Original.

Unit 2 Life Science — Genetics

— Study Guide —

By the end of this unit, you should be able to complete the following tasks:

- Relate the genetic code to the assembly of different proteins
- Apply the principles that govern the inheritance of traits in problems involving Mendelian genetics
- Summarize factors that may lead to different types of mutations, including chemical, biological, and physical factors
- Distinguish among positive, neutral, and negative effects of various mutations
- Analyze the implications of biomedical, genetic, and reproductive technologies.

You will not need to refer to your *Data Booklet* for this unit.

By the end of this unit, you should know these three key ideas:

2.1 Genetics follows a set of rules that govern inheritance.
2.2 Mutations affect living things in a variety of ways.
2.3 Biomedical technologies have revolutionized medicine.

Go to **bcscience.com** for more information and links for each of these ideas.

By the end of this unit, you should know these key terms:

- albino
- allele
- codominance
- dominant
- F_1 generation
- F_2 generation
- gene
- genotype
- hemophilia
- heterozygous
- homozygous
- hybrid
- incomplete dominance
- intermediate phenotype
- masked
- monohybrid cross
- mutation
- P generation
- phenotype
- phenotypic ratio
- probability
- Punnett square
- purebred
- recessive
- sex linkage
- toxins
- trait

2.1 Genetics follows a set of rules that govern inheritance.

2.1.1 From Gene to Protein

The Role of Genes

Genetics is the study of how inheritable characteristics, such as eye colour in humans and flower colour in plants, are passed on from generation to generation. Before examining patterns of inheritance associated with these characteristics, it's useful to study the role of **genes** and how they relate to the production of protein. Why? Because the protein made by our cells determines a vast number of characteristics—from how tall we are likely to grow, to the complexion of our skin, to the colour of our hair, and to whether we grow up as males or as females. Genes contain the information needed to make protein. And genes are what parents pass on to their offspring during reproduction.

Molecular biologists in the last century explored how genes work. In doing so, they discovered the **genetic code**—the chemical language through which the information needed to produce a complete human is transmitted. They found that:

- Genetic information (genes) is located in our chromosomes. In Unit 1, you learned that chromosomes are composed of long strands of a molecule called deoxyribonucleic acid (DNA).
- Genetic information is used by our cells to make protein. Genes determine which of 20 kinds of amino acids are to be linked together into a chain that, when finished, makes a long protein molecule. Human DNA contains enough information to assemble about 100 000 different kinds of protein.
- Nearly every cell in the human body contains all the genetic information necessary to produce a new human.

Molecular biologists also discovered that:

- All known life forms use the same genetic code and the same, or closely related, cellular apparatus to produce protein. This is why a human gene can be placed into a bacterium to produce the life-saving protein called insulin, used to treat many people with diabetes.
- The genes in humans and chimpanzees are 98% identical. We even share many genes with organisms that appear vastly different from us. For example, almost all of the genes present in a tiny worm called a nematode are also present in humans (although we have many additional ones that they do not have).
- Viruses attack our cells by substituting their own genes into the cellular apparatus of human cells. Instead of making human protein, our infected cells make viral protein. Because of similarities in biochemistry, a virus can spread from a goose to a pig to a human. In fact, most forms of the common flu are believed to have originated in birds from Asia, where they are raised in close proximity to pigs and humans.

For more information about the relationship between genes and protein, check out bcscience.com.

The Genetic Code

All cells contain an intricate biochemical apparatus that reads the information in genes and then uses it to construct protein. This apparatus is passed on from the parent cell to the daughter cell during cytokinesis, when the daughter cell receives a portion of the cytoplasm.

By analogy, genes act like a DVD that has been placed into a DVD player. Specific markings on the DVD correspond to specific pixels that are lit up on the TV screen. The genetic code relates the ordering of four special chemicals in DNA to the ordering of specific amino acids in protein.

The four special chemicals that make up the long DNA molecule are called bases. These four bases are represented by the letters C, G, T, and A, and can join together to form a very long chain. In humans, these chains, or strands, are several million bases long. Each strand contains many genes. The strands come together in pairs to form the DNA molecule: They wind around each other in a special way to form a double spiral, called a double helix. Opposite every C on one DNA strand is a G on the other strand; opposite every T on one strand is an A on the other (Figure 2.1).

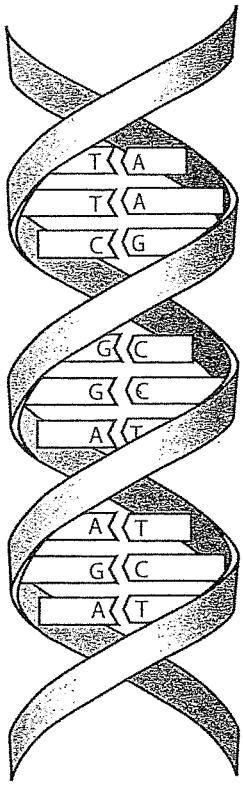


FIGURE 2.1 The double helix. DNA is a double strand that contains two long chains of bases. Each chain contains the information needed to assemble a protein.

The Role of Protein

Protein plays a critical role in our biochemistry. Table 2.1 shows some examples of different proteins hard at work in our bodies.

For more information on protein building, check out bcscience.com.

TABLE 2.1 Examples of How Protein Works in the Body

Location in Body	Role
Chromatin	Proteins wind up and unwind the DNA in our chromosomes. Some can split open a DNA molecule like a zipper, and others can zip it up again. Proteins can move up and down the DNA molecule and repair certain kinds of genetic mistakes. Some proteins can activate genes to produce a new protein; while others can turn the genes off.
Cytoplasm	Proteins assist in chemical reactions in all cells, helping the reactions to go faster. The chemicals in such reactions are called enzymes.
Cell membrane	Proteins sit in the cell membrane and control the passage of chemicals through it in both directions. Proteins also protrude from the outside of the membrane and act as markers. These markers help white blood cells determine whether or not the cell is a foreign invader.
Bloodstream	Proteins float in the bloodstream. Some attack invading bacteria and work by ripping the cell membranes of bacteria open. Some proteins activate white blood cells to detect and destroy invading cells. Others signal distant parts of the body to prepare for changes, such as sudden increases or decreases in physical activity.

The examples in Table 2.1 show the importance of protein—and the importance of genes, which control the production of protein.

2.1.1 Review Questions

1. Does a skin cell in an adult human contain the genetic information needed to make a whole human?

2. What is DNA, and how many kinds of bases are used to make a DNA strand?

3. What is protein and where are three places it can be found in a cell?

4. Describe the relationship between genes and protein.

5. Does the genetic code vary from one species to another? Could a gene from a spider be read by the protein-making apparatus of a tomato plant if a spider gene was substituted for a tomato gene?

6. One strand of DNA has a short sequence of bases arranged in the following order:

   GATTACACATAGA

   Write the order of the bases on the second DNA strand that is wound around this one.

7. When scientists realized that DNA consisted of two connected strands wound around each other, they were sure they had also discovered something new about mitosis. How does the idea of the double helix help explain how genes make copies of themselves during mitosis?

2.1.2 Mendel and the Gene Hypothesis

The Birth of Genetics

Children usually resemble their birth parents. Brothers and sisters also carry resemblances to each other, as well as to their grandparents, cousins, uncles, and aunts. Somehow parents pass on a mixture of family characteristics to their children. This section will explore the basis for the inheritance of visible characteristics from one generation to the next.

Try the following experiment. Clasp your hands together, allowing your fingers and thumbs to interlock. Once you have done this, check to see whether your right thumb or your left thumb is on top. Now reverse the position of your hands so that your other thumb is on the top. Do you have a preference for one position or the other? Compare your preference with those of your parents, siblings, or classmates (Figure 2.2).

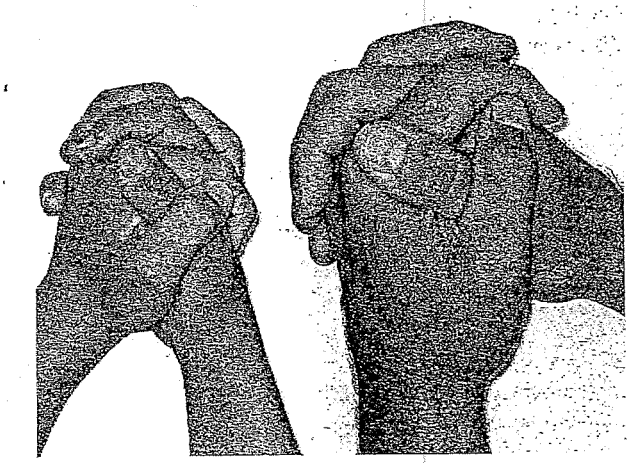


FIGURE 2.2 Hand clasping results of a father and son

We don't get to choose which hand-clasping position is the most comfortable—the preference is inborn. This is because we inherit the preference from our parents. Surprisingly, sometimes *both* parents will have the opposite preference compared to one or more of their children. In these cases, it's worthwhile looking for patterns in the preferences of the four grandparents. It turns out that observations made across three generations are essential in sorting out patterns of inheritance. Gregor Mendel (1822–1884), an Austrian monk, realized this and made the first careful observations of inheritance (Figure 2.3). His insights lead to the birth of the science of genetics.

FIGURE 2.3 Gregor Mendel studied how pea plants passed genetic information from one generation to another.

Mendel's Experiments with Peas

Although Gregor Mendel lived in a monastery (in what is now the Czech Republic), he was by no means isolated. He was well educated and knew a number of prominent scientists. Among his duties at the monastery was the cultivation of pea plants. His records show that he grew more than 50 000 plants over a 10-year period. This allowed him to observe patterns in very large sample sizes. Pea plants turned out to be excellent organisms to study for a number of reasons:

For more information about the work of Gregor Mendel, check out bcscience.com.

- Several generations of plants could be grown during one season.
- Pea plants have the ability to both self-pollinate and cross-pollinate. This means that a single pea plant has both male and female parts, and that a plant can fertilize itself. If pollen moves between two plants, then cross-pollination can occur.
- It is easy to control whether a plant self-pollinates or cross-pollinates by covering or removing reproductive structures in the flower, and by using a paint brush to collect and transfer pollen within or between plants.
- Pea plants have a number of easily observable inheritable qualities that are strictly "either/or" (Figure 2.4). For example, a pea plant is either tall or short. Remarkably, these plants do not normally grow to an in-between height. Mendel's pea plants also had either purple flowers or white flowers. No other colours, not even light purple, occurred.

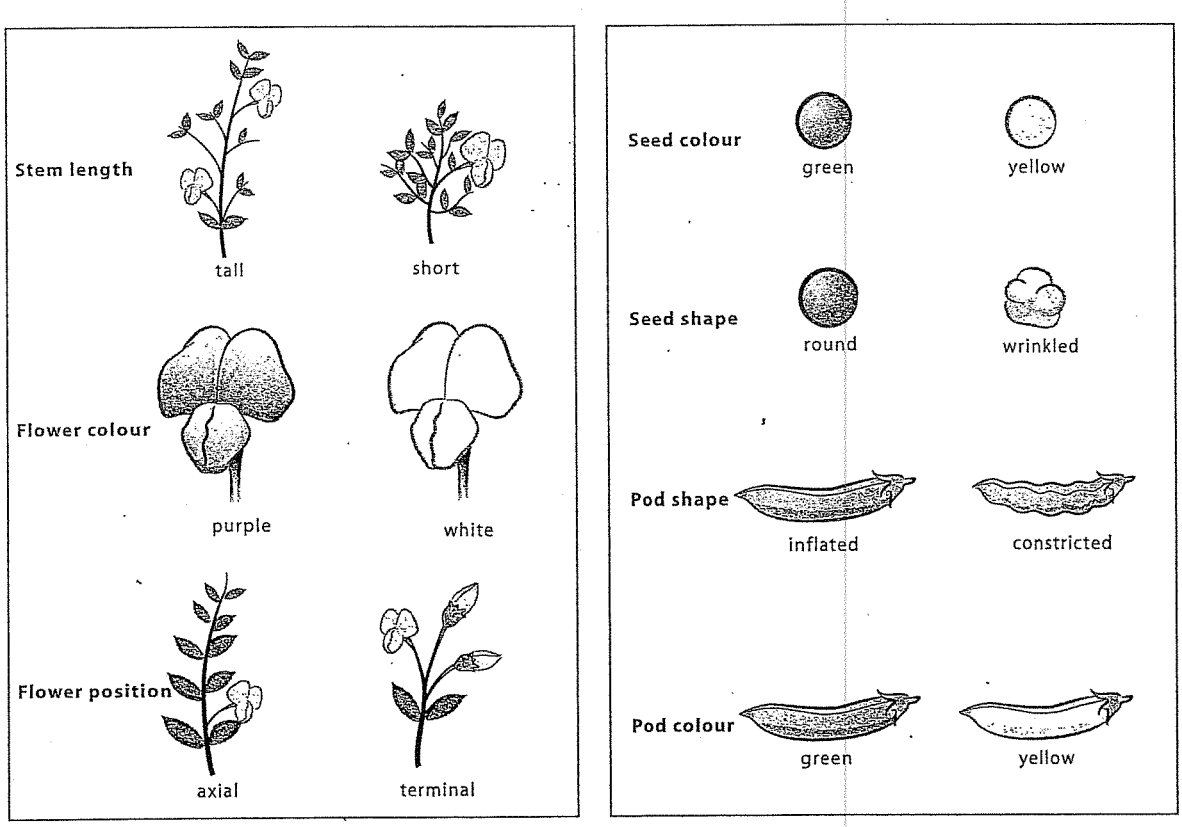


FIGURE 2.4 Mendel studied seven "either/or" characteristics in peas.

Genetics Vocabulary

Table 2.2 includes some of the vocabulary that was introduced after Mendel's time. Knowing these terms is useful when studying his experiments today.

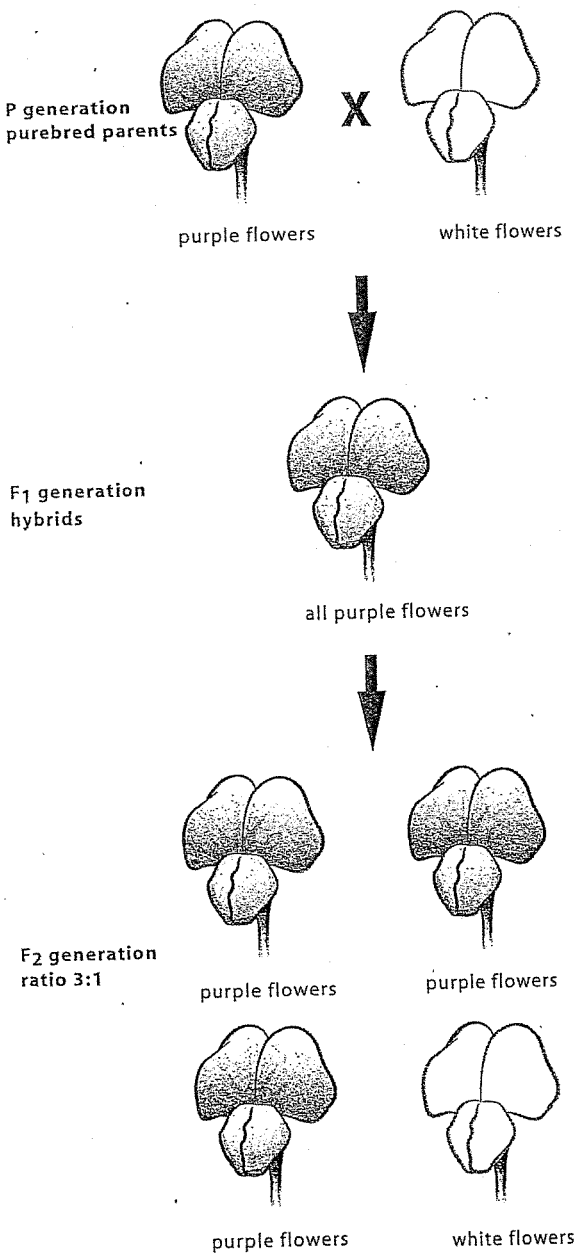
TABLE 2.2 Genetics Terminology

Term	Description
Characteristic	A **characteristic** is some observable feature that can appear in more than one form, such as flower colour.
Trait	A **trait** is a variation that can exist for a characteristic. The flowers on Mendel's pea plants were either purple or white. Mendel was interested in how these traits were passed from one generation to another.
Purebred	A **purebred** pea plant is one in which all offspring and their descendents have the same trait for a particular characteristic when they are self-pollinated. For example, when a plant is purebred for the purple flower trait, the flower colour is purple and remains purple in all the descendents of the plant when self-pollinated for several generations. Mendel used purebred plants for his experiments, which turned out to be of enormous help when analyzing his results.
Hybrid	A **hybrid** results from the mating or crossing of two purebred plants that have different traits, such as crossing a plant with purple flowers with a plant that has white flowers. The symbol for crossing is "×," and is written as "purple × white."
Monohybrid cross	A **monohybrid cross** refers to a crossbreeding experiment that follows the inheritance of a single characteristic across one or more generations.

Monohybrid Cross Experiment

Mendel found that it was necessary to follow at least three generations to determine inheritance patterns. At first, he followed only one characteristic at a time, such as flower colour or plant height. Mendel labelled the first three generations of his monohybrid cross experiment as follows:

- **P generation**—the parent generation. Often the parents would be purebred for a given trait.
- **F_1 generation**—the first filial generation. This generation is the offspring of the P generation. The F_1 offspring are usually hybrids.
- **F_2 generation**—the second filial generation. This generation is the offspring of the F_1 generation when the F_1 generation is self-pollinated, or when two individuals from the F_1 generation are crossed.



Mendel observed inheritance of flower colour by crossing purebred plants with the purple flower trait with purebred plants having the white flower trait (P generation: purple × white). When he did this, all the offspring (F_1 generation) had purple flowers. It seemed that the white trait had disappeared. Mendel called the purple trait "dominant" and the white trait "recessive."

- A **dominant** trait is fully expressed in the offspring, even in a hybrid.
- A **recessive** trait is not expressed in a hybrid, meaning that the recessive trait is not visible.

Mendel then took the offspring, all with purple flowers, and either self-pollinated them, or pollinated them with other plants in the F_1 generation. The results were astounding: about ¾ of the third generation (F_2 generation) continued to have the purple trait, but about ¼ of the third generation had completely white flowers. The recessive trait had reappeared, totally undiluted by the dominant trait.

Mendel reasoned that the recessive white-flower trait must have been present in the F_1 generation, but **masked,** or hidden. He noted that in the F_2 generation, the traits appeared in a 3:1 ratio of the dominant trait (purple) to the recessive trait (white). This is shown in Figure 2.5.

FIGURE 2.5 Mendel crossed purebred parents (P generation) and followed the traits across the F_1 and F_2 generations.

Quick Check

1. It is possible for the sperm and egg from the same pea plant to combine to produce healthy offspring. True False
2. The F_2 generation are the parents of the F_1 generation. True False
3. When two purebred plants with different traits for the same characteristic are crossed, the offspring is always a hybrid. True False
4. If two possible traits are yellow peas and green peas, the characteristic for this trait could be "pea colour." True False
5. The "either/or" nature of stem length means that the stem can be either long, or short, or some length in between. True False

Develop Your Skills

You can conduct a coin-flipping experiment to model some of the inheritance patterns Mendel explored. Take two coins and flip them simultaneously 100 times. Collate your results and record them on the board, showing how often each combination occurred. Use the headings HH (head/head), HT (head/tail), and TT (tail/tail). (**Note:** HT and TH count as the same thing.) This activity is best done with 10 to 15 groups.

Important! Even if you already can predict the most probable outcome of this experiment, it is still critical to complete all the trials. Why? Because the most probable totals for the combinations almost never happen. So flip away.

Questions

1. Complete the following table of combinations using HH, HT, or TT. Then state the most probable number of times each combination will occur for 100 coin flips.

	H	T
H		
T		

2. Examine the class results.
   a) How often did the most probable result—25 HH, 50 HT, and 25 TT—occur?

   b) Why is the most probable result so unlikely to occur?

3. Examine your own results.
   a) What percentage of the outcomes had at least one head showing? _____
   b) What percentage had no heads showing? _____
   (Note that these two percentages must add up to 100%.)

4. Using your own results, divide the number of combinations that had at least one head showing by the number of outcomes that had no heads showing, and round to two decimal places. Did you get a ratio that was close to 3:1?

5. Explain the origin of the 3:1 ratio that Mendel found in the F_2 generation when he crossbred plants with purple and white traits.

Probability

Because the outcomes of breeding experiments resulted from pure chance, Mendel's results did not show an exact 3:1 ratio. For example, in one series of crosses, the results for the F_2 generation were 705 purple flowering plants to 224 white. This is a ratio of 3.15:1. Far from being a mistake, this suggested that **probability** was at work in determining the passing on of traits. Probability is a measure of the likelihood that

one or another kind of outcome can happen, and is governed by the rules of chance. Consider the results of your own class. If everyone had gotten a ratio of exactly 75:25 something other than chance would have to be at work. This understanding helped Mendel to generate his gene hypothesis.

Mendel's Gene Hypothesis

Without any knowledge of chromosomes or DNA, but with data from numerous experiments, Mendel generated the following ideas:

- A hereditary unit of information, called a gene, is passed from parent to offspring, such as the gene for the characteristic "flower colour." (Today, we know that the gene is a length of DNA located in a particular place on one of the plant's chromosomes, as shown in Figure 2.6.)
- An **allele** is one of the possible versions of the gene, such as the allele for the purple trait or the allele for the white trait. (The DNA sequence for the purple colour is different from the DNA sequence for the white colour. This means that different proteins are produced depending on which allele is present. It is the protein that does the biochemical work of determining, in this case, the pigment molecules that give the flower its colour.)

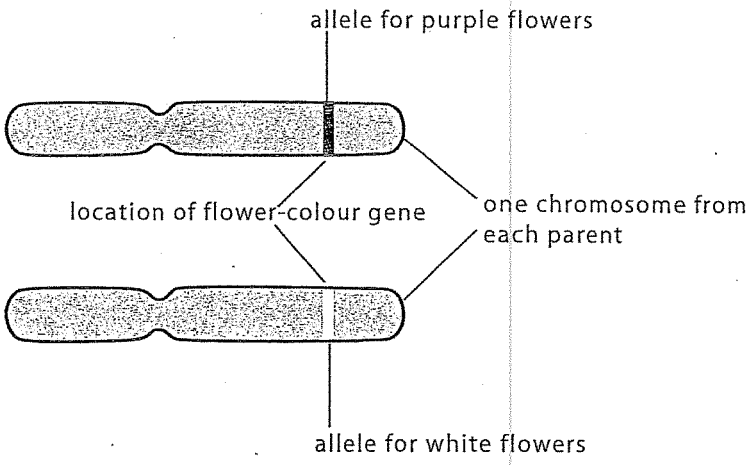


FIGURE 2.6 The gene for flower colour is located at a particular spot on a chromosome. The pea plant has two genes for flower colour—one from each parent.

Mendel took his ideas about genes and alleles and made the following hypotheses:

1. The presence of different alleles is responsible for the variation in the appearance of the organism.

2. An organism always has two genes present for each characteristic—one inherited from each parent. (Even in self-pollination, an egg contributes one gene and a sperm contributes the other.)

3. If the alleles on both of the genes are the same (e.g., both express purple or both express white), then the organism is purebred.

4. If the two alleles are different, then the organism is a hybrid for a characteristic such as flower colour. One trait (purple) will be dominant and one (white) will be recessive. Only the dominant trait is expressed. (Mendel had no idea why the recessive trait was not expressed, but the 3:1 ratio in his experiments implied that it wasn't.)

Most Traits Are Independently Sorted

Mendel studied seven characteristics in pea plants (recall Figure 2.4), and often he studied more than one characteristic at a time. For example, he might follow patterns involving plant height, pod shape, and flower colour all at once. What he concluded was that none of the traits had anything to do with any of the other traits. This means that whether or not a pod shape is round or wrinkled has no influence on whether the same plant is tall or short, or how tallness or shortness is passed on to the next generation. This idea became a major principle for Mendel, which he called his law of independent assortment.

Let's look again at Mendel's experiment where he crossed purebred purple-flowered plants with purebred white-flowered plants (purple × white). One way of symbolizing this cross is to use "P" to represent the purple allele and "p" to represent the white allele. Using this system:

- the allele for the dominant trait is P = purple flower allele
- the allele for the recessive trait is p = white flower allele

We can now track gene combinations through the three generations to see how a 3:1 ratio of purple-flowered plants to white-flowered plant originates. This is summarized in Figure 2.7.

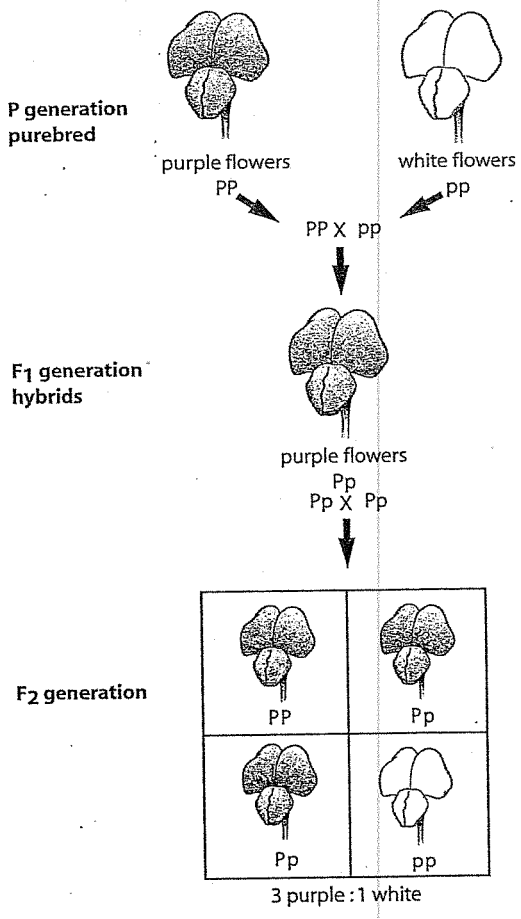


FIGURE 2.7 Gene combinations through three generations reveal the origin of the 3:1 ratio in flower colour.

Quick Check

One of the characteristics that Mendel studied in his peas was the colour of the pod. A pod was either green or yellow. In one series of experiments, he found that when hybrid green-pod plants self-pollinated, 580 offspring resulted—428 had green pods and 152 had yellow pods.

Circle true or false for each of the following statements.

1. For the characteristic "pod colour," green is dominant and yellow is recessive. True False
2. The hybrid plants had two alleles, one for green and one for yellow. True False
3. The yellow-pod plants had only one type of allele—the one for yellow. True False
4. The ratio 428:152 reduces to 2.82 : 1. The ratio should have been 3:1, but some mistakes were probably made when collecting the data. True False
5. The 152 plants with yellow pods were purebred for the yellow trait. True False

Develop Your Skills

Mendel's pea plants had two heights, so the characteristic for height had two traits: tall (T) and short (t). The capital T shows that tall is dominant. A **Punnett square** is a chart that makes it easier to predict the outcome of gene combinations. (You used one in the previous Develop Your Skills activity.) In this activity, you will use a Punnett square to predict the outcome of the following experiment:

A purebred tall plant is crossed with a purebred short plant. Individuals from the F_1 generation are then crossed.

1. Complete the Punnett square for the P generation (TT × tt).

	T	T
t		
t		

2. Complete the Punnett square to show the crossing of two members of the F_1 generation.

3. What percentage of the F_2 generation is tall and what percentage is short?

Phenotype and Genotype

So far we have been discussing the inheritance of genetic information in two ways:

- How traits are passed from parents to offspring. That is, what visible characteristics are passed on? (Are the flowers purple or are they white?)
- How genes are passed from parents to offspring. That is, are the two alleles for every trait the same or different? (Are the gene combinations PP, Pp, or pp?)

Phenotype refers to the appearance of a particular characteristic in an organism. That is, phenotype describes which trait is expressed. For example, the colour in the pea plants that Mendel studied showed either the purple phenotype or the white phenotype.

The **phenotypic ratio** compares the number of each phenotype that is expressed in the offspring. For example, in a particular cross, if 30 pea plants are tall and 10 are short, the phenotypic ratio is 3:1.

Genotype refers to the genetic makeup of an organism. The two genes for each trait may have matching alleles (PP and pp) or non-matching alleles (Pp). They may be alleles that are dominant (PP) or recessive (pp).

Organisms that have matching alleles are said to be **homozygous** for that trait (*homo* means same). All purebred traits are homozygous. Organisms may be purebred for the dominant trait (PP), which makes them **homozygous dominant**, or for the recessive trait (pp), which makes them **homozygous recessive**. Organisms that have non-matching alleles (Pp) are hybrids. They are called **heterozygous** for that trait (*hetero* means different). These ideas are summarized in Table 2.3.

TABLE 2.3 Genotype Summary

Genotype	Gene Combination	Description
Homozygous	PP or pp	organisms with matching alleles
Homozygous dominant	PP	organisms with matching dominant alleles
Homozygous recessive	pp	organisms with matching recessive alleles
Heterozygous	Pp	organisms whose alleles are not the same (hybrid)

The **genotypic ratio** compares the number of each genotype that is expressed in the offspring. If the results in the pea height example above were 10 homozygous dominant (PP), 20 heterozygous (Pp), and 10 homozygous recessive (pp), the genotypic ratio would be 1:2:1.

Figure 2.8 shows the phenotype and genotype for the F_2 generation resulting from a monohybrid cross of F_1 parents whose genotypes are both heterozygous (Pp).

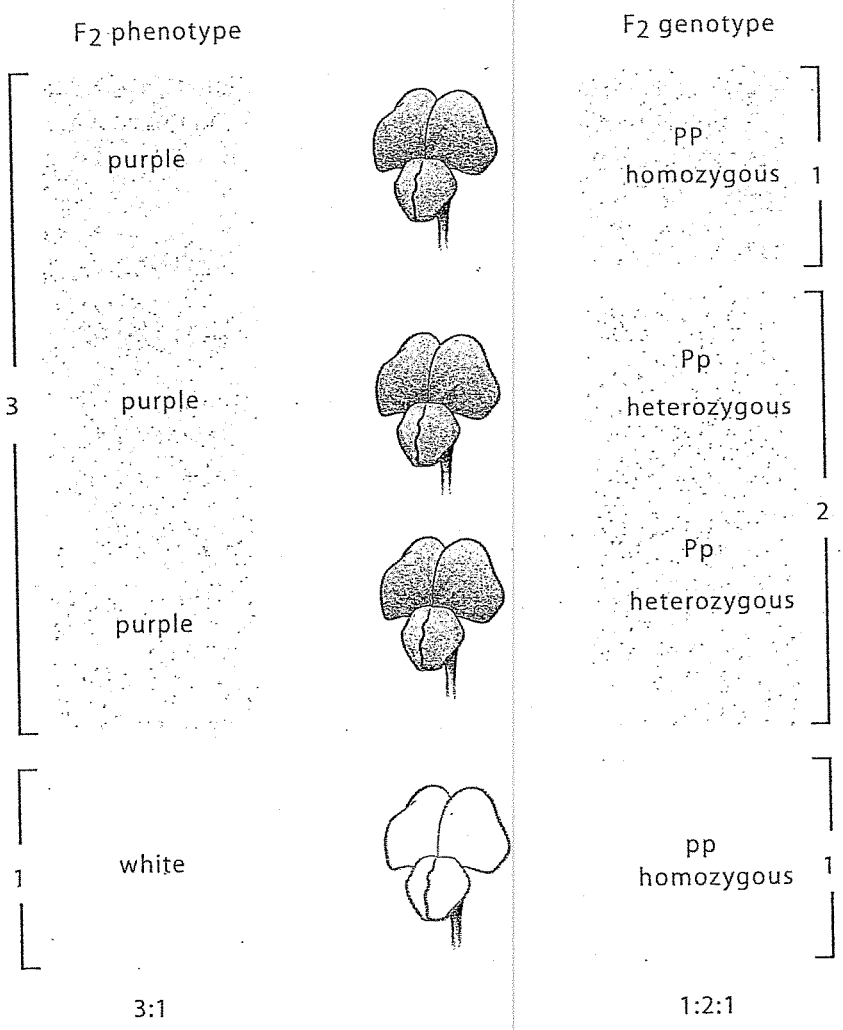


FIGURE 2.8 Phenotype and genotype in the F_2 generation of a monohybrid cross. The phenotypic ratio is 3:1. The genotypic ratio is 1:2:1.

Study Prep Create a concept map for all the bolded terms used since the start of this unit.

Develop Your Skills

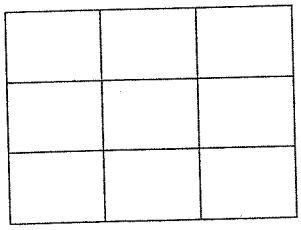
Another characteristic that Mendel observed in his pea plants was pea shape. A pea was either round or wrinkled. He found that the dominant trait was round (R), and the recessive trait was wrinkled (r). In this activity, you will practise using some of the vocabulary already introduced in this unit and determine phenotypic and genotypic ratios for the cross described below.

Questions

1. What is the phenotype of a plant whose genotype is heterozygous for pea shape?

2. What is the phenotype if the genotype is homozygous recessive for pea shape?

3. Fill in this Punnett square to show the cross between a heterozygous and homozygous recessive for pea shape (Rr × rr).



4. Assume 40 pea plants were produced.
   a) How many plants have round peas? _____
   b) How many plants have wrinkled peas? _____
   c) What is the phenotypic ratio of round peas compared to wrinkled peas? _____

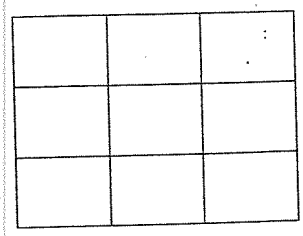
5. Assume that 60 pea plants were produced.
   a) How many plants are heterozygous? _____
   b) How many plants are homozygous dominant? _____
   c) How many plants are homozygous recessive? _____
   d) What is the genotypic ratio of heterozygous plants compared to homozygous recessive plants? _____

2.1.2 Review Questions

1. A homozygous white hamster is crossed with a heterozygous brown hamster.
   a) Which trait is dominant, white or brown?

   b) Write the genotype for the white hamster and for the brown hamster.

   c) Complete a Punnett square showing the cross between the white and brown hamsters.



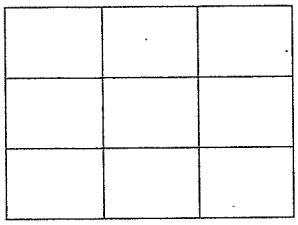
   d) What percentage of hamster offspring are likely to be white? _____

2. If a litter of 8 hamsters is born as a result of the cross in question 1, how many of them are likely to be white? _____

3. A short-tailed cat mates with a long-tailed cat resulting in 100% of the offspring having long tails. Then the same short-tailed cat mates with a different long-tailed cat. This time 50% of the offspring have long tails and 50% have short tails. Explain how this can happen.

4. Corn plants can be either tall or short. Imagine a homozygous tall corn plant crossed with a heterozygous tall corn plant.
   a) Which trait is dominant, tall or short?

   b) Complete a Punnett square for this cross.



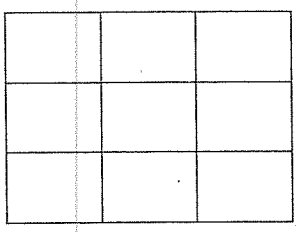
   c) What percentage of the offspring do you predict to be
   - homozygous? _____
   - heterozygous? _____

   d) What percentage of the offspring do you predict to be tall? _____

   e) What is the phenotypic ratio of tall plants compared to short plants? _____

5. In hand clasping, the left thumb on top is dominant and the right thumb on top is recessive. A man notices that when he clasps his hands he prefers to have his right thumb on top. The man has two sons, both of whom also prefer to have their right thumbs on top. Is it possible that the boys' mother has a preference for having her left thumb on top? Explain your answer.

6. A certain dog is heterozygous for a dark spot on its back. The presence of the spot is the dominant trait. Having no spot at this location is the recessive trait.
   a) Complete a Punnett square for the cross of two dogs that are heterozygous for the dark spot.



   b) In a litter of 8 puppies, how many of them are likely to have no spot on their backs? _____

   c) Is it possible that all 8 puppies could be missing the spot? Explain your answer.

2.1.3 Other Patterns of Inheritance

Through insight, good luck, or both, all of the characteristics that Mendel studied in his pea plants exhibited a pattern of inheritance called **complete dominance**: All the traits were either dominant or recessive. This allowed him to formulate the main principles by which genes are inherited. While Mendel's principles apply all the time, not all characteristics show complete dominance. Sometimes characteristics show patterns of inheritance called incomplete dominance and codominance.

Incomplete dominance

In **incomplete dominance**, the hybrid expresses a mixture of the traits displayed by its purebred parents. Each trait is present in the hybrid, but is only partly expressed. That is, the phenotype of the offspring is a mixture of the phenotypes of the parents. These offspring are said to have an **intermediate phenotype**. In the case of carnation flowers, if a purebred carnation with red flowers is crossed with a purebred carnation with white flowers, the offspring's flowers will be pink (Figure 2.9). Why? Because red-flowering carnations have two alleles for the red colour. The hybrid has only one allele, or half as much red colour, so pink flowers result.

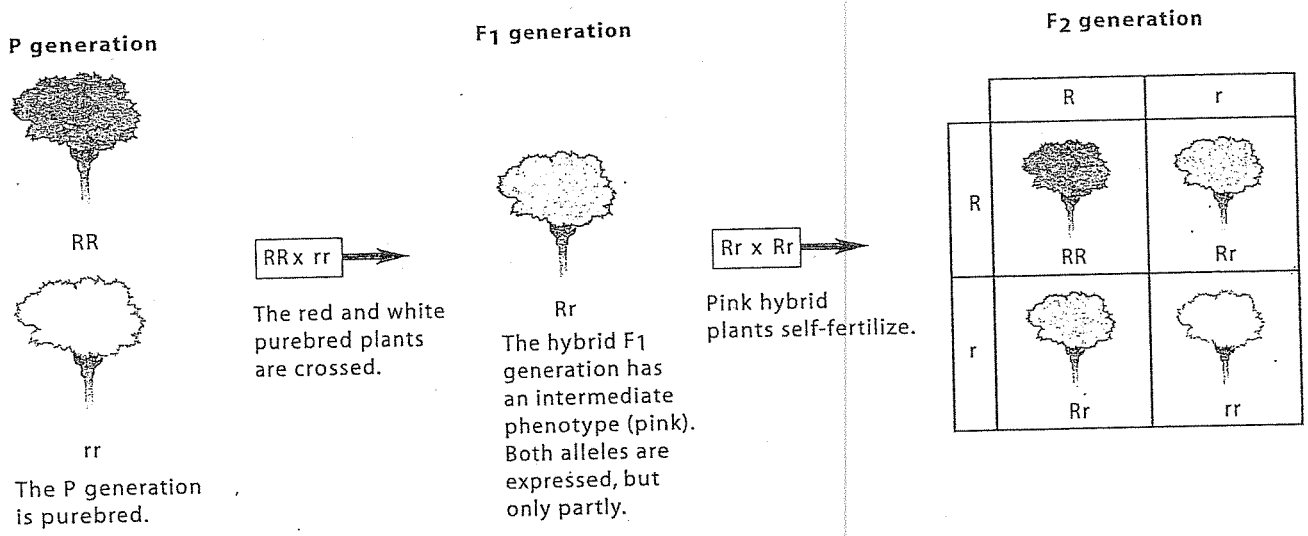


FIGURE 2.9 The hybrid F_1 generation shows incomplete dominance, expressing neither the red trait nor the white trait completely. What happens when the pink hybrid self-fertilizes?

Codominance

In **codominance**, both traits for a characteristic are completely expressed in the hybrid. Human A and B blood types display codominance. A person with Type A blood has a certain kind of molecule attached to the outside of the cell membranes of her red blood cells. Call it molecule A.

Another person, who has Type B blood, has a different molecule, molecule B, attached to the membranes of his red blood cells. Suppose a person with two alleles for A has a child with a person who has two alleles for B. The child will have both an A and a B allele. Studies show that the child will test positive for both Type A and Type B blood (Figure 2.10). The child's blood type is called AB.

For more information about complete dominance, incomplete dominance, and codominance, check out bcscience.com.

	A	A
B	AB	AB
B	AB	AB

FIGURE 2.10 Codominance in A and B human blood types means that the offspring test positive for both Type A molecules and Type B molecules on the surfaces of their red blood cells.

Sex Chromosomes

About 50 years after Mendel conducted his experiments, Thomas Morgan (1866–1945), who worked in the United States, made the connection between genes and chromosomes. His main test subjects were fruit flies. Fruit flies make excellent study subjects because they have only four pairs of chromosomes, and are relatively easy to view under a microscope. Also, it takes only 14 days to breed a new generation of fruit flies, and a single mated pair can produce several hundred offspring at one time.

Morgan knew that the eight chromosomes in fruit flies could be sorted according to size and shape. Six of the chromosomes divide up into three pairs, in which each member of the pair looks identical. One member of each pair is inherited from the mother and the other from the father. If one chromosome has a gene for eye colour on a certain location on the gene, then its pair also has a gene for eye colour on the same location. However, the genes may have different alleles. One allele for fruit-fly eye colour may be for red eyes; the other may be for white eyes. Morgan confirmed the gene-chromosome link underlying Mendel's hypothesis—that each organism has only two genes for each trait.

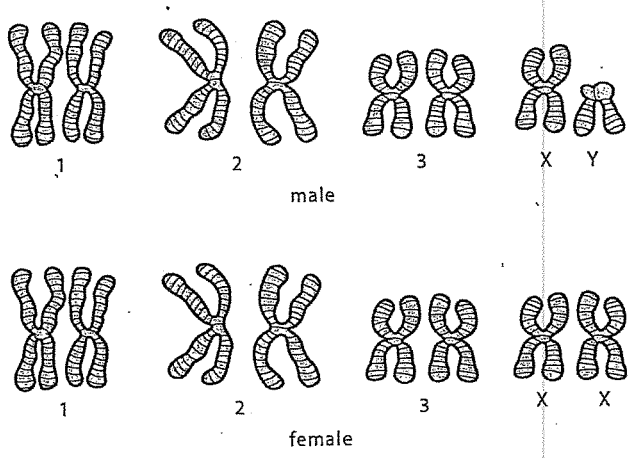


FIGURE 2.11 A male and female fruit fly karyotype

In a male fruit fly, the last two chromosomes are not identical in size or shape (Figure 2.11). They are called the **X chromosome** and the **Y chromosome**, and any fruit fly with an XY combination is a male. In a female, these chromosomes are both X, so that a female fruit fly has an XX combination. It's the same in humans: the combination of X and Y chromosomes in an organism determines the sex.

The Y chromosome has very few genes on it. Those chromosomes that are present code for proteins that trigger a host of mechanisms, which activate the production of male hormones. These hormones affect the way cells and tissues specialize. For example, in humans, the testes and the ovaries develop from the same tissue in the growing fetus. The presence of the Y chromosome means that more male hormone will be present, and that the unspecialized tissue will develop into testes rather than ovaries.

Sex Linkage

Up to this point, it hasn't made any difference which parent carries the dominant or recessive alleles for a given characteristic. For example, in following the inheritance of height in a pea plant (e.g., TT × tt) it doesn't matter whether TT comes from the male part of the plant or the female part. Some traits, however, are inherited differently depending on whether the organism is male or female. One such trait in humans is colour blindness. One form of colour blindness involves the inability to distinguish between red and green, and many more males have this trait than females. This is due to a pattern of inheritance called **sex linkage**.

A sex-linked gene is located on a sex chromosome. In the case of red-green colour blindness, the gene for this characteristic is located on the X chromosome. This means that females (XX) have two copies of this gene, but males (XY) have only one copy. This is because the Y chromosome in males does not have a matching gene for this characteristic.

For more information on sex-linked disorders, check out bcscience.com

The colour blindness allele is recessive and the full-colour allele is dominant. For a female to have red-green colour blindness, she needs to carry the colour blindness allele on both of her X chromosomes. If one X chromosome has the gene for full-colour vision and the other for colour blindness, then she will still have full-colour vision. On the other hand, if a male carries the allele for colour blindness, he will be colour blind, because his Y chromosome does not have a corresponding allele that can give him full-colour vision. All of these ideas were first worked out in Thomas Morgan's research labs, where he conducted his fruit-fly breeding experiments.

In fruit flies, Morgan discovered that the gene for eye colour is located on the X chromosome. There are two alleles for fruit-fly eye colour: red and white. Red is dominant. This means that a female has two alleles for eye colour, one on each of her X chromosomes. However, a male fruit fly has only one allele, because the X chromosome does not have the same genes on it as the Y.

Since red eye colour (R) is dominant and white eye colour (r) is recessive, the alleles are X^R, X^r, and Y. Recall that Y does not have an allele for eye colour. A mating of a female with white eyes and a male with red eyes produces females with red eyes and males with white eyes, as Figure 2.12 shows.

	♂		
		X^R	Y
♀	X^r	$X^R X^r$	$X^r Y$
	X^r	$X^R X^r$	$X^r Y$

FIGURE 2.12 The sex-linked chromosomes for the female (♀) fruit fly and the male (♂) fruit fly are shown. Eye colour is distributed differently between males and females.

In the above example, the female offspring have two chances to inherit red eyes, and in this particular cross, they receive the red allele from their father. The males have only one chance to inherit red eyes, and only the mother can supply the allele. This mother does not have a red allele to donate, and the Y chromosome from the father does not even carry a gene for eye colour.

Notice that any XX × XY cross predicts an outcome of 50% female and 50% male offspring. Also notice that it is always the father's sex gene that determines the sex of the offspring.

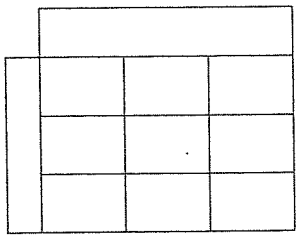
Develop Your Skills

The eye colour of fruit flies is the result of a sex-linked pattern of inheritance. Use the following symbols for the Punnett square below.

♀ = female ♂ = male

X^R = red eye (dominant) X^r = white eye (recessive)

1. Fill in this Punnett square to show the outcome of a mating between a female fruit fly with two alleles for red eyes and a white-eyed male.



2. What percentage of the offspring will have:
   a) white eyes? _____
   b) red eyes? _____

3. Are the male offspring able to pass the trait for white eyes on to the next generation? Explain your answer.

4. Are the female offspring able to pass the trait for white eyes on to the next generation? Explain your answer.

5. a) If having white eyes resulted in reduced vision in a fly, would any of the offspring also have reduced vision? Explain your answer.

   b) Would any of the offspring be carriers of the reduced-vision trait? Explain your answer.

   c) Would any of the offspring be genetically free of the reduced-vision trait? Explain your answer.

Investigation Activity

Problem-Solving Skills Focus

— Creating New Animation Characters —

Purpose

To use the principles of genetics to create a series of new characters for an animated movie

Materials and Equipment

2 coins per group of two students

Procedure

1. You are a genetics consultant who has been approached by a movie studio. The studio is developing a new animated science fiction movie about two aliens. The movie's producer wants his alien stars to have a scientific genetic basis. He would like you to provide some background information to his screenwriters and help create the aliens.

   The producer has prepared a table of genotypes and phenotypes for various traits he would like you to use.

Genetic Basis of Aliens

Trait	Phenotype	Genotype	Type of Inheritance
Hair type	curly hair no hair	CC, Cc cc	complete dominance
Nose colour	green red	GG, Gg gg	complete dominance
Lip colour	pink orange yellow	PP PY (incomplete) YY	incomplete dominance
Antenna type	one brown antenna one brown and one purple antenna one purple antenna	BB BP (codominance) PP	codominance
Body colour	yellow green blue	WW WN (incomplete) NN	incomplete dominance
Eye shape (sex linked)	pop-out eye flat eye	X^EX^E, X^EX^e, X^EY X^eX^e, X^eY	complete dominance sex linked

2. Prepare a table similar to one below to record the genotype of the parents.

Name	Sex	Eye Shape	Nose Colour	Lip Colour	Antenna Type	Body Colour	Hair Type
Alien 1 name	XX						
Alien 2 name	XY						

3. To determine the genotype for each character, flip two coins. Two heads is homozygous dominant. Two tails is homozygous recessive. One head/one tail is heterozygous. (**Note:** Only the X chromosome has the eye-shape gene, which is a sex-linked gene. For eye shape in the female, flip two coins to determine the genotype. For eye shape in the male, flip only one coin.)
4. Using the genetic information from your table, draw and describe your aliens.

Questions

1. You have done such a good job helping design the aliens that the producer wants to write into the script that the two aliens fall in love and have a baby. Prepare a table similar to the one in step 2 above. Create a genotype for a baby alien from the two parents, as follows:
   a) Decide which X chromosome the mother donates. Let heads represent one of her chromosomes, and tails represent the other. If she has X^EX^E or X^eX^e, there is no need to flip because both alleles are identical.
   b) Decide whether the father donates his X or his Y chromosome by flipping. If X is chosen, record the genotype showing the sex-linked trait for eye shape (X^E or X^e) that the father has.
   c) Record XX or XY in the sex column. In the eye-shape column, record the eye shape genotype (X^EX^E, X^EX^e, X^EY, X^eX^e, or X^eY).
2. Other characteristics of the alien baby are determined by flipping two coins. Let heads represent the first allele and tails represent the second allele for each trait. For example, heterozygous curly hair would be heads (C) and tails (c).
3. Draw and describe the baby alien.

Conclusion

Use your data and drawings to help you prepare a summary report for the movie producer.

2.1.3 Review Questions

1. For a particular plant, a cross between a purebred variety with blue flowers and a purebred variety with white flowers results in a plant with light-blue flowers. The cross is written as:
   BB (blue) × bb (white) → Bb (light blue)
   a) What kind of dominance is suggested by this result? Explain why.

   b) Draw a Punnett square for a cross between two plants with light-blue flowers. Show both the genotype and the phenotype of the offspring in each box.

2. If 120 flowers are produced in the F_2 generation from the cross in question 1,
   a) predict how many flowers will have the genotypes:
   - BB _____
   - Bb _____
   - bb _____

   b) predict how many will have the phenotypes:
   - blue _____
   - light blue _____
   - white _____

3. a) An imaginary flowering plant with orange petals is crossed with another plant with the same phenotype. The offspring consist of 10 plants with orange petals, 5 plants with red petals, and 5 plants with yellow petals. Suggest an explanation for this pattern of inheritance.

   b) A plant with an orange flower is crossed with a plant with a red flower. If 60 offspring are produced, how many plants of each phenotype (red, orange, and yellow) are likely to be produced?
   - red _____
   - orange _____
   - yellow _____

4. Three common alleles in human blood types are A, B, and o. The o allele is recessive to both the A and the B alleles. Allele A makes a protein that produces molecule A, which attaches to the red blood cell's membrane. Allele B works the same way, resulting in molecule B attaching to the cell's membrane. The o allele does not code for a protein, and no molecule attaches to the membrane for this allele. Match each genotype with the appropriate blood type: Type A, Type O, Type B, or Type AB. Record your answers on the lines provided.

   Genotype

   a) oo _____
   b) AA _____
   c) Bo _____
   d) Ao _____
   e) BB _____
   f) AB _____

5. Draw a Punnett square showing a cross between a father with genotype Ao and a mother with genotype AB.

a) What is the probability that the child will have blood Type O? _____
b) What is the probability that the child will be homozygous Type O? _____

6. A mother has Type A blood and her daughter has Type B blood. Is it possible that the father has Type O blood? Explain your answer.

7. A mother has Type A blood and the father has Type B blood. Is it possible for their son to have Type O blood? Explain your answer.

8. The inheritance of eye colour in fruit flies is sex linked.

♀ = female ♂ = male
X^R = red eye (dominant)
X^r = white eye (recessive)

a) Use the symbols above to draw a Punnett square showing the outcome of a mating of a female with one allele for red eyes and one allele for white eyes with a white-eyed male.

b) What percentage of the offspring will have:
- white eyes? _____
- red eyes? _____

c) Are the red-eyed male offspring able to pass the white-eyed trait on to the next generation? Explain your answer.

d) Are the red-eyed female offspring able to pass the white-eyed trait on to the next generation? Explain your answer.

2.2 Mutations affect living things in a variety of ways.

2.2.1 The Effects of Mutations

A **mutation** is a change in the DNA of a gene. Since DNA is involved in the assembly of proteins, a mutation has the potential for far-reaching effects on the biochemistry of an individual. Mutations are rarely helpful to an individual, usually having some negative effect or some effect that is neutral or unnoticeable. However, mutations are responsible for genetic diversity within a population. A population whose members are genetically different is better able to deal with new diseases or changes in the environment.

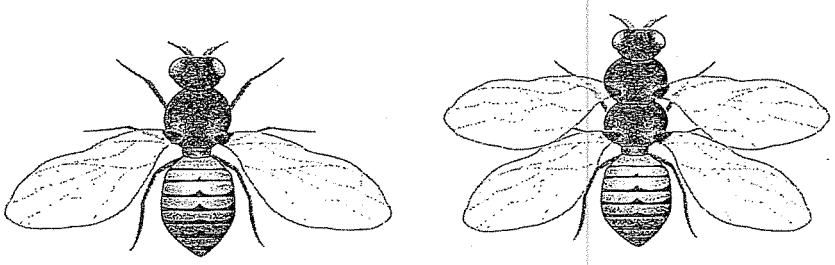
A modified portion of DNA that does not affect a protein's function is called a **neutral mutation.** For example, a gene responsible for producing adrenaline, a chemical messenger, might still be able do so even after its amino acid sequence has been altered slightly.

A mutation that does cause a change in protein function would still be considered a neutral mutation provided it had no visible effect on an individual's health, chances of survival, or ability to reproduce. For example, if the change in a protein results in the production of yellow pigment instead of red pigment, the environment that the organism lives in would determine the effect of the mutation. If the change improved the organism's ability to hide from predators, it would be a **positive mutation.** If the alteration decreased the organism's ability to camouflage itself, it would be a **negative mutation.**

Table 2.4 provides a summary of neutral, positive, and negative mutations.

TABLE 2.4 Types of Mutations and Their Effects

Mutation	Effect	Examples
Neutral	A neutral mutation has no effect on an organism.	A gene responsible for producing a red pigment might still do so even after its amino acid sequence had been altered. This is why a carnation with a mutated gene for pigment might still have a red flower.
Positive	A positive mutation can enhance an organism's ability to survive or reproduce successfully.	A bacterium can mutate in the presence of an antibiotic and become resistant to that antibiotic. It can then pass along this resistance, enabling the bacterial colony to survive and continue reproduction. Superbugs in hospitals are examples of antibiotic-resistant bacteria.
Negative	A negative mutation can seriously impair an organism's ability to survive or reproduce successfully.	Because of a mutation of just one gene, some fruit flies will inherit an extra pair of wings (Figure 2.13). Fruit flies with a double pair of wings are unable to fly. These flies cannot feed and die without reproducing.



Normal fruit fly

Mutant fruit fly

FIGURE 2.13 A mutation has resulted in an extra pair of wings for the fruit fly on the right. For fruit files, this is a negative mutation. (Fruit flies are about 1–2 mm in size.)

Albinism

A negative mutation may persist indefinitely in a population. For example, one form of mutation present in virtually all animal species, including in humans, leads to albinism. An **albino** is an individual who does not have any ability to produce melanin, which is the pigment that gives your skin its colour. Albinism is a recessive trait, so the albinism gene must be inherited from both parents. Melanin helps protect the skin from the effects of ultraviolet light. Since albinos lack this pigment, they are very sensitive to sunlight.

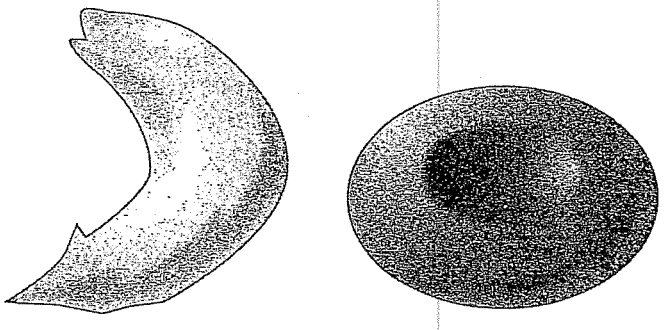
Hemophilia

You have seen that some mutations negatively affect an organism's ability to survive. For example, a mutation in a gene that produces a clotting factor in blood may result in the inability of an organism to form a blood clot. Such a mutation results in a disease in humans called **hemophilia**. Hemophilia is a sex-linked disorder more common in males than in females. The appearance of hemophilia in a previously unafflicted population is the result of a mutation. Once in a population, hemophilia can then be inherited by members of succeeding generations.

Mutations with Both Negative and Positive Effects

Some mutations have both negative and positive effects. For example, there is a condition originating with a mutation in a certain gene that produces hemoglobin. Hemoglobin carries oxygen in our blood. The defective gene causes hemoglobin molecules to stick together. The result is a red blood cell with an elongated shape that is relatively inefficient at carrying oxygen (Figure 2.14). The negative effect of this condition is that people with two alleles for the defective hemoglobin gene develop a painful and life-shortening disorder called sickle cell anemia.

For more information about hemophilia and the famous people who had it, check out bcscience.com.



Sickled red blood cell

Normal red blood cell

FIGURE 2.14 The sickled red blood cell is both a negative and positive mutation. (Red blood cells are about 7–8 μm in size.)

The positive effect of this mutation is that people with one normal and one defective hemoglobin allele have an immunity to malaria, a disease that is also painful and sometimes life-threatening. Many people of central African descent carry the sickle-cell gene, where it has been an advantage in a region where malaria is endemic.

Mutagenic Factors

A factor that causes a mutation is called a **mutagen**. Mutagenic factors can be physical, chemical, or biological. Some kinds of mutation alter the genes of a cell in such a way that it begins to grow and duplicate uncontrollably. Such uncontrolled cell growth is at the basis of all forms of cancer. Of course, not all mutagenic factors lead to cancer. However, because most mutations randomly affect the DNA, they almost always have a negative impact on health.

Physical

Radiation is a physical mutagenic factor that can affect DNA. Ionizing radiation, such as ultraviolet light (UV), can cause chemical changes in DNA itself, or can cause changes in nearby substances, such as oxygen molecules, which then damage the DNA. X-rays also produce enough energy to cause mutations. This is why you wear a lead-lined apron when your teeth are X-rayed, and also why the dental technician stands behind a lead-lined wall when the X-ray generator is turned on.

Chemical

Many chemicals can cause mutations. For example, burning tobacco releases over 4000 chemicals, many hundreds of which are known to be **toxins**. Toxins are substances that act as poisons, or have some other negative effect, such as causing cancer. Over 40 of the chemicals found in cigarette smoke are known carcinogens, or cancer-causing agents.

A huge multi-billion dollar industry exists around the world trying to determine which chemicals planned for use in pharmaceuticals, cosmetics, and manufacturing contain chemical mutagens. For example, polychlorobiphenyl (PCB) is a chemical that was once widely used in electrical transformers. Researchers eventually discovered that PCB can cause mutations in humans that lead to cancer. Efforts continue to remove PCB from the environment. During the past 10 years in British Columbia, over 700 tonnes of PCB waste have been disposed of through incineration.

Biological

Both bacteria and viruses have been linked to cancer, which means that it is almost certain that some kinds of bacteria and viruses are mutagens. For example, both hepatitis B and hepatitis C are known to cause liver cancer. Both of these diseases are caused by viruses. It has long been suspected that viruses are biological mutagens because of the way they reproduce. A virus invades a cell and then substitutes its own DNA into the cell's protein-making apparatus. In fact, some kinds of viruses, such as the AIDS virus, actually attach their own DNA to a cell's own genes. Any modification of the DNA in this way is considered to be a mutation.

2.2.1 Review Questions

1. Identify each of the following as a biological, chemical, or physical mutagenic factor.
   a) cigarette smoke _____
   b) sunburn _____
   c) benzene, a component of gasoline _____
   d) viral infection _____
   e) radioactive radon gas _____
   f) nitrosamines, produced in heavily charred barbequed meat _____
   g) UV radiation from overexposure to a tanning light _____

2. Distinguish between the following terms: mutation, mutagen, and mutant.

3. Suppose a particular mutation causes a leopard with a yellow coat and black spots to become completely white. Suggest some different environments in which this mutation could be considered to be:
   a) positive

   b) negative

   c) neutral

4. A single bacterium may divide in only 20 minutes. At this rate, one bacterium may produce over a million genetically identical copies of itself in 24 hours. An antibiotic is a chemical that can kill bacteria. Suppose someone was infected with 1 billion bacteria.
   a) Explain how an antibiotic that can kill 99.99% of these bacteria might become ineffective against that same kind of bacteria after only a few weeks of use.

   b) Explain why it is important to use all the antibiotic prescribed by a physician and not to stop using it as soon as the symptoms of the illness disappear.

5. Explain how each of the following can lead to a mutation.
   a) X-ray radiation

   b) the virus that causes AIDS

2.3 Biomedical technologies have revolutionized medicine.

2.3.1 Biomedical Technologies in Use Today

Genetic Testing

Genetic testing involves the analysis of a person's DNA in order to diagnose genetic disorders. Such tests can be carried out before symptoms occur, which might be done if a particular genetic disorder runs in a family. For many disorders, genetic testing can even be done before birth. **Amniocentesis** is a medical procedure used to obtain a sample of an unborn child's DNA by withdrawing a small amount of the amniotic fluid that surrounds the growing fetus. The fluid contains skin cells that have been shed by the fetus.

For more information about Down's syndrome, check out bcscience.com.

Pregnant women over the age of 40 routinely have amniocentesis in order to test their unborn child for the genetic condition known as Down's syndrome (also called Trisomy 21). The syndrome is more likely to affect babies born to women over 40. In Down's syndrome, an individual has an extra chromosome 21, giving them 47 chromosomes in all. About one person in 1000 has the condition. Down's syndrome can involve delayed physical and mental development, heart impairment, and altered physical features. Despite the disabilities associated with the condition, many people with Down's syndrome lead rich and fulfilling lives.

Carriers

For some diseases, individuals can be tested to determine if they are carriers. Carriers have no symptoms but can pass on a disease, such as muscular dystrophy or cystic fibrosis, to the next generation because they carry one recessive allele for the disease. Using the patterns of inheritance, a genetic counselor or physician may be able to predict the probability of whether these individuals will pass on such a disease to their children.

Genetic Markers

Sometimes tests are available for genetic disorders for which there is not yet any treatment. For example, Alzheimer's disease is a brain-wasting disease that causes severe memory loss and, ultimately, death. About 5% of Alzheimer's sufferers carry a genetic marker for the disease. A test can be performed to determine if this marker is present in an individual. If it is, the person will develop the disease. At present, there is no way of adequately treating Alzheimer's or halting its progress. If you could know when you were young that you were certain to get the disease in your fifties, would you *want* to know? Would it affect whether you wanted to have children? And if you did have children, would you want them to know? What about life insurance? Any medical information that you know would have to be disclosed for the insurance to be valid.

Gene Therapy

A fairly recent biomedical technology is **gene therapy**. In gene therapy, genetic engineering is used to correct a genetic disorder. Gene therapy is most useful in cases where only one faulty gene is responsible for causing the disease. While it is not possible to correct the faulty gene, progress is being made in refining the techniques used to insert a properly functioning gene somewhere into the DNA of the person with the disorder. Certain viruses, called **retroviruses**, infect a cell by inserting their own DNA into the DNA of the host. Gene therapy involves genetically modifying such a virus so that it has the functioning gene that is missing in the person with the genetic disorder. This modified virus carrying the new gene is then inserted into the affected individual.

Such treatments are still in early stages of development, but trials have already been conducted for some forms of cystic fibrosis. Modifying genes effectively and delivering them to the correct location on a person's DNA remains a challenge. For example, a person with diabetes may not be able to produce insulin. However, too much insulin is just as dangerous as too little insulin. Will it be possible to insert a new gene that delivers the right amount of insulin without endangering the recipient's life by producing too much?

As with most biomedical technologies, gene therapy poses ethical questions. For example, should a modified gene be inserted into reproductive cells? If so, the positive and negative effects of this gene would be passed on to a person's children, grandchildren, and succeeding generations.

Pharmaceuticals

In 95% of cases, people infected with hepatitis B recover completely. However, about 5% harbour the disease for many years. Over time, this can result in serious liver damage, as well as liver cancer. The good news is that since 1992, children in grade 6 in British Columbia have received a vaccination for hepatitis B. The mass production of the vaccine was made possible by genetically engineering yeast using **recombinant DNA**. In this case, the recombinant DNA process involves implanting yeast cells with human genes. The yeast cells then make proteins that are normally produced only in the human genes. The modified yeast is grown in large vats similar to those used to make beer. At the end of the process, the viral protein is extracted and made into a vaccine. Long-term studies show that in British Columbia hepatitis B has been eliminated among those who were vaccinated in grade 6.

Forensics

David Milgaard, Guy Paul Morin, and Thomas Sophonow are all Canadians who have been convicted of murder and served long prison terms. They also have something else in common: they are all innocent. Forensic evidence obtained from the bodies of the murder victims and subjected to DNA analysis showed in each case that these men were not the murderers. One by one, their murder convictions were overturned, and they were exonerated. DNA profiling, which is sometimes called DNA "fingerprinting," is the biotechnology used to prove their innocence. This technology, however, was not available at the time of their convictions. These are fairly isolated cases, but they do occur. For example, between 1992 and 2001, a total of 82 convictions in the United States were overturned as a result of DNA analysis. Ten of these overturned convictions were for people awaiting execution.

Study Prep

Add one more paragraph to this page describing another biomedical technology used today. Use print and electronic resources in your research.

2.3.1 Review Questions

1. a) What is amniocentesis?

   b) Give an example of its use in genetic testing.

2. Muscular dystrophy is a muscle-wasting disease that is caused by a defect in a single gene. The muscular dystrophy allele is recessive. If a man and a woman each carry one muscular dystrophy allele and one normal allele, what is the probability that a child born to them:
   a) will have the disease? _____
   b) will be a carrier (no symptoms but can pass the gene on to offspring)? _____
   c) will be free of the gene? _____

3. In gene therapy, a properly functioning gene is inserted into some of the cells of a person who is missing the correct gene. Explain how it is possible to insert such a gene.

4. Insulin is a hormone used by our bodies to control blood sugar levels. A person who is unable to produce insulin has a condition called Type I diabetes. Treatment for diabetes became possible when insulin, extracted from cows and pigs, became available. It was expensive and yielded only small amounts. However, it is now possible to produce human insulin in large quantities using bacteria. Explain how this is done.

5. Investigate or illustrate some aspect of current or emerging biomedical technology. Consult with your teacher to determine an area of research. For example, you may wish to focus on emerging technologies related to a particular genetic disease or research a debate on an ethical question related to the use of biotechnology. You will need to choose some method of reporting on your research, such as a 500-word summary, well-labelled diagram, informational poster, PowerPoint presentation, or mock debate.

Unit 2 Review

INSTRUCTIONS: For each question, select the **best** answer and circle your choice.

1. Recessive traits are masked in a hybrid.
   A. True
   B. False

2. Heredity is the passing on of traits from generation to generation.
   A. True
   B. False

3. What do we call the crossing of two purebred individuals, each showing different forms of the same trait?
   A. dominance
   B. codominance
   C. hybridization
   D. incomplete dominance

4. Which of the following is homozygous dominant?
   A. kk
   B. sS
   C. PP
   D. Qq

5. Which of the following shows the results of the offspring of a cross between a purebred recessive short-haired animal and a purebred dominant long-haired animal?
   A. 100% short hair
   B. 100% long hair
   C. 50% short hair and 50% long hair
   D. 75% long hair and 25% short hair

For questions 13 to 16, classify each as (G) genotype or (P) phenotype.

13. RR ____
14. a tall cat ____
15. the genes an individual organism has with respect to a specific trait ____
16. the physical appearance of an organism with respect to a particular trait ____

17. Mutation can have no effect on an organism.
   A. True
   B. False

18. Dominant traits always get expressed over recessive traits.
   A. True
   B. False

19. A white female cat mates with a black male cat. All the offspring are white. What would be the best description of the genotype of the female parent?
   A. recessive
   B. homozygous dominant
   C. codominant
   D. homozygous recessive

Match each description on the left with the correct term on the right. Each term may be used as often as necessary. Record your answers on the lines provided.

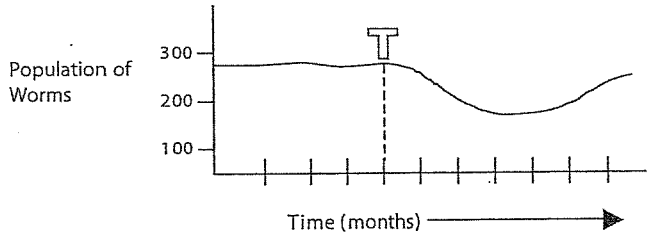
Description	Term
6. one of several forms of the same gene ____	A. dominant
7. the physical appearance of an individual ____	B. allele
8. this trait can be masked ____	C. genotype
9. the genetic makeup of an individual ____	D. recessive
10. both of these alleles affect the phenotype ____	E. phenotype
11. this trait will be expressed ____	F. codominant
12. the pair of alleles possessed by an individual for a given characteristic ____	

20. Long fur (F) is dominant in a certain type of bat. If there is a 50% probability that the F_1 generation will have short fur, what are the genotypes of the parents?
    A. FF × Ff
    B. FF × ff
    C. Ff × Ff
    D. Ff × ff

21. A particular kind of lizard can be found in two colours: S for solid green, and s for striped. If two Ss lizards are crossed, what would the probability be of producing a solid green lizard?
    A. 25%
    B. 50%
    C. 75%
    D. 100%

Use the following graph of a population of worms over a period of a few months to answer questions 22 to 24.

The graph shows the number of worms in a population over a period of months. At time, T, a mutation began appearing in the population.



For each question below:
Circle A if the statement is supported by the graph.
Circle B if the statement is refuted by the graph.
Circle C if the statement is neither supported nor refuted by the graph.

22. Before the mutation of the worms, the population was relatively stable. A B C

23. The mutation had no effect on the worm population. A B C

24. The bird population was affected by the worm mutation. A B C

Use the following fictitious article to answer questions 25 and 26.

Spuzzum, BC (Permanent Press)
With great celebration and ceremony, scientists working for Sybil Enterprises announced Thursday that they have successfully cloned the first human baby. Working in highly secretive laboratories deep inside caves in the Spuzzum area of British Columbia, genetic material from a single female donor was used to produce several identical offspring. Geneticists from around the world were immediately excited about the claim. When asked about the details of the procedure, Sybil Enterprises spokesperson, Stan Sham, would say only that "it takes about 9 months." The science community is reserving judgment on the claim until details about the process are revealed, and the results can be duplicated. The press were not allowed to view the babies up close, but were shown pictures. Sham added, "Notice how similar they look. Although they are identical, we can't get them to agree on anything—much less on political parties." The government issued a statement indicating they may be cancelling their funding of the project.

25. What type of reproduction was used to produce the babies described in the article?
    A. sexual
    B. asexual
    C. budding
    D. fragmentation

26. Why should people not believe the claims made by Sybil Enterprises?
    A. The babies looked identical.
    B. There was only a single donor.
    C. The process has never been done before.
    D. The procedure was not revealed and could not be tested.

Go to bcscience.com for more unit review questions.