to draw a pedigree for the trait.
4. Try to determine how your trait is inherited.

Analysis
1. What trait did you study? Can you determine from your pedigree what the apparent inheritance pattern of the trait is?
2. How is the study of inheritance patterns limited by pedigree analysis?

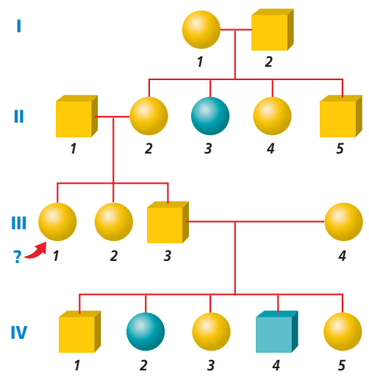


Figure 12.2 This pedigree shows how a rare, recessive allele is transmitted from generation to generation.

represents a male. Shaded circles and squares represent individuals showing the trait being studied. Unshaded circles and squares designate individuals that do not show the trait. A half-shaded circle or square represents a **carrier,** a heterozygous individual. A horizontal line connecting a circle and a square indicates that the individuals are parents, and a vertical line connects a set of parents with their offspring. Each horizontal row of circles and squares in a pedigree designates a generation, with the most recent generation shown at the bottom. The generations are identified in sequence by Roman numerals, and each individual is given an Arabic number. You can practice using these symbols to make a pedigree in the *MiniLab* on this page.

Analyzing a pedigree

An example of a pedigree for a fictitious rare, recessive disorder in humans is shown in ***Figure 12.2.*** This disorder could be any of several recessive disorders in which the disorder shows up only if the affected person carries two recessive alleles for the trait. Follow the pedigree as you read how to analyze it.

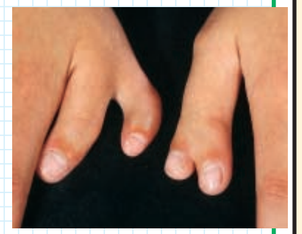
Suppose individual III-1 in the pedigree wants to know the likelihood of passing on this allele to her children. By studying the pedigree, the individual will be able to determine the likelihood that she carries the allele. Notice that information can also be gained about other members of the family by studying the pedigree. For example, you know that I-1 and I-2 are both carriers of the recessive allele for the trait because they have produced II-3, who shows the recessive phenotype. If you drew a Punnett square for the mating of individuals I-1 and I-2, you would find, according to Mendelian segregation, that the ratio of homozygous dominant to heterozygous to homozygous recessive genotypes among their children would be 1: 2: 1. Of those genotypes possible for the members of generation II, only the homozygous recessive genotype will express the trait, which is the case for II-3.

You can't tell the genotypes of II-4 and II-5, but they have a normal phenotype. If you look at the Punnett square you made, you can see that the probability of II-4 and of II-5 being a carrier is each two out of three because they can have only two possible genotypes—homozygous normal and heterozygous. The homozygous recessive genotype is not a possibility in these individuals because neither of them shows the affected phenotype.

Because none of the children in generation III are affected and because the recessive allele is rare, it is reasonably safe to assume that II-1 is not a carrier. You know that individual II-2 must be a carrier like her parents because she has passed on the recessive allele to subsequent generation IV. Because individual III-1 has one parent who is heterozygous and the other parent who is assumed to be homozygous normal, III-1 most likely has a one-in-two chance of being a carrier. If her parent II-1 had been heterozygous instead of homozygous normal, III-1's chances of being a carrier are increased to two in three.

Problem-Solving Lab 12-1 Applying Concepts

What are the chances? Using a Punnett square allows you to calculate the chance that offspring will be born with certain traits. In order to do this, however, you must first know the genotype of the parents and whether the trait that is being described is dominant or recessive.


Polydactyly—having six fingers

Analysis
The following traits and their alleles are to be used in solving problems.

Table 12.1 Human traits

Trait	Dominant allele	Recessive allele
Number of fingers	*D* = six	*d* = five
Tongue rolling	*T* = can roll	*t* = cannot roll
Cystic fibrosis	*C* = normal	*c* = disorder

Thinking Critically
1. What are the chances that a child will be born with six fingers if
   a. both parents are heterozygous?
   b. one parent has five fingers, the other is heterozygous?
   c. both parents have five fingers?
2. How many children in a family of four will be able to roll their tongues if
   a. one parent is a nonroller and the other is a homozygous roller?
   b. both parents are rollers and both are homozygous?
   c. both parents are rollers and each of them has a parent who cannot roll his or her tongue?
3. A child is born with cystic fibrosis but both parents are normal.
   a. What are the genotypes and phenotypes for the parents?
   b. What is the genotype and phenotype for the child?

Simple Recessive Heredity

Most genetic disorders are caused by recessive alleles. Many of these alleles are relatively rare, but a few are common in certain ethnic groups. You can practice calculating the chance that offspring will be born with some of these genetic traits in the *Problem-Solving Lab* above.

Portfolio

Blue People
Linguistic Have students read "The Blue People of Troublesome Creek," by Cathy Trost, *Science 82,* Nov. 1982, pp. 34-39, and construct a pedigree from the article. These people have an autosomal recessive gene that causes their skin to appear dark blue. Have students explain this disorder. L2

GLENCOE TECHNOLOGY
CD-ROM
Biology: The Dynamics of Life
Exploration: *Trait Inheritance*
Disc 2

TECHPREP

Human Genetic Disorders
Have students make a notebook collection of newspaper or magazine articles on human genetic disorders. Ask them to write a paragraph or two about the sensitivity of these articles. L2

MEETING INDIVIDUAL NEEDS

Gifted
Intrapersonal Have interested students research a genetic disorder commonly found in Amish populations, polydactyly, or other disorders not mentioned in the chapter (achondroplasia, Marfan's syndrome, albinism, galactosemia, or thalassemia are examples). L3

Problem-Solving Lab 12-1

Purpose
Students will use Punnett squares to determine the chance of offspring receiving certain traits.

Process Skills
apply concepts, draw a conclusion, predict, think critically

Teaching Strategies
- Review the technique for setting up, using, and completing Punnett squares.
- Review the terminology used in describing traits: homozygous, heterozygous, dominant, recessive, genotype, phenotype.
- Review the meaning of the phrase "chance that" when referring to the outcome of a Punnett square.

Thinking Critically
1. a. three out of four
   b. two out of four
   c. no chance of child having six fingers
2. a. all will roll their tongues
   b. all children will be rollers
   c. three out of four will be rollers
3. a. Both parents are *Cc* and have normal phenotypes.
   b. The child is *cc* and has cystic fibrosis.

Assessment
Performance Take a class survey for tongue rolling. Ask students to predict their genotypes. *Only those who cannot roll their tongues can predict correctly. All others are either homozygous dominant or heterozygous.* Use the Performance Task Assessment List for Conducting a Survey and Graphing the Results in **PASC,** p. 35. L1

Assessment

Performance Assessment in the Biology Classroom, p. 15, *Inheritance of Human Traits.* Have students carry out this activity after they have learned about Mendelian inheritance. L1

Visual Learning

Figure 12.3 Ask students why this pedigree is a characteristic of a recessive trait. *An individual must have two recessive alleles to show a trait. Because these traits are rare, an affected individual most likely will mate with an individual with two dominant alleles. The offspring will be heterozygous and will not show the trait. The trait may reappear when two heterozygotes mate.*

Quick Demo

Visual-Spatial Draw a Punnett square on the board showing the mating between two heterozygotes for a trait such as Tay-Sachs disease. Then draw a pedigree for the trait. Explain to students that a Punnett square predicts the probability of inheriting a trait in one mating, whereas a pedigree can follow a trait for generations. L1

Resource Manager

Reteaching Skills Transparency 20 and Master L1 ELL
Concept Mapping, p. 12 L3 ELL

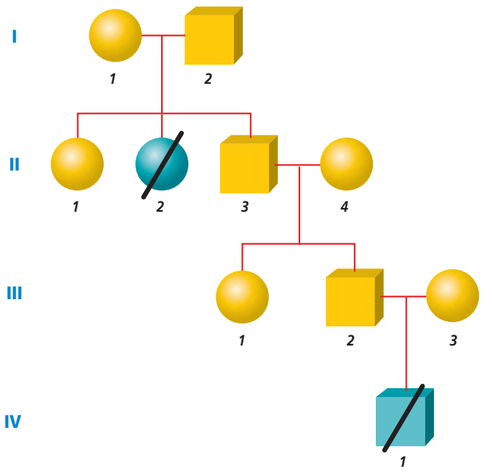
Cystic fibrosis

Cystic fibrosis (CF) is the most common genetic disorder among white Americans. Approximately one in 20 white Americans carries the recessive allele, and one in 2000 children born to white Americans inherits the disorder. Due to a defective protein in the plasma membrane, cystic fibrosis results in the formation and accumulation of thick mucus in the lungs and digestive tract. Physical therapy, special diets, and new drug therapies have continued to raise the average life expectancy of CF patients.

Tay-Sachs disease

Tay-Sachs (tay saks) disease is a recessive disorder of the central nervous system. In this disorder, a recessive allele results in the absence of an enzyme that normally breaks down a lipid produced and stored in tissues of the central nervous system. Therefore, this lipid fails to break down properly and accumulates in the cells. The allele for Tay-Sachs is especially common in the United States among the Amish people and among Ashkenazic Jews, whose ancestors came from eastern Europe. ***Figure 12.3*** shows a typical pedigree for Tay-Sachs disease.

Figure 12.3
A study of families who have children with Tay-Sachs disease shows typical pedigrees for traits inherited as simple recessives. Note that the trait appears to skip generations, a characteristic of a recessive trait.



Phenylketonuria

Phenylketonuria (fen ul keet un YOOR ee uh), also called PKU, is a recessive disorder that results from the absence of an enzyme that converts one amino acid, phenylalanine, to a different amino acid, tyrosine. Because phenylalanine cannot be broken down, it and its by-products accumulate in the body and result in severe damage to the central nervous system. The PKU allele is most common among people whose ancestors came from Norway or Sweden.

A homozygous PKU newborn appears healthy at first because its mother's normal enzyme level prevented phenylalanine accumulation during development. However, once the infant begins drinking milk, which is rich in phenylalanine, the amino acid accumulates and mental retardation occurs. Today, a PKU test is normally performed on all infants a few days after birth. Infants affected by PKU are given a diet that is low in phenylalanine until their brains are fully developed. With this special diet, the toxic effects of the disorder can be avoided.

Ironically, the success of treating phenylketonuria infants has resulted in a new problem. If a female who is homozygous recessive for PKU becomes pregnant, the high phenylalanine levels in her blood can damage her **fetus**—the developing baby. This problem occurs even if the fetus is heterozygous and would be phenotypically normal. You may have noticed PKU warnings on cans of diet soft drinks. Because most diet drinks are sweetened with an artificial sweetener that contains phenylalanine, a pregnant woman who is homozygous recessive must limit her intake of diet foods.

Internet Address Book

internNET CONNECTION Note Internet addresses that you find useful in the space below for quick reference.

_____

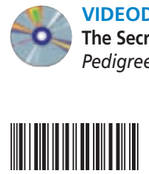
_____

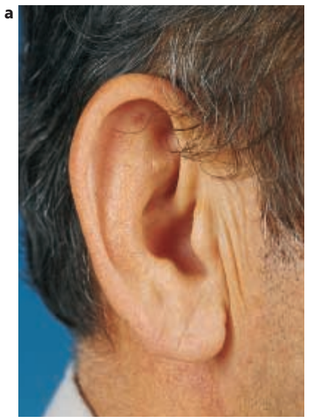
_____

_____

GLENCOE TECHNOLOGY

VIDEODISC
The Secret of Life
Pedigree/Family—PKU





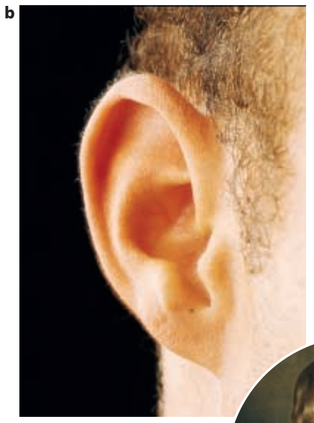


Figure 12.4
The allele *F* for freely hanging earlobes (a) is dominant to the allele *f* for attached earlobes (b). The Hapsburg lip, a protruding lower lip that results in a half-open mouth, has been traced back to the fourteenth century through portraits of members of the Hapsburg Dynasty of Europe (c).

Simple Dominant Heredity

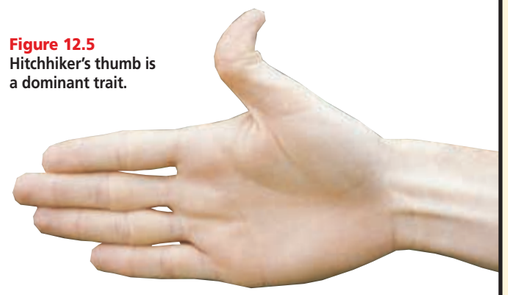
Unlike the inheritance of recessive traits in which a recessive allele must be inherited from both parents for a person to show the recessive phenotype, many traits are inherited just as the rule of dominance predicts. Remember that in Mendelian inheritance, a single dominant allele inherited from one parent is all that is needed for a person to show the dominant trait.

Simple dominant traits

Tongue rolling is one example of a simple dominant trait. If you can roll your tongue, you've inherited the dominant allele from at least one of your parents. A Hapsburg lip is shown in ***Figure 12.4*** along with earlobe types, another dominant trait that is determined by simple Mendelian inheritance. Having earlobes that are attached to the head is a recessive trait *(ff)*, whereas heterozygous *(Ff)* and homozygous dominant *(FF)* individuals have earlobes that hang freely.

There are many other human traits that are inherited by simple dominant inheritance. ***Figure 12.5*** shows one of these traits—hitchhiker's thumb, the ability to bend your thumb tip

Figure 12.5
Hitchhiker's thumb is a dominant trait.



Biology Journal

Huntington's Disease

Linguistic Have students write a paragraph in which they discuss the pros and cons of genetic testing for this disorder. Would they want to know whether they carry the allele if either parent had the disorder? L2

Chalkboard Example

Place Punnett squares on the chalkboard to demonstrate possible inheritance patterns of each genetic disorder described in the text.

Display

Collect articles and pamphlets on various genetic disorders and post them on the bulletin board. The March of Dimes organization is a good source of materials.

GLENCOE TECHNOLOGY

VIDEODISC
The Infinite Voyage
A Taste of Health
Genetic Links to Cholesterol
(Ch. 6), 4 min.

The Infinite Voyage
The Geometry of Life
Huntington's Disease and Inheritance of the Deadly Gene
(Ch. 6), 6 min. 30 sec.

VIDEODISC
VIDEOTAPE
The Secret of Life
Tinkering with our Genes: Genetic Medicine

Resource Manager

Tech Prep Applications, pp. 17-18 L2
Reinforcement and Study Guide, p. 51 L2
Content Mastery, p. 58 L1

3 Assess

Check for Understanding

Ask students to summarize why the study of genetics is important to couples considering having children.

Reteach

Visual-Spatial Have students make a table of the genetic disorders described in this section, including the type of inheritance and the effects of the disorder on an affected individual. L1

Extension

Ask student groups to contact the local March of Dimes organization to gather information on the help it gives individuals with genetic disorders. Students can give a report on their findings. L1 COOP LEARN

Assessment

Skill Ask students to design a handout that tells about a genetic disorder. Students could draw Punnett squares and illustrate the chances of offspring inheriting the disorder from parents who are carriers. L1

4 Close

Discussion

Discuss with students whether genetic testing should be required before obtaining a marriage license.

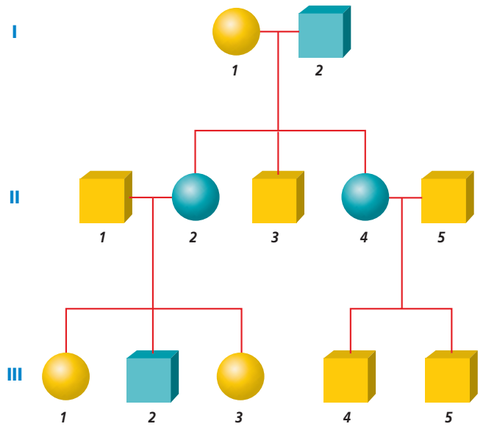


Figure 12.6
A typical pedigree for a simple dominant trait such as Huntington's disease shows the trait in each generation and equally distributed among males and females.

backward more than 30 degrees. A straight thumb is recessive. Other dominant traits in humans include almond-shaped eyes (round eyes are recessive), thick lips (thin lips are recessive), and the presence of hair on the middle section of your fingers.

Huntington's disease

Huntington's disease is a lethal genetic disorder caused by a rare dominant allele. It results in a breakdown of certain areas of the brain. No effective treatment exists.

Ordinarily, a dominant allele with such severe effects would result in death before the affected individual could have children and pass the allele on to the next generation. But because the onset of Huntington's disease usually occurs between the ages of 30 and 50, an individual may have children before knowing whether he or she carries the allele. A genetic test has been developed that allows individuals to check their DNA. Although this test allows carriers to decide whether they want to have children and risk passing the trait on to future generations, it also places a tremendous burden on them in knowing they will develop the disease. For this reason, some people may choose not to be tested. The pedigree in ***Figure 12.6*** shows a typical pattern of occurrence of Huntington's disease in a family.

Notice that every child of an affected individual has a 50 percent chance of being affected and then a 50 percent chance of passing the defective allele to his or her own child.

Section Assessment

Understanding Main Ideas

1. In your own words, define the following symbols used in a pedigree: a square, a circle, an unshaded circle, a shaded square, a horizontal line, and a vertical line.
2. Describe one genetic disorder that is inherited as a recessive trait.
3. How are the cause and onset of symptoms of Huntington's disease different from those of PKU and Tay-Sachs disease?
4. Describe one trait that is inherited as a dominant allele. If you carried that trait, would you necessarily pass it on to your children?

Thinking Critically

5. Suppose that a child with free-hanging earlobes has a mother with attached earlobes. Can a man with attached earlobes be the child's father?

Skill Review

6. **Interpreting Scientific Illustrations** Make a pedigree for three generations of a family that shows at least one member of each generation who demonstrates a particular trait. Would this trait be dominant or recessive? For more help, refer to *Thinking Critically* in the **Skill Handbook.**

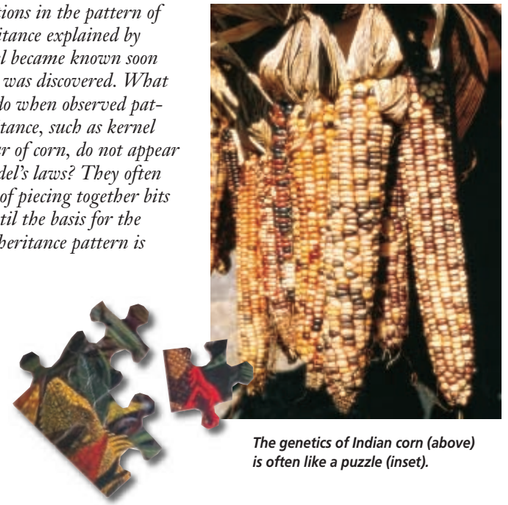
Section Assessment

1. A square represents a male, a circle a female. An unshaded circle is an unaffected female. A shaded square is an affected male. A horizontal line indicates two parents. A vertical line indicates offspring (children).
2. Students could describe cystic fibrosis, Tay-Sachs, or phenylketonuria.
3. Huntington's disease is an autosomal dominant disorder with onset between the ages of 30 and 50, whereas PKU and Tay-Sachs disease are autosomal recessive disorders with onset at birth.
4. Huntington's disease, tongue rolling, widow's peak, a Hapsburg lip are all examples of dominant traits. If your children inherit even one dominant allele from you, they will express a dominant trait.
5. The man cannot be the father because the child had to receive an allele for free-hanging earlobes from one parent; the father would have to have at least one dominant allele for this trait.
6. This trait would be dominant. See Figure 12.6 for a sample pedigree.

Section

12.2 When Heredity Follows Different Rules

Variations in the pattern of inheritance explained by Mendel became known soon after his work was discovered. What do geneticists do when observed patterns of inheritance, such as kernel color in this ear of corn, do not appear to follow Mendel's laws? They often use a strategy of piecing together bits of a puzzle until the basis for the unfamiliar inheritance pattern is understood.



The genetics of Indian corn (above) is often like a puzzle (inset).

SECTION PREVIEW

Objectives

Distinguish between incompletely dominant and codominant alleles.

Compare multiple allelic and polygenic inheritance.

Analyze the pattern of sex-linked inheritance.

Summarize how internal and external environments affect gene expression.

Vocabulary

incomplete dominance
codominant alleles
multiple alleles
autosome
sex chromosome
sex-linked trait
polygenic inheritance

Complex Patterns of Inheritance

Patterns of inheritance that are explained by Mendel's experiments are often referred to as simple Mendelian inheritance—the inheritance controlled by dominant and recessive paired alleles. However, many inheritance patterns are more complex than those studied by Mendel. As you will learn, most traits are not simply dominant or recessive. The *BioLab* at the end of this chapter investigates a type of inheritance that doesn't even involve chromosomes.

Incomplete dominance: Appearance of a third phenotype

When inheritance follows a pattern of dominance, heterozygous and homozygous dominant individuals both have the same phenotype. When traits are inherited in an **incomplete dominance** pattern, however, the phenotype of the heterozygote is intermediate between those of the two homozygotes. For example, if a homozygous red-flowered snapdragon plant *(RR)* is crossed with a homozygous white-flowered snapdragon plant *(R'R')*, all of the F_1 offspring will have pink

Biology Journal

Codominance

Provide students with practice working with codominance by having them determine the phenotypes of offspring resulting from the following crosses. (a) a checkered rooster mated to a checkered hen; (b) a checkered rooster mated to a white hen; (c) a checkered rooster mated to a black hen. L2

Portfolio

Comparing Inheritance Patterns

Have students show through a series of Punnett squares how the genotypic and phenotypic ratios of the offspring would differ if the trait for chicken feather color were inherited through Mendelian dominance and incomplete dominance compared with the actual pattern of codominance. L3 P

Prepare

Key Concepts

Students are shown the difference between codominance and incomplete dominance and are given examples of multiple-allelic traits, sex-linked traits, and polygenic inheritance. The section ends with a brief description of how internal and external environmental factors can affect the appearance of certain traits.

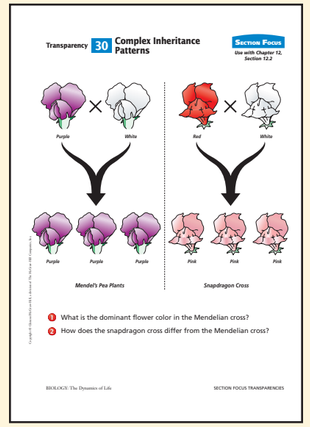
Planning

- Gather small pots, soil, and lights for the BioLab.
- Make cardboard X and Y chromosomes for Meeting Individual Needs.
- Buy mustard seeds for the Project.

1 Focus

Bellringer

Before presenting the lesson, display **Section Focus Transparency 30** on the overhead projector and have students answer the accompanying questions. L1 ELL



2 Teach

Discussion

Exhibit photos of a red shorthorn bull, a white shorthorn cow, and a roan shorthorn cow. Tell students that the roan cow, offspring of the red bull and the white cow, has both red and white hairs. Ask students whether Mendel's law of dominance applies to the inheritance of coat color in cattle. Why or why not? *No, because a third phenotype appears when the red and white cattle are crossed, and traits that Mendel studied had only two phenotypes.* Ask students what type of inheritance pattern explains how roan cattle express their coat color. *codominance*

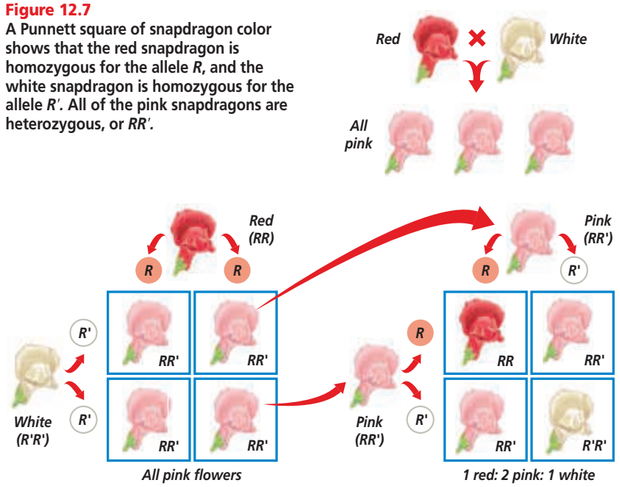
GLENCOE TECHNOLOGY

VIDEODISC
The Secret of Life
Incomplete Dominance

DESIGN YOUR OWN BioLab
The BioLab at the end of the chapter can be used at this point in the lesson.

Resource Manager
Section Focus Transparency 30 and Master L1 ELL

Figure 12.7
A Punnett square of snapdragon color shows that the red snapdragon is homozygous for the allele *R*, and the white snapdragon is homozygous for the allele *R′*. All of the pink snapdragons are heterozygous, or *RR′*.



flowers, as shown in ***Figure 12.7.*** The intermediate pink form of the trait occurs because neither allele of the pair is completely dominant. Note that the letters *R* and *R′*, rather than *R* and *r*, are used to show that these alleles are incompletely dominant.

The new phenotype occurs because the flowers contain a colored pigment. The *R* allele codes for an enzyme that produces a red pigment. The *R′* allele codes for a defective enzyme that makes no pigment. Because the heterozygote has only one copy of the *R* allele, its flowers produce only half the amount of red pigment that the flowers of the red homozygote produce, and they appear pink. The *R′R′* homozygote has no normal enzyme, produces no red pigment, and appears white.

Note that the segregation of alleles is the same as in simple Mendelian inheritance. However, because neither allele is dominant, the plants of the F_1 generation all have pink flowers. When pink-flowered F_1 plants are crossed with each other, the offspring in the F_2 generation appear in a 1: 2: 1 phenotypic ratio of red to pink to white flowers. This result supports Mendel's law of independent assortment, which states that the alleles are inherited independently.

Codominance: Expression of both alleles

In chickens, black-feathered and white-feathered birds are homozygotes for the *B* and *W* alleles, respectively. Two different uppercase letters are used to represent the alleles in codominant inheritance.

One of the resulting heterozygous offspring in a breeding experiment between a black rooster and a white hen is shown in ***Figure 12.8.*** You might expect that heterozygous chickens, *BW*, would be black if the pattern of inheritance followed Mendel's law of dominance, or gray if the trait were incompletely dominant. Notice, however, that the heterozygote is neither black nor gray. Instead, all of the offspring are checkered; some feathers are black and other feathers are white. In such situations, the inheritance pattern is said to be codominant. **Codominant alleles** cause the phenotypes of both homozygotes to be produced in heterozygous individuals. In codominance, both alleles are expressed equally.

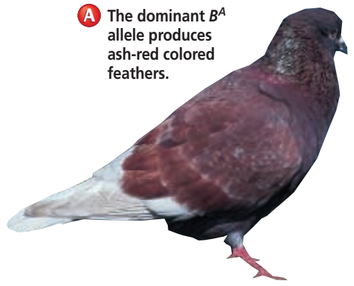
Figure 12.8
When a certain variety of black chicken is crossed with a white chicken, all of the offspring are checkered. Both feather colors are produced by codominant alleles.

Multiple phenotypes from multiple alleles

Although each trait has only two alleles in the patterns of heredity you have studied thus far, it is common for more than two alleles to control a trait in a population. This is understandable when you recall that a new allele can be formed any time a mutation occurs in a nitrogen base somewhere within a gene. Although only two alleles of a gene can exist within a diploid cell, multiple alleles for a single gene can be studied in a population of organisms.

Traits controlled by more than two alleles have **multiple alleles.** The pigeons pictured in ***Figure 12.9*** show the effects of multiple alleles for feather color. Three alleles of a single gene govern their feather color, although each pigeon can have only two of these alleles. The number of alleles for any particular trait is not limited to three, and there are instances in which more than 100

Figure 12.9
In pigeons, a single gene that controls feather color has three alleles. An enzyme that activates the production of a pigment is controlled by the *B* allele. This enzyme is lacking in *bb* pigeons.



A **The dominant B^A allele produces ash-red colored feathers.**

B **The *B* allele produces wild-type blue feathers. *B* is dominant to *b* but recessive to B^A.**

C **The allele *b* produces a chocolate-colored feather and is recessive to both other alleles.**

Quick Demo

Copy the Punnett squares demonstrating incomplete dominance in Figure 12.7 onto the chalkboard using colored chalk to demonstrate different phenotypes. To demonstrate codominance, draw a Punnett square for a mating that would produce a checkered chicken like the one shown in Figure 12.8.

Assessment

Performance Have students each write two questions about multiple allelic inheritance. Divide students into pairs and have them quiz each other. L1

Alternative Lab 12.1

Incomplete Dominance

Purpose
Students will observe the phenotypic ratio that appears with incomplete dominance.

Materials
petri dish, paper toweling, tobacco seeds

Procedure
Give the following directions to students.

1. Label the top of a petri dish with your name and the date. Place several layers of paper toweling inside the dish.
2. Moisten the toweling with water and place 20 tobacco seeds on it.
3. Cover the dish and place it where it will receive light.
4. Check the seeds for the next 10 days. Keep the toweling moist but not soaked. After 8-10 days, count the number of plants with green, yellow-green, and yellow leaves.
5. Design a data table to record your results and class totals.
6. Wash your hands after handling seeds.

Expected Results
Data will approach a 1: 2: 1 ratio of phenotypes.

Analysis

1. What ratio of phenotypes does your data show? Is this ratio close to the expected ratio of 1: 2: 1 with incomplete dominance? *ratio of phenotypes will vary; not very close to the expected ratio*
2. Why might your data not be close to a 1: 2: 1 ratio? *small sample size*
3. What ratio of phenotypes do you get when using class totals? Why is this ratio closer to what was expected? *close to 1: 2: 1; large sample size*

Assessment

Skill Have students assign letters to represent the genotypes of the parents and offspring. Then have them draw a Punnett square to show the expected results of a cross between plants with green leaves and plants with yellow leaves. Use the Performance Task Assessment List for Scientific Drawing in **PASC,** p. 55. L2 ELL

Problem-Solving Lab 12-2

Purpose

Students will work with problems that deal with multiple alleles.

Process Skills

acquire information, apply concepts, predict, think critically

Teaching Strategies

- Have students sequence the genotypes in order from dominant to recessive. L2
- Emphasize again that only two alleles at a time govern coat color. However, there are 10 different combinations that are possible when dealing with four different alleles in a multiple allele situation.
- Have students define in their own words the meaning of multiple allele.

Thinking Critically

1. **a.** *CC*, Cc^{ch}, Cc^{h}, *Cc*
   b. $c^{ch}c^{ch}$, $c^{ch}c^{h}$, $c^{ch}c$
   c. $c^{h}c^{h}$, $c^{h}c$
   d. *cc*
2. Chinchilla; the c^{ch} allele for chinchilla is dominant to the c^{h} allele for Himalayan. Dark gray; the *C* allele is dominant to all other alleles.
3. Yes, if the chinchilla rabbit is $c^{ch}c$.
4. No; Himalayan and white rabbits have no alleles for chinchilla.
5. The chinchilla parent is $c^{ch}c$ and the Himalayan parent is $c^{h}c$.

Assessment

Portfolio Ask students to plan a breeding program that would produce all Himalayan rabbit offspring when starting with one white parent and one dark gray parent known to be Cc^{ch}. Punnett squares should be included where appropriate. All work should be placed in student portfolios. Use the Performance Task Assessment List for Designing an Experiment in **PASC,** p. 23. L3 P

Problem-Solving Lab 12-2 Predicting

How is coat color in rabbits inherited? Coat color in rabbits is inherited as a series of multiple alleles. This means that there can be more than just two alleles for a single gene. In the case of coat color in rabbits, there are four alleles, and each one is expressed with a different phenotype.

Analysis

Examine ***Table 12.2.*** Use this information to answer the questions. Remember, each rabbit can have only two alleles for coat color.

Table 12.2 Coat color in rabbits

Phenotype	Allele	Pattern of inheritance
Dark gray coat	*C*	dominant to all other alleles
Chinchilla	c^{ch}	dominant to Himilayan and to white
Himalayan	c^{h}	dominant to white
White	*c*	recessive

Thinking Critically

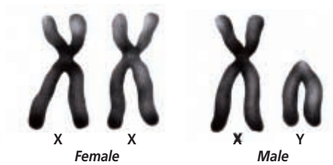
1. List all possible genotypes for a
   a. dark gray-coated rabbit (there are 4).
   b. chinchilla rabbit (there are 3).
   c. Himalayan rabbit (there are 2).
   d. white rabbit (there is 1).
2. Predict the phenotype for a rabbit with a $c^{h}c^{ch}$ and with a Cc^{h} genotype. Explain your answer.
3. Would it be possible to obtain white rabbits if one parent is white and the other is chinchilla? Explain your answer.
4. Would it be possible to obtain chinchilla rabbits if one parent is Himalayan and the other is white? Explain.
5. A chinchilla rabbit is mated with a Himalayan. Some offspring are white. What are the parents' genotypes?

alleles are known to exist for a single trait! You can learn about another example of multiple alleles in the *Problem-Solving Lab* shown here.

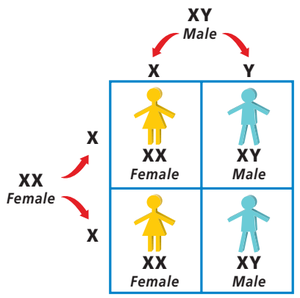
Sex determination

Recall that in humans the diploid number of chromosomes is 46, or 23 pairs. There are 22 pairs of matching homologous chromosomes called **autosomes.** Homologous autosomes look exactly alike. The 23rd pair of chromosomes differs in males and females. These two chromosomes, which determine the sex of an individual, are called **sex chromosomes.** In humans, the chromosomes that control the inheritance of sex characteristics are indicated by the letters X and Y. If you are a human female, XX, your 23rd pair of chromosomes are homologous and look alike, as shown in ***Figure 12.10A.*** However, if you are a male, XY, your 23rd pair of chromosomes look different. Males, which have one X and one Y chromosome, produce two kinds of gametes, X and Y, by meiosis. Females have two X chromosomes, so they produce only X gametes. ***Figure 12.10B*** shows that after fertilization, a 1: 1 ratio of males to females is expected. Because fertilization is governed by the laws of probability, the ratio usually is not exactly 1: 1 in a small population.

Figure 12.10
The sex chromosomes in humans are called X and Y.



A The sex chromosomes are named for the letters they resemble.



B Half the offspring of any mating between humans will have two X chromosomes, XX, which is female. The other half of the offspring will have one X and one Y chromosome, XY, which is male.

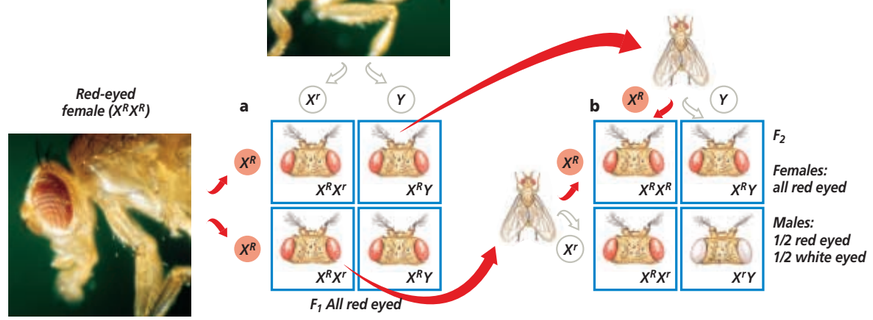
Sex-linked inheritance

Drosophila (droh SAHF uh luh), commonly known as fruit flies, inherit sex chromosomes in the same way as humans do. Traits controlled by genes located on sex chromosomes are called **sex-linked traits.** The alleles for sex-linked traits are written as superscripts of the X or Y chromosome. Because the X and Y chromosomes are not homologous, the Y chromosome has no corresponding allele to one on the X chromosome and no superscript is used. Also remember that any allele on the X chromosome of a male will not be masked by a corresponding allele on the Y chromosome.

In 1910, Thomas Hunt Morgan discovered traits linked to sex chromosomes. Morgan noticed one day that one male fly had white eyes rather than the usual red eyes. He crossed the white-eyed male with a homozygous red-eyed female. All of the F_1 offspring had red eyes, indicating that the white-eyed trait is recessive. Then Morgan allowed the F_1 flies to mate among themselves. According to simple Mendelian inheritance, if the trait were recessive, the offspring in the F_2 generation would show a 3: 1 ratio of red-eyed to white-eyed flies. As you can see in ***Figure 12.11,*** this is what Morgan observed. However, he also noticed that the trait of white eyes appeared only in male flies.

Morgan hypothesized that the red-eye allele was dominant and the white-eye allele was recessive. He also reasoned that the gene for eye color was located on the X chromosome and was not present on the Y chromosome. In heterozygous females, the dominant allele for red eyes masks the recessive allele for white eyes. In males, however, a single recessive allele is expressed as a white-eyed phenotype. When Morgan crossed a heterozygous red-eyed

Figure 12.11
Morgan crossed a white-eyed male fruit fly with a normal homozygous red-eyed female (a). He then allowed the F_1 flies to mate (b). The superscripts *R* and *r* are the dominant and recessive alleles for eye color in fruit flies.



Visual Learning

Figure 12.10 Ask students why the X and Y chromosomes are not homologous? *They do not have the same size, shape, or similar genes. However, they are able to pair during meiosis because they have a small homologous region at one end of each of the chromosomes.*

Make it clear to students that there is a 50% chance that each offspring will receive XX chromosomes, which is female, and a 50% chance that each offspring will receive XY chromosomes, which is male.

Reinforcement

Draw a Punnett square. Place sex chromosomes X and X along the left side, and X and Y along the top to represent gametes. Ask students why each gamete has only one sex chromosome. *The sex chromosomes are separated during meiosis.*

Meeting Individual Needs

Learning Disabled/Visually Impaired

Kinesthetic Make large cardboard X and Y chromosomes. Have students manipulate them to see how each parent donates one of his/her sex chromosomes to each gamete and how they come together during fertilization to produce offspring of each sex. L1 ELL

Glencoe Technology

VIDEODISC
VIDEOTAPE
The Secret of Life
Sex and the Single Gene: Cell Development

Portfolio

Eye Color

Visual-Spatial Provide students with a pedigree outline that involves a sex-linked trait such as white eye color in *Drosophila*. Have students record above each symbol the sex chromosomes and alleles that each fly possesses for the trait. L1 P

Misconception

Students may believe that all the alleles present on the X and Y chromosomes are related to maleness or femaleness. This is not the case, however. Explain that the alleles for blood clotting and color vision are located on human sex chromosomes. These traits have little to do with being male or female.

GLENCOE TECHNOLOGY

CD-ROM
Biology: The Dynamics of Life
Video: *Fruit Fly Genetics*
Disc 2

Resource Manager

Reteaching Skills Transparency 21 and Master
L1 ELL

female with a white-eyed male, half of all the males and half of all the females inherited white eyes. The only explanation of these results is Morgan's hypothesis: The allele for eye color is carried on the X chromosome and the Y chromosome has no allele for eye color.

Traits dependent on genes that follow the inheritance pattern of a sex chromosome are called sex-linked traits. Eye color in fruit flies is an example of an X-linked trait. Y-linked traits are passed only from male to male.

WORD Origin

polygenic
From the Greek words *polys,* meaning "many," and *genos,* meaning "kind." Polygenic inheritance involves many genes.

Polygenic inheritance

Some traits, such as skin color and height in humans, and cob length in corn, vary over a wide range. Such ranges occur because these traits are governed by many different genes. **Polygenic inheritance** is the inheritance pattern of a trait that is controlled by two or more genes. The genes may be on the same chromosome or on different chromosomes, and each gene may have two or more alleles. For simplicity, uppercase and lowercase letters are used to represent the alleles, as they are in Mendelian inheritance. Keep in mind, however, that the allele represented by an uppercase letter is not dominant. All heterozygotes are intermediate in phenotype.

In polygenic inheritance, each allele represented by an uppercase letter contributes a small, but equal, portion to the trait being expressed. The result is that the phenotypes usually show a continuous range of variability from the minimum value of the trait to the maximum value.

Suppose, for example, that stem length in a plant is controlled by three different genes: *A*, *B*, and *C*. Each gene is on a different chromosome and has two alleles, which can be represented by uppercase or lowercase letters. Thus, each diploid plant has a total of six alleles for stem length. A plant that is homozygous for short alleles at all three gene locations *(aabbcc)* might grow to be only 4 cm tall, the base height. A plant that is homozygous for tall alleles at all three gene locations *(AABBCC)* might be 16 cm tall. The difference between the tallest possible plant and the shortest possible plant is 12 cm, or 2 cm per each of the six tall alleles. You could say that each allele represented by an uppercase letter contributes 2 cm to the total height of the plant.

Suppose a 16-cm-tall plant were crossed with a 4-cm-tall plant. In the F_1 generation, all the offspring would be *AaBbCc*. If each of the three tall genes *A*, *B*, and *C* contributed 2 cm of height to the base height of 4 cm, the plants would be 10 cm tall (4 cm + 6 cm)—intermediate in height. If they are allowed to interbreed, the F_2 offspring will show a broad range of heights. A Punnett square of this trihybrid cross would show that 10-cm-tall plants are most often expected, and the tallest and shortest plants are seldom expected. Notice in ***Figure 12.12*** that when these results are graphed, the shape of the graph confirms the prediction of the Punnett square.

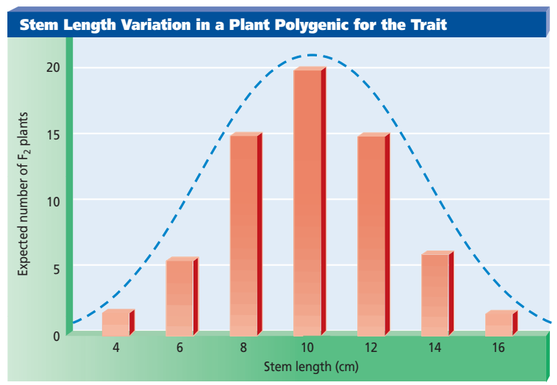


Figure 12.12
In this example of polygenic inheritance, three genes each have two alleles that contribute to the trait. When the distribution of plant heights is graphed, a bell-shaped curve is formed. Intermediate heights occur most often.

Environmental Influences

Even when you understand dominance and recessiveness and you have solved the puzzles of the other patterns of heredity, the inheritance picture is not complete. The genetic makeup of an organism at fertilization determines only the organism's potential to develop and function. As the organism develops, many factors can influence how the gene is expressed, or even whether the gene is expressed at all. Two such influences are the organism's external and internal environments.

Influence of external environment

Sometimes, individuals known to have a particular gene fail to express the phenotype specified by that gene. Temperature, nutrition, light, chemicals, and infectious agents all can influence gene expression. In certain bacteria, temperature has an effect on the expression of color, as shown in ***Figure 12.13***. External influences can also be seen in leaves. Leaves on a tree can have different sizes and shapes depending on the amount of light they receive.

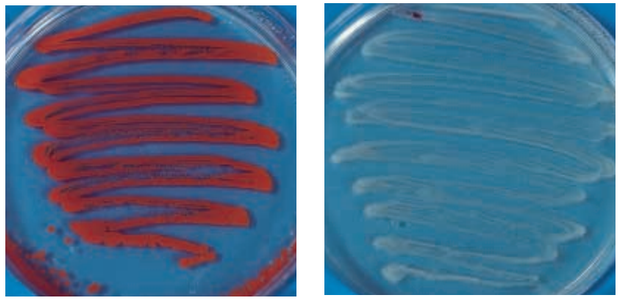


Figure 12.13
***Serratia marcescens* is a bacterium that forms brick-red growth on solid media at 25°C. When the same bacteria are grown at 30°C, the growth is cream colored.**

Influence of internal environment

The internal environments of males and females are different because of hormones and structural differences, ***Figure 12.14.*** For example, traits such as horn size in mountain sheep, male-pattern baldness in humans, and feather color in peacocks are expressed differently in the

Figure 12.14
The horns of a ram (male) are much heavier and more coiled than those of a ewe (female) although their genotypes are identical.

3 Assess

Check for Understanding

Have students explain how the following differ from one another. (a) incomplete dominance and codominance; (b) multiple alleles and polygenic inheritance; (c) autosomes and sex chromosomes; (d) sex-linked trait and autosomal trait. L1

Reteach

Ask students to provide an example of each of the following patterns or types of inheritance: (a) incomplete dominance; (b) codominance; (c) multiple allelic trait; (d) polygenic trait; (e) sex-linked trait. L1

Extension

Intrapersonal Have students describe and record some of the changes associated with human aging that alter gene expression. To get students started, provide them with a hint such as a change in hair color from black or blond to gray. L2

MEETING INDIVIDUAL NEEDS

Visually Impaired

Kinesthetic Provide large cutouts of leaves of different sizes. Have students group the leaves according to size, then count the number of leaves in each pile and make a bar graph. A partner can record the data and make a tactile bar graph for the visually impaired student. L1 ELL

Gifted

Visual-Spatial Have students illustrate the cross between two plants that are each heterozygous for three genes that control a single trait using a Punnett square that consists of 64 squares. Have students determine the gametes that appear along the side and top of the square, using *AaBbCc* as the genotype for each parent. L3

PROJECT

Genes and the Environment

Kinesthetic Have student groups germinate mustard seeds (available from the condiment section of a grocery store) in petri dishes that have been lined with paper toweling. They should moisten the toweling with water and add 20 seeds. Cover the dish and place it in the dark. Examine the seedlings after about 7 days. All seedlings will be white. Remove the dishes from the dark, place them in bright light for 24 hours, and then note their color. Have students write a report in which they explain how this project illustrates the role of the environment in influencing gene expression. L2 COOP LEARN

Assessment

Performance Ask students to illustrate through the use of Punnett squares how sex-linked inheritance differs from autosomal inheritance. They should use the same allele letters and parental genotypes. L2

4 Close

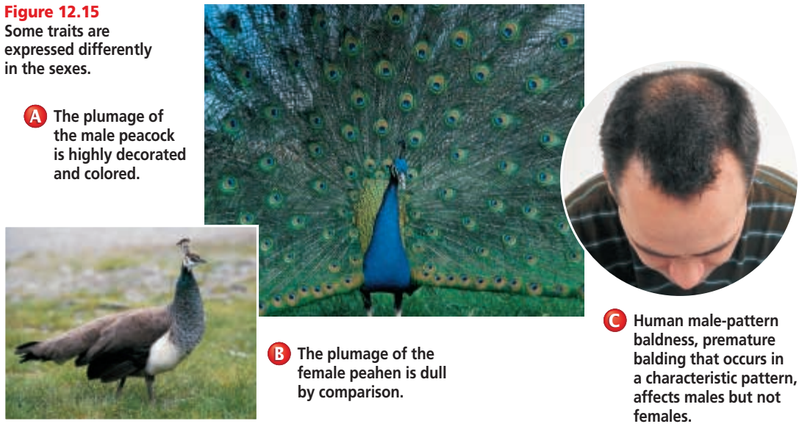
Activity

Logical-Mathematical Ask students to prepare genotypes that illustrate the difference between Mendelian and incomplete dominance in radish root shape. Radish roots are long, oval, or round. Have students use the symbols *L*, *l*, and *L′*. For Mendelian dominance, the genotypes are *LL* and *Ll* for long and *ll* for short. For incomplete dominance, the genotypes are *LL* for long, *LL′* for oval, and *L′L′* for round. L2

Resource Manager

Reinforcement and Study Guide, pp. 52-53 L2
Content Mastery, p. 59 L1

Figure 12.15
Some traits are expressed differently in the sexes.



A The plumage of the male peacock is highly decorated and colored.

B The plumage of the female peahen is dull by comparison.

C Human male-pattern baldness, premature balding that occurs in a characteristic pattern, affects males but not females.

sexes, as you can see in ***Figure 12.15.*** These differences are controlled by different hormones, which are determined by different sets of genes.

An organism's age also affects gene function. The nature of such a pattern is not well understood, but it is known that the internal environment of an organism changes with age.

You can now see that you must learn how genes interact with each other and with the environment to form a more complete picture of inheritance. Mendel's idea that heredity is a composite of many individual traits still holds. Later researchers have filled in more details of Mendel's great contributions.

Section Assessment

Understanding Main Ideas

1. A cross between a purebred animal with red hairs and a purebred animal with white hairs produces an animal that has both red hairs and white hairs. What type of inheritance pattern is involved?
2. In a cross between individuals of a species of tropical fish, all of the male offspring have long tail fins, and none of the females possess the trait. Mating of the F_1 fish fails to produce females with the trait. Explain a possible inheritance pattern of the trait.
3. A red-flowered sweet pea plant is crossed with a white-flowered sweet pea plant. All of the offspring are pink. What is the inheritance pattern being expressed?
4. The color of wheat grains shows a wide variability between red and white with multiple phenotypes. What type of inheritance pattern is being expressed?

Thinking Critically

5. Armadillos always have four offspring that have identical genetic makeup. Suppose that, within a litter, each young armadillo is found to have a different phenotype for a particular trait. How could you explain this phenomenon?

Skill Review

6. **Forming a Hypothesis** An ecologist observes that a population of plants in a meadow has flowers that may be red, yellow, white, pink, or purple. Hypothesize what the inheritance pattern might be. For more help, refer to *Practicing Scientific Methods* in the **Skill Handbook.**

Section Assessment

1. Alleles for both red and white hairs are expressed, which is typical of a pattern of codominance.
2. The inheritance pattern of this trait is that of a sex-linked gene located on the Y chromosome, which is possessed by males only.
3. Incomplete dominance is being expressed because the heterozygous plant is an intermediate form between red and white.
4. polygenic inheritance
5. The environment in the mother's uterus before birth may have been different for each of the offspring. The external environment can affect gene expression.
6. This is probably a case of multiple allelic or polygenic inheritance.

Section

12.3 Complex Inheritance of Human Traits

SECTION PREVIEW

Objectives

Compare codominance, multiple allelic, sex-linked, and polygenic patterns of inheritance in humans.

Distinguish among conditions in which extra autosomal or sex chromosomes exist.

Vocabulary

karyotype

For decades, movies and literature have portrayed times when people could genetically program their future offspring to have specific characteristics. You have probably thought about how you would change certain of your features if given the opportunity. As scientists study the inheritance of traits such as height and eye color, they are discovering that the passing of these traits can be very complex.

Eye color and height are complex traits.

Codominance in Humans

Remember that in codominance, the phenotypes of both homozygotes are produced in the heterozygote. One example of this type of inheritance in humans is the disorder sickle-cell anemia.

Sickle-cell anemia

Sickle-cell anemia is a major health problem in the United States and in Africa. In the United States, it is most common in black Americans whose families originated in Africa and in white Americans whose families originated in the countries surrounding the Mediterranean Sea. About one in 12 African Americans, a much larger proportion than in most populations, is heterozygous for the disorder.

In an individual who is homozygous for the sickle-cell allele, the oxygen-carrying protein hemoglobin differs by one amino acid from normal hemoglobin. This defective hemoglobin forms crystal-like structures that change the shape of the red blood cells. The abnormal red blood cells are shaped like a sickle, or half-moon. The change in shape occurs in the body's narrow capillaries after the hemoglobin releases oxygen to the cells. Abnormally shaped blood cells,

Cultural Diversity

Mary Styles Harris

In your discussion of sickle-cell anemia, point out contributions of contemporary African American scientists in the treatment and etiology of this disorder. One of the more prominent workers in this field has been geneticist Mary Styles Harris (born 1949). From 1977 to 1979, Harris was the executive director of the Sickle Cell Foundation of Georgia, and she has published many papers on this subject. In 1980, Harris was honored as one of *Glamour* magazine's Outstanding Women Scientists. Around this time, she also wrote, narrated, and produced an educational science series for Georgia TV through a grant from the National Science Foundation.

Prepare

Key Concepts

Complex inheritance patterns in humans are presented. Sickle-cell anemia is used as an example of codominance, blood types as an example of multiple allelic inheritance, color-blindness and hemophilia as examples of sex-linked patterns, and skin color as an example of polygenic inheritance. The section concludes with a discussion of changes in chromosome numbers.

Planning

- Obtain magnifying glasses and colored pencils for MiniLab 12-2.
- Obtain color blindness testing charts for Meeting Individual Needs.

1 Focus

Bellringer

Before presenting the lesson, display **Section Focus Transparency 31** on the overhead projector and have students answer the accompanying questions. L1 ELL

2 Teach

Microscope Activity

Visual-Spatial Have students view a prepared slide of sickled blood cells and compare it with a slide of normal blood cells. L1 ELL

Assessment

Portfolio Have students write a short paragraph explaining why it is so important to type blood before it is used for a transfusion. L1 P

GLENCOE TECHNOLOGY

VIDEOTAPE
The Secret of Life
It's in the Genes: Evolution

CD-ROM
Biology: The Dynamics of Life
Exploration: *Blood Types*
Disc 5

Resource Manager

Critical Thinking/Problem Solving, p. 12 L3
Section Focus Transparency 31 and Master L1 ELL
Laboratory Manual, pp. 83-86 L2

Figure 12.16
In sickle-cell anemia, the gene for hemoglobin produces a protein that is different by one amino acid. This hemoglobin crystallizes when oxygen levels are low, forcing the red blood cells into a sickle shape (a). A normal red blood cell is disc shaped (b).

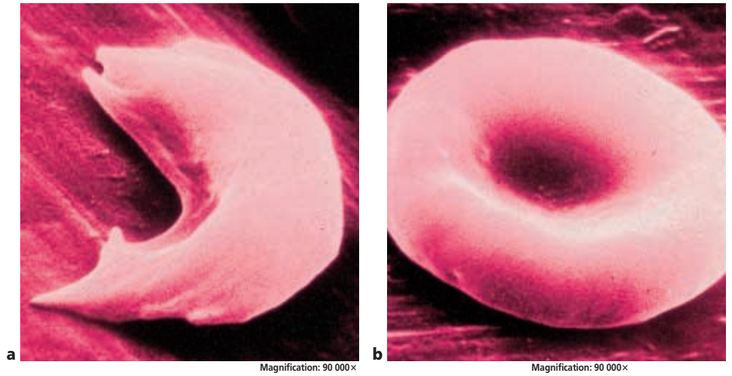


Figure 12.16, slow blood flow, block small vessels, and result in tissue damage and pain. Because sickled cells have a shorter life span than normal red blood cells, the person suffers from anemia, a condition in which there is a low number of red blood cells.

Individuals who are heterozygous for the allele produce both normal and sickled hemoglobin, an example of codominance. They produce enough normal hemoglobin that they do not have the serious health problems of those homozygous for the allele and can lead relatively normal lives. Individuals who are heterozygous are said to have the sickle-cell trait because they can show some signs of sickle-cell anemia if the availability of oxygen is reduced.

Multiple Alleles in Humans

Traits that are governed by simple Mendelian heredity have only two alleles. However, you have learned that more than two alleles of a gene are possible for certain traits. The ABO blood group is a classic example of a single gene that has multiple alleles in humans. How many alleles does this gene have? Read the *Inside Story* to answer this question.

Multiple alleles govern blood type

Human blood types, listed in ***Table 12.3,*** are determined by the presence or absence of certain molecules on the surfaces of red blood cells. As the determinant of blood types A, B, AB, and O, the gene *I* has three alleles: I^A, I^B, and *i*.

The importance of blood typing

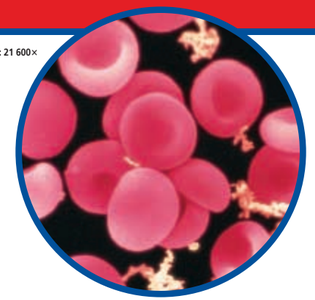
Determining blood type is necessary before a person can receive a blood transfusion because the red blood cells of incompatible blood types could clump together, causing death. Blood typing can also be helpful in solving cases of disputed parentage. For example, if a child has type AB blood and its mother has type A, a man with type O blood could not possibly be the father. But blood tests cannot prove that a certain man definitely is the father; they indicate only that he could be. DNA tests are necessary to determine actual parenthood.

INSIDE STORY

The ABO Blood Group

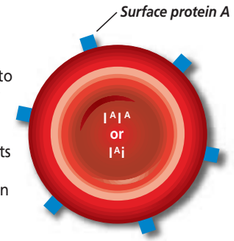
The gene for blood type, gene* I, *codes for a membrane protein found on the surface of red blood cells. Each of the three alleles codes for a different protein. Your immune system recognizes the red blood cells as belonging to you. If cells with a different protein enter your body, your immune system will attack them.

Critical Thinking ***If you inherit* ii *from your parents, what is your blood type?***


Magnification: 21 600×

Red blood cells

1 Phenotype A The I^A allele is dominant to *i*, so inheriting either the $I^A i$ alleles or the $I^A I^A$ alleles from your two parents will give you type A blood. Surface protein A is produced.



2 Phenotype B The I^B allele is also dominant to *i*. To have type B blood, you must inherit the I^B allele from one parent and either another I^B allele or the *i* allele from the other. Surface protein B is produced.

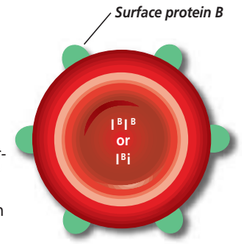
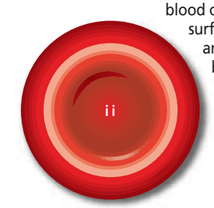
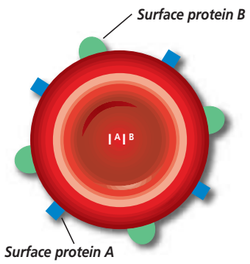


Table 12.3 Human blood types

Genotypes	Surface Proteins	Phenotypes
$I^A I^A$ or $I^A i$	A	A
$I^B I^B$ or $I^B i$	B	B
$I^A I^B$	A and B	AB
ii	none	O

4 Phenotype O The *i* allele is recessive and produces no surface molecule. Therefore, if you are homozygous *ii*, your blood cells have no surface proteins and you have blood type O.





3 Phenotype AB The I^A and I^B alleles are codominant to each other. This means that if you inherit the I^A allele from one parent and the I^B allele from the other, your red blood cells will produce both surface proteins and you will have type AB blood.

Portfolio

Alzheimer's Disease

Linguistic Have students research the connection between chromosome 21 and Alzheimer's disease. Ask them to include a copy of their findings in their portfolios. L3 P

BIOLOGY JOURNAL

"Improved" Children

Linguistic Some day, scientists may have the capability to change genes, making offspring smarter, physically stronger, and better looking. Ask students to write a short essay on whether they would have their genes changed to "improve" their children if they were given the opportunity. L2

INSIDE STORY

Purpose

Students will learn the genetic basis of ABO blood types

Teaching Strategies

- Give students a genotype and ask them to identify the phenotype on red blood cells.

Visual Learning

- Have students create a table with genotypes as the headings. Under each genotype, have them correctly place the resulting phenotype. L1
- Ask students to draw red blood cells with cell surface proteins in their journals. Have them draw red blood cells for all four blood types and write possible genotypes underneath the cells. L1

Critical Thinking

You will be blood type O.

GLENCOE TECHNOLOGY

VIDEODISC
The Secret of Life
Blood Types
Biology: The Dynamics of Life
Sex-Linked Traits (Ch. 35)
Disc 1, Side 1, 1 min. 49 sec.

CD-ROM
Biology: The Dynamics of Life
Animation: *Sex-Linked Traits*
Disc 2

Problem-Solving Lab 12-3

Purpose
Students will determine the pattern of inheritance for Duchenne's muscular dystrophy.

Process Skills
observe and infer, recognize cause and effect

Background
Because various forms of muscular dystrophy can be inherited as an autosomal dominant, an autosomal recessive, or a sex-linked disorder, a family pedigree must be analyzed to determine the exact pattern of inheritance. From the pedigree, the mode of inheritance of Duchenne's muscular dystrophy can be inferred to be X-linked.

Teaching Strategies
■ Ask students which individuals in the pedigree were keys to determining the type of inheritance involved.

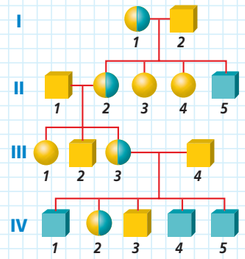
Thinking Critically
There is a 100% probability that the daughter will be a carrier because the only X chromosome she can inherit from her father would have the defective gene. The son would not inherit the disorder because his X chromosome would come from his mother, who presumably is not a carrier.

Assessment

Knowledge Ask students what mating would have to occur to produce a female child with Duchenne's muscular dystrophy. *mating a female carrier or an affected female with an affected male* Use the Performance Task Assessment List for Formulating a Hypothesis in **PASC,** p. 21. L2

Problem-Solving Lab 12-3 Drawing a Conclusion

How is Duchenne's muscular dystrophy inherited? Muscular dystrophy is often thought of as a single disorder, but it is actually a group of genetic disorders that produce muscular weakness, progressive deterioration of muscular tissue, and loss of coordination. Different forms of muscular dystrophy can be inherited as a dominant autosomal, a recessive autosomal, or a sex-linked disorder. These three patterns of inheritance appear different from one another when a pedigree is made. One rare form of muscular dystrophy, called Duchenne's muscular dystrophy, affects three in 10 000 American males.



Typical pedigree

Analysis
The pedigree shown here represents the typical inheritance pattern for Duchenne's muscular dystrophy. Refer to ***Figure 12.1*** if you need help interpreting the symbols. Analyze the pedigree to determine the pattern of inheritance. Is this an autosomal or a sex-linked disorder?

Thinking Critically
If individual IV-1 had a daughter and a son, what would be the probability that the daughter is a carrier? That the son inherited the disorder?

Sex-Linked Traits in Humans

Several human traits are determined by genes that are carried on the sex chromosomes; most of these genes are located on the X chromosome. The pattern of sex-linked inheritance is explained by the fact that males, who are XY, pass an X chromosome to each of their daughters and a Y chromosome to each son. Females, who are XX, pass one of their X chromosomes to each child, ***Figure 12.17***. If a son receives an X chromosome with a recessive allele from his mother, he will express the recessive phenotype because he has no chance of inheriting from his father a dominant allele that would mask the expression of the recessive allele.

Two traits that are governed by X-linked inheritance in humans are certain forms of color blindness and hemophilia. Determine whether Duchenne's muscular dystrophy is sex-linked by reading the *Problem-Solving Lab* on this page.

Red-green color blindness
People who have red-green color blindness can't differentiate these two colors. Red-green color blindness was first described in a boy who could not be trained to harvest only the ripe, red apples from his father's orchard. Instead, he chose green apples as often as he chose red.

Other more serious problems can result from this disorder, such as the inability of color-blind people to identify red and green traffic lights by color. Color blindness is caused by the inheritance of either of two recessive alleles at two gene sites on the X chromosome that affect red and green receptors in the cells of the eyes.

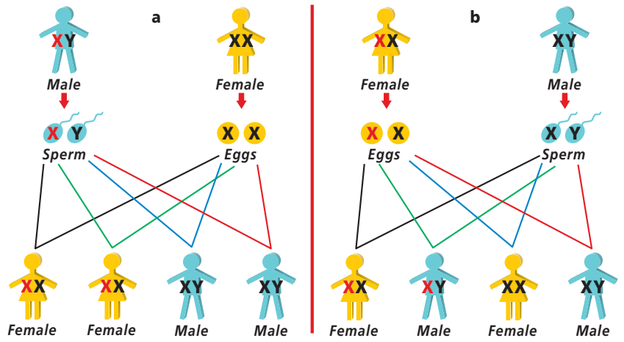


Figure 12.17
If a trait is X-linked, males pass the X-linked allele to all of their daughters but to none of their sons (a). Heterozygous females have a 50 percent chance of passing a recessive X-linked allele to each child (b).

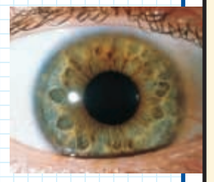
Hemophilia: An X-linked disorder
Did you ever wonder about why a cut stops bleeding so quickly? This human adaptation is essential. If your blood didn't have the ability to clot at all, any cut could take a long time to stop bleeding. Of greater concern would be internal bleeding resulting in a bruise, which a person may not immediately notice.

Hemophilia A is an X-linked disorder that causes just such a problem with blood clotting. About one male in every 10 000 has hemophilia, but only about one in 100 million females inherits the same disorder. Why? Males inherit the allele for hemophilia on the X chromosome from their carrier mothers. A single recessive allele for hemophilia will cause the disorder in males. Females would need two recessive alleles to inherit hemophilia. The family of Queen Victoria, pictured in the *Social Studies Connection* at the end of this chapter, is the best-known study of hemophilia A, also called royal hemophilia.

Hemophilia A can be treated with blood transfusions and injections of Factor VIII, the blood-clotting enzyme that is absent in people affected by the condition. However, both treatments are expensive. New methods of DNA technology are being used to develop a cheaper source of the clotting factor.

MiniLab 12-2 Observing and Inferring

Detecting Colors and Patterns in Eyes Human eye color, like skin color, is determined by polygenic inheritance. You can detect several shades of eye color, especially if you look closely at the iris with a magnifying glass. Often, the pigment is deposited so that light reflects from the eye, causing the iris to appear blue, green, gray, or hazel (brown-green). In actuality, the pigment may be yellowish or brown, but not blue.


Hazel eye color

Procedure
1. Use a magnifying glass to observe the patterns and colors of pigment in the eyes of five classmates.
2. Use colored pencils to make drawings of the five irises.
3. Describe your observations in your journal.

Analysis
1. How many different pigments were you able to detect in each eye?
2. From your data, do you suspect that eye color might not be inherited by simple Mendelian rules? Explain.
3. Suppose that two people have brown eyes. They have two children with brown eyes, one with blue eyes, and one with green eyes. What pattern might this suggest?

Polygenic Inheritance in Humans

Think of all the traits you inherited from your parents. Although many of your traits were inherited through simple Mendelian patterns or through multiple alleles, many other human traits are determined by polygenic inheritance. These kinds of traits usually represent a range of variation that is measurable. The *MiniLab* shown here examines one of these traits—the color variations in human eyes.

MiniLab 12-2

Purpose
Students will observe the colors and patterns in the eyes of several classmates in order to hypothesize how eye color is inherited.

Process Skills
observe and infer, recognize cause and effect

Teaching Strategies
■ Provide students with five cards, each with a circle and a line under the circle. Students should write the name of the person on the line and then draw the iris within the circle. Provide colored pencils. L1 ELL

Expected Results
Students will detect many different pigments, suggesting polygenic inheritance.

Analysis
1. Students may detect brown, blue, yellow, gray, green, and black pigments in each eye.
2. Eye color is probably not inherited by simple Mendelian rules because there are so many phenotypes.
3. The pattern suggests polygenic inheritance.

Assessment

Knowledge Ask students to write a paragraph telling how they could determine the number of genes involved in the inheritance of eye color. Use the Performance Task Assessment List for Writing in Science in **PASC,** p. 87. L2

Alternative Lab 12.2

Barr Bodies

Purpose
Students will locate Barr bodies in cells.

Materials
prepared slides of male and female cheek cells, microscope

Background
Females have two X chromosomes, but early in development of a female embryo, one of the X chromosomes in each cell becomes inactive. The inactive chromosome becomes condensed and can be seen as a Barr body. Cells of males do not contain Barr bodies.

Procedure
Give students the following directions.
1. Place the slide of female cheek cell on the microscope.
2. Examine cells under high power. A Barr body will be seen in each cell as a darkly stained mass just inside the nuclear membrane.
3. Examine the slide of male cheek cells for the presence of Barr bodies.
4. Draw a cell with a Barr body and one without a Barr body.
5. Wash your hands when you have finished your observations.

Expected Results
Students will see Barr bodies in cells from females but not in those from males.

Analysis
1. Do all your body cells have Barr bodies? *yes for females; no for males*
2. What percentage of a female's cells have visible Barr bodies? *100%*
3. How many Barr bodies would you find in a cell of an XXX female? *2*

Assessment

Performance Students should include a summary of the lab, their drawings, and the answers to the Analysis questions in their journals. Use the Performance Task Assessment List for Lab Report in **PASC,** p. 47. L3

Concept Development

Many different types of color-blindness are possible. Make color-blindness testing charts available to students. Color-blindness testing kits are also available. Have pairs of students use the kits.

Quick Demo

Visual-Spatial Have students re-examine the section opener photograph of students whose heights form a bell-shaped curve. Which figure in this chapter does the inheritance pattern of height most closely resemble? *The pattern of inheritance exhibited by the students' heights most closely resembles that of Figures 12.12 and 18.18 demonstrating polygenic inheritance.*

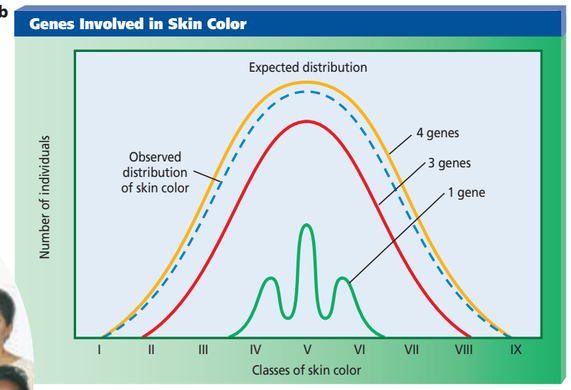
Visual Learning

Figure 12.18 The graph of what number of genes most closely matches the observed distribution of skin color? *The actual data match the 4-gene graph best.*

Assessment

Performance Assessment in the Biology Classroom, *Analyzing Human Pedigrees*, p. 21. Have students carry out this activity after they have learned about inheritance of human traits. L2

Figure 12.18
This graph (b) shows the expected distribution of human skin color if controlled by one, three, or four genes. The observed distribution of skin color (a) closely matches the distribution shown by four genes.



Skin color: A polygenic trait

In the early 1900s, the idea that polygenic inheritance occurs in humans was first tested using data collected on skin color. Scientists found that when light-skinned people mate with dark-skinned people, their offspring have intermediate skin colors. When these children produce the F_2 generation, the resulting skin colors range from the light-skin color to the dark-skin color of the grandparents (the P_1 generation), with most children having an intermediate skin color. As ***Figure 12.18*** shows, the variation in skin color indicates that between three and four genes are involved.

Word Origin

autosome
From the Greek words *autos*, meaning "self," and *soma*, meaning "body." An autosome is a chromosome that is not a sex chromosome.

Changes in Chromosome Numbers

You have been reading about traits that are caused by one or several genes on chromosomes. What would happen if an entire chromosome or part of a chromosome were missing from the complete set? What if cells had an extra chromosome? As you have learned, abnormal numbers of chromosomes usually, but not always, result from accidents of meiosis. Many abnormal phenotypic effects result from such mistakes.

Unusual numbers of autosomes

You know that a human usually has 23 pairs of chromosomes, or 46 chromosomes altogether. Of these 23 pairs of chromosomes, 22 pairs are autosomes. Humans who have an unusual number of autosomes all are trisomic—that is, they have three of a particular autosome instead of just two. In other words, they have 47 chromosomes. Recall that trisomy usually results from nondisjunction, which occurs when paired homologous chromosomes fail to separate properly during meiosis.

To identify an abnormal number of chromosomes, a sample of cells is obtained from an individual or from a fetus. Metaphase chromosomes are photographed, and the chromosome pictures are then enlarged, cut apart, and arranged in pairs on a chart according to length and location of the centromere, as ***Figure 12.19*** shows. This chart of chromosome pairs is called a **karyotype,** and it is valuable in pinpointing unusual chromosome numbers in cells.

Down syndrome: Trisomy 21

Most disorders of chromosome number that occur in humans cause symptoms so severe that the developing fetus dies, often before the woman even realizes she is pregnant. Fortunately, these disorders occur only rarely. Down syndrome is the only autosomal trisomy in which affected individuals survive to adulthood. It occurs in about one in 700 live births.

Down syndrome is a group of symptoms that results from trisomy of chromosome 21. Individuals who have Down syndrome have at least some degree of mental retardation. The incidence of Down syndrome births is higher in older mothers, especially those over 40.

Unusual numbers of sex chromosomes

Many abnormalities in the number of sex chromosomes are known to exist. An X chromosome may be missing (designated as XO) or there may be an extra one (XXX or XXY). There may also be an extra Y chromosome (XYY), as you can see by examining ***Figure 12.19***. Any individual with at least one Y chromosome is a male, and any individual without a Y chromosome is a female. Most of these individuals lead normal lives, but they cannot have children and some have varying degrees of mental retardation.

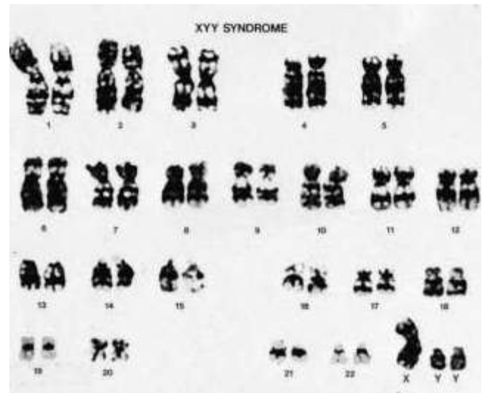


Figure 12.19
This karyotype demonstrates XYY syndrome, where two Y chromosomes are inherited in addition to an X chromosome.

Section Assessment

Understanding Main Ideas

1. Why are sex-linked traits such as red-green color blindness and hemophilia more commonly found in males than in females? Explain your answer in terms of the X chromosome.
2. In addition to revealing chromosome abnormalities, what other information would a karyotype show?
3. What would the genotypes of parents have to be for them to have a color-blind daughter? Explain.
4. Describe a genetic trait in humans that is inherited as codominance. Describe the phenotypes of the two homozygotes and that of the heterozygote. Why is this trait an example of codominance?

Thinking Critically

5. A man is accused of fathering two children, one with type O blood and another with type A blood. The mother of the children has type B blood. The man has type AB blood. Could he be the father of both children? Explain your answer

Skill Review

6. **Making and Using Tables** Construct a table of the traits discussed in this section. For column heads, use Trait, Pattern of inheritance, and Characteristics. For more help, refer to *Organizing Information* in the **Skill Handbook.**

3 Assess

Check for Understanding

Linguistic Ask students to summarize the patterns shown by multiple allelic, polygenic, and sex-linked inheritance. L1

Reteach

Visual-Spatial Have students draw the phases of meiosis to demonstrate how various changes in chromosome numbers occur. L1 ELL

Extension

Ask students to research the rare sex-linked disorder severe combined immune deficiency (SCID). The "boy in the bubble" had this disorder. What experimental treatments are currently being used to treat or cure this disorder? L3

Assessment

Skill Provide students with filled-in Punnett squares showing genotypes and phenotypes of offspring. Have students determine the pattern of inheritance from the information given. L1

4 Close

Discussion

Ask students to explain why hemophilia is extremely rare in females. *Because the allele is rare in the general population, there is only a small likelihood that a male with hemophilia would marry a carrier female or a female with hemophilia.*

Resource Manager

BioLab and MiniLab Worksheets, pp. 58-60 L2
Reinforcement and Study Guide, p. 54 L2
Content Mastery, pp. 57, 60 L1
Laboratory Manual, pp. 87-90 L2

Internet Address Book

internet CONNECTION Note Internet addresses that you find useful in the space below for quick reference.

_____

_____

_____

_____

Section Assessment

1. Males inherit only one X chromosome. If it carries an allele for a disorder, the male will show the trait.
2. the sex of the child
3. The father must be color-blind (have recessive allele on his X chromosome). The mother must have at least one X chromosome with the color-blind allele since a female receives one X from each parent.
4. In sickle-cell anemia, an individual homozygous for normal hemoglobin will produce only normal hemoglobin. An individual homozygous for sickle-cell anemia will produce only abnormal hemoglobin. A heterozygote will produce both types of hemoglobin.
5. The mother could be I^Bi or I^BI^B and the father is I^AI^B. If a child received I^A from the father and i from the mother, it would be type A so the man could have fathered the type A child. This man could not father a type O child because he has no i allele.
6. Material for the table can be found on pages 329-335 of the text.

DESIGN YOUR OWN BioLab

Time Allotment

Initial session: one class period for planting of P_1 generation, then 5 minutes daily for watering; one class period for cross-pollination; 10 days later, one class period for collecting and planting of F_1 seeds; 10 days later: one class period for examination of F_2 plants.

Process Skills

form a hypothesis, observe and infer, collect data

Safety Precautions

Have students use caution when handling, using, and plugging in light fixtures or light banks. Students should use caution when using a razor blade.

Preparation

- Seeds of normal and variegated *Brassica rapa* (Wisconsin Fast Plants) can be ordered from biological supply houses. The variegated gene is carried on chloroplast DNA.
- It is critical to provide light in fluorescent banks (cool-white, 40 watts/bulb) in order to achieve the complete life cycle in such a short time. Light banks should be adjustable so that they remain about 5-8 cm above the plants' growing tips at all times. Lights remain on continuously for 24 hours each day.
- Soil must be kept constantly moist, especially during the germination period.

Possible Hypotheses

If the trait is inherited through the cytoplasm, then the female parent contributes the trait.

If the trait is inherited through the cytoplasm, then the male parent contributes the trait.

DESIGN YOUR OWN BioLab

What is the pattern of cytoplasmic inheritance?

The mitochondria of all eukaryotes and the chloroplasts of plants and algae contain DNA. This DNA is not coiled into chromosomes, but it still carries genes that control genetic traits. Many of the mitochondrial genes control steps in the respiration process.

The DNA in chloroplasts controls traits such as chlorophyll production. Lack of chlorophyll in some cells causes the appearance of white patches in a leaf. This trait is known as variegated leaf. In this BioLab, you will carry out an experiment to determine the pattern of cytoplasmic inheritance of the variegated leaf trait in Brassica rapa.

Preparation

Problem

What inheritance pattern does the variegated leaf trait in *Brassica* show?

Hypotheses

Consider the possible evidence you could collect that would answer the problem question. Among the people in your group, form a hypothesis that you can test to answer the question, and write the hypothesis in your journal.

Objectives

In this BioLab, you will:

- **Determine** which crosses of *Brassica* plants will reveal the pattern of cytoplasmic inheritance.
- **Analyze** data from *Brassica* crosses.

Possible Materials

Brassica rapa seeds, normal and variegated
potting soil and trays
paintbrushes
forceps
single-edge razor blade
light source
labels

Safety Precautions

Always wear goggles in the lab. Handle the razor blade with extreme caution. Always cut away from you. Wash your hands with soap and water after working with plant material.

Skill Handbook

Use the **Skill Handbook** if you need additional help with this lab.

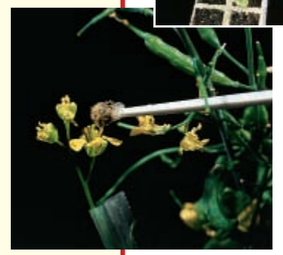
Plan the Experiment

1. Decide which crosses will be needed to test your hypothesis.
2. Keep the available materials in mind as you plan your procedure. How many seeds will you need?
3. Record your procedure, and list the materials and quantities you will need.
4. Assign a task to each member of the group. One person should write data in a journal, another can pollinate the flowers, while a third can set up the plant trays. Determine who will set up and clean up materials.
5. Design and construct a data table for recording your observations.

Check the Plan

Discuss the following points with other group members to decide the final procedure for your experiment.

1. What data will you collect, and how will data be recorded?
2. When will you pollinate the flowers? How many flowers will you pollinate?
3. How will you transfer pollen from one flower to another?
4. How and when will you collect the seeds that result from your crosses?
5. What variables will have to be controlled? What controls will be used?
6. When will you end the experiment?
7. ***Make sure your teacher has approved your experimental plan before you proceed further.***
8. Carry out your experiment.



Analyze and Conclude

1. **Checking Your Hypothesis** Did your data support your hypothesis? Why or why not?
2. **Interpreting Observations** What is the inheritance pattern of variegated leaves in *Brassica?*
3. **Making Inferences** Explain why genes in the chloroplast are inherited in this pattern.
4. **Drawing Conclusions** Which parent is responsible for passing the variegated trait to its offspring?
5. **Making Scientific Illustrations** Draw a diagram tracing the inheritance of this trait through cell division.

Going Further

Project Make crosses between normal *Brassica* plants and genetically dwarfed, mutant *Brassica* plants to determine the inheritance pattern of the dwarf mutation.

internet CONNECTION To find out more about inheritance of traits, visit the Glencoe Science Web Site.
www.glencoe.com/sec/science

DESIGN YOUR OWN BioLab

Analyze and Conclude

1. Student answers will vary depending on their hypotheses.
2. Variegation is inherited as a cytoplasmic trait from the female parent.
3. Sperm cells contain little to no cytoplasm. Cytoplasm containing chloroplasts is contributed only by the egg.
4. female
5. Diagrams should show the trait being transmitted in an egg cell of the female but not in pollen of the male.

Error Analysis

Sufficient light must be supplied to the plants to maximize the contrast between green and white leaves.

Assessment

Skill Have students draw Punnett squares to explain the inheritance pattern in offspring if this trait were inherited as a simple dominant allele. Have them show how cytoplasmic inheritance deviates from this pattern. Use the Performance Task Assessment List for Scientific Drawing in **PASC,** p. 55. L2

Going Further

Have students carry out crosses between nonvariegated male and female parents as well as variegated male and female parents. L3 ELL

Plan the Experiment

Teaching Strategies

- Variegated plants tend to grow a little slower than nonvariegated plants. Therefore, these seeds should be started about 4 days earlier.
- Review the process of fertilization and make sure students realize that the egg contributes most of the cytoplasm and organelles to the zygote. The sperm is almost all nucleus.
- Students should work in groups.
- *Brassica* will not self-pollinate. Therefore, keep the two plant types separate from each other to avoid random cross-pollination, or have students remove flowers that were not used in cross-pollination.

Possible Procedures

- Both variegated and normal seed types should be planted and grown. After 13-15 days, the plants will flower. Students will then perform the following cross-pollinations depending on their hypotheses: variegated female with nonvariegated male (transfer of pollen from nonvariegated male anther via brush to pistil of variegated female) and nonvariegated female with variegated male. Pods of seeds will mature between days 28 and 30. These seeds will then be planted, and new offspring will be observed for the presence of the variegated trait.

Data and Observations

Variegated F_1 plants will appear in crosses where the female parent was variegated.

Social Studies Connection

Purpose

Students will learn why hemophilia has been called the royal disease.

Teaching Strategies

- Inform students that about 1 in 10 000 males has hemophilia, whereas about 1 in 100 000 000 females inherits this disorder. Make sure students realize that the reason for this is the fact that hemophilia is an X-linked disorder.
- Have students hypothesize how Queen Victoria became a carrier of the disease when neither of her parents had the disorder. Students should be able to deduce that one of Victoria's parents developed a spontaneous mutation in his or her X chromosome, which was then passed to her. The mutation could not have occurred during the production of one of Victoria's egg cells because so many of her children were affected. L2

Connection to Biology

Four genotypes are possible in the offspring. Half the girls will be carriers and half will be normal. Among the boys, half will have hemophilia and half will be normal. Thus, one-fourth of all children of a female carrier and a normal male will be carriers of a sex-linked trait.

Social Studies Connection

Queen Victoria and Royal Hemophilia

One of the most famous examples of a pedigree demonstrating inheritance of a sex-linked trait is the family of Queen Victoria of England and hemophilia.

Queen Victoria and her family

Queen Victoria had four sons and five daughters. Her son Leopold had hemophilia and died as a result of a minor fall. Two of her daughters, Alice and Beatrice, were carriers for the trait and passed the disorder to royal families in Spain, Prussia, and Russia over four generations.

The Spanish royal family Victoria's daughter Beatrice, a carrier for the trait, married Prince Henry of Battenberg, a descendent of Prussian royalty. Two of their sons inherited the trait, both dying before the age of 35. Her daughter, Victoria, was a carrier and married King Alfonso XIII of Spain, thus transmitting the allele to the Spanish royal family. Two of their sons died of hemophilia, also by their early thirties.

The Prussian royal family Alice, another of Victoria's daughters, married Louis IV of Hesse, part of the Prussian royal family and related to Prince Henry of Battenberg. One of Alice's sons, Frederick, died at the age of three from hemophilia. One of her daughters, Irene, continued to pass the trait to the next generation of Prussian royalty by giving it to two of her sons.

The Russian royal family Irene's sister and Queen Victoria's granddaughter, Alix (Alexandra), married Czar Nicholas II of Russia. Four healthy daughters were born, but the first male heir, Alexis, showed signs of bleeding and bruising at only six weeks of age. Having a brother, an uncle, and two cousins who had suffered from the disorder and died at early ages, you can imagine the despair Alix felt for her son and the future heir. In desperation, the family turned to Rasputin, a man who claimed to have healing abilities and used Alexis' illness for his own political power. The series of events surrounding Alexis and his hemophilia played a role in the downfall of the Russian monarchy.

The British throne today Queen Elizabeth II, the current English monarch, is descended from Queen Victoria's eldest son, Edward VII. Because he did not inherit the trait, he could not pass it on to his children. Therefore, the British monarchy today does not carry the recessive allele for hemophilia, at least not inherited from Queen Victoria.

Connection to Biology

If you were the child of a female carrier for a sex-linked trait such as hemophilia, what would be your chances of carrying the trait?

interNET CONNECTION To find out more about hemophilia, visit the Glencoe Science Web Site.
www.glencoe.com/sec/science

Internet Address Book

interNET CONNECTION Note Internet addresses that you find useful in the space below for quick reference.

Chapter 12 Assessment

Summary

Section 12.1 Mendelian Inheritance of Human Traits

Main Ideas
- A pedigree is a family tree of inheritance.
- Most human genetic disorders are inherited as rare recessive alleles, but a few are inherited as dominant alleles.

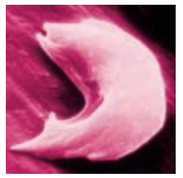
Vocabulary
carrier (p. 316)
fetus (p. 318)
pedigree (p. 315)

Section 12.2 When Heredity Follows Different Rules

Main Ideas
- Alleles can be incompletely dominant or codominant.
- There may be many alleles for one trait or many genes that interact to produce a trait.
- Inheritance patterns of genes located on sex chromosomes are due to differences in the number and kind of sex chromosomes in males and in females.
- The expression of some traits is affected by the internal and external environments of the organism.

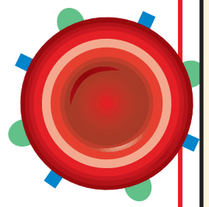
Vocabulary
autosome (p. 324)
codominant alleles (p. 323)
incomplete dominance (p. 321)
multiple alleles (p. 323)
polygenic inheritance (p. 326)
sex chromosome (p. 324)
sex-linked trait (p. 325)

Section 12.3 Complex Inheritance of Human Traits



Main Ideas
- The majority of human traits are controlled by multiple alleles or by polygenic inheritance. The inheritance patterns of these traits are highly variable.
- Sex-linked traits are determined by inheritance of sex chromosomes. X-linked traits are usually passed from carrier females to their male offspring. Y-linked traits are passed only from male to male.
- Mistakes in meiosis, usually due to nondisjunction, may result in an abnormal number of chromosomes. Autosomes or sex chromosomes can be affected.

Vocabulary
karyotype (p. 335)



Understanding Main Ideas

1. If a trait is X-linked, males pass the X-linked allele to _____ of their daughters.
   a. all **c.** none
   b. half **d.** 1/4

2. Stem length demonstrates a range of phenotypes. This is an example of _____.
   a. autosomal dominant
   b. autosomal recessive
   c. sex-linkage
   d. polygenic inheritance

GLENCOE TECHNOLOGY

VIDEOTAPE
MindJogger Videoquizzes
Chapter 12: *Patterns of Heredity and Human Genetics*
Have students work in groups as they play the videoquiz game to review key chapter concepts.

Resource Manager

Chapter Assessment, pp. 67-72
MindJogger Videoquizzes
Computer Test Bank
BDOL Interactive CD-ROM, Chapter 12 quiz

Chapter 12 Assessment

Main Ideas

Summary statements can be used by students to review the major concepts of the chapter.

Using the Vocabulary

To reinforce chapter vocabulary, use the Content Mastery Booklet and the activities in the Interactive Tutor for Biology: The Dynamics of Life on the Glencoe Science Web Site.
www.glencoe.com/sec/science

THE PRINCETON REVIEW

All Chapter Assessment questions and answers have been validated for accuracy and suitability by The Princeton Review.

Understanding Main Ideas

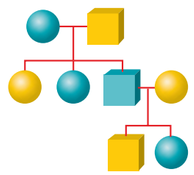
1. a
2. d

3. b
4. d
5. c
6. d
7. b
8. d
9. b
10. b
11. two
12. Down syndrome
13. son
14. XY, XX
15. numbers of chromosomes, karyotype
16. Nondisjunction
17. autosomal recessive
18. *Yy*
19. multiple allelic
20. incomplete dominance, codominance

Applying Main Ideas

21. If the woman's father had the allele on his X chromosome, he would have had hemophilia, but he did not. Thus, the X chromosome she received from him is free of the allele. It is possible, but unlikely, that she received an X chromosome that carries the allele from her mother. In that case, she could pass it to her son.

3. Two parents with normal phenotypes have a daughter with a genetically inherited disorder. This is an example of a(n) _____ trait.
   a. autosomal dominant **c.** sex-linked
   b. autosomal recessive **d.** polygenic
4. Which of the following disorders would be inherited according to the pedigree shown here?



   a. Tay-Sachs disease
   b. sickle-cell anemia
   c. cystic fibrosis
   d. Huntington's disease
5. Which of the following disorders is likely to be inherited by more males than females?
   a. Huntington's disease
   b. Down syndrome
   c. hemophilia
   d. cystic fibrosis
6. Infants with PKU cannot break down the amino acid _____.
   a. tyrosine **c.** methionine
   b. lysine **d.** phenylalanine
7. A karyotype reveals _____.
   a. an abnormal number of genes
   b. an abnormal number of chromosomes
   c. polygenic traits
   d. multiple alleles for a trait
8. A mother with blood type I^Bi and a father with blood type I^AI^B have children. Which of the following genotypes would be possible for their children?
   a. AB **c.** B
   b. O **d.** a and c are correct
9. Normally, lethal autosomal dominant traits are eliminated from a population because they _____.
   a. have a late onset
   b. have an early onset
   c. don't produce phenotypes that affect a carrier's health
   d. aren't dominant
10. Whose chromosomes determine the sex of offspring in humans?
    a. mother's **c.** both parents'
    b. father's **d.** neither parents'
11. A single individual carries _____ alleles for a trait.
12. _____ is a disorder that results from trisomy of chromosome 21.
13. Most sex-linked traits are passed from mother to _____.
14. The normal sex chromosomes of human males are _____, and the normal sex chromosomes of females are _____.
15. To analyze _____, geneticists make a chart of chromosomes called a(n) _____.
16. _____ during meiosis might result in monosomy or trisomy.
17. The inheritance pattern that occurs equally in both sexes and skips generations is _____.
18. The genotype of the individual represented by this pedigree symbol is _____. Use the letters *Y* and *y* to represent alleles.

19. Feather colors in pigeons are produced by _____ inheritance.
20. If a trait has three different phenotypes, the trait is inherited by _____ or _____.

Test-Taking Tip

Get to the Root of Things

If you don't know a word's meaning, you can still get an idea of its meaning if you focus on its roots, prefixes, and suffixes. For instance, words that start with non-, un-, a-, dis-, and in- generally reverse what the rest of the word means.

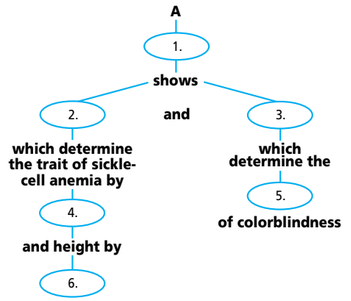
Applying Main Ideas

21. The brother of a woman's father has hemophilia. Her father was unaffected, but she worries that she may have an affected son. Should she worry? Explain.

22. If a child has type O blood and its mother has type A, could a man with type B be the father? Why couldn't a blood test be used to prove that he is the father?
23. Why do certain human genetic disorders, such as sickle-cell anemia and Tay-Sachs disease, occur more frequently among one ethnic group than another?
24. How can a single gene mutation in a protein such as hemoglobin affect several body systems?

Thinking Critically

25. **Recognizing Cause and Effect** Explain why a male with a recessive X-linked trait usually produces no female offspring with the trait.
26. **Comparing and Contrasting** Compare multiple allelic with polygenic inheritance.
27. **Concept Mapping** Complete the concept map by using the following vocabulary terms: sex-linked trait, autosomes, karyotype, sex chromosomes, polygenic inheritance, codominant alleles.

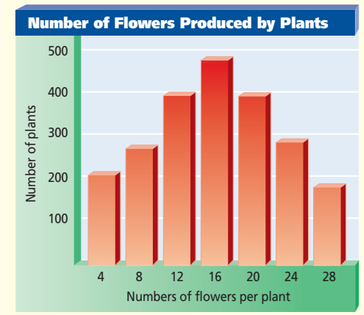


CD-ROM

For additional review, use the assessment options for this chapter found on the ***Biology: The Dynamics of Life Interactive CD-ROM*** and on the Glencoe Science Web Site.
www.glencoe.com/sec/science

Assessing Knowledge & Skills

The following graph illustrates the number of flowers produced per plant by a certain plant population.



Interpreting Data Use the graph to answer the questions that follow.

1. How many flowers are produced by plants that have only dominant genes for flower production?
   a. 4 **c.** 16
   b. 12 **d.** 28
2. How many flowers are produced by plants that have half the possible number of dominant genes for flower production?
   a. 4 **c.** 16
   b. 12 **d.** 28
3. What pattern of inheritance is suggested by the graph?
   a. multiple alleles
   b. incomplete dominance
   c. polygenic inheritance
   d. sex-linkage
4. **Observing and Inferring** From the above graph, estimate the number of gene pairs that control the number of flowers in these plants.

Assessing Knowledge & Skills

1. d
2. c
3. c
4. There are three gene pairs governing the number of flowers produced per plant.

22. The man could be I^Bi and be the father. A blood test can show only that he could possibly be the father, but not that he is the father.
23. People tend to marry within their own ethnic groups, allowing recessive alleles to show up more frequently in the populations.
24. The protein may be one that is transported or used in many systems. Malfunctions of one body system usually affect others.

Thinking Critically

25. All X chromosomes from the male parent are contributed to female offspring. If the female parent is homozygous dominant for the trait, all female offspring will be heterozygous and will not show the trait. The female parent would have to be heterozygous for that trait in order for half her female offspring to show the trait.
26. In multiple allelic inheritance, many forms of a trait may be found in a population, but they are based on only two alleles for the trait in each individual. In polygenic inheritance, the forms of the trait appear continuous, and individuals have many genes that add to the inheritance of the trait.
27. 1. Karyotype; 2. Autosomes; 3. Sex chromosomes; 4. Codominant alleles; 5. Sex-linked trait; 6. Polygenic inheritance