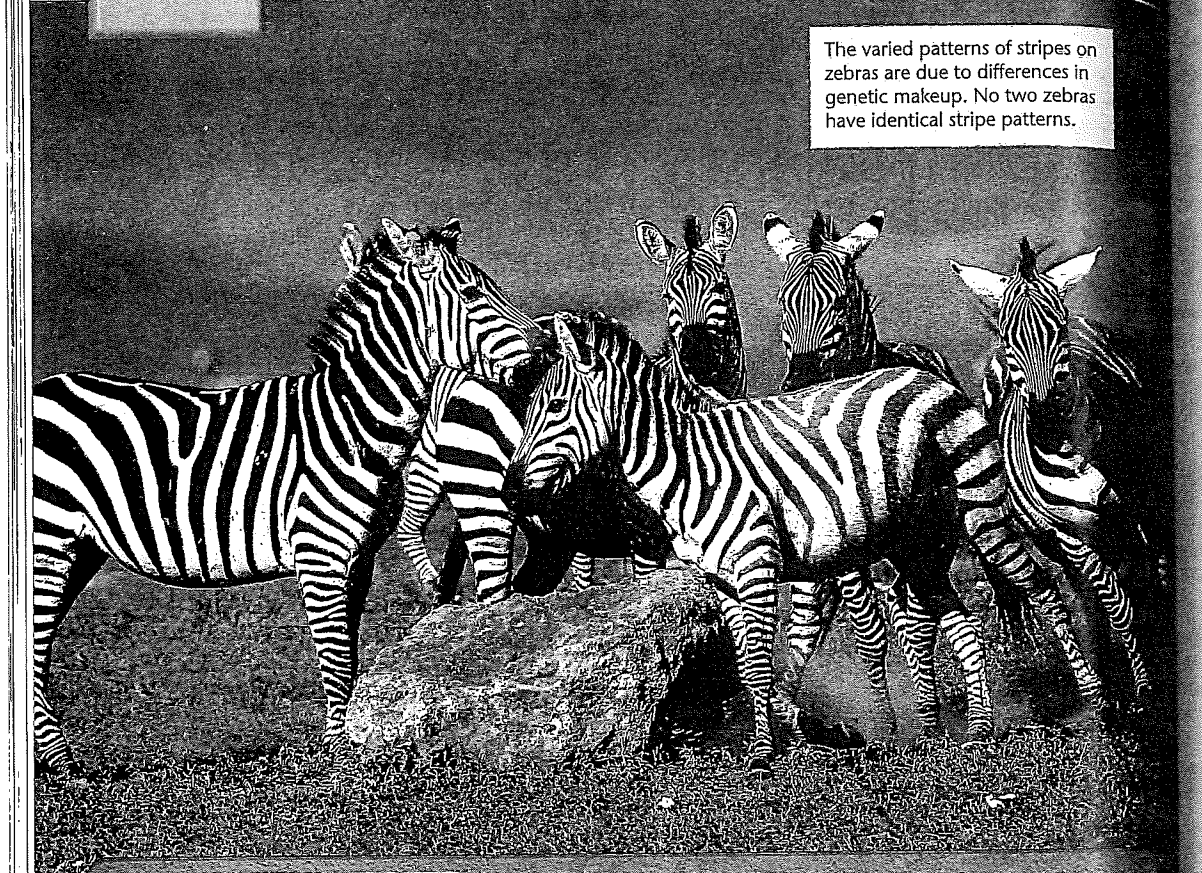
CHAPTER 11

Introduction to Genetics



The varied patterns of stripes on zebras are due to differences in genetic makeup. No two zebras have identical stripe patterns.

Inquiry Activity

Are traits inherited?

Procedure

1. Look at your classmates. Note how they vary in the shape of the front hairline, the space between the two upper front teeth, and the way in which the earlobes are attached.
2. Make a list of the different forms of these traits that you have observed in the class or among other people you know.

Think About It

1. **Inferring** Could these traits be inherited? From whom could they be inherited?
2. **Inferring** How is it possible that these traits could be found in a person and his or her biological grandparents but not in the biological parents?

11–1 The Work of Gregor Mendel

Guide for Reading

Key Concepts
- What is the principle of dominance?
- What happens during segregation?

Vocabulary
genetics • fertilization
true-breeding • trait • hybrid
gene • allele • segregation
gamete

Reading Strategy: Finding Main Ideas As you read, find evidence to support the following statement: Mendel's ideas about genetics were the beginning of a new area of biology.

What is an inheritance? To most people, it is money or property left to them by a relative who has passed away. That kind of inheritance is important, of course. There is another form of inheritance, however, that matters even more. This inheritance has been with you from the very first day you were alive—your genes.

Every living thing—plant or animal, microbe or human being—has a set of characteristics inherited from its parent or parents. Since the beginning of recorded history, people have wanted to understand how that inheritance is passed from generation to generation. More recently, however, scientists have begun to appreciate that heredity holds the key to understanding what makes each species unique. As a result, **genetics,** the scientific study of heredity, is now at the core of a revolution in understanding biology.

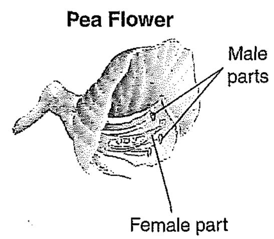
Gregor Mendel's Peas

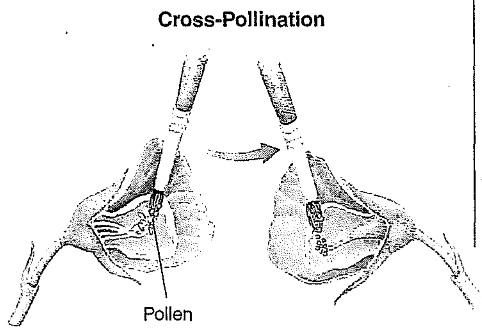
The work of an Austrian monk named Gregor Mendel, shown in **Figure 11–1,** was particularly important to understanding biological inheritance. Gregor Mendel was born in 1822 in what is now the Czech Republic. After becoming a priest, Mendel spent several years studying science and mathematics at the University of Vienna. He spent the next 14 years working in the monastery and teaching at the high school. In addition to his teaching duties, Mendel was in charge of the monastery garden. In this ordinary garden, he was to do the work that changed biology forever.

Mendel carried out his work with ordinary garden peas. He knew that part of each flower produces pollen, which contains the plant's male reproductive cells, or sperm. Similarly, the female portion of the flower produces egg cells. During sexual reproduction, male and female reproductive cells join, a process known as **fertilization.** Fertilization produces a new cell, which develops into a tiny embryo encased within a seed. Pea flowers are normally self-pollinating, which means that sperm cells in pollen fertilize the egg cells in the same flower. The seeds that are produced by self-pollination inherit all of their characteristics from the single plant that bore them. In effect, they have a single parent.

When Mendel took charge of the monastery garden, he had several stocks of pea plants. These peas were **true-breeding,** meaning that if they were allowed to self-pollinate, they would produce offspring identical to themselves. One stock of seeds would produce only tall plants, another only short ones. One line produced only green seeds, another only yellow seeds. These true-breeding plants were the basis of Mendel's experiments.

▲ **Figure 11–1** Gregor Mendel's experiments with pea plants laid the foundations of the science of genetics.





◀ **Figure 11–2** To cross-pollinate pea plants, Mendel cut off the male parts of one flower and then dusted it with pollen from another flower. **Applying Concepts** *How did this procedure prevent self-pollination?*

Mendel wanted to produce seeds by joining male and female reproductive cells from two different plants. To do this, he had to prevent self-pollination. He accomplished this by cutting away the pollen-bearing male parts as shown in **Figure 11–2** and then dusting pollen from another plant onto the flower. This process, which is known as cross-pollination, produced seeds that had two different plants as parents. This made it possible for Mendel to cross-breed plants with different characteristics and then to study the results.

CHECKPOINT *What is fertilization?*

Genes and Dominance

Mendel studied seven different pea plant traits. A **trait** is a specific characteristic, such as seed color or plant height, that varies from one individual to another. Each of the seven traits Mendel studied had two contrasting characters, for example, green seed color and yellow seed color. Mendel crossed plants with each of the seven contrasting characters and studied their offspring. We call each original pair of plants the P (parental) generation. The offspring are called the F_1, or "first filial," generation. *Filius* and *filia* are the Latin words for "son" and "daughter." The offspring of crosses between parents with different traits are called **hybrids.**

▼ **Figure 11–3** When Mendel crossed plants with contrasting characters for the same trait, the resulting offspring had only one of the characters. **From these experiments, Mendel concluded that some alleles are dominant and others are recessive.**

Mendel's Seven F_1 Crosses on Pea Plants

	Seed Shape	Seed Color	Seed Coat Color	Pod Shape	Pod Color	Flower Position	Plant Height
P	Round X Wrinkled	Yellow X Green	Gray X White	Smooth X Constricted	Green X Yellow	Axial X Terminal	Tall X Short
F_1	Round	Yellow	Gray	Smooth	Green	Axial	Tall

What were those F_1 hybrid plants like? Did the characters of the parent plants blend in the offspring? Not at all. To Mendel's surprise, all of the offspring had the character of only one of the parents, as shown in **Figure 11–3.** In each cross, the character of the other parent seemed to have disappeared.

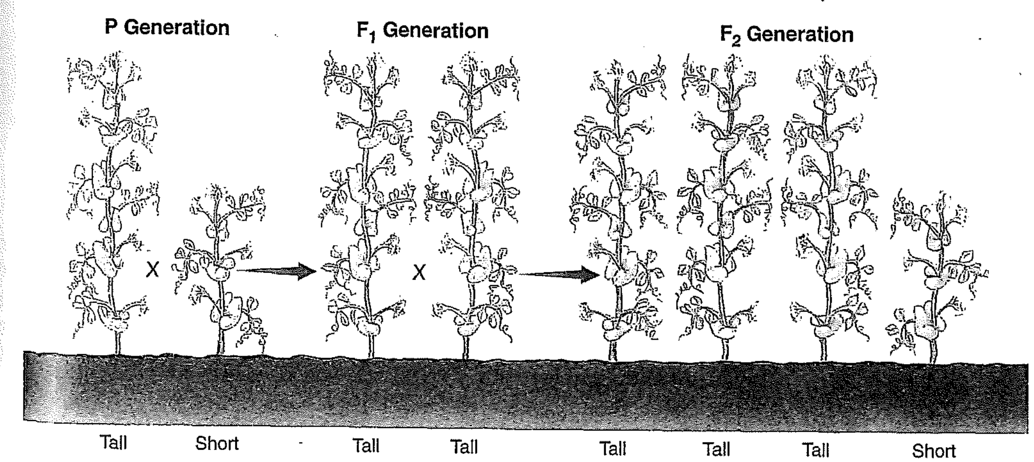
From this set of experiments, Mendel drew two conclusions. Mendel's first conclusion was that biological inheritance is determined by factors that are passed from one generation to the next. Today, scientists call the chemical factors that determine traits **genes.** Each of the traits Mendel studied was controlled by one gene that occurred in two contrasting forms. These contrasting forms produced the different characters of each trait. For example, the gene for plant height occurs in one form that produces tall plants and in another form that produces short plants. The different forms of a gene are called **alleles** (uh-LEELZ).

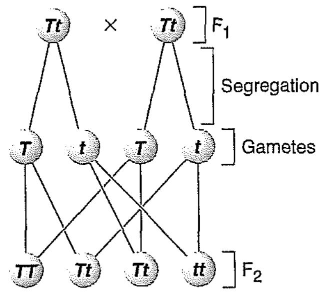
Mendel's second conclusion is called the principle of dominance. **The principle of dominance states that some alleles are dominant and others are recessive.** An organism with a dominant allele for a particular form of a trait will always exhibit that form of the trait. An organism with a recessive allele for a particular form of a trait will exhibit that form only when the dominant allele for the trait is not present. In Mendel's experiments, the allele for tall plants was dominant and the allele for short plants was recessive. The allele for yellow seeds was dominant, while the allele for green seeds was recessive.

Segregation

Mendel wanted the answer to another question: Had the recessive alleles disappeared, or were they still present in the F_1 plants? To answer this question, he allowed all seven kinds of F_1 hybrid plants to produce an F_2 (second filial) generation by self-pollination. In effect, he crossed the F_1 generation with itself to produce the F_2 offspring, as shown in **Figure 11–4.**

▼ **Figure 11–4** When Mendel allowed the F_1 plants to reproduce by self-pollination, the traits controlled by recessive alleles reappeared in about one fourth of the F_2 plants in each cross. **Calculating** *What proportion of the F_2 plants had a trait controlled by a dominant allele?*





▲ **Figure 11–5** **During gamete formation, alleles segregate from each other so that each gamete carries only a single copy of each gene. Each F_1 plant produces two types of gametes—those with the allele for tallness and those with the allele for shortness.** The alleles are paired up again when gametes fuse during fertilization. The *TT* and *Tt* allele combinations produce tall pea plants; *tt* is the only allele combination that produces a short pea plant.

The F_1 Cross The results of the F_1 cross were remarkable. When Mendel compared the F_2 plants, he discovered that the traits controlled by the recessive alleles had reappeared! Roughly one fourth of the F_2 plants showed the trait controlled by the recessive allele. Why did the recessive alleles seem to disappear in the F_1 generation and then reappear in the F_2 generation? To answer this question, let's take a closer look at one of Mendel's crosses.

Explaining the F_1 Cross To begin with, Mendel assumed that a dominant allele had masked the corresponding recessive allele in the F_1 generation. However, the trait controlled by the recessive allele showed up in some of the F_2 plants. This reappearance indicated that at some point the allele for shortness had been separated from the allele for tallness. How did this separation, or **segregation,** of alleles occur? Mendel suggested that the alleles for tallness and shortness in the F_1 plants segregated from each other during the formation of the sex cells, or **gametes** (GAM-eetz). Did that suggestion make sense?

Let's assume, as perhaps Mendel did, that the F_1 plants inherited an allele for tallness from the tall parent and an allele for shortness from the short parent. Because the allele for tallness is dominant, all the F_1 plants are tall. **When each F_1 plant flowers and produces gametes, the two alleles segregate from each other so that each gamete carries only a single copy of each gene. Therefore, each F_1 plant produces two types of gametes—those with the allele for tallness and those with the allele for shortness.**

Look at **Figure 11–5** to see how alleles separated during gamete formation and then paired up again in the F_2 generation. A capital letter *T* represents a dominant allele. A lowercase letter *t* represents a recessive allele. The result of this process is an F_2 generation with new combinations of alleles.

11–1 Section Assessment

1. **Key Concept** What are dominant and recessive alleles?
2. **Key Concept** What is segregation? What happens to alleles during segregation?
3. What did Mendel conclude determines biological inheritance?
4. Describe how Mendel cross-pollinated pea plants.
5. Why did only about one fourth of Mendel's F_2 plants exhibit the recessive trait?
6. **Critical Thinking Applying Concepts** Why were true-breeding pea plants important for Mendel's experiments?

Thinking Visually

Using Diagrams
Use a diagram to explain Mendel's principles of dominance and segregation. Your diagram should show how the alleles segregate during gamete formation.

11–2 Probability and Punnett Squares

Guide for Reading

Key Concepts
- How do geneticists use the principles of probability?
- How do geneticists use Punnett squares?

Vocabulary
probability
Punnett square
homozygous
heterozygous
phenotype
genotype

Reading Strategy: Building Vocabulary Before you read, preview the list of new vocabulary words. Predict the relationship between phenotype and genotype. As you read, check to see if your predictions were correct.

Whenever Mendel performed a cross with pea plants, he carefully categorized and counted the many offspring. Every time Mendel repeated a particular cross, he obtained similar results. For example, whenever Mendel crossed two plants that were hybrid for stem height (*Tt*), about three fourths of the resulting plants were tall and about one fourth were short. Mendel realized that the principles of probability could be used to explain the results of genetic crosses.

Genetics and Probability

The likelihood that a particular event will occur is called **probability.** As an example of probability, consider an ordinary event like the coin flip shown in **Figure 11–6.** There are two possible outcomes: The coin may land heads up or tails up. The chances, or probabilities, of either outcome are equal. Therefore, the probability that a single coin flip will come up heads is 1 chance in 2. This is 1/2, or 50 percent.

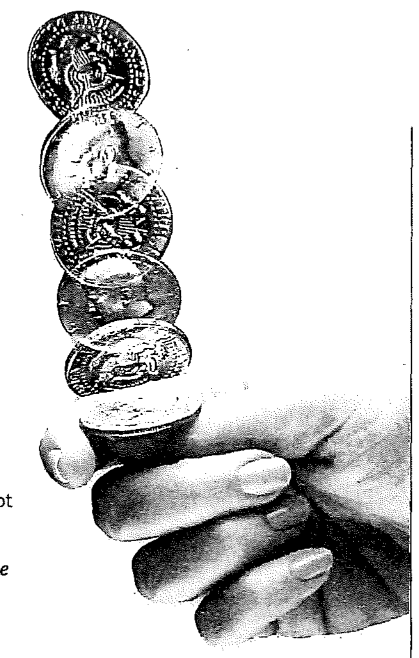
If you flip a coin three times in a row, what is the probability that it will land heads up every time? Because each coin flip is an independent event, the probability of each coin's landing heads up is 1/2. Therefore, the probability of flipping three heads in a row is:

$$\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{8}.$$

As you can see, you have 1 chance in 8 of flipping heads three times in a row. That the individual probabilities are multiplied together illustrates an important point—past outcomes do not affect future ones.

How is coin flipping relevant to genetics? The way in which alleles segregate is completely random, like a coin flip. **The principles of probability can be used to predict the outcomes of genetic crosses.**

✓CHECKPOINT *What is the probability that a tossed coin will come up tails twice in a row?*



▶ **Figure 11–6** The mathematical concept of probability allows you to calculate the likelihood that a particular event will occur. **Predicting** *What is the probability that the coin will land heads up?*

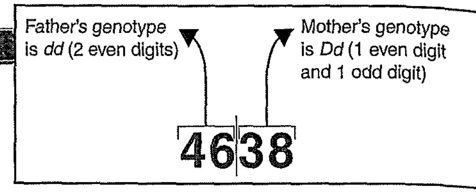
Quick Lab

How are dimples inherited?

Materials copy of page from telephone book, calculator

Procedure

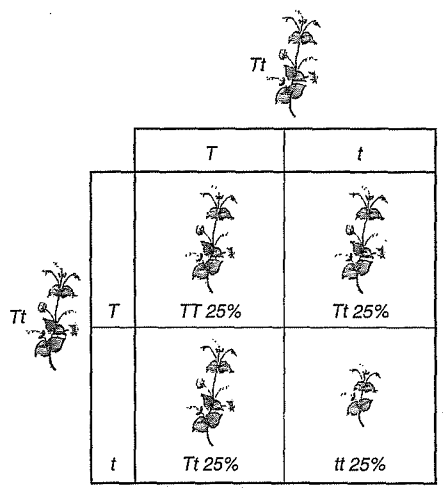
1. Write the last 4 digits of any telephone number. These 4 random digits represent the alleles of a gene that determines whether a person will have dimples. Odd digits represent the allele for the dominant trait of dimples. Even digits stand for the allele for the recessive trait of no dimples.
2. Use the first 2 digits to represent a certain father's genotype. Use the symbols *D* and *d* to write his genotype, as shown in the example.
3. Use the last 2 digits the same way to find the mother's genotype. Write her genotype.



4. Use **Figure 11–7** as an example to construct a Punnett square for the cross of these parents. Then, using the Punnett square, determine the probability that their child will have dimples.
5. Determine the class average of the percent of children with dimples.

Analyze and Conclude

1. **Applying Concepts** How does the class average compare with the result of a cross of two heterozygous parents?
2. **Drawing Conclusions** What percentage of the children will be expected to have dimples if one parent is homozygous for dimples *(DD)* and the other is heterozygous *(Dd)*?



▲ **Figure 11–7 The principles of probability can be used to predict the outcomes of genetic crosses.** This Punnett square shows the probability of each possible outcome of a cross between hybrid tall *(Tt)* pea plants.

Punnett Squares

The gene combinations that might result from a genetic cross can be determined by drawing a diagram known as a **Punnett square.** The Punnett square in **Figure 11–7** shows one of Mendel's segregation experiments. The types of gametes produced by each F_1 parent are shown along the top and left sides of the square. The possible gene combinations for the F_2 offspring appear in the four boxes that make up the square. The letters in the Punnett square represent alleles. In this example, *T* represents the dominant allele for tallness and *t* represents the recessive allele for shortness. **Punnett squares can be used to predict and compare the genetic variations that will result from a cross.**

Organisms that have two identical alleles for a particular trait—*TT* or *tt* in this example—are said to be **homozygous** (hoh-moh-ZY-gus). Organisms that have two different alleles for the same trait are **heterozygous** (het-ur-oh-ZY-gus). Homozygous organisms are true-breeding for a particular trait. Heterozygous organisms are hybrid for a particular trait.

All of the tall plants have the same **phenotype,** or physical characteristics. They do not, however, have the same **genotype,** or genetic makeup. The genotype of one third of the tall plants is *TT*, while the genotype of two thirds of the tall plants is *Tt*. The plants in **Figure 11–8** have the same phenotype but different genotypes.

Probability and Segregation

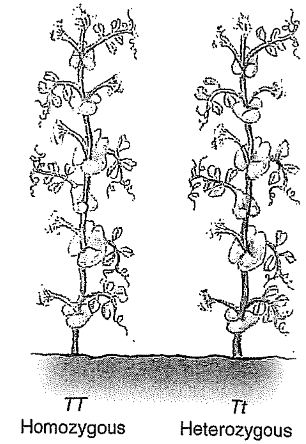
Look again at **Figure 11–7.** One fourth (1/4) of the F_2 plants have two alleles for tallness *(TT)*; 2/4, or 1/2, of the F_2 plants have one allele for tallness and one allele for shortness *(Tt)*. Because the allele for tallness is dominant over the allele for shortness, 3/4 of the F_2 plants should be tall. Overall, there are 3 tall plants for every 1 short plant in the F_2 generation. Thus, the ratio of tall plants to short plants is 3 : 1. This assumes, of course, that Mendel's model of segregation is correct.

Did the data from Mendel's experiments fit his model? Yes. The predicted ratio—3 dominant to 1 recessive—showed up consistently, indicating that Mendel's assumptions about segregation had been correct. For each of his seven crosses, about 3/4 of the plants showed the trait controlled by the dominant allele. About 1/4 showed the trait controlled by the recessive allele. Segregation did indeed occur according to Mendel's model.

Probabilities Predict Averages

Probabilities predict the average outcome of a large number of events. However, probability cannot predict the precise outcome of an individual event. If you flip a coin twice, you are likely to get one head and one tail. However, you might also get two heads or two tails. To be more likely to get the expected 50 : 50 ratio, you would have to flip the coin many times.

The same is true of genetics. The larger the number of offspring, the closer the resulting numbers will get to expected values. If an F_1 generation contains just three or four offspring, it may not match Mendelian predicted ratios. When an F_1 generation contains hundreds or thousands of individuals, however, the ratios usually come very close to matching expectations.



▲ **Figure 11–8** Although these plants have different genotypes (*TT* and *Tt*), they have the same phenotype (tall). **Predicting** *If you crossed these two plants, would their offspring be tall or short?*

11–2 Section Assessment

1. **Key Concept** How are the principles of probability used to predict the outcomes of genetic crosses?
2. **Key Concept** How are Punnett squares used?
3. What is probability?
4. Define the terms *genotype* and *phenotype.*
5. **Critical Thinking Problem Solving** An F_1 plant that is homozygous for shortness is crossed with a heterozygous F_1 plant. What is the probability that a seed from the cross will produce a tall plant? Use a Punnett square to explain your answer and to compare the probable genetic variations in the F_2 plants.

Thinking Visually

Drawing Punnett Squares Imagine that you came upon a tall pea plant similar to those Mendel used in his experiments. How could you determine the plant's genotype with respect to height? Draw two Punnett squares to show your answer.

11–3 Exploring Mendelian Genetics

Guide for Reading

Key Concepts
- What is the principle of independent assortment?
- What inheritance patterns exist aside from simple dominance?

Vocabulary
independent assortment
incomplete dominance
codominance
multiple alleles
polygenic traits

Reading Strategy: Finding Main Ideas Before you read, draw a line down the center of a sheet of paper. On the left side, write down the main topics of the section. On the right side, note supporting details and examples.

After showing that alleles segregate during the formation of gametes, Mendel wondered if they did so independently. In other words, does the segregation of one pair of alleles affect the segregation of another pair of alleles? For example, does the gene that determines whether a seed is round or wrinkled in shape have anything to do with the gene for seed color? Must a round seed also be yellow?

Independent Assortment

To answer these questions, Mendel performed an experiment to follow two different genes as they passed from one generation to the next. Mendel's experiment is known as a two-factor cross.

The Two-Factor Cross: F_1 First, Mendel crossed true-breeding plants that produced only round yellow peas (genotype *RRYY*) with plants that produced wrinkled green peas (genotype *rryy*). All of the F_1 offspring produced round yellow peas. This shows that the alleles for yellow and round peas are dominant over the alleles for green and wrinkled peas. A Punnett square for this cross, shown in **Figure 11–9**, shows that the genotype of each of these F_1 plants is *RrYy*.

This cross does not indicate whether genes assort, or segregate, independently. However, it provides the hybrid plants needed for the next cross—the cross of F_1 plants to produce the F_2 generation.

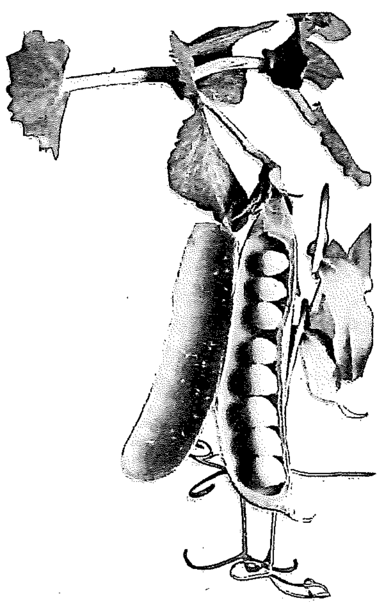


Figure 11–9 Mendel crossed plants that were homozygous dominant for round yellow peas with plants that were homozygous recessive for wrinkled green peas. All of the F_1 offspring were heterozygous dominant for round yellow peas. **Interpreting Graphics** *How is the genotype of the offspring different from that of the homozygous dominant parent?*

rryy × *RRYY*

	ry	ry	ry	ry
RY	RrYy	RrYy	RrYy	RrYy
RY	RrYy	RrYy	RrYy	RrYy
RY	RrYy	RrYy	RrYy	RrYy
RY	RrYy	RrYy	RrYy	RrYy

The Two-Factor Cross: F_2 Mendel knew that the F_1 plants had genotypes of *RrYy*. In other words, the F_1 plants were all heterozygous for both the seed shape and seed color genes. How would the alleles segregate when the F_1 plants were crossed to each other to produce an F_2 generation? Remember that each plant in the F_1 generation was formed by the fusion of a gamete carrying the dominant *RY* alleles with another gamete carrying the recessive *ry* alleles. Did this mean that the two dominant alleles would always stay together? Or would they "segregate independently," so that any combination of alleles was possible?

In Mendel's experiment, the F_2 plants produced 556 seeds. Mendel compared the variation in the seeds. He observed that 315 seeds were round and yellow and another 32 were wrinkled and green, the two parental phenotypes. However, 209 of the seeds had combinations of phenotypes—and therefore combinations of alleles—not found in either parent. This clearly meant that the alleles for seed shape segregated independently of those for seed color—a principle known as ***independent assortment.*** Put another way, genes that segregate independently—such as the genes for seed shape and seed color in pea plants—do not influence each other's inheritance. Mendel's experimental results were very close to the 9 : 3 : 3 : 1 ratio that the Punnett square shown in **Figure 11–10** predicts. Mendel had discovered the principle of independent assortment. **The principle of independent assortment states that genes for different traits can segregate independently during the formation of gametes. Independent assortment helps account for the many genetic variations observed in plants, animals, and other organisms.**

RrYy × *RrYy*

	RY	Ry	rY	ry
RY	RRYY	RRYy	RrYY	RrYy
Ry	RRYy	RRyy	RrYy	Rryy
rY	RrYY	RrYy	rrYY	rrYy
ry	RrYy	Rryy	rrYy	rryy

F_2 Generation

▲ **Figure 11–10** **When Mendel crossed plants that were heterozygous dominant for round yellow peas, he found that the alleles segregated independently to produce the F_2 generation.**

Problem Solving

Producing True-Breeding Seeds

Suppose you work for a company that specializes in ornamental flowers. One spring, you find an ornamental plant with beautiful lavender flowers. Knowing that these plants are self-pollinating, you harvest seeds from it. You plant the seeds the following season. Of the 106 test plants, 31 have white flowers. Is there a way to develop seeds that produce only lavender flowers?

Defining the Problem Describe the problem that must be solved to make the lavender-flowered plants a commercial success.

Organizing Information The first lavender flower produced offspring with both lavender and white flowers when allowed to self-pollinate. Use your knowledge of Mendelian genetics, including Punnett squares, to draw conclusions about the nature of the allele for these lavender flowers.

Creating a Solution Write a description of how you would produce seeds guaranteed to produce 100 percent lavender plants. A single plant can produce as many as 1000 seeds.

Presenting Your Plan Prepare a step-by-step outline of your plan, including Punnett squares when appropriate. Present the procedure to your class.

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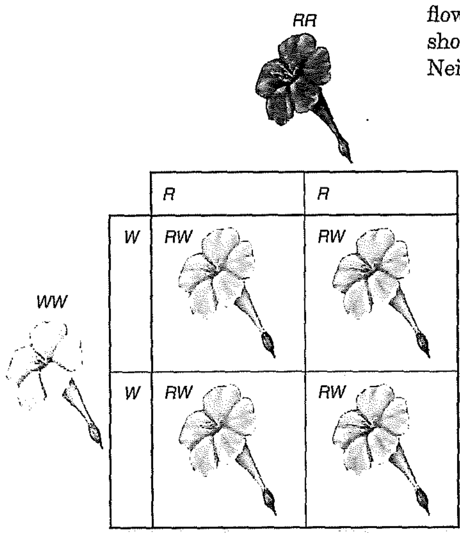
active art
For: Punnett Square activity
Visit: PHSchool.com
Web Code: cbp-4112

▼ **Figure 11–11** **Some alleles are neither dominant nor recessive.** In four o'clock plants, for example, the alleles for red and white flowers show incomplete dominance. Heterozygous *(RW)* plants have pink flowers—a mix of red and white coloring.



A Summary of Mendel's Principles

Mendel's principles form the basis of the modern science of genetics. These principles can be summarized as follows:

- The inheritance of biological characteristics is determined by individual units known as genes. Genes are passed from parents to their offspring.
- In cases in which two or more forms (alleles) of the gene for a single trait exist, some forms of the gene may be dominant and others may be recessive.
- In most sexually reproducing organisms, each adult has two copies of each gene—one from each parent. These genes are segregated from each other when gametes are formed.
- The alleles for different genes usually segregate independently of one another.

Beyond Dominant and Recessive Alleles

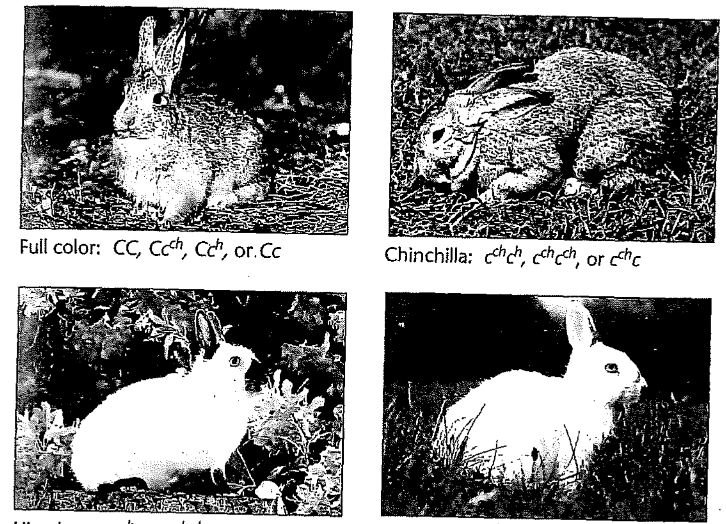
Despite the importance of Mendel's work, there are important exceptions to most of his principles. For example, not all genes show simple patterns of dominant and recessive alleles. In most organisms, genetics is more complicated, because the majority of genes have more than two alleles. In addition, many important traits are controlled by more than one gene. **Some alleles are neither dominant nor recessive, and many traits are controlled by multiple alleles or multiple genes.**

Incomplete Dominance A cross between two four o'clock (Mirabilis) plants shows one of these complications. The F_1 generation produced by a cross between red-flowered *(RR)* and white-flowered *(WW)* plants consists of pink-colored flowers *(RW)*, as shown in **Figure 11–11.** Which allele is dominant in this case? Neither one. Cases in which one allele is not completely dominant over another are called **incomplete dominance.** In incomplete dominance, the heterozygous phenotype is somewhere in between the two homozygous phenotypes.

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

Figure 11–12 Multiple Alleles

Coat color in rabbits is determined by a single gene that has at least four different alleles. Different combinations of alleles result in the four colors you see here. **Interpreting Graphics** *What allele combinations can a chinchilla rabbit have?*



Full color: CC, Cc^{ch}, Cc^{h}, or Cc

Chinchilla: $c^{ch}c^{h}$, $c^{ch}c^{ch}$, or $c^{ch}c$

Himalayan: $c^{h}c$ or $c^{h}c^{h}$

Albino: cc

Key

C = full color; dominant to all other alleles

c^{ch} = chinchilla; partial defect in pigmentation; dominant to c^{h} and c alleles

c^{h} = Himalayan; color in certain parts of body; dominant to c allele

c = albino; no color; recessive to all other alleles

Multiple Alleles Many genes have more than two alleles and are therefore said to have **multiple alleles.** This does not mean that an individual can have more than two alleles. It only means that more than two possible alleles exist in a population. One of the best-known examples is coat color in rabbits. A rabbit's coat color is determined by a single gene that has at least four different alleles. The four known alleles display a pattern of simple dominance that can produce four possible coat colors, as shown in **Figure 11–12.** Many other genes have multiple alleles, including the human genes for blood type.

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

✓CHECKPOINT *What are multiple alleles?*

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▲ **Figure 11–13** The common fruit fly is a popular organism for genetic research. **Inferring** *Why are fruit flies easier to use for genetic research than large animals, such as dogs?*

Applying Mendel's Principles

Mendel's principles don't apply only to plants. At the beginning of the 1900s, the American geneticist Thomas Hunt Morgan decided to look for a model organism to advance the study of genetics. He wanted an animal that was small, easy to keep in the laboratory, and able to produce large numbers of offspring in a short period of time. He decided to work on a tiny insect that kept showing up, uninvited, in his laboratory. The insect was the common fruit fly, *Drosophila melanogaster,* shown in **Figure 11–13.**

Morgan grew the flies in small milk bottles stoppered with cotton gauze. *Drosophila* was an ideal organism for genetics because it could produce plenty of offspring, and it did so quickly. A single pair of flies could produce as many as 100 offspring. Before long, Morgan and other biologists had tested every one of Mendel's principles and learned that they applied not just to pea plants but to other organisms as well.

Mendel's principles also apply to humans. The basic principles of Mendelian genetics can be used to study the inheritance of human traits and to calculate the probability of certain traits appearing in the next generation. You will learn more about human genetics in Chapter 14.

Genetics and the Environment

The characteristics of any organism, whether bacterium, fruit fly, or human being, are not determined solely by the genes it inherits. Rather, characteristics are determined by interaction between genes and the environment. For example, genes may affect a sunflower plant's height and the color of its flowers. However, these same characteristics are also influenced by climate, soil conditions, and the availability of water. Genes provide a plan for development, but how that plan unfolds also depends on the environment.

11–3 Section Assessment

1. **Key Concept** Explain what *independent assortment* means.
2. **Key Concept** Describe two inheritance patterns besides simple dominance.
3. What is the difference between incomplete dominance and codominance?
4. Why are fruit flies an ideal organism for genetic research?
5. **Critical Thinking Comparing and Contrasting** A geneticist studying coat color in animals crosses a male rabbit having the genotype *CC* with a female having genotype Cc^{ch}. The geneticist then crosses a cc^{ch} male with a Cc^{c} female. In which of the two crosses are the offspring more likely to show greater genetic variation? Use Punnett squares to explain your answer.

Sharpen Your Skills

Problem Solving

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

11–4 Meiosis

Guide for Reading

Key Concepts
- What happens during the process of meiosis?
- How is meiosis different from mitosis?

Vocabulary
homologous
diploid
haploid
meiosis
tetrad
crossing-over

Reading Strategy: Using Visuals Before you read, preview **Figure 11–15.** As you read, note what happens at each stage of meiosis.

Gregor Mendel did not know where the genes he had discovered were located. Fortunately, his predictions of how genes should behave were so specific that it was not long before biologists were certain they had found them—on the chromosomes. The chromosomal theory of inheritance states that genes are located in specific positions on chromosomes.

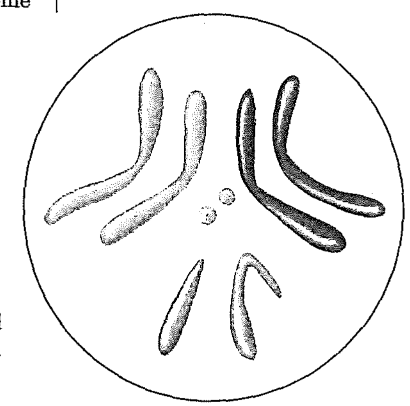
Mendel's principles of genetics require at least two things. First, each organism must inherit a single copy of every gene from each of its "parents." A single copy of every chromosome is indeed passed along from parent to offspring in this way. Second, when an organism produces its own gametes, those two sets of genes must be separated so that each gamete contains just one set of genes. Chromosomes are separated in exactly this way during gamete formation, just as the chromosomal theory of inheritance would predict.

Chromosome Number

As an example of how chromosomal inheritance works, let's consider the fruit fly, *Drosophila.* A body cell in an adult fruit fly has 8 chromosomes, as shown in **Figure 11–14.** Four of the chromosomes came from the fruit fly's male parent, and 4 came from its female parent. These two sets of chromosomes are **homologous** (hoh-MAHL-uh-guhs), meaning that each of the 4 chromosomes that came from the male parent has a corresponding chromosome from the female parent.

A cell that contains both sets of homologous chromosomes is said to be **diploid,** which means "two sets." The number of chromosomes in a diploid cell is sometimes represented by the symbol 2N. Thus for *Drosophila,* the diploid number is 8, which can be written 2N = 8. Diploid cells contain two complete sets of chromosomes and two complete sets of genes. This agrees with Mendel's idea that the cells of an adult organism contain two copies of each gene.

By contrast, the gametes of sexually reproducing organisms, including fruit flies and peas, contain only a single set of chromosomes, and therefore only a single set of genes. Such cells are said to be **haploid,** which means "one set." For *Drosophila,* this can be written as N = 4, meaning that the haploid number is 4.



▶ **Figure 11–14** These chromosomes are from a fruit fly. Each of the fruit fly's body cells has 8 chromosomes.

Phases of Meiosis

How are haploid (N) gamete cells produced from diploid (2N) cells? That's where **meiosis** (my-OH-sis) comes in. **Meiosis is a process of reduction division in which the number of chromosomes per cell is cut in half through the separation of homologous chromosomes in a diploid cell.**