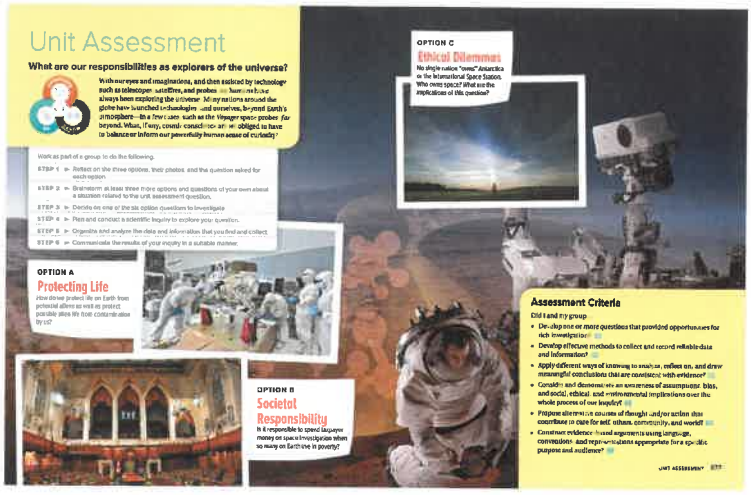
Unit Assessment

This cutting-edge, multimedia-based, interactive activity enables you to demonstrate and apply knowledge, skills, and processes that you have been developing throughout the unit.



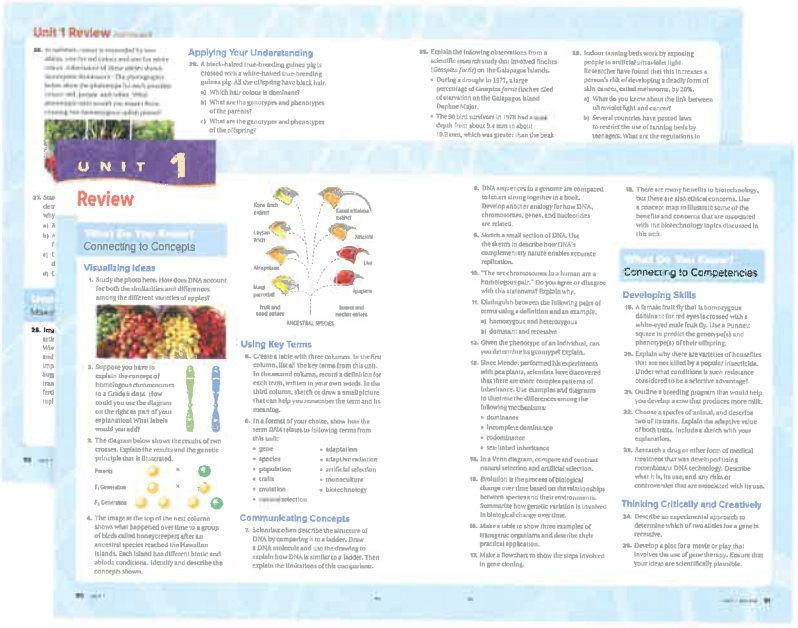
Unit Summary

This reviews the Topic titles and Concept titles from the unit, along with Key Terms that appear in each Topic.

Unit Review

At the end of each unit, these pages can help you assess...

- what you know—your recall of essential information
- what you can do—your ability to engage and apply your critical and creative thinking skills
- what you understand—your ability to apply your knowledge and skills to make new connections to yourself, to society, and to the worlds that you share with all other beings



UNIT 1

DNA is the foundation for the unity and diversity of living things.

Organisms live in almost every imaginable habitat in, on, and above Earth's surface. Even our own bodies are home to trillions of microbes—we are *their* habitat! The thread that binds all living things, that is responsible for the unity and diversity of life, is the double-helix molecule: DNA.

"It never occurred to me that there was going to be any stumbling block. Not that I had the answer, but [I had] the joy of going at it. When you have that joy, you do the right experiments. You let the material tell you where to go, and it tells you at every step what the next has to be because you're integrating with an overall brand new pattern in mind."

Barbara McClintock
Geneticist, Nobel Prize Winner

- What do you think makes you different from the fish in the photo? How are you different from the plants in the photo? How are you different from the person next to you? What do you think makes you similar to another organism?
- What molecules and processes do you think account for the diversity of living things?
- What questions do you have about—these photos? the introduction? the quotation? the title for this unit? ...?

UNIT 1

At a Glance

You will demonstrate what you know, can do, and understand by being able to

- Perform investigations and use other investigative methods to explore DNA, simple patterns of inheritance, and mechanisms for the diversity of life
- Seek patterns and connections to describe, explain, and apply findings and understandings
- Apply a variety of ways of knowing, including First Peoples perspectives and knowledge, to reflect on and investigate the unity and diversity of life
- Use scientific understandings to evaluate scientific and technological applications of gene manipulation

ESSENTIAL QUESTION

How is DNA the foundation of unity and diversity of living things?

TOPIC 1.1:

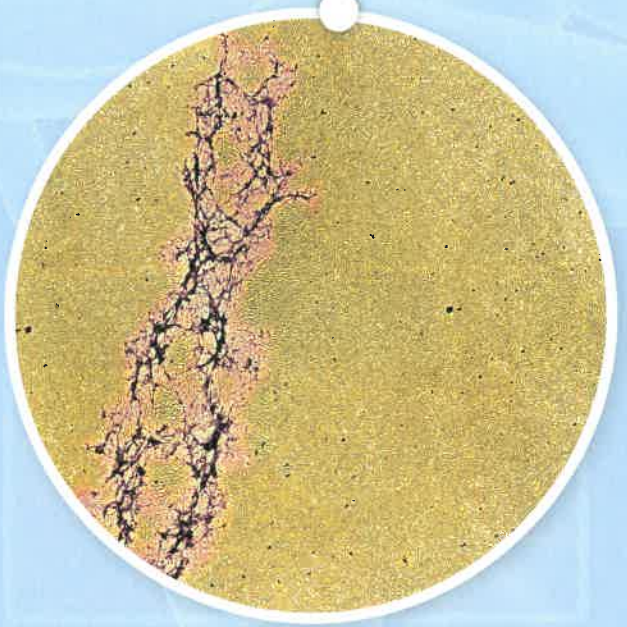
How does an understanding of DNA help us investigate living things?

Some things you will do:

- formulate physical and mental models
- consider social, ethical, and environmental implications of findings
- generate and introduce new or refined ideas

Some things you will come to know:

- DNA accounts for variation in living things.
- The structure of DNA is related to its function.



TOPIC 1.2:

How is hereditary information passed from one generation to the next?

Some things you will do:

- formulate multiple hypotheses and predict multiple outcomes
- demonstrate an awareness of assumptions and bias in your work and in secondary sources

Some things you will come to know:

- Genes pass on inherited traits from parent to offspring.
- Punnett squares are tools to show the probability of inheriting specific traits.

TOPIC 1.3:

How can natural and artificial selection influence changes in populations?

Some things you will do:

- select and use appropriate equipment to collect and record data
- ensure safety and ethical guidelines are followed in investigations
- draw conclusions that are consistent with evidence

Some things you will come to know:

- Genetic variation provides natural selection with the raw material with which it can interact and effect change.
- Humans select, and therefore affect, characteristics in certain organisms in order to suit our needs and wants.

TOPIC 1.4:

How and why are the genes of organisms manipulated?

Some things you will do:

- exercise healthy, informed skepticism to plan investigations and evaluate claims
- critically analyze and evaluate validity of information
- express and reflect on experiences, perspectives, and worldviews through place

Some things you will come to know:

- Biotechnology has benefits and risks and raises some ethical issues.

UNIT 1

Connect To What You Already Know

This feature helps you reflect on what you know about some foundational ideas that you have learned in previous grades. Work alone or quietly in small groups to answer the questions. Reach out to your classmates to ask about things that you are unsure about or to offer assistance. Your teacher also can provide additional reinforcement materials to help you prepare for this unit.

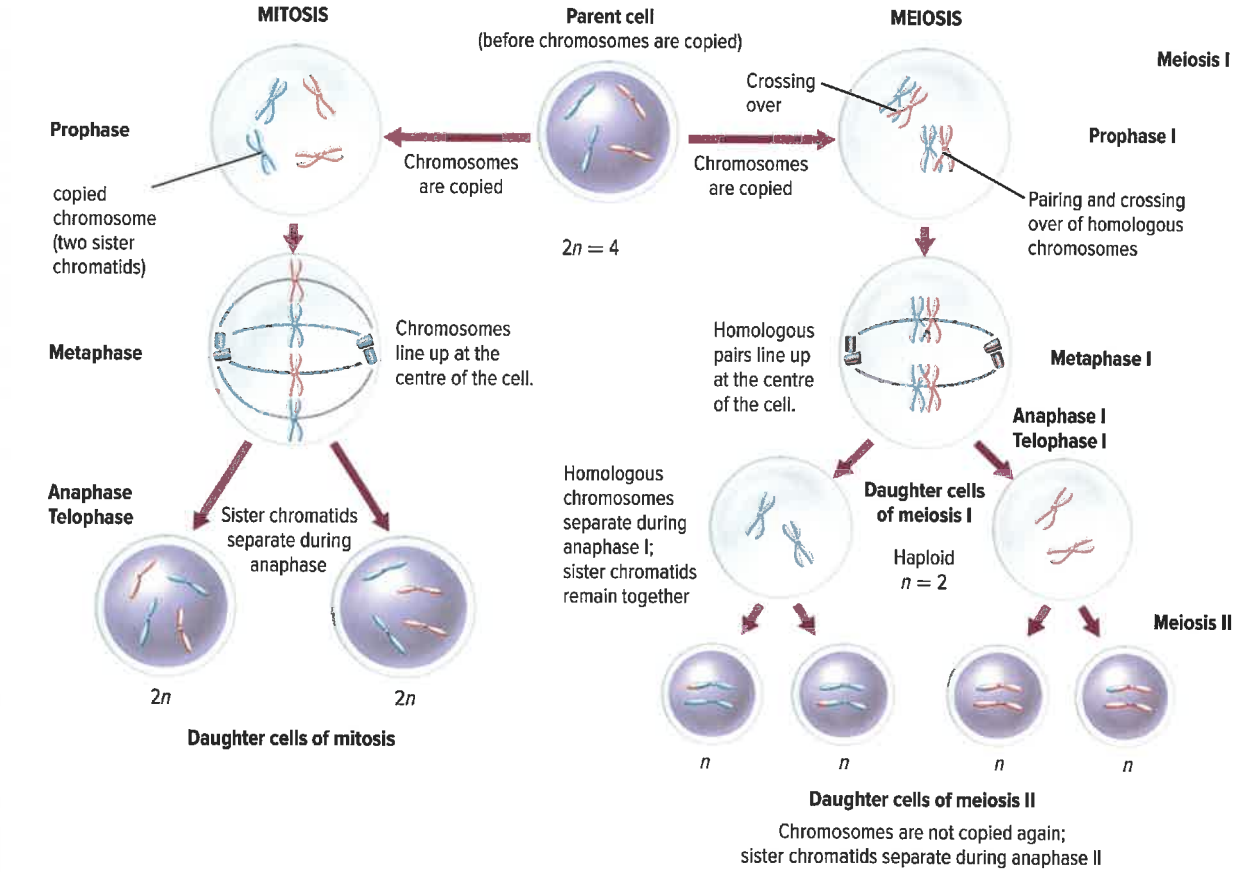
1. Compare and contrast asexual reproduction and sexual reproduction.
2. All eukaryotic cells reproduce by the cell cycle.
   a) Make an illustration of the cell cycle. Show the two stages and include the labels interphase, mitosis, and cytokinesis.
   b) Explain what happens during each stage.
3. Create a series of illustrations, with captions, to describe mitosis to Grade 5 students.
4. What happens to DNA in each stage of mitosis? Why is it important that DNA is replicated during interphase?
5. Draw a diagram of a cell with six chromosomes going through meiosis.
6. Identify whether each of the following is an event in meiosis I or meiosis II.
   a) Individual chromosomes move to the middle of the cell.
   b) Homologous pairs of chromosomes move together to the middle of the cell.
   c) Crossing over occurs.
   d) Homologous chromosomes move to opposite sides of the cell.
7. Explain why meiosis is related to the diversity of living things on Earth.
8. Make flowchart to show the steps involved in the formation of a zygote, beginning with one gamete from a genetic male and one gamete from a genetic female.
9. Explain the difference between haploid and diploid cells.
10. What role does meiosis play in sexual reproduction?
11. A dog has 76 chromosomes.
    a) How many pairs of homologous chromosomes does it have?
    b) How many chromosomes are in each sperm cell of a male dog?
12. Which phases of meiosis are most similar to the phases of mitosis? Explain your answer.
13. Create a table to show the number of chromosomes of the following list of cells before, during, and as a result of mitosis.
    a) human cell: 46 chromosomes
    b) horse cell: 64 chromosomes
    c) apple cell: 34 chromosomes
14. Repeat question 12 for the same list of cells before, during, and as a result of meiosis.
15. Copy and complete this table.

	Mitosis	Meiosis
Function		
Type of cells it occurs in		
Number of divisions		
Number of chromosomes in parent cell		
Number of daughter cells produced by each parent cell		
Number of chromosomes in daughter cells		
Are daughter cells genetically identical?		

Mitosis and meiosis both result in cell division, and they have many other similarities as well. For example, the DNA is copied before the start of meiosis and mitosis. However, there are some important differences too, which are summarized in Table 1. The events in meiosis I are unique to meiosis. The events in meiosis II and mitosis are virtually identical. But it is very important to keep in mind that the cell is haploid at the start of meiosis II and diploid at the start of mitosis.

Table 1 Mitosis and Meiosis

Mitosis	Meiosis
• One division occurs during mitosis.	• Two sets of divisions occur during meiosis: meiosis I and meiosis II.
• DNA is copied during interphase.	• DNA is copied once before meiosis I.
• Pairing of homologous chromosomes does not occur.	• Pairing of homologous chromosomes occurs during prophase I.
• Two diploid cells ($2n$) are formed per cell cycle.	• Four haploid cells (n) are formed per cell cycle.
• The daughter cells are genetically identical.	• The daughter cells are not genetically identical.
• Mitosis occurs only in body cells.	• Meiosis occurs only in reproductive cells.
• Mitosis is involved in growth and repair.	• Meiosis is involved in the production of gametes and providing genetic variation in organisms.



TOPIC
1.1

How does an understanding of DNA help us investigate living things?

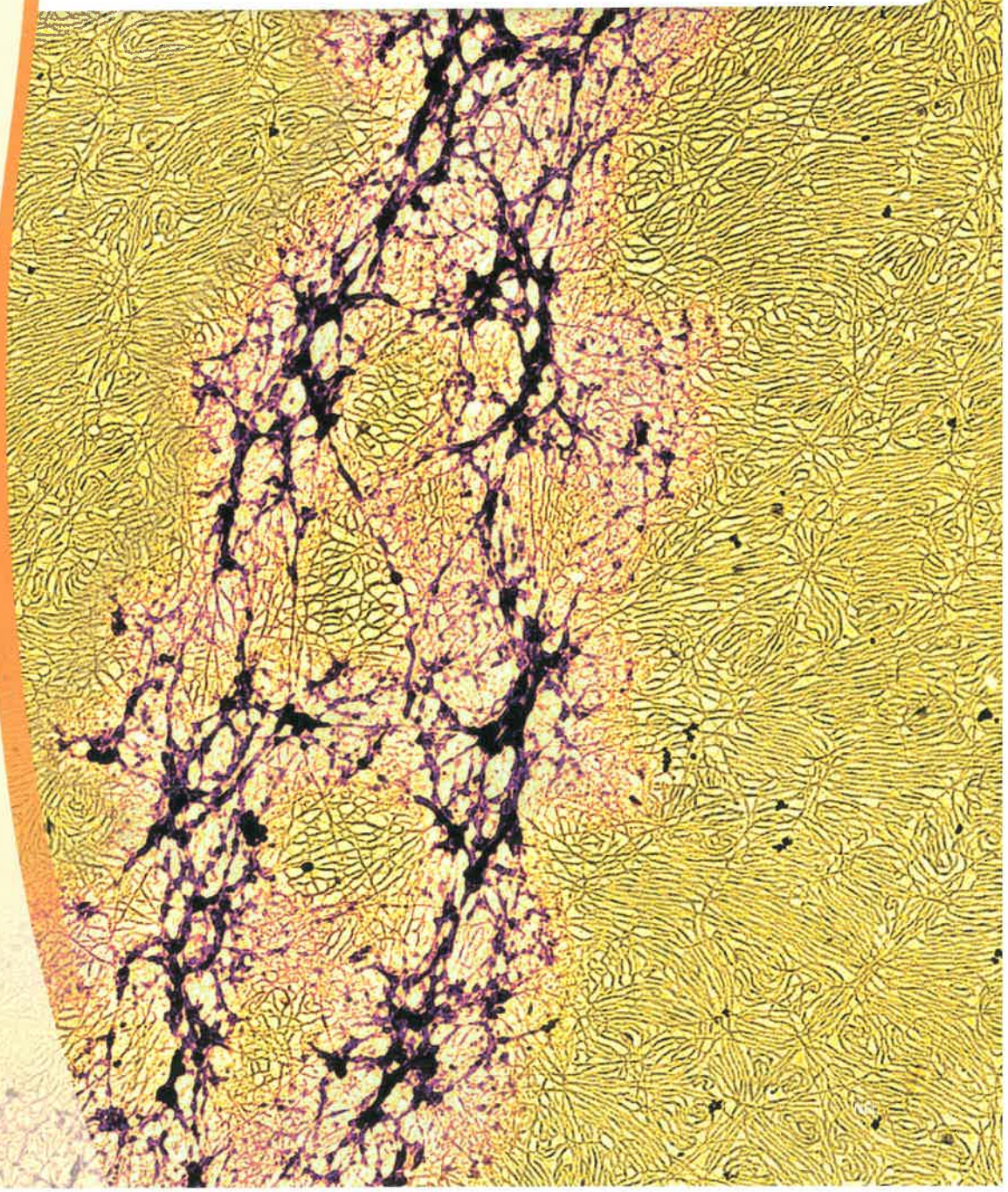
The nuclei of your cells have an average width of only 5 micrometres, which is about 10 times smaller than the width of a single human hair. One of the structures stored in the nucleus is DNA—about 2 metres' worth. How can all this DNA fit in the nucleus of your cells? The millions of coiled threads you see here, called chromatin, help with this. Chromatin, along with certain proteins, is condensed DNA. As chromatin, DNA is compact and fits into the nucleus of a cell. This is like stuffing 100 km of string into a lunch box. In this Topic, you will learn about the structure and function of DNA and its importance to living things.

Key Concepts

- The variation in living things we see around us is due to DNA.
- DNA is made of many nucleotides linked together in a specific order.
- DNA exists in chromosomes, which contain thousands of genes.
- The structure of DNA is important to passing on information.
- The different genetic make-up of organisms is reflected in the diversity of living things.

Curricular Competencies

- Make observations aimed at identifying your own questions.
- Consider changes in knowledge over time.
- Consider the role of scientists in innovation.



Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** What do you recall about the structure and function of DNA from previous studies? Skim through the pages of this unit. How does the text and visual information you see in this unit compare with what you recall?
2. **Making Connections** How many different kinds of living things do you think there are on Earth? How might this diversity be important or valuable? Where does this diversity come from?
3. **Applying First Peoples Perspectives** Some scientists speculate that a living organism without DNA could exist. Nevertheless, as far as we know, the genetic information of all living things is stored using the same molecules: nucleic acids. How does this reflect the First Peoples world view that everything is interconnected?

Key Terms

There are 13 key terms that are highlighted in bold type in this Topic:

- DNA
- complementary bases
- chromosome
- allele
- population
- nucleotide
- protein
- homologous chromosome
- karyotype
- nitrogenous bases
- chromatin
- gene
- species

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

The variation in living things we see around us is due to DNA.

Activity

Gallery of Living Things

Think about the variety of organisms you know. Brainstorm examples that best fit these categories: largest; smallest; most unusual; most important. Create five more categories, and list examples. How are your lists alike and different? How can you explain the differences? How do your lists compare with your classmates' lists?

DNA deoxyribonucleic acid, a double-stranded nucleic acid that stores genetic information

Within and around the places you know, you can identify many different organisms, such as people, trees, grass, dogs, flies, and crows. If you think about just one of these—grass, for example—you likely can identify many ways one blade or patch of grass differs from another. Despite all this variation, you know that all life shares characteristics such as being made up of cells, using energy, growing, and reproducing. In addition to these, all the living things that we see are closely linked to something we cannot see—a molecule called DNA.

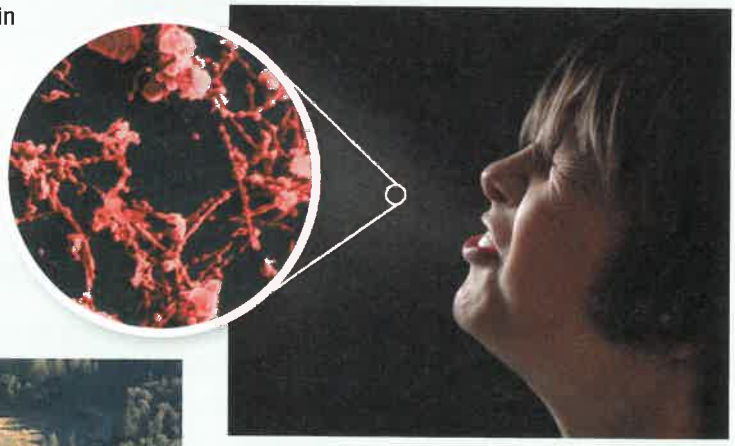
DNA (deoxyribonucleic acid) is genetic material that stores information. DNA is responsible for variation among all living things. Most cells of an organism contain genetic information that has an influence on its appearance and life processes. Figure 1.1 shows some of the similarities and differences in organisms that result from DNA.

Figure 1.1 Life, variety, and DNA. **Questioning: What is the role of DNA in the variety of Earth's organisms? Do you think it is the only factor?**

Plants have some form of roots, a stem, and leaves. Plants carry out photosynthesis to produce their own food. But differences in DNA result in variations in root systems, types of stems, and leaf shape that enable plants to live in ecosystems as diverse as temperate rainforests, alpine meadows, and bogs.

Animals are multicellular, must ingest food, and display some form of movement. But differences in DNA result in variations in body shape, types and numbers of limbs, and organ systems. These and other variations enable animals to live in ecosystems as diverse as deciduous forests, lakes and ponds, and coniferous forests.

Bacteria are single-celled and microscopic. They are found in almost every ecosystem on Earth, including living in and on humans and other organisms. Scientists estimate that there are over 100 000 species of bacteria. Some are critical to the health of an ecosystem, such as those that decompose dead material. Some are harmful, such as those that cause diseases like pneumonia (shown in the photo). As with other organisms, differences in the DNA of bacteria enable them to live and thrive in a multitude of ecosystems, including living on and within us.



Protists are single-celled, microscopic organisms. You might recognize the names of different types, such as *Paramecium*, *Euglena*, or amoebas. Protists are found in aquatic ecosystems (and are often the cause of the algal blooms in Burgoyne Bay, shown on the left) and in soil. Variation in protist species is due to differences in DNA. Fungi, such as the mushrooms shown on the left, are multicellular organisms that decompose organic matter to get energy. Like other groups of organisms, different species of fungi exist because of variations in DNA.

Before you leave this page . . .

1. Why is there variation among organisms on Earth?
2. Choose one group of organisms in **Figure 1.1** and describe some of the similarities and differences between species in that group. Use examples not already listed in the text.

CONCEPT 2

DNA is made of many nucleotides linked together in a specific order.

Activity

Follow the Instructions

Think of something that has to be put together a certain way in order for it to function properly, such as a bicycle. Draw the basic steps needed to put together your example. Can your example be put together in any way? Why or why not?

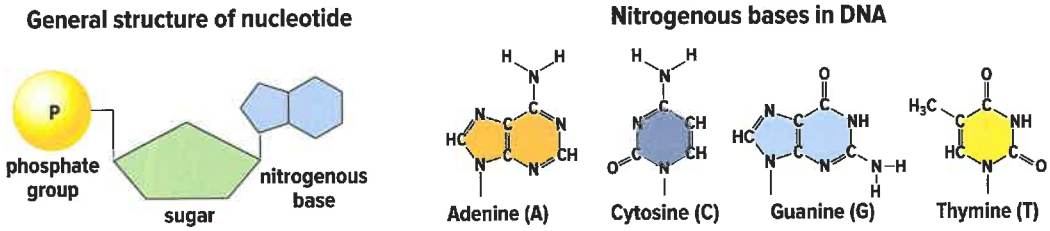


Figure 1.2 Nucleotides are the basic building blocks of DNA and RNA.

The Structure of DNA

Cells contain two types of *nucleic acids*: DNA and RNA (ribonucleic acid). Nucleic acids are large molecules made of smaller components called **nucleotides**. Figure 1.2 shows the general structure of nucleotides. Each consists of a phosphate group, a sugar, and a nitrogen-containing molecule called a **nitrogenous base**. The nitrogenous bases in DNA are adenine (A), cytosine (C), guanine (G), and thymine (T).

nucleotide consists of a phosphate group, a sugar, and a nitrogenous base; found in DNA and RNA

nitrogenous base part of the structure of a nucleotide; nitrogenous bases in DNA are adenine (A), cytosine (C), guanine (G), and thymine (T)

complementary bases nitrogenous bases that pair together in a specific way; A and T always pair together, and G and C always pair together

As shown in Figure 1.3, DNA is a molecule made up of two strands of nucleotides linked together. The structure of DNA looks like a twisted ladder, or double helix. The sides of the ladder are made up of the sugar and phosphate groups. Each rung of the ladder is made up of two nitrogenous bases bonded together as a base pair. The two strands are joined by hydrogen bonds that form between the nitrogenous bases of each strand. In Figure 1.3, you can see that each set of base pairs in the "rungs" of DNA must pair in a specific way. Adenine always pairs with thymine and guanine always pairs with cytosine. Nitrogenous bases that bond, or pair together in this way, are called **complementary bases**.

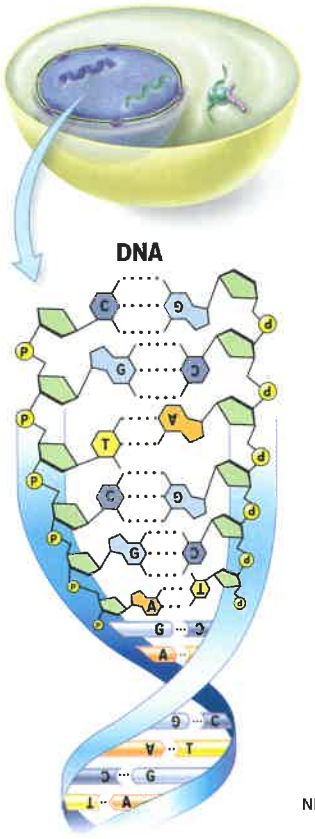


Figure 1.3 DNA is found in the nucleus of a cell. The bases of the nucleotides pair only in specific ways.

The Function of DNA

DNA stores genetic information. Organisms inherit DNA from their biological parents (or parent, for certain types of organisms). The genetic information stored in DNA is found in the order, or sequences, of bases along one side of the molecule. This genetic information tells each cell what **proteins** to make and how to make them. Protein molecules make up much of the structure of cells in all organisms as well as tissues in plants and animals. In addition, various proteins control how a cell is formed and how it functions. The instructions provided by DNA are therefore responsible for the development of an organism and the function of all of its parts.

protein an organic chemical composed of a chain of building-block molecules called amino acids

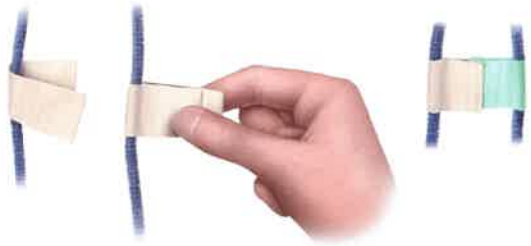
The complete DNA sequence in each cell of an organism is called the organism's *genome*. The human genome consists of about three billion base pairs. These are found distributed in the 46 chromosomes in every cell that forms the human body.

Activity

Modelling DNA

In this activity you will use the materials provided by your teacher to assemble your own DNA model.

1. Place two pipe cleaners of the same colour in an orientation that represents the sugar-phosphate backbones of DNA.
2. Write a sequence of bases that you will use to build your DNA model. Be sure to use each base at least once. Decide which colour of tape will represent each base. Wrap a piece of tape to one of the pipe cleaners, according to the following instructions and the diagram on the right.
   a) Choose the colour of tape that matches the first base in your sequence. Start at one end of the pipe cleaner, 2 cm to 3 cm from the end.
   b) Centre a piece of tape on the pipe cleaner. Fold and press the tape around it.
   c) Repeat step b with the other pipe cleaner. Use a piece of tape that represents a complementary base, but leave some of the sticky side of the tape exposed. Connect the two pipe cleaners by overlapping the sticky side of the tape with the piece of tape on the opposite pipe cleaner.
   d) Continue steps b and c, adding "bases" along the length of each pipe cleaner.



3. Holding both ends of the double-stranded DNA model, twist the two ends in opposite directions to form a helix structure.
4. Use your model to answer the questions.
   - What determined the bases you added in step c?
   - What are the strengths and weaknesses of your model?

Before you leave this page . . .

1. If the bases on one strand of DNA are ATGGGCTA, what is the sequence of complementary bases on the other strand of DNA?
2. Think of an analogy to describe base pairs. Share it with a classmate.

CONCEPT 3

DNA exists in chromosomes, which contain thousands of genes.

Activity

Coiled and Condensed

Recall the photo that began this Topic. Then examine the yarn and the box provided by your teacher. Can you get all the yarn to fit inside? How does this experience help you appreciate the structure of DNA and the complexity of life?

chromatin fibres of DNA in its condensed form; the usual form of DNA in the nucleus during interphase

chromosome structure composed of DNA as a very condensed form of chromatin; visible only during cell division

Figure 1.4 shows the relationship among DNA, **chromatin**, and **chromosomes**. During most of the cell cycle, DNA exists as strands of chromatin. Once the cell's nucleus and genetic material begin to divide (mitosis), the chromatin condenses into distinct chromosomes.

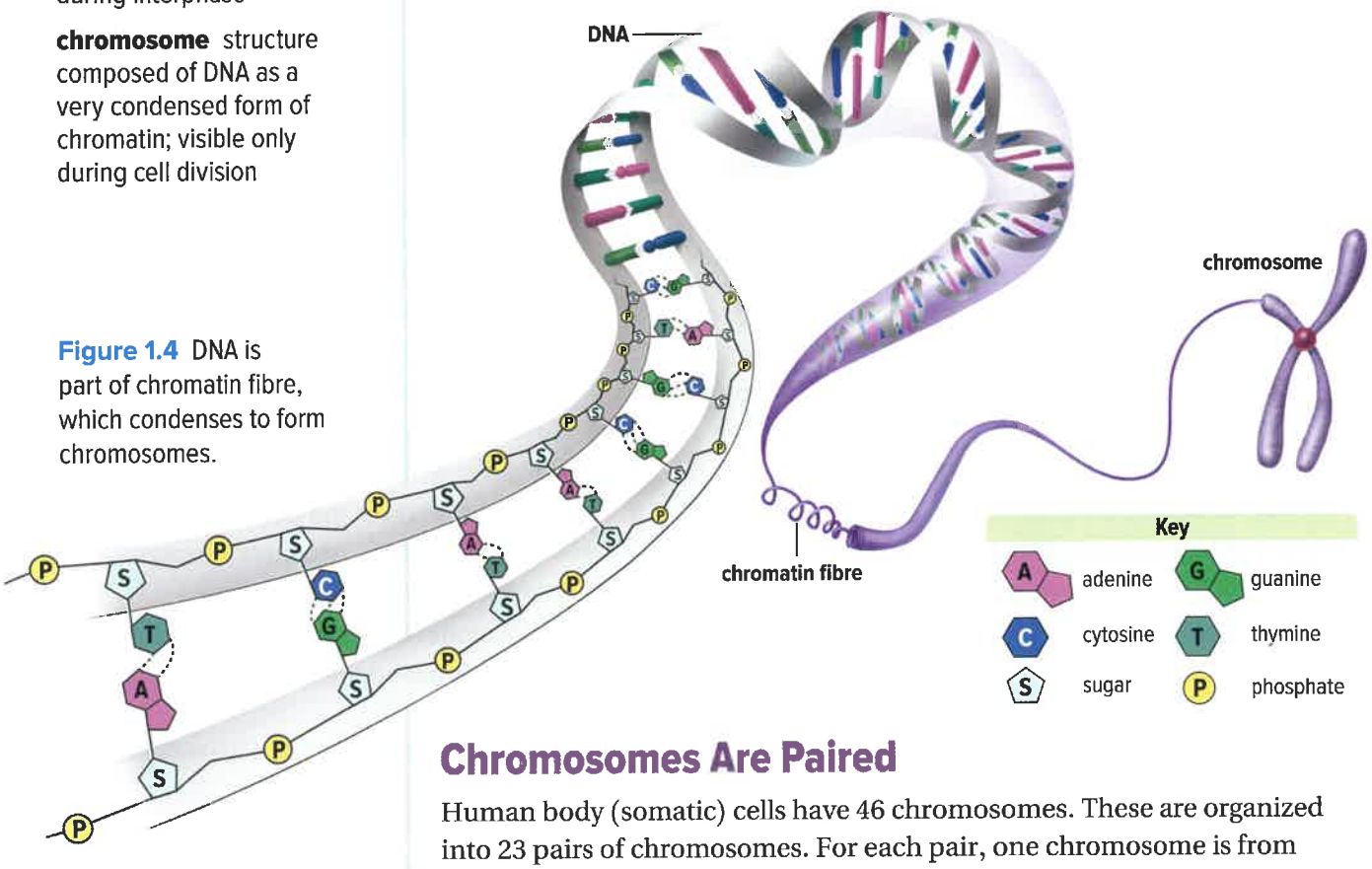


Figure 1.4 DNA is part of chromatin fibre, which condenses to form chromosomes.

Chromosomes Are Paired

Human body (somatic) cells have 46 chromosomes. These are organized into 23 pairs of chromosomes. For each pair, one chromosome is from the biological father and one is from the biological mother. One of these chromosome pairs is the *sex chromosomes*. The sex chromosomes, called X and Y, determine the genetic sex of an individual. A genetic female has two X chromosomes. A genetic male has one X chromosome and one Y chromosome. The sex chromosomes are always counted as a pair, even though X and Y are not similar. The remaining 22 pairs of chromosomes are called *autosomes*. Chromosomes are paired based on sharing similar characteristics.

Homologous Chromosomes Contain Alleles

As shown in Figure 1.5, **homologous chromosomes** are pairs of chromosomes that are similar in features such as length and centromere location but are not identical to each other. As you know, chromosomes contain the cell's DNA. **Genes** are sections of DNA that contain genetic information for the inheritance of specific traits. Homologous chromosomes carry genes for the same traits, such as hair type, at the same location. However, they can carry different forms of the same gene. Different forms of the same gene are called **alleles**. These different forms account for differences in specific traits, such as straight hair versus curly hair.

homologous chromosome a chromosome that contains the same sequence of genes as another chromosome

gene a part of a chromosome that governs the expression of a trait and is passed on to offspring; it has a specific DNA base sequence

allele a different form of the same gene

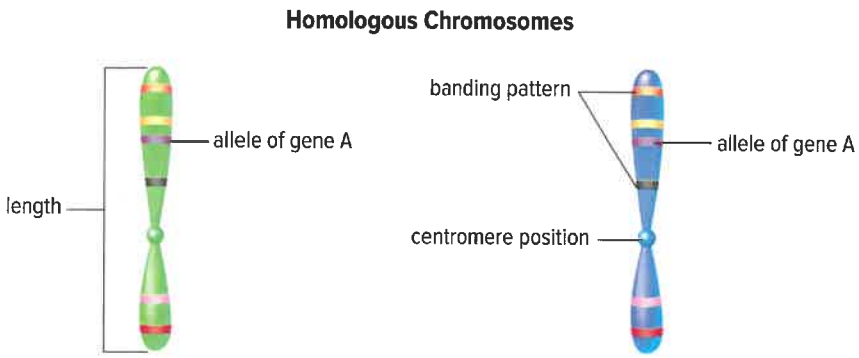


Figure 1.5 Homologous chromosomes have several characteristics in common, but they are not identical.

Examining Chromosomes: The Karyotype

The particular set of chromosomes that an organism has can be seen in a **karyotype** [CARRY-oh-type]. To prepare a karyotype, a cell sample is collected and treated to stop cell division during metaphase of mitosis. The sample is stained, which produces a banding pattern on the chromosomes that is clearly visible under a microscope. The chromosomes are then sorted and paired. The autosomes are numbered 1 through 22, and the sex chromosomes are labelled as X or Y. For example, Figure 1.6 shows the karyotype of a genetic female, because there are two X chromosomes.

karyotype a photograph of pairs of homologous chromosomes in a cell

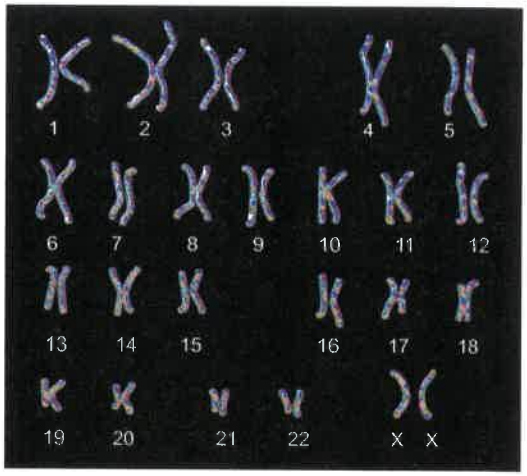


Figure 1.6 This is a human karyotype. The chromosome pairs are arranged and numbered in order of their length, from longest to shortest. The sex chromosomes are placed last.

Before you leave this page . . .

1. Describe the relationships among chromatin, a chromosome, DNA, and a gene.
2. Make an analogy that helps explain homologous chromosomes.

CONCEPT 4

The structure of DNA is important to passing on genetic information.

Activity

Mitosis and Meiosis

Use your prior knowledge to explain what needs to happen to genetic material in order for cells to reproduce. Share your explanations with a partner and then the class to be sure everyone agrees and understands.

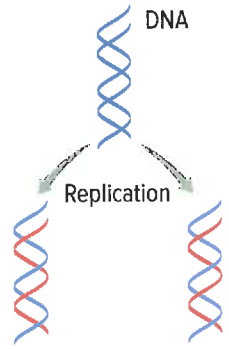


Figure 1.7 During DNA replication, two molecules of DNA are made from one. The resulting new molecules are identical to the original. Each new molecule contains one original strand of DNA (shown here in blue) and one new strand (shown in red).

DNA Replication

Replication is the process of creating an exact copy of a molecule of DNA. A cell replicates all of its DNA—its whole genome—once, and only once, in the cell cycle. A human cell can copy all of its DNA in a few hours, with an error rate of only about one per one billion nucleotide pairs. The speed and accuracy of replication relies on the structural features of DNA and the action of a set of specialized proteins.Each new molecule of DNA serves as a template for the formation of its complementary strand. As shown in **Figure 1.7**, each new molecule of DNA contains one strand of the original complementary DNA molecule and one new daughter strand.

After DNA replicates, the genetic code is copied to RNA and translated so that proteins can be made. **Figure 1.8** summarizes the overall path of how proteins are made. When needed, a cell accesses the genetic information coded within a single gene to create protein for cellular activities. An enzyme is used to copy the sequence of DNA's nitrogenous bases to create a single strand of RNA nucleotides. Next, this single strand of RNA is used to produce the correct sequence of amino acids to build the protein. Thus, the sequence of bases in DNA's genetic code will determine the sequence of bases on a strand of RNA, which in turn will determine the sequence of amino acids needed to make a protein.

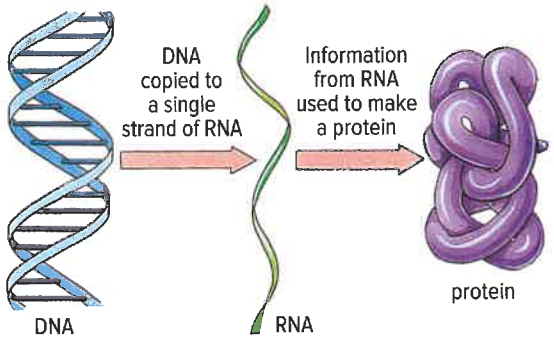


Figure 1.8 Genetic information passes from the genes (DNA) to an RNA copy of the gene, and the RNA copy directs the sequential assembly of a chain of amino acids to produce a protein.

Before you leave this page . . .

1. Explain how the structure of DNA is related to how genetic material is passed from one generation to the next.
2. How are genes involved in the production of proteins?

CONCEPT 5

The different genetic make-up of organisms is reflected in the diversity of life.

Activity

Variety—The Spice of Life

Think about and list the variety of organisms that live in your area. Also consider the variety of places (habitats, ecosystems) where they live. Compare your lists with others in the class. How would you classify the biodiversity of your area? Is there a lot of variety? Only some? How did you arrive at your opinions?

When you hear or read the word *biodiversity*, you may think first about species diversity. *Species diversity* is the variety and abundance of **species** in a given area. However, the concept of biodiversity involves more than just numbers of species. Also included are genetic and ecosystem diversity. *Genetic diversity* is evident in the variety of inherited traits *within* a species. For example, the patterns on the tails of humpback whales (Figure 1.9) are evidence of genetic diversity within this species. *Ecosystem diversity* is the rich diversity of ecosystems found on Earth, each of which contains many species.

species group of organisms that can interbreed in nature and produce fertile offspring

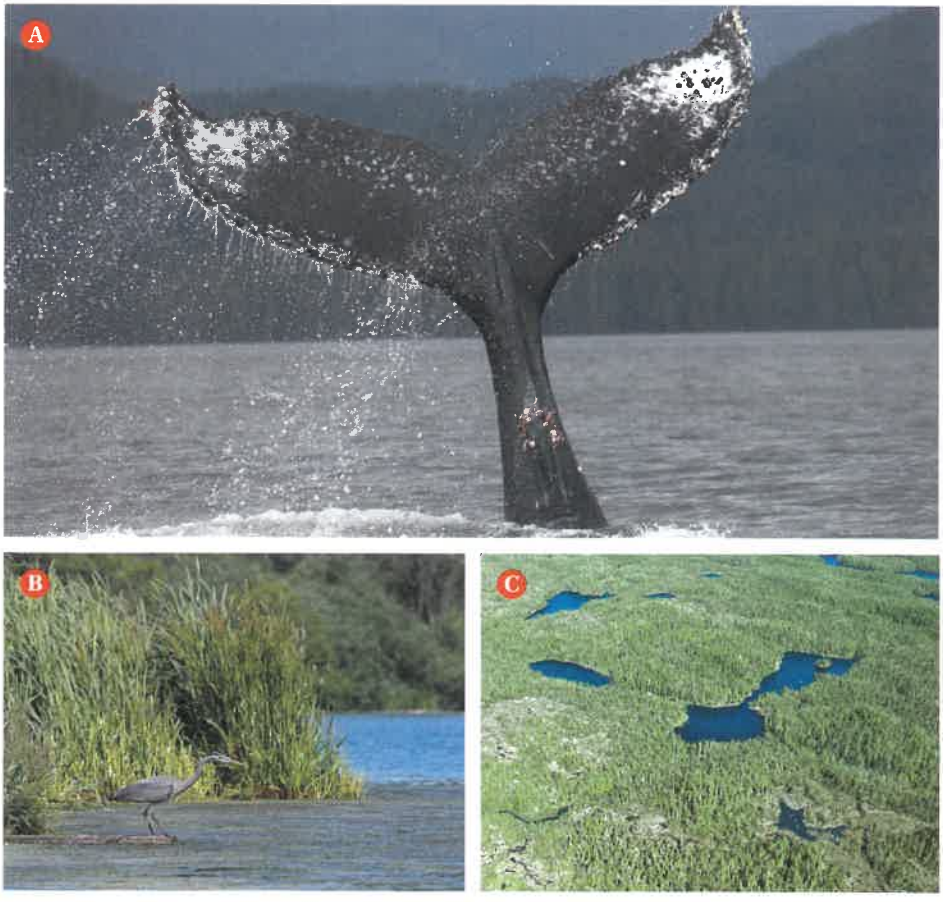


Figure 1.9 Biological diversity exists at different levels. A Within species there is *genetic diversity*, as evident in the different tail patterns of humpback whales. B Within ecosystems, like this freshwater wetland, is *species diversity*. C Finally, a variety of ecosystems, such as this one in Great Bear Rainforest Park, make up *ecosystem diversity*.

Genetic Diversity

population members of the same species living in the same geographical area at the same time

Genes are the genetic material that control the expression and inheritance of traits, such as sugar content in blueberries, pattern arrangement in ladybeetles, and height in humans. The variation among individuals in a **population** is largely a result of the differences in their genes. Genetic diversity *within a population* is known as the *gene pool*. In other words, the gene pool is the sum of all the versions (alleles) of all the genes in a population. The genetic diversity *within* a species is always greater than it is within a population, because the gene pools of separate populations usually contain different types or combinations of alleles.

Genetic diversity within a species results from mutations to genes. You will read more about mutations later in this unit. The variation in genes among individuals in a population and within a species, along with other factors, can lead to the formation of a new species.

Species Diversity

From microscopic bacteria to carnivorous plants, from whales that migrate thousands of kilometres to fungi that help break down dead trees, there are millions of species on Earth. To date, scientists have identified about 2 million species. This is a large number, and new species are discovered every day. However, biologists estimate that the total number of species ranges from 5 million to one trillion! As you read this unit, you will learn how new species form and how variation in genes is critical to the formation of a new species.

Ecosystem Diversity

If the smallest scale at which scientists consider biodiversity is genetic diversity, then the largest scale is ecosystem diversity. Ecosystem diversity refers to the variety of ecosystems in the biosphere. Recall that ecosystems are made up of two components—biotic factors and abiotic factors. Biotic factors are all of the living organisms in an environment. Examples of abiotic factors include altitude, latitude, geology, soil nutrients, climate, and light levels. Because of the diversity of relationships among organisms and the variety of abiotic factors, Earth's surface is highly varied physically and chemically, making ecosystem diversity very rich. So many species exist and thrive in all of Earth's ecosystems because of genetic diversity and factors that affect the gene pool.

Before you leave this page . . .

1. Describe the differences among the three types of biodiversity.
2. Explain how variation in genes is related to all three types of biodiversity.

AT ISSUE

What Are the Accomplishments and Legacies of the Human Genome Project?

What's the Issue?

The international Human Genome Project (HGP) was completed in 2003. Its main goals were to determine, nucleotide by nucleotide, the complete sequence of the human genome and to identify all of the genes. This genetic blueprint for a human has shown us that

- the human genome consists of about 3 billion base pairs of DNA
- humans have about 21 000 genes, which is much fewer than scientists had predicted
- our genes are only about 1.5% of our DNA. Scientists have found that sections of the remaining 98.5% are extremely important, but there is still much of the genome that is poorly understood.

The HGP Is Complete, but There's Still Work to Do

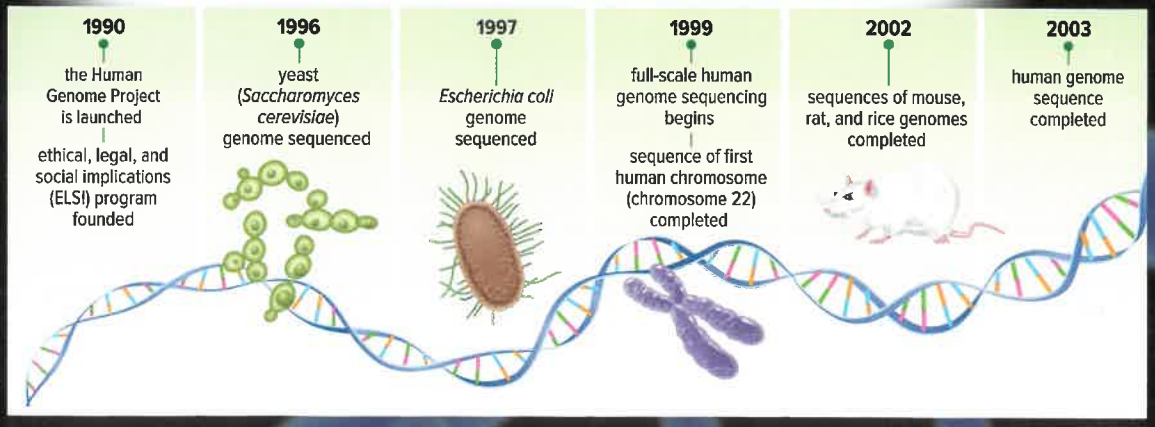
Though the HGP is finished, analysis of the data generated from this project will continue for decades. To complete this huge task, researchers have also studied the genomes of other organisms, including the fruit fly, the mouse, and *Escherichia coli*—a bacterium present in our intestines.

The DNA sequences of the genomes of thousands of organisms have also now been determined. Studies on non-human organisms help to develop the technology required to handle the large amounts of data produced by the HGP. These technologies help to interpret the function of newly identified human genes. Although the HGP represents a huge advance in science and technology, it also has raised many social, legal, and ethical questions.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. Who owns and controls genetic information? How will the genetic information of individuals be used, and by whom?
2. How does the use of genetic information for research affect isolated communities?
3. Why is it important to regulate research that involves genetic information?



AT ISSUE

Seeding the Future: Native and Heritage Varieties

What's the Issue?

Most fruits and vegetables you see in a grocery store are *hybrids*. Hybrids, which are created by crossing two plant lines, are bred to enhance selected features such as size, appearance, or longer shelf life. However, hybrids may be less flavourful, and their crops often cannot produce fertile seeds. This means that farmers must purchase new seeds each year from the commercial seed market.

Advantages of Native and Heritage Varieties

An alternative to growing hybrids is to plant native and heritage varieties of crop plants. Heritage (also called heirloom) varieties are usually defined as being at least 50 years old, and are often linked to a particular region. Both native species and heritage varieties are non-patented, naturally pollinated plants that produce fertile seeds.

Native and local heritage varieties are adapted to a region's environmental conditions. These adaptations give them increased resistance to pests and disease, which in turn means they require less maintenance and irrigation. Maintaining more plant varieties in the gene pool also provides greater genetic diversity.

Seed Libraries and Seed Banks

To help maintain genetic diversity, mechanisms for distributing and preserving seeds have been established. *Seed libraries* provide seeds and information about heritage plant varieties. *Seed banks* preserve seeds in case a disaster destroys other seed reserves. Some seeds can be kept for decades by drying and storing them in cold conditions. A combination of seed banking, seed sharing, and the planting of native and heritage plants may be the best way to preserve biodiversity for the future.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. In a group, brainstorm how you could encourage people to plant and purchase heritage crops in your community. Give at least three detailed ideas.
2. How does the Twin Sisters Native Plants Nursery at Moberly Lake balance sustainability and economics in their approach to renewing and restoring areas damaged by human activity?

Check Your Understanding of Topic 1.1

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

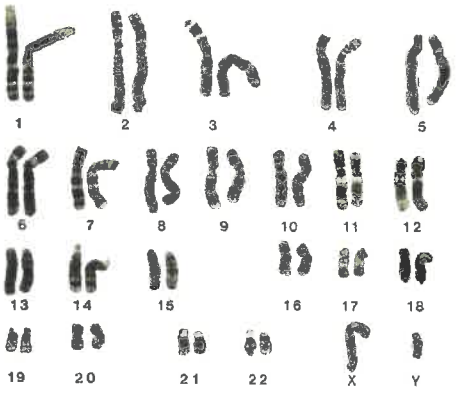
1. Think about a time you have seen a flock of Canada geese flying overhead. If you could examine the geese closely, would they look identical? Would they be genetically identical? Explain your answers. PA C
2. Describe the structure of DNA. C
3. What is the role of DNA in cells? C
4. Suppose a section of DNA has 27 percent thymine (T). PA
   a) What percentage of cytosine (C) does it have?
   b) What percentage of adenine (A) does it have?
   c) What percentage of guanine (G) does it have?
5. What is a genome? PA
6. Using a diagram or flowchart, illustrate the relationships among nucleotide, DNA, gene, allele, chromatin, and chromosome. C
7. Why is the word *homologous* used to describe chromosome pairs, rather than the word *identical*? PA
8. How are homologous chromosomes alike? How are they different? Make a diagram to help explain your answer. PA C
9. Draw and label a karyotype for an organism that has three pairs of homologous chromosomes. PA C
10. Why are the X and Y chromosomes commonly referred to as the sex chromosomes? PA
11. How does DNA replication ensure that daughter cells can produce the same proteins? PA

Connecting Ideas

12. Use a graphic organizer to show the relationships among the terms *biodiversity*, *genetic diversity*, *species diversity*, and *ecosystem diversity*. PA C
13. What is the difference between a gene and an allele? How is each related to diversity among living things? PA

Making New Connections

14. The human genome contains about 3.0×10^9 pairs of bases. Humans have approximately 21 000 genes, and a typical gene has 3000 base pairs. Suppose that the genome is a railway track and each base pair is a railway tie. If each railway tie is 1 m from the next, how many kilometres long is the track? Given this information, how much of the human genome consists of DNA that does not code for proteins? AI
15. The image below shows chromosomes in a human cell. PA
    a) What is this representation called and how is it prepared?
    b) Identify the sex of the individual.
    c) Does this individual have the correct number of chromosomes? How do you know?



INVESTIGATION
1-A

GUIDED INQUIRY

Using Karyotypes to Diagnose Genetic Disorders

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing Data
- Evaluating
- Communicating

Safety

- Handle scissors with care.

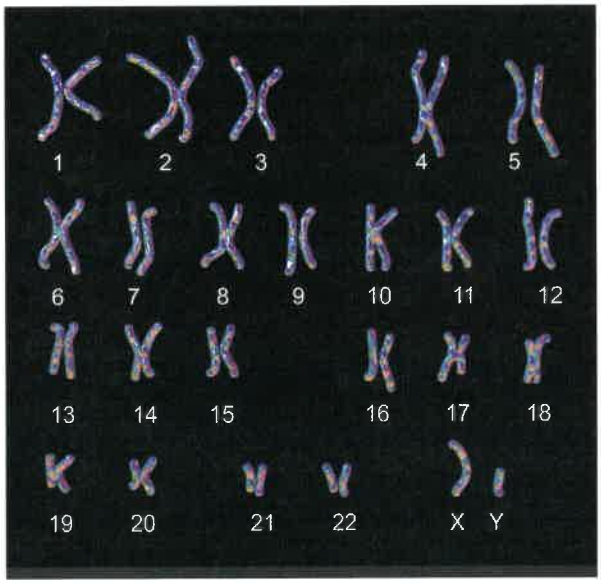
What You Need

- model chromosome image
- scissors
- tape or glue stick
- paper

In this activity, you will model and analyze a karyotype. A karyotype can be prepared before or after a baby is born to look for abnormalities in the number or structure of chromosomes within the cells. To prepare a karyotype, scientists take a tissue sample and then grow it in a culture dish in the lab. A chemical is added to the sample to stop cells during mitosis. Cells from this tissue are then placed on a microscope slide, stained, and treated with a chemical that makes the cells burst open. The stained chromosomes are then photographed through a microscope.

Question

What information can you infer from a karyotype?



To make a karyotype, the chromosomes are paired, placed in order of decreasing size, and numbered. **Identifying: Is this the karyotype of a genetic male or female? Explain.**

Procedure

1. Your teacher will supply you with a model image of a person's chromosomes.
   a) Cut out the chromosomes, and examine them closely to help you decide how to match them up in pairs. Remember that the sex chromosomes are not an identical pair. The X chromosome is larger than the Y chromosome.
   b) Compare your pairings with those of other groups. Confirm your decisions before moving on to the next step.

2. Tape or glue the chromosomes to a piece of paper. Arrange and number the pairs from largest to smallest. Leave a few centimetres of space between each pair. Place the sex chromosomes last. Number each pair of chromosomes from 1 to 22. Then label the sex chromosomes.
3. Examine your karyotype. Record the number of autosomes and the number of sex chromosomes.
4. Your teacher will give you an additional chromosome. Try to match it with one of the pairs in your original karyotype. Tape it in place next to the correct pair.
5. Examine your new karyotype. Note how it differs from your original.

Analyze and Interpret

1. Was your first karyotype from a somatic cell (body cell) or a gamete (sex cell)? How can you tell?
2. Based on your first karyotype, how confident are you that it represents someone who has no genetic abnormalities? Explain your reasoning.
3. Diagnose the disorder indicated by your karyotype in Procedure step 4. Give evidence for your answer. (Trisomy 13 = Patau syndrome; Trisomy 18 = Edward syndrome; Trisomy 21 = Down syndrome)
4. Cri-du-chat syndrome is a genetic disorder that results from a deletion of genes on the short arm of a chromosome 5. Make a sketch to show how the fifth chromosome pair might look in the karyotype of a child who has cri-du-chat syndrome.
5. Could you use a karyotype to detect a mutation in a single gene? Explain why or why not.

Conclude and Communicate

6. Did you find it difficult to match up the chromosome pairs? What features were most helpful when you were trying to identify homologous chromosomes?
7. You worked with a model image of chromosomes. Why might it be more challenging to interpret a photo taken through a microscope? What do you think is the likelihood of error when scientists interpret a karyotype?

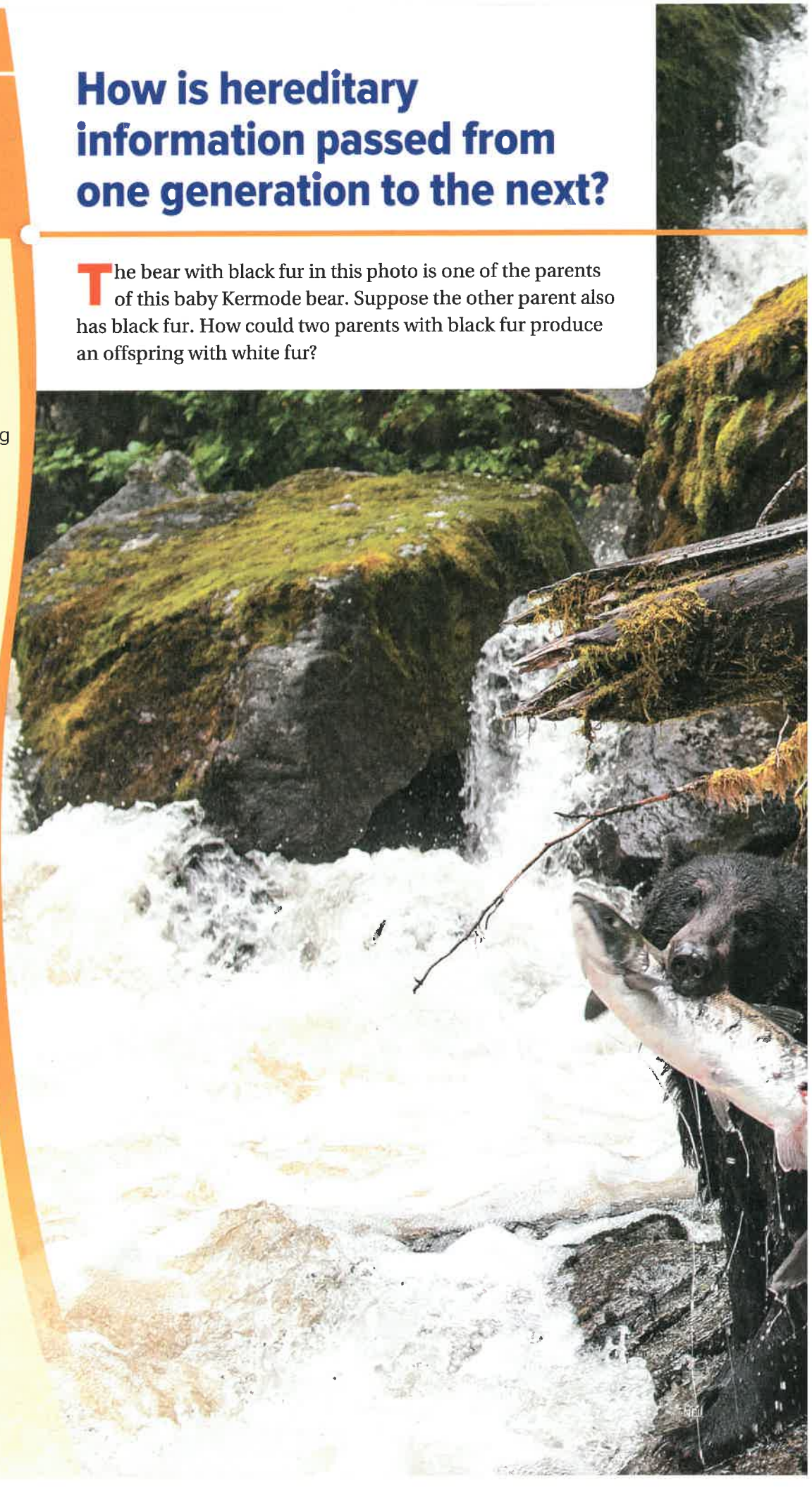
Extend Further

8. Research and describe the cause and symptoms of Williams syndrome. Can it be detected using a karyotype? Why or why not?

TOPIC
1.2

How is hereditary information passed from one generation to the next?

The bear with black fur in this photo is one of the parents of this baby Kermode bear. Suppose the other parent also has black fur. How could two parents with black fur produce an offspring with white fur?

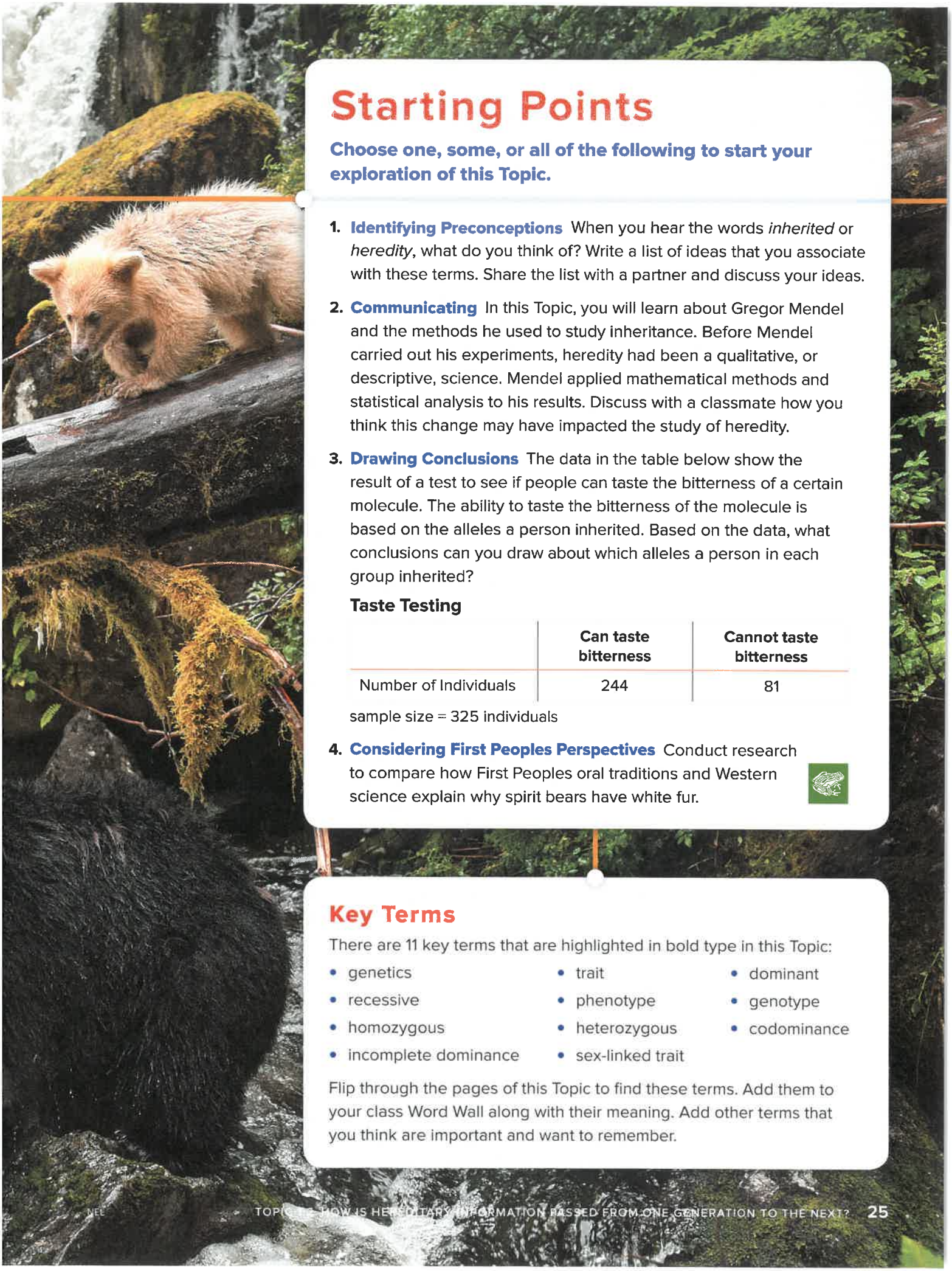


Key Concepts

- Genes pass on inherited traits from parent to offspring.
- Punnett squares show the probability of offspring inheriting specific traits.
- Both alleles are expressed in codominance.
- In incomplete dominance, alleles are neither dominant nor recessive.
- Some inherited traits are due to alleles on the sex chromosomes.

Curricular Competencies

- Plan, select, and use appropriate methods to collect reliable data.
- Analyze cause-and-effect relationships.
- Evaluate your methods and experimental conditions
- Describe ways to improve investigation methods and data quality.



Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** When you hear the words *inherited* or *heredity*, what do you think of? Write a list of ideas that you associate with these terms. Share the list with a partner and discuss your ideas.

2. **Communicating** In this Topic, you will learn about Gregor Mendel and the methods he used to study inheritance. Before Mendel carried out his experiments, heredity had been a qualitative, or descriptive, science. Mendel applied mathematical methods and statistical analysis to his results. Discuss with a classmate how you think this change may have impacted the study of heredity.

3. **Drawing Conclusions** The data in the table below show the result of a test to see if people can taste the bitterness of a certain molecule. The ability to taste the bitterness of the molecule is based on the alleles a person inherited. Based on the data, what conclusions can you draw about which alleles a person in each group inherited?

Taste Testing

	Can taste bitterness	Cannot taste bitterness
Number of Individuals	244	81

sample size = 325 individuals

4. **Considering First Peoples Perspectives** Conduct research to compare how First Peoples oral traditions and Western science explain why spirit bears have white fur.

Key Terms

There are 11 key terms that are highlighted in bold type in this Topic:

- genetics
- trait
- dominant
- recessive
- phenotype
- genotype
- homozygous
- heterozygous
- codominance
- incomplete dominance
- sex-linked trait

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Genes pass on inherited traits from parent to offspring.

Activity

DNA and Sexual Reproduction

Use your prior knowledge of meiosis and fertilization to model how an offspring gets half of its DNA from a genetic female and half of its DNA from a genetic male. Share your models with other groups. As a class, discuss how this concept is related to the traits an organism inherits.

genetics a field of biology that studies heredity, or the passing of traits from parents to offspring

trait an inherited characteristic, such as eye colour or hair colour

Genetics is a field of biology that studies heredity, which is the passing of **traits** from parents to offspring. People have been doing genetics experiments for thousands of years. These early experiments involved growing and raising food crops such as wheat and corn, livestock such as cows, and companion animals such as horses and dogs.

First Modern Experiments in Genetics

An Austrian monk, Gregor Mendel, made the first discoveries about how traits are passed from one generation to the next. In the 1860s, he experimented with pea plants. Pea plants reproduce by sexual reproduction, but they usually self-pollinate. Self-pollination occurs when a male gamete within a flower combines with a female gamete in the same flower. Cross-pollination occurs when a male gamete from one flower combines with a female gamete from flower of a different plant. Mendel discovered that he could transfer a male gamete from the flower of one pea plant to the female reproductive organ in a flower of another pea plant. By deliberately cross-pollinating plants, he could control which plants, with certain traits, were producing offspring.

Mendel kept careful records of the traits in the pea plants that he bred. He analyzed the results of his experiments and formed hypotheses about how the traits were inherited. By working in this methodical, controlled way, Mendel founded the modern science of genetics.

Mendel's Experiments

Mendel started his studies with pea plants that had purple flowers and pea plants that had white flowers. He knew that when purple-flowered plants self-fertilized, they produced new plants (offspring) with only purple flowers. He also knew that when white-flowered plants self-fertilized, they produced offspring with only white flowers. Plants that reproduce with these kinds of reliable, predictable results are called *true-breeding* plants. True-breeding plants consistently produce offspring with only one form of a trait.

Figure 1.10 outlines the procedure that Mendel developed and followed in his experiments with true-breeding plants and flower colour. The numbered steps in the text below correspond to the numbered parts of the diagram.

1. Mendel bred true-breeding purple-flowered plants with true-breeding white-flowered plants.
2. All the offspring from this cross are called first generation plants, or F_1. Mendel observed that all the first generation plants had purple flowers. He wanted to know what happened to the white-flower trait that disappeared. So he allowed the first generation plants to self-fertilize.
3. In the second generation plants, or F_2, Mendel observed that the white-flower trait reappeared in some of the offspring. Each time Mendel repeated the experiment and counted the plants in the second generation, there was always a ratio of approximately three purple-flowered plants to one white-flowered plant—a ratio of about 3:1.

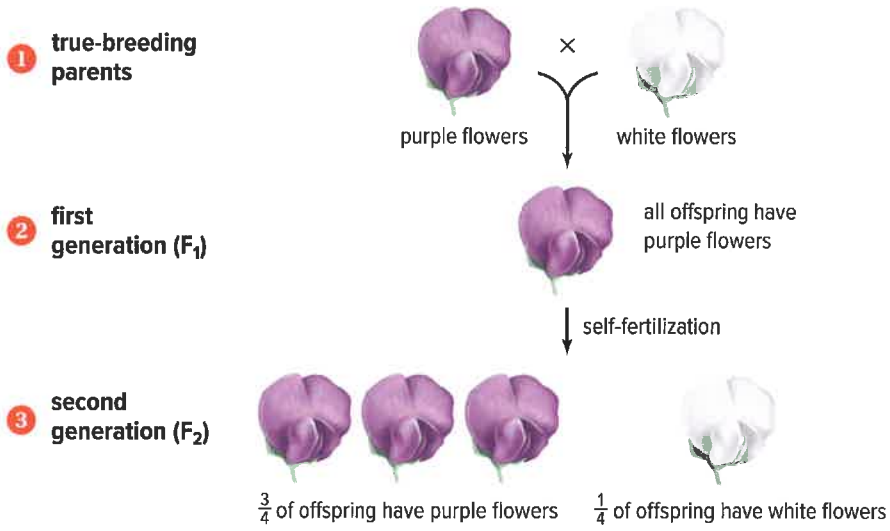


Figure 1.10 These are the results of Mendel's cross involving true-breeding pea plants with purple flowers and true-breeding pea plants with white flowers. **Analyzing: Why are all the F_1 flowers purple?**

Mendel observed the same results when he studied other traits in true-breeding pea plants, such as seed colour, seed shape, and stem length. In each case, one trait disappeared in F_1 plants, and then re-appeared in the F_2 plants. To explain his observations, Mendel proposed the following:

- Each plant had two factors that act as sets of instructions for each trait.
- Each parent donates one of these factors to the offspring.
- One factor or trait may dominate over the other if it is present.

It might seem obvious that offspring will be similar to their parents, but the reasons for this are complex. For example, do you have straight hair or curly hair? What colour are your eyes? These are traits you have because of genes you inherited from your biological parents. However, your biological parents may have a different set of traits than you do. How can that happen? Scientists have been trying to answer this question for hundreds of years. A complete answer is still not known. However, due to the work of Mendel and later scientists, many of the basic principles of heredity are understood.

Homologous Chromosomes and Gametes

Look again at Figure 1.5 (on page 15) to remind yourself about homologous chromosomes. Also recall that chromosomes may carry different versions of the same gene: alleles. During meiosis, the pairs of homologous chromosomes are separated so that each gamete receives one member of each pair. Therefore, allele pairs that are on homologous chromosomes are also separated, and each gamete carries only one allele of each pair.

When male and female gametes meet during fertilization, the genetic material combines. A diploid cell forms and the homologous chromosomes—and the associated alleles—are again paired up. The offspring inherits one set of chromosomes and its alleles from the biological mother, and the other set of chromosomes and its alleles from the biological father. Together, these two sets of chromosomes form a set of homologous chromosomes.

The Law of Segregation

The *law of segregation* describes the genetic basis for how characteristics are inherited. It states that alleles for each inherited trait separate, or segregate, from each other during gamete formation. Each gamete carries one allele for each characteristic. When fertilization takes place, each gamete contributes its allele for a characteristic. The two "factors" that Mendel referred to in his conclusions are what we now call alleles.

Dominant and Recessive Alleles

As you now know, Mendel observed that one trait could dominate over the other. For example, Mendel found that purple flowers were dominant over white flowers. Today, we know this occurs because alleles can be **dominant** or **recessive**. The presence or absence of each type of allele determines which trait is observed. If an individual has two, or even only one dominant allele, then the trait associated with it is the dominant trait, and that is what is observed. The trait that is associated with the recessive allele is observed only if an individual carries two recessive alleles.

dominant the allele or trait that is expressed, regardless of the identity of the other allele for the characteristic

recessive the allele or trait that is expressed only when two alleles are present; the expression of the allele or trait that is "hidden" or suppressed if the dominant allele is present

Geneticists have devised a system to represent alleles so that they can be tracked from one generation to the next. The dominant allele is represented with an upper-case letter. The recessive allele is represented with the lower-case version of the same letter used for the dominant allele. The example below applies this system to Mendel's studies of flower colour in pea plants:

- The dominant allele is for purple flower colour and can be indicated by *B*.
- The recessive allele is for white flower colour and can be indicated by *b*.
- The pairs of alleles for flower colour in plants with purple flowers can be either *BB* or *Bb*.
- The pair of alleles for flower colour in plants with white flowers can only be *bb*.

Figure 1.11 summarizes how the law of segregation and dominant and recessive alleles apply to the inheritance and expression of a trait. Although flower colour is used in the example, this summary applies to all characteristics that are determined by one gene. Since the time of Mendel's work, research has shown that the law of segregation applies to all organisms that reproduce sexually, including humans.

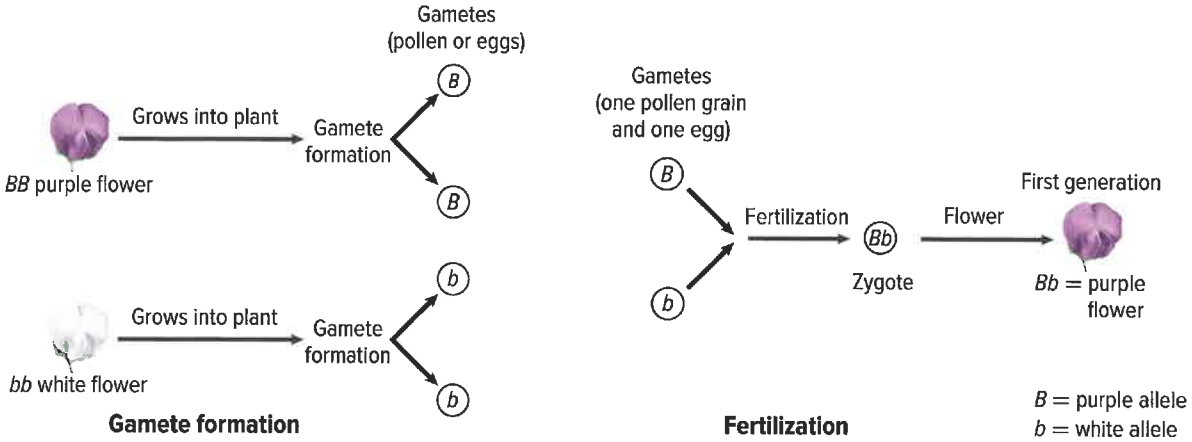


Figure 1.11 These are the results of Mendel's cross involving true-breeding pea plants with purple flowers and pea plants with white flowers.

Genotypes and Phenotypes

You know that the physical appearance of an organism does not necessarily indicate the alleles it has for a characteristic. Pea plants with purple flowers could have two dominant alleles (*BB*) or a dominant allele and a recessive allele (*Bb*) for flower colour. Therefore, scientists distinguish between an organism's physical traits and its genetic make-up. **Phenotype** is the physical expression of an organism's trait, such as purple flower colour. An organism's **genotype** is the specific combination of alleles it has for a trait. If an organism has two identical alleles, it is said to be **homozygous**. If both alleles are dominant, then the organism is *homozygous dominant*. If both alleles are recessive, the organism is *homozygous recessive*. If an organism has two different alleles for a trait, it is **heterozygous**. Figure 1.12 shows the three possible genotypes for a trait that is determined by two alleles of a gene.

phenotype the physical description of an organism's trait

genotype the specific combination of alleles an organism has for a trait

homozygous an organism with two of the same alleles for a particular trait

heterozygous an organism with two different alleles for a particular trait

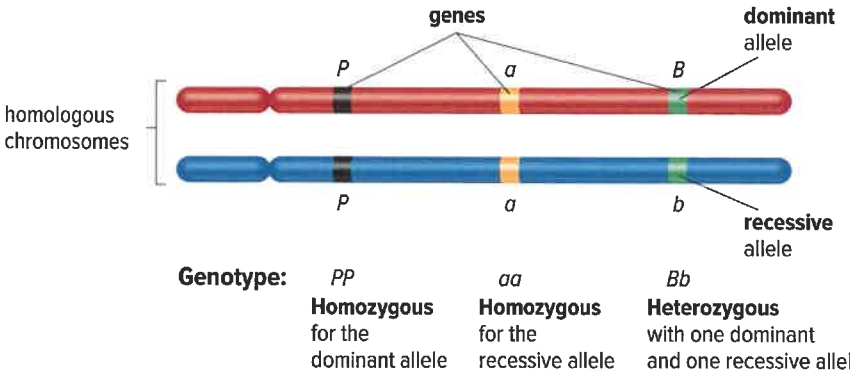


Figure 1.12 Three different genes on homologous chromosomes are indicated. Each example shows one of the three possible combinations (genotypes) of dominant and recessive alleles.

Activity

Dominant or Recessive Trait?

Do you think that broccoli and other leafy green vegetables taste bitter, while the person next to you loves broccoli as a side dish? This could be explained by your genes. In this activity, you will compile data to determine whether a particular gene is dominant or recessive for the trait of tasting the bitterness of a certain chemical.

1. Your teacher will provide you with a strip of paper that contains a chemical called phenylthiocarbamide (PTC).
2. Place the paper on the tip of your tongue and record whether it tastes bitter to you or not.
3. Combine your class data in a table like the one shown below.

Data Table

Number of People for Whom the PTC Was Bitter	
Number of People for Whom the PTC Was Not Bitter	
Total Number of People	
Percent of People for Whom the PTC Was Bitter	
Percent of People for Whom the PTC Was Not Bitter	

4. Calculate the percent of people with or without the trait. Do your results confirm that a trait is dominant or recessive according to the table? Why or why not?
5. Freckles show a dominant inheritance pattern. Do a survey in your class of how many people have freckles and how many do not. Calculate the percent of people with or without the trait. Do your results confirm that a trait is dominant? Research why your results may not confirm this.

Extending the Connections

Not Always as Simple as It Seems

In the past, scientists thought that certain traits in humans, such as the shape of a person's hairline, were controlled by a single gene. Scientists now know that the expression of a trait is often due to more than one gene. Examples include human eye colour and hair colour. How have scientists' views about applying Mendelian genetics to human traits changed, and why?

Before you leave this page . . .

1. Write a definition for genetics in your own words.
2. Seed shape in pea plants can either be round or wrinkled. The allele for round shape is indicated by *R*. Is round seed shape dominant or recessive?
3. The allele for freckles is indicated by *F*. What is the genotype of a person who is heterozygous for freckles?

CONCEPT 2

Punnett squares show the probability of offspring inheriting specific traits.

Activity

What Do You Know about Probability?

Probability is the chance that a given event will occur. If you flip a coin ten times, what is the probability that it will land on heads each time? Discuss your ideas with a partner, then test them. How might the heads-or-tails result of a coin flip be similar to alleles on homologous chromosomes?

A genetic cross is any type of deliberate breeding between a genetic male and a genetic female to produce offspring that carry the genetic material of each parent. When the parents differ in one particular trait that is being studied, the cross is called a *monohybrid cross*. A hybrid is an offspring of parents that have different traits. Often, scientists represent simple genetic crosses using the abbreviated form shown in **Figure 1.13**.

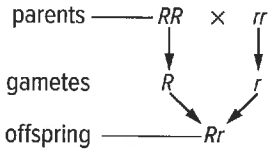


Figure 1.13 A monohybrid cross between a homozygous dominant individual and a homozygous recessive individual. Each parent contributes one type of allele to the offspring. The symbol "×" represents the word *cross*.

Punnett Squares

A *Punnett square* is another way to represent the inheritance of traits in monohybrid crosses. This model is a simple grid that shows the possible genotypes of offspring based on the genotypes of the parents. The Punnett square shown in **Figure 1.14** represents a monohybrid cross to study the inheritance of hair colour in horses. The allele for black hair (*B*) is dominant to the allele for red hair (*b*). The cross shown is between a black-haired female with the genotype *Bb* and a red-haired male with the genotype *bb*. The female gametes can contribute either a *B* allele or a *b* allele. The male gamete can contribute only the *b* allele, since its genotype is *bb*. All possible genotypes of the offspring are shown in the grid. In this case, offspring will have either a *Bb* genotype or a *bb* genotype.

A Punnett square can also indicate how often genotypes are predicted to appear in the offspring. Since the *Bb* genotype appears in two of the four squares, it is predicted that two quarters—or one half—of the offspring will have that genotype. The same frequency is predicted for offspring with the genotype *bb*. In this case, the frequency of the phenotypes in offspring, called the *phenotypic ratio*, is predicted to be the same as the genotypes. Half are predicted to have black hair and half are predicted to have red hair. The steps for how to use a Punnett square to analyze monohybrid crosses are outlined in **Figure 1.15**.

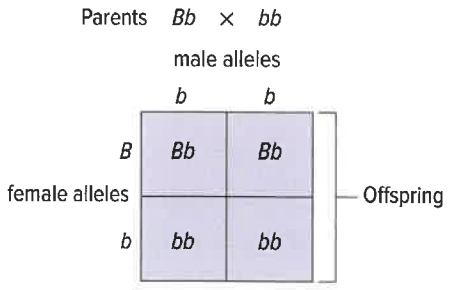
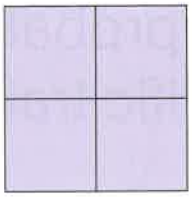
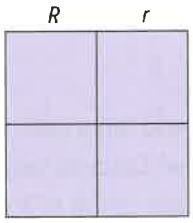


Figure 1.14 In this cross, the female horse can contribute either a *B* allele or a *b* allele to offspring. The male horse can contribute only the *b* allele. The genotypes of the offspring are all possible combinations of alleles that can occur when the gametes combine at fertilization.

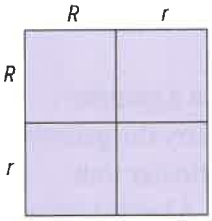
Figure 1.15 Steps for drawing and using a Punnett square.



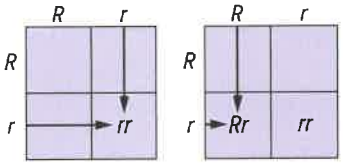
Step 1: Draw a box and divide it into four squares.



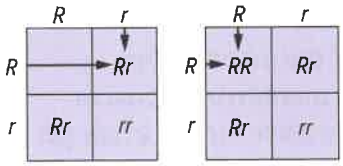
Step 2: Above the top squares, write the genotype of one parent. Place the letter for one allele above each square. Each of these represents the alleles present in that parent's gametes. The example on the left is for a parent that contributes the *R* and *r* alleles.



Step 3: Beside the squares on the left side of the grid, write the genotype of the other parent. Place the letter for one allele beside each square. Each of these represents the alleles present in that parent's gametes. The example here is for a parent that contributes the *R* and *r* alleles.



Step 4: In each square of the grid, write the symbols for the alleles above it and beside it. Each two-letter pair is the genotype of an offspring that would result from fertilization of gametes with the alleles listed above and beside the square.



Step 5: Determine the number of different genotypes and express each as a ratio and/or a fraction. This represents the expected ratio of offspring with that genotype for that cross.

Ratio: 1*RR*:2*Rr*:1*rr*

Fraction: $\frac{1}{4}RR$: $\frac{1}{2}Rr$: $\frac{1}{4}rr$

Activity

Working with Punnett Squares

Draw a Punnett square that represents a monohybrid cross between a female with genotype *Rr* and a male with genotype *RR*. What fraction of offspring is predicted to have the dominant trait?

Before you leave this page . . .

1. A monohybrid cross produces half the offspring with one genotype and half the offspring with another genotype. Express this in the form of a ratio.
2. What do the alleles that are written along the top and beside a Punnett square represent?

CONCEPT 3

Both alleles are expressed in codominance.

Activity

What Happens If Both Alleles Are Equally Expressed?

You have read that some patterns of inheritance result in phenotypes in which the dominant or recessive allele is expressed. However, that does not always happen. Some patterns of inheritance result in phenotypes that are created when both alleles for a trait are equally expressed. In horses, the alleles for chestnut coloured hair and white coloured hair are expressed equally. Suppose a horse inherits one allele for chestnut coloured hair and one allele for white coloured hair. If you looked closely at the individual hairs, what do you think you would see? What colour do you think this horse will be?

In **codominance**, both alleles are fully expressed. A roan animal is an excellent, visible example of codominance. A roan animal is a heterozygote in which both the base colour and white are fully expressed. For example, the coat of the bull in Figure 1.16 has a mixture of red hairs and white hairs. One allele is expressed in the white hairs, and the other allele is expressed in the red hairs. Codominant alleles are represented using one capital letter for the gene, with different superscript letters for each allele. For example, the roan would be H^RH^W.

codominance the condition in which both alleles for a trait are equally expressed in a heterozygote; both alleles are dominant

Figure 1.16 A roan bull (H^RH^W) is the product of a mating between a red cow (H^RH^R) and a white bull (H^WH^W). The red and white hairs may be present in patches, as shown here, or they may be completely intermingled.

Sickle Cell Anemia—Another Example of Codominance

Sickle cell anemia is one of the most thoroughly studied genetic disorders. It is caused by a specific form of the gene that directs the synthesis of hemoglobin. Hemoglobin is a protein in red blood cells that carries oxygen in the blood. The hemoglobin molecule that is made in people who have the sickle cell allele leads to a C-shaped (or sickled) red blood cell. These misshaped red blood cells, like the one shown in Figure 1.17, do not transport oxygen effectively because they cannot pass through small blood vessels. This leads to blockages and tissue damage.

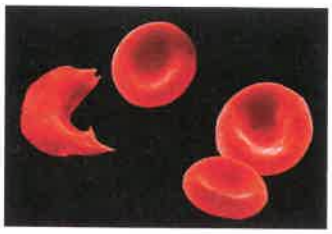


Figure 1.17 Normal red blood cells are flat and disk-shaped. Sickle-shaped cells are elongated and "C" shaped.

Sickle Cell Anemia and Malaria

The allele for normal hemoglobin is represented as Hb^A, and the allele for sickle cell hemoglobin is represented as Hb^S. As shown in **Figure 1.18**, individuals who are homozygous (Hb^SHb^S) have sickle cell anemia. Individuals who are heterozygous (Hb^AHb^S) have some normal and some sickled red blood cells. These people are said to have the sickle cell trait, but they rarely experience any symptoms. In fact, having the sickle cell trait can be an advantage, because these heterozygotes are resistant to malaria. Malaria is a life-threatening disease caused by a parasite that is transmitted to humans through mosquito bites. The parasite infects the liver and eventually the red blood cells. The sickling of red blood cells is thought to prevent the parasites from infecting the cells. Resistance to malaria is beneficial in certain parts of Africa, where deadly epidemics can occur.

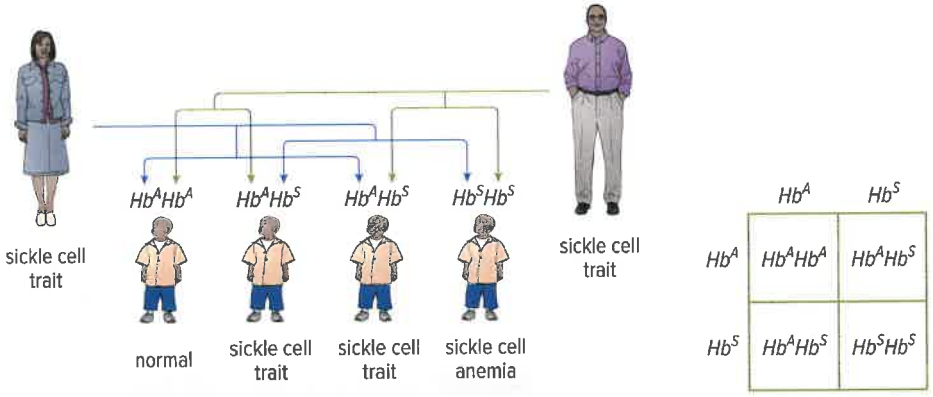


Figure 1.18 When a man and a woman are both heterozygous for the sickle cell gene, there is a one in four chance that they will have a child with sickle cell anemia.

Activity

Human Blood Groups

Do you know what blood type you are? In humans, a single gene determines a person's ABO blood type. The gene is designated *I*, and it has three common alleles: I^A, I^B, and *i*. The different combinations of the three alleles produce four phenotypes, which are commonly called blood types. These four blood types are:

- A (I^AI^A homozygotes or I^Ai heterozygotes)
- B (I^BI^B homozygotes or I^Bi heterozygotes)
- AB (I^AI^B heterozygotes)
- O (*ii* homozygotes)

Of the three alleles that determine blood type, one (*i*) is recessive to the other two, and the other two (I^A and I^B) are codominant.

Make a table with nine cells to show how different combinations of the three *I* alleles result in four different blood types. At the top of the table show the possible alleles from a genetic female as I^A or I^B or *i*. Along the left side of the table show the possible alleles from a genetic male as I^A or I^B or *i*. Fill in your table, and make a key to identify the different blood types that can result.

Before you leave this page . . .

1. What is codominance? Give three examples of codominance.
2. Hypothesize why the frequency of the sickle cell allele is much higher in Africa than in other areas of the world.

CONCEPT 4

In incomplete dominance, alleles are neither dominant nor recessive.

A condition in which neither of the two alleles for the same gene can completely conceal the presence of the other is called **incomplete dominance**. In incomplete dominance, a heterozygote shows a phenotype that is between a dominant phenotype and a recessive phenotype.

An example of incomplete dominance is the flower colour of the four o'clock plant. As you can see in Figure 1.19, a cross between a true-breeding red-flowered plant and a true-breeding white-flowered plant produces offspring with pink flowers in the F_1 generation. If the F_1 plants are allowed to self-fertilize, the F_2 generation will include offspring with all three phenotypes—red, pink, and white. The Punnett square in Figure 1.19 predicts that all three phenotypes will be observed in the F_2 generation in a ratio of 1:2:1 (red:pink:white). Experiments show that is exactly what happens.

incomplete dominance a condition in which neither allele for a gene completely conceals the presence of the other; it results in intermediate expression of a trait

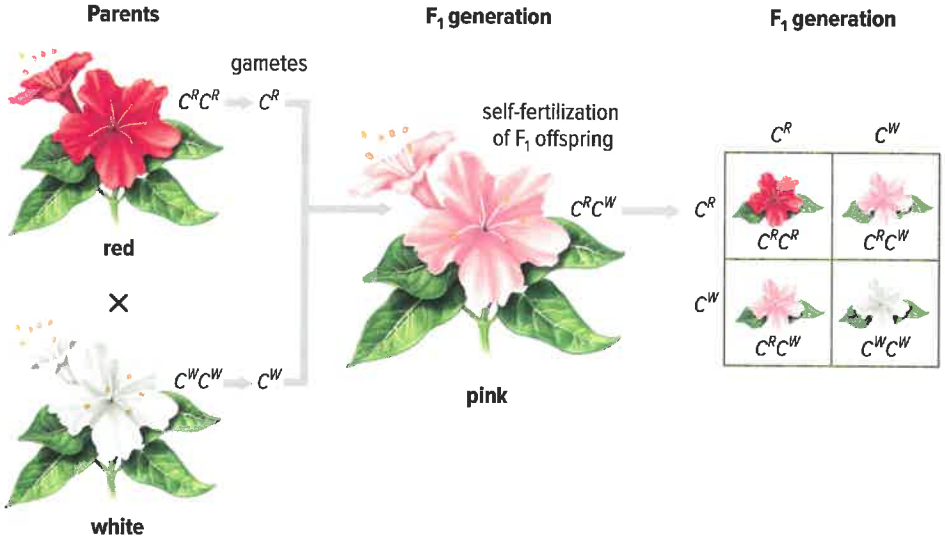


Figure 1.19 When red (C^RC^R) flowers and white (C^WC^W) flowers of the four o'clock are crossed, the resulting offspring have an intermediate phenotype, pink flowers (C^RC^W). In the F_2 generation, all three phenotypes are observed.

One way to represent alleles in incomplete dominance is to use superscripts, as you saw with codominance. For example, with four o'clocks, both alleles affect the colour of the flower, *C*. The two alleles are represented as superscripts, R for red (C^R), and W for white (C^W). Lower-case letters are used only to represent a recessive allele.

Before you leave this page . . .

1. What is the difference between incomplete dominance and codominance?
2. A plant that produces white flowers is crossed with a plant that produces purple flowers. Describe the phenotype of the offspring if the inheritance pattern for flower colour is
   a) incomplete dominance
   b) codominance

CONCEPT 5

Some inherited traits are due to alleles on the sex chromosomes.

Activity

Colour Perception

Some people's perception of colour differs from other people. One form of colour vision deficiency involves difficulty distinguishing between the colours red and green. Your teacher may provide a red-green colour vision deficiency test or data from such a test. Based on the data, what conclusions about the pattern of inheritance for red-green colour vision deficiency can you make?

sex-linked trait a trait controlled by genes on sex chromosomes

Traits controlled by genes located on the sex chromosomes are called **sex-linked traits**. Traits controlled by genes on the X chromosome are called *X-linked traits*. Because genetic males have only one X chromosome, they are affected by recessive X-linked traits more often than are genetic females. Females are less likely to express a recessive X-linked trait, because the other X chromosome may mask the effect of the trait.

Red-Green Colour Vision Deficiency

The trait for red-green colour vision deficiency is a recessive X-linked trait. Figures 1.20A and 1.20B show how a person with red-green colour vision deficiency might view colours compared to a person who does not.

Use the Punnett square in Figure 1.20C to study colour vision deficiency further. The mother is a *carrier* for the trait, because she has the recessive allele on one of her X chromosomes. The father is not colour vision deficient, because he does not have the recessive allele. Notice that the only offspring that can have red-green colour vision deficiency is a male child. As a result of it being an X-linked trait, red-green colour vision deficiency is very rare in females.

C

	X^B	Y
X^B	X^BX^B	X^BY
X^b	X^BX^b	X^bY

X^B = Normal
X^b = Red-green colour vision deficiency
Y = Y chromosome

Figure 1.20 As an X-linked trait, colour vision deficiency occurs more often in males than in females. A A person who is not colour vision deficient can see all colours. B People with red-green colour vision deficiency view red and green as shades of grey. C The Punnett square shows how the sex-linked trait is inherited.

Before you leave this page . . .

1. What are sex-linked traits?
2. Use vocabulary terms to describe the genotype of a male who is red-green colour vision deficient.

AT ISSUE Hemophilia

What's the Issue?

One way to examine how a trait is inherited in different generations is to use a pedigree. A *pedigree* is a type of flowchart that uses symbols to show patterns of relationships and traits in a family over many generations. The well-studied pedigree shown below represents the family of Queen Victoria of England, who lived from 1819–1901. Her son Leopold died of hemophilia. *Hemophilia* is a recessive X-linked disorder. Blood does not clot properly in people with hemophilia. As a result, they may bleed to death if they are cut or injured.

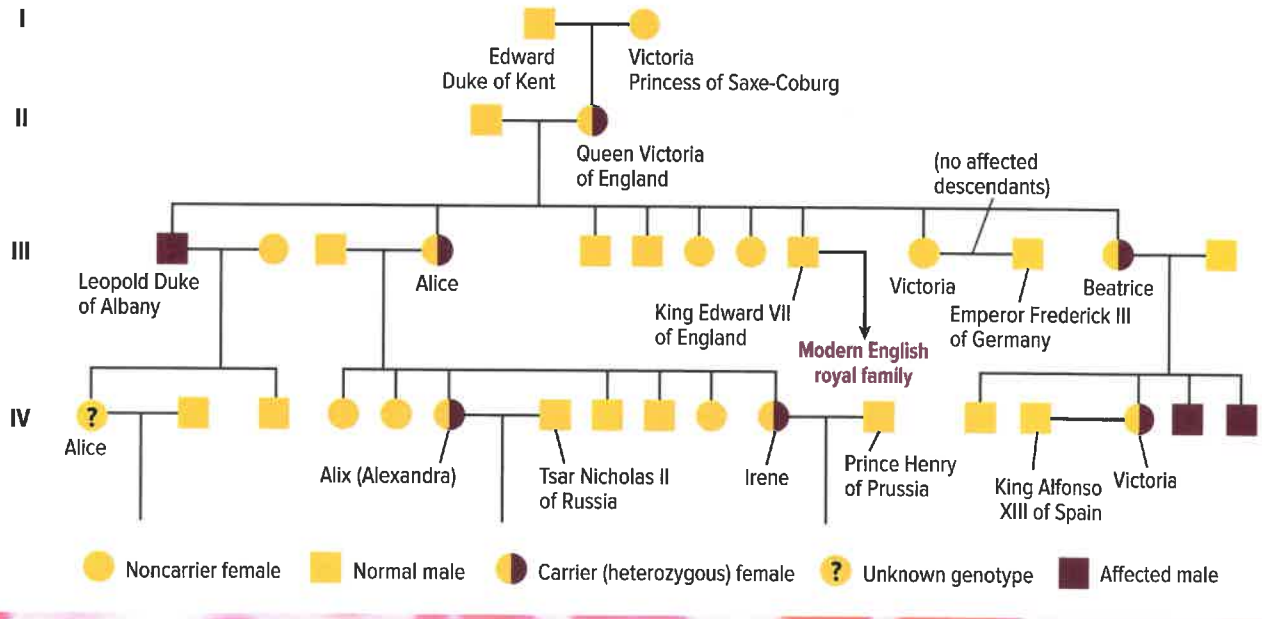
Use the pedigree to determine whether Alice—the daughter of Leopold, Duke of Albany—had hemophilia, was a carrier, or did not have the illness. Genetic females are carriers of a recessive sex-linked disorder if they inherit the allele for the disorder on one X chromosome.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. Use a Punnett square to determine whether Alice (the daughter of Leopold, Duke of Albany) had hemophilia, was a carrier, or did not have the illness. (Hint: What is Alice's genotype?)
2. If Alice had a son with hemophilia, would that change or confirm your decision? Explain why. (Assume the father did not have hemophilia.)

Queen Victoria's Pedigree



BE Inspired

Make a Difference

Dr. Nadine Caron

Dr. Nadine Caron is a surgeon, public health researcher, and teacher in Prince George. "I love being a physician and surgeon, meeting people in the hospital and clinic," says Caron. "It's such an honour to hear their stories, not just about their health, but to get a glimpse of the lives they lead."

Dr. Caron also works to improve healthcare for northern and Indigenous Canadians through the Silent Genomes Project. "The 'silent' refers to the relative and significant absence of Indigenous Canadians in the area of genomics," says Caron. "Genomics is revolutionizing healthcare and we're looking at how Indigenous Canadians can be at the table...on their own terms."

Dr. Caron dreamt of being a basketball player after high school, then became the first female First Nations general surgeon in Canada. "Learning is a lifelong endeavour," says Caron. "Find your passion and be open to it; be the curious one, and apply yourself."

Apply and Innovate

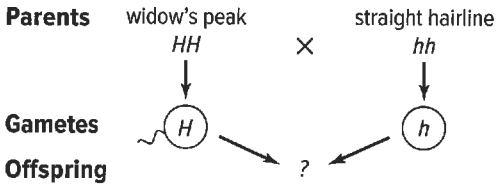
1. One application of genomics requires comparison of DNA sequences in a genome of interest (e.g. a patient with a genetic disease) to a background population of healthy patients. Dr. Caron likens this to a "spellcheck program on a computer." Explain this analogy, outlining its strengths and limitations. Devise another analogy, and explain why you think it is effective.
2. Dr. Caron began with basketball and eventually became a surgeon. What are your interests and passions now? Where do you think they might lead you? In what unexpected directions could you imagine they might lead you instead?

Check Your Understanding of Topic 1.2

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Explain how Mendel used selective breeding to learn more about heredity. C
2. In terms of experimental design, why was it important that Mendel used true-breeding plants to explore patterns of inheritance? PA
3. Explain the differences between the following sets of terms and give an example of each term: PA C
   a) dominant and recessive
   b) genotype and phenotype
   c) homozygous and heterozygous
4. The diagram below represents the genotypes of two parents and one gamete from each parent. AI C



   a) What is the genotype of the offspring?
   b) What is the phenotype of the offspring? Explain your reasoning.
5. Suppose that two siblings both have attached earlobes, and their parents have unattached earlobes. Unattached earlobes are represented as E, and attached earlobes are represented by e. What are the genotypes of the parents? Explain your reasoning. AI C
6. Copy the Punnett square into your notebook. The ability of a person to roll his or her tongue is dominant (T), and the inability is recessive (t). Fill in the blank genotypes and describe the phenotypes for each. AI C

	T	t
t	Tt	
t	Tt	

7. In pigeons, the checker pattern of feathers (F) is dominant to the non-checker pattern (f). Suppose a checkered pigeon with the genotype Ff mates with a non-checkered pigeon. Draw a Punnett square to predict the genotypes of their offspring. QP
8. A white-flowered plant is crossed with a red-flowered plant. What is the likely mode of inheritance if the offspring produced are PA
   a) plants with pink flowers?
   b) plants with red flowers?
9. How does sex-linked inheritance occur? C

Connecting Ideas

10. The Punnett square shows the genotype of the female parent and the genotypes of the offspring. AI

	?	?
X^b	X^bX^b	X^bY
X^b	X^bX^b	X^bY

X^B = Normal
X^b = Red-green colour vision deficiency
Y = Y chromosome
   a) What is the genotype of the male parent?
   b) What is the phenotype of the male parent?

Making New Connections

11. Sometimes breeders of plants and animals need to know if a plant or animal that has a dominant phenotype has a genotype that is homozygous dominant or heterozygous. One way to determine this is by doing a test cross. A test cross involves
   - mating the individual of unknown genotype with an individual who is homozygous recessive for the trait
   - analyzing the phenotypes of the offspring.

   Explain how this helps breeders identify the unknown genotype. Use a Punnett square to work through possible crosses. AI C

INVESTIGATION
1-B

STRUCTURED INQUIRY

Understanding Probability

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing Data
- Evaluating
- Communicating

What You Need

- three coins
- game boards

Probability is the chance that a given event will occur. You can use an understanding of probability to predict the occurrence of certain traits. In this investigation, you will play a probability game, and then analyze the results.

Question

How can probability be used to predict outcome ratios or percentages?

Procedure

1. Obtain a game board from your teacher.
2. Decide which of you will represent "heads" and which will represent "tails." Use one of the coins with heads side up and the other with tails side up as game pieces (tokens).
3. Start the game with both token coins at the centre line on the game board. Each "turn" will be determined by a flip of the third coin. If the coin lands heads side up, the "heads" player moves one square toward the "heads" finish line. If it lands tails side up, the "tails" player moves one square toward the "tails" finish line. The first player to reach the finish line wins the game.
4. Record the results of each coin flip in a data table. Share the results of your game with the rest of your class.
5. Record the class data for the number of "heads" winners and the number of "tails" winners.

Analyze and Interpret

1. Do you think the game was fair? Explain why or why not.
2. Calculate how many times "heads" came up during your game. Express this outcome as a percentage and as a ratio.
3. Use the class outcome data to calculate how many times "heads" or "tails" won the game. Express this relationship as a percentage and as a ratio.
4. Did the outcome percentage and ratio from your game match that of the outcome data for the class? Why or why not?

Conclude and Communicate

5. What aspects of this game are similar to events occurring during meiosis? What aspects are different? Evaluate the effectiveness of flipping a coin to model the inheritance of traits.

INVESTIGATION
1-C

GUIDED INQUIRY

Corn Genetics

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing Data
- Evaluating
- Communicating

What You Need

- ear of corn representing the F_2 generation

When you look at an ear of corn, each one of the kernels is actually a separate offspring resulting from the union of an egg and a pollen grain, with its own unique genetics. In this investigation, you will examine the pattern of inheritance of one trait in corn: kernel colour. The allele for purple kernels is dominant to the allele for yellow kernels. By counting the number of purple and yellow kernels produced in the F_2 generation, you can verify the pattern of inheritance for kernel colour.

Question

What is the predicted phenotypic ratio for kernel colour in the F_2 generation?

Procedure

1. Design a table to record the number of purple and yellow kernels in the ear of corn.
2. Count the number of purple and yellow kernels, and record the results in the table.

Analyze and Interpret

1. Determine the ratio of purple to yellow kernels in the ear of corn.

Conclude and Communicate

2. How does the actual ratio of purple to yellow kernels compare to the theoretical ratio?
3. Is the actual ratio close enough to the theoretical ratio to confirm that the allele for purple kernel colour is dominant to the allele for yellow kernel colour? Explain any differences.

Evaluate and Apply

4. What improvement could you make to the procedure to increase your confidence in the results?
5. Corn, also known as maize, has been used to investigate genetic processes for more than 75 years. Barbara McClintock is a scientist whose studies of corn have made significant contributions to genetics. Do research to find out about and report on her work.

INVESTIGATION 1-D

STRUCTURED INQUIRY

Performing a Monohybrid Cross

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing Data
- Evaluating
- Communicating

Safety

- Be sure to pick up all materials after the lab. Beads left on the floor could cause someone to slip and fall.

What You Need

- silver and white paper clips, pipe cleaners, beads, or other materials to represent different alleles (any two colours can be used)

A monohybrid cross is performed by breeding two individuals that differ in a particular trait under study. Gregor Mendel never used this term to describe his work, but he did perform monohybrid crosses when he fertilized homozygous dominant purple-flowered pea plants with homozygous recessive white-flowered pea plants. Mendel performed the same type of cross for several other traits in the pea plant. In this lab, you will repeat Mendel's monohybrid cross experiment using a model system, and then analyze your results.

Question

How can you model a monohybrid cross to replicate Mendel's results?

Procedure

1. The homozygous dominant parent is represented by two silver paper clips. The homozygous recessive parent is represented by two white paper clips. Working with a partner, decide who will take the role of each parent.
2. Use a table like the one below to record your results. The table should show the number of times a cross results in each of the possible combinations: two silver paper clips, two white paper clips, or one silver and one white paper clip. Leave space for data from your true-breeding crosses (which result in the F_1 generation) and your F_1 crosses (which result in the F_2 generation). Also leave space to include class results for both the true-breeding and F_1 crosses.

Results of Crosses

	2 Silver	2 White	1 Silver/1 White
F_1			
F_2			
F_1–Class			
F_2–Class			

3. One partner at a time, use this process to perform a cross.
   a) Cup your two paper clips between your palms, shake them, and then close each fist separately around only one paper clip (without looking at the clips or allowing your partner to see them). Keep your fists closed.
   b) Have your partner choose either your left or right hand.

c) Place the paper clip from that hand on the table.

d) Repeat this process for your partner's paper clips.

4. Record the outcome of each cross in the F_1 row of your table. Repeat the process nine more times, for a total of ten crosses.

5. Now perform a cross between your first generation "offspring." Each partner will start with the same combination of paper clips that resulted from the tenth cross in your first set of crosses.

6. Repeat steps 3 and 4. This time, record the results of each cross in the F_2 row of your table.

7. When you have collected data for 20 crosses in total (10 true-breeding crosses and 10 F_1 crosses), share your results with the class.

8. Record the class results in your table.

Analyze and Interpret

1. What did each paper clip represent in this model? What did each combination of two paper clips represent?

2. What was the purpose of repeating each set of crosses 9 times?

Conclude and Communicate

3. Calculate the genotypic and phenotypic ratios for the true-breeding crosses and the F_1 crosses for your own data, and then for the class data.

   a) How do each of these ratios compare to the expected ratios? (Hint: Recall the ratios for a comparable F_1 cross shown on page 27.)

   b) If the class results were closer to the expected ratios, why do you think this occurred?

4. The table below shows the results of some of Mendel's monohybrid crosses.

   a) Calculate the phenotypic ratio that resulted from each F_1 cross. Are all of the ratios exactly 3:1? Why or why not?

   b) Notice the number of offspring in the F_2 generation. How do you think using so many plants helped Mendel get results that were close to a 3:1 ratio?

   c) Reflect on your ability to model Mendel's monohybrid crosses effectively. What changes to the procedure you would recommend to improve the intent and results of this lab?

Mendel's Monohybrid Crosses

Trait	Homozygous Dominant Form	Homozygous Recessive Form	F_1 Offspring (from cross between true-breeding plants)	F_2 Offspring (from cross between F_1 plants)
Flower colour	purple	white	all purple	705 purple 224 white
Seed colour	yellow	green	all yellow	6022 yellow 2001 green
Seed shape	round	wrinkled	all round	5474 round 1850 wrinkled
Pod colour	green	yellow	all green	428 green 152 yellow
Stem length	tall	short	all tall	787 tall 277 short

TOPIC 1.3

How can natural and artificial selection influence changes in populations?

Key Concepts

- DNA mutations produce genetic diversity within a population.
- Natural selection favours traits that make an organism better suited to its environment.
- Natural selection can lead to the formation of new species.
- Environmental factors can cause mutations.
- Humans select desired characteristics in organisms to be passed on to the next generation.

Curricular Competencies

- Experience and interpret the local environment.
- Contribute to care for self, others, community, and world.
- Contribute to finding solutions to problems.

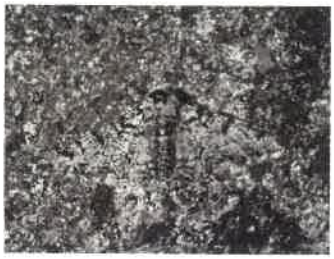
There are thousands of species of birds on Earth. Some, such as the Steller's jay shown here, have beaks that enable them to open the hardest seeds and nuts. Others eat fish, like the belted kingfisher shown below. Some birds eat insects, some eat rodents and other small animals, some eat seeds, and some feed on the nectar from flowers. Why are there so many variations in birds, and why are there so many different kinds of beaks? In this Topic, you will learn about the relationship between different adaptations of an organism, such as a bird's beak, and the organism's environment.

Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** Explain to a partner how the following terms are related, and discuss your ideas: organism, species of organisms, and populations of organisms. Compare your ideas with the class, and make sure everyone understands.

2. **Inferring** Can you spot the peppered moth in the photo below? Birds are more likely to prey on moths that are easier to see. Light-coloured moths are harder to detect on tree trunks covered with white lichen. In mid 19th century England, soot from industrial pollution covered the trees. The once rare, dark-coloured form of the moths became predominant. When the air became cleaner in the 1970s, the light-coloured form of the moths became more common again. How could you explain how the colour of the moths in the population changed over time?



3. **Considering First Peoples Perspectives** The original North American horse became extinct 10 000 years ago. After the Spanish brought them back to the Americas in the 1400s, horses became essential to the way of life for many Indigenous groups. They became experts not only in raising and riding horses, but also in using selective breeding to develop unique breeds. Find out which modern breeds of horses owe their existence to First Peoples knowledge of selective breeding.

Key Terms

There are 10 key terms that are highlighted in bold type in this Topic:

- mutation
- selective advantage
- natural selection
- adaptation
- adaptive radiation
- extinction
- mutagen
- carcinogen
- artificial selection
- monoculture

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

DNA mutations produce genetic diversity within a population.

Activity

Getting a Message Through

Form a line of at least eight people. Your teacher will whisper a message to the first person in line. Whisper-share this message from person to person, and have the last person say it out loud. Did the message change in any way? Keep this experience in mind as you discuss how changes in DNA from one generation to the next might affect an organism and a population of these organisms over time.

mutation a permanent change in the genetic material of an organism; a source of new genetic variation

You and your classmates are all the same species, but there is a great deal of variety among the individual members of your species. This variation is the result of genes. Offspring have a combination of genetic material from both biological parents. Through sexual reproduction, parents pass on genes to their offspring. How does genetic variation occur in a species or population? Why does genetic variation happen at all? **Mutations** are changes in the DNA of an organism. Mutations provide new alleles and are a source of new genetic variation when inherited.

Mutations happen continuously in the DNA of any living organism. They can occur spontaneously when DNA is copied before a cell divides. Mutations may also result from environmental agents such as ultraviolet radiation.

When there is a mutation in the DNA, a cell may exhibit new characteristics. Mutations that significantly alter DNA can be harmful. For example, a cell could die, malfunction, or multiply more than it should. However, not all mutations are harmful. Many mutations have no effect, and some mutations can be beneficial.

Whatever the result, if the mutation occurs in a somatic (body) cell, the mutation disappears from the population when the organism dies. However, if the mutation alters the DNA in a gamete, the mutation may be passed on to succeeding generations as a new allele. For example, if the kittens in Figure 1.21 have mutations in their egg or sperm cells, these mutations could be passed on to their offspring. These mutations were not present in their parents' DNA. Thus, mutations are the starting point for genetic variation in populations.

Figure 1.21 The kittens in this litter have different fur colour and patterns, partly because each kitten inherited a different combination of alleles from its parents.

Before you leave this page . . .

1. What is a mutation? Are all mutations harmful? Explain.
2. Explain why mutations are the starting point for genetic variation.

CONCEPT 2

Natural selection favours traits that make an organism better suited to its environment.

Activity

What are the advantages?

Study the photos of organisms provided by your teacher. Identify the traits that each organism has that give it an advantage for surviving in its environment. Share your ideas with other groups. How were your ideas similar and/or different?

Mutations that were once no advantage, or even a disadvantage, may become favourable in a changing environment. In this situation, the mutation provides a selective advantage. A **selective advantage** is a genetic advantage of one organism over its competitors. Over time, a selective advantage enables the organism to be favoured in terms of survival and reproduction. In other words, a selective advantage helps an organism survive changing environmental conditions and reproduce.

selective advantage a genetic advantage that improves an organism's chance of survival, usually in a changing environment

natural selection the process by which characteristics of a population change over many generations as organisms with heritable traits survive and reproduce, passing their traits to offspring

adaptation a structural or behavioural feature or physiological process that helps an organism survive and reproduce in a particular environment

Natural Selection

Natural selection is the process that results when the characteristics of a *population* of organisms change over many generations. This change, or evolution, happens because *individuals* with certain inherited traits are more successful in specific local environmental conditions and, as a result, may pass on their alleles to the next generation through reproduction. For natural selection to occur, there must be genetic diversity, or variation, within a species.

Selective Pressure

Staphylococcus aureus, shown in Figure 1.22, is a common bacterium that can affect human health by causing infections. Each individual bacterium reproduces asexually very quickly. Such rapid reproduction helps **adaptation** to occur very quickly. Each bacterium that has an advantageous mutation may survive a changing environment and reproduce; bacteria without an advantageous mutation may not. The surviving bacteria reproduce quickly. This rapid adaptation often leads to problems when doctors treat a *Staphylococcus aureus* infection (or other bacterial infection) with an antibiotic.

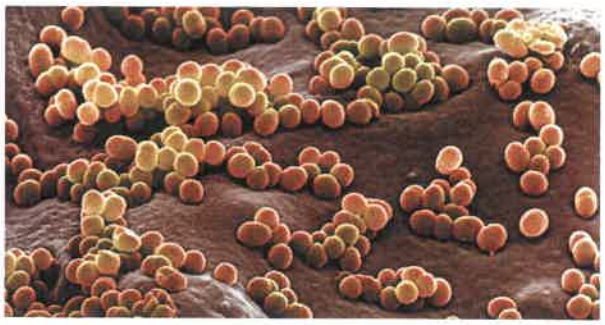


Figure 1.22 These *Staphylococcus aureus* bacteria appear to be identical, but some may have a mutation that makes them resistant to antibiotics.

Natural Selection Acts on Populations

An antibiotic is a drug used to treat infections caused by bacteria. The problem is that some individuals of the bacterial species may have a new allele, from a random genetic mutation, that makes them resistant to the antibiotic. Only the individuals with the new allele are able to survive and reproduce. They can then pass on the genetic information that resulted in resistance to that particular antibiotic to their daughter cells. Individual members of the population do not change during their lifetime. Rather, over time, the population changes in its ability to resist certain antibiotics. It is important to emphasize that the *population* changes, not *individuals*.

In the population of *Staphylococcus aureus*, the individual members of the population were *selected for* by their environment. An abiotic (non-living) environmental condition can be said to select *for* certain characteristics in some individuals and select *against* different characteristics in others. In this way, the environment exerts *selective pressure* on a population. Selective pressure may result from biotic factors as well, such as predators, parasites, and competition for resources.

As another example of selective pressure, consider the forest shown in Figure 1.23. Those individual trees that are able to grow successfully in the shade of the taller trees will reproduce and pass on the alleles to the next generation, increasing the abundance of shade-tolerant alleles. In the next generation, the abundance of the alleles to be more successful in shady conditions will increase in the population, because more of the individuals will have survived and reproduced. Over time, the population of smaller, shade-tolerant trees will be able to grow, survive, and reproduce in the shady conditions. If a change were to occur to the environment, such as a big increase in the light levels the trees were exposed to, the trait for resisting these conditions will no longer be an advantage. In fact, if no single member in the population can withstand the increased light levels, the population may not survive in that environment.

Figure 1.23 The forest shown here is very dense. As a result, little sunlight reaches the ground where young trees are growing. Populations become adapted to their environment over many generations through natural selection. The environmental pressures result in some individuals being more likely to survive and pass along their genetic traits to their offspring. The trees able to grow in an environment with low light levels are more likely to be able to survive, reproduce, and pass on to their offspring the alleles that helped them survive.

Natural Selection Is Situational

Natural selection has no will, purpose, or direction. Instead, natural selection is situational. A trait that at one time in one situation seems to have no apparent relevance to survival may be the trait that, at a different time in a different situation, helps certain individuals in a population survive and reproduce. The alleles for this trait will then be inherited by the offspring of the survivors. As a result, over many generations, there will be more and more individuals that inherit the allele for the trait that helps them survive the change in environment. Those individuals form a population that is better adapted to their environment.

Activity

Modelling Natural Selection

Using the background information and materials provided by your teacher, work in small groups and follow the steps below.

1. Your teacher will give you a bag of 20 "berries." In a data table like the one shown on the right, record the total number of berries, the number of blueberries, and the number of raspberries. Give your table a title. Allow for four populations of berries.
2. Read all the steps and predict what will happen to the numbers of berries.
3. Each bear in the group "eats" four berries each year. Where bears prefer blueberries over raspberries, to "eat" four berries, remove four counters and place them in a container. If you do not have four blueberries (blue counters) in your bag, then eat whatever blueberries you do have, plus one to three raspberries (red counters) for a total of four berries.
4. A season passes. Each berry left in your bag produces five new berries of the same colour, for a total of 20 for the next season. Replenish your supply of berries from your teacher to make up the correct complement of berries for the next season.
5. Repeat steps 3 and 4 for three more populations/seasons of berries.
6. Graph each population result. Use your results to answer the following questions.
   - What happened to each population of berries? Explain your answer.
   - Is this an accurate model for natural selection? Explain your answer.
   - Evaluate your prediction.

	Total Number of Berries	Number of Blueberries	Number of Raspberries
Population 1 (Season 1)			

Before you leave this page . . .

1. Why does genetic variation make it possible for changes in populations to occur through natural selection? Explain your answer.
2. Using the example shown in Figure 1.23, make a graphic organizer to show the steps by which natural selection favours a population of plants to grow in a shady environment.

CONCEPT 3

Natural selection can lead to the formation of new species.

Activity

Two Species or One?

Do you think the owls in **Figure 1.24** are the same species? Why or why not? What other information would you want to know to help you decide? For example, in the past, biologists defined species in terms of their physical form. What other characteristics could be useful to distinguish species?

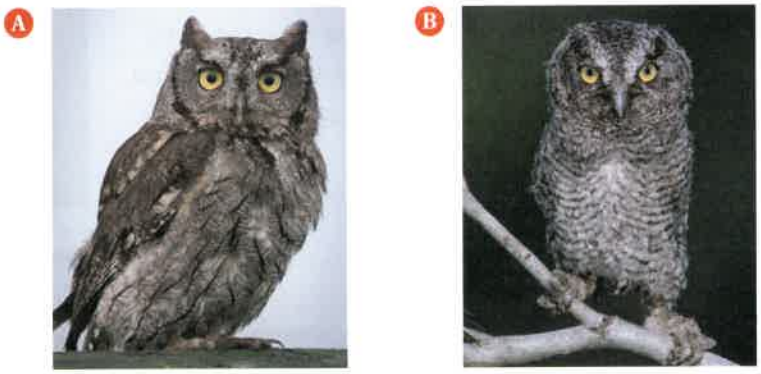


Figure 1.24 The Western Screech-Owl (*Megascrops kennicottii*) in A is found in Alberta and British Columbia whereas the Eastern Screech-Owl (*Megascrops asio*) in B is found in in Ontario and Quebec.

Recall that a species is a population or group of populations in nature whose members can interbreed to produce fertile offspring that also can interbreed. Earlier in this Topic, you learned that various factors cause changes within populations. When some members of a sexually reproducing population change so much that they are no longer able to produce fertile offspring with members of the original population, speciation has occurred. *Speciation* is the formation of new species from existing species.

One Type of Speciation: Adaptive Radiation

Sometimes a population is split into two or more isolated groups by a geographical barrier. Eventually, the gene pool of the split population becomes so distinct that the two groups are unable to interbreed even if they are brought back together. Examples of geographical barriers that can lead to the formation of new species include a glacier or lava flow that isolates populations, fluctuations in ocean levels that turn a peninsula into an island, and a few individuals reaching a geographically separate habitat.

Over time, natural selection and other factors act on each of the populations. Mutations that result in new traits that are advantageous to individuals in their environment are passed from one generation to the next. In some cases, after a longer geological timeframe, the two populations are so different from each other that they are no longer the same species. This concept is illustrated in **Figure 1.25** on the next page.

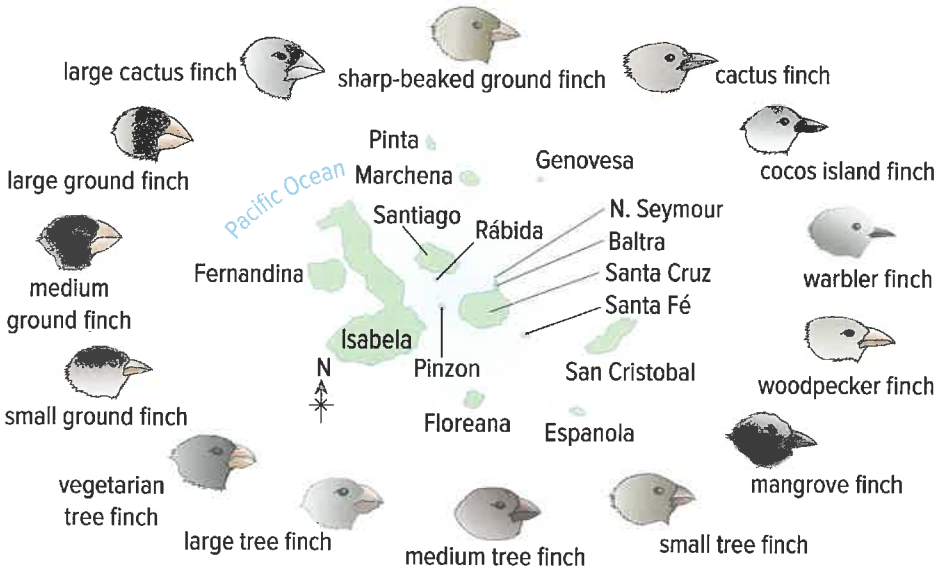


Figure 1.25 One common example of new species forming from a common ancestor are finches on the Galapagos Islands. The Galapagos Islands are located on the equator in the Pacific Ocean. The islands are volcanic in origin and contain a number of ecosystems, ranging from dry and desert-like to humid forests. Notice the difference in the shape and size of the birds' beaks.

At some time in the past, members of the ancestral finch species reached one of the islands in the Galapagos, perhaps by being blown off course during a tropical storm. With no other land birds on this island, the ancestral finch species had many unoccupied ecosystems to move into. During the time that this occurred, individual finches were subjected to different types of selective pressures, and some may have flown to nearby islands with still more unoccupied ecosystems to live in.

As a result, over time, the ancestral species divided into different populations, and some of these evolved into new species—the species that now populate the many islands of the Galapagos. This type of speciation, in which a common ancestral species diversifies into a variety of differently adapted species, is called **adaptive radiation**. Islands are excellent places to study adaptive radiation, and biologists sometimes refer to them as living laboratories. Islands give organisms that have dispersed from a parent population the opportunity to change in response to new environmental conditions in relative isolation.

adaptive radiation the diversification of a common ancestral species into a variety of differently adapted species

Activity

Galapagos Finches

Use **Figure 1.25** to answer the following questions about the 14 species of finches on the Galapagos Islands.

1. What is the major physical difference among the species illustrated? Form a hypothesis that might explain the difference between the large tree finch and the cactus finch.
2. Ground finches that depend primarily on seeds as a source of food mostly live on solidified lava beds. How can you explain the differences in beak size and shape among the different types of ground finches? What about the tree finches?

Adaptive Radiation: Another Example

Another example of how new species can form also comes from the Galapagos Islands. The tortoises on the individual islands are all different. Figure 1.26 and the points below outline the conditions that may have resulted in the speciation of the tortoises in the Galapagos Islands.

- Individuals from a species of South American tortoise found their way to the Galapagos Islands, and different ones were better suited to each specific island's new environment.
- As these tortoises looked for and ate food on the islands, the differences in their traits allowed them to survive and reproduce in the different environmental conditions, resulting in some tortoises living longer, being stronger or better fed, and reproducing more. (Mutations ensure that the genetic make-up of each individual in a species is slightly varied.)
- The next generation would have more individuals with characteristics that enabled them to have greater success in the new environment.
- Through natural selection, the descendants of the ancestral tortoise population began to change. Over time, new species arose.

Figure 1.26 This figure illustrates how the various factors interact to form a new species.

Adaptive radiation does not occur just on islands. In 1991, two biologists at the University of British Columbia, Anna Lindholm and Craig Benkman, studied a particular type of finch, called a red crossbill, to demonstrate speciation. The twisted beak of the crossbill, shown in Figure 1.27, allows it to pry open closed conifer cones.

Figure 1.27 The crossed bill of the red crossbill (*Loxia curvirostra*) enables it to extract seeds from even the most tightly closed of conifer cones.

The beaks of seven birds, which specialize in eating the tightly closed cones of western hemlock, were "uncrossed" by trimming them with nail clippers—a painless procedure. The scientists observed that birds with clipped bills were as effective as those with crossed bills at getting seeds from open cones. However, birds with clipped bills could not open closed cones. As their bills grew back and began to cross again, the birds gradually became better at opening the closed cones.

The development of the crossed bill did not arise all at once. The crossed bill changed gradually by selective pressure, one generation after the next, until the birds were expert at opening tightly closed cones. The crossed bill gave these birds an advantage over other bird species in the same habitat because it allowed them to eat food no other bird could. Individuals with this variation were then able to radiate into other habitats.

Extinction and Selective Pressure

You have learned one way that new species can form, but how do species end? The environment is a strong influence on both the formation of new species as well as their **extinction**. Environmental influences create selective pressure, and these influences can have positive and negative outcomes. In some cases, new species will arise. In other cases, existing species may go extinct.

extinction occurs when a species completely disappears from Earth

One of the most famous examples of extinction is that of dinosaurs 65 million years ago. Recent scientific research supports the hypothesis that this extinction event was triggered by the impact of a large asteroid. This may have caused massive forest fires. As a result, huge amounts of soot and other particles may have been thrown into the air, blocking the Sun for months. During this time period, more than half the existing marine species and many families of terrestrial plants and animals, including the dinosaurs, became extinct.

Overall, biological diversity has increased since about 500 million years ago. While the general trend has been an increase in the number of species, there have also been several sharp declines in the number of species. These are known as mass extinction events. Five major mass extinctions have been identified, as shown in Figure 1.28. After each extinction event, the number of species decreased. For example, after an extinction event about 250 million years ago, about 96 percent of all species are thought to have gone extinct.

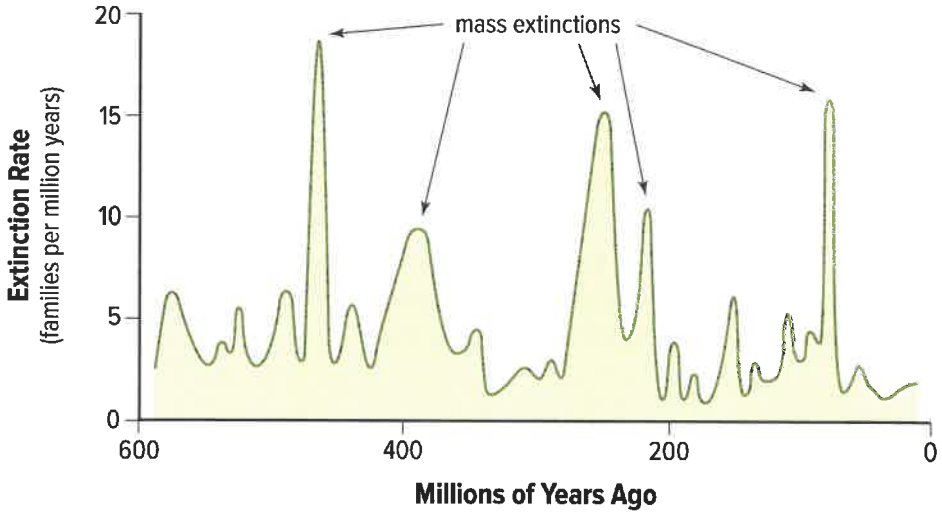


Figure 1.28 The five major mass extinction events

Before you leave this page . . .

1. What is adaptive radiation?
2. Explain why it would have been possible for an ancestral finch species, having arrived on one of the Galapagos Islands, to have diversified and evolved into other species over time.
3. How is extinction related to selective pressure?

CONCEPT 4

Environmental factors can cause mutations.

Activity

Increased Cancer Risk

Work with your group to make a list of substances or activities that are associated with an increased risk of cancer. Compare your list with other groups and agree on a list as a class. Discuss how you know the substances or activities are associated with the development of cancer.

mutagen a substance or event that increases the rate of mutation

carcinogen a substance or agent that causes cancer

Figure 1.29 Applying sunscreen before going out in the sun can help reduce a person's exposure to ultraviolet radiation.

Mutations are important to the process of natural selection and the formation of new species, because mutations are a key source of variation in genes. Certain environmental factors can increase the rate of mutation. A **mutagen** is a substance or event that increases the rate of mutation. *Physical mutagens* cause physical changes to the structure of DNA. Examples include X-rays and ultraviolet (UV) radiation. *Chemical mutagens* are molecules that can enter the nucleus of a cell and chemically react with DNA. Examples include nitrites, which are used in food preservation, and gasoline fumes.

Some mutagens are carcinogenic. A **carcinogen** is a substance or agent that causes cancer. Exposure to ultraviolet radiation increases a person's risk of developing skin cancer. That is why many health organizations recommend avoiding spending a lot of time in the sun during certain hours of the day, or using sunscreen (Figure 1.29), and wearing a hat and sunglasses when people are exposed to sunlight. Nitrites and other compounds found in cigarette smoke are also carcinogens. Smoking cigarettes and breathing second-hand smoke increase a person's risk of developing lung cancer.

Recall that genes carry instructions for the production of proteins. If a mutation occurs, it can change the instructions on the gene, which can lead to problems with the production of a specific protein.

Activity

How effective are different sunscreens?

Your teacher will provide your group with a set of beads that are sensitive to UV radiation. Your teacher will also provide you with information and a worksheet about how to test the effectiveness of sunscreens.

Before you leave this page . . .

1. What is a mutagen?
2. Explain how mutagens and the production of proteins are related.

CONCEPT 5

Humans select desired characteristics in organisms to be passed on to the next generation.

Activity

Tomato, Tomahto?

Study the photos of tomatoes provided by your teacher. What traits do you think were chosen for each type of tomato based on their appearance? What other traits might gardeners or farmers choose when breeding tomatoes?

Natural selection occurs in a population in response to changes in the environment. However, people have been artificially selecting organisms for particular traits for thousands of years. This process, called artificial selection, is sometimes referred to as selective breeding. **Artificial selection** is selective pressure exerted by humans on populations in order to improve or modify particular desirable traits. It has had a huge impact on human survival.

artificial selection selective pressure exerted by humans on populations in order to improve or modify desirable traits

Most of the food we eat—grains, fruits, vegetables, meat, and milk—comes from species that have been selectively bred. For instance, artificial selection has resulted in cows that produce more milk. Some varieties of chicken are bred to grow quickly and have large muscles for increased amounts of meat. Other varieties of chicken have been bred to produce large numbers of eggs. Some animals, such as domestic cats, are bred for their appearance (Figure 1.30). All domestic cats are the same species, *Felis catus*, so they can interbreed and produce fertile offspring. Over many generations, breeders can change how a particular cat breed looks.

The key difference between natural selection and artificial selection is that in natural selection, the environment plays the role that humans play in artificial selection. In natural selection, the environmental conditions determine which members of a population will survive and reproduce in the current conditions. This, in turn, affects the gene pools of individuals of future populations, because those that survive will pass on their genes to their offspring.

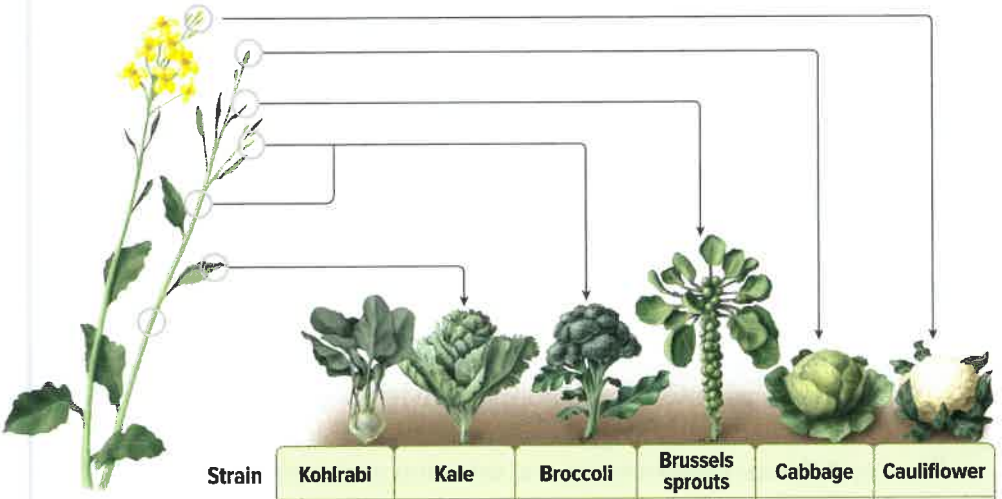
Figure 1.30 By selecting the parents that carry the genetic material that breeders are interested in, cat breeders produce cats with distinctive features. All the cats shown here carry the same kinds of genes (for example, for fur, size, and ear length). However, the alleles for these genes differ among the cats, allowing humans to select for or against certain characteristics.

Artificial Selection and Food Crops

The food crops that we depend on for most of our diet—rice, corn, wheat, and vegetables—are the result of selective breeding. Figure 1.31 shows how one example—the wild mustard plant (*Brassica oleracea*)—has been modified by selective breeding to create many common food crops.

Plant breeders began to modify the traits of the wild mustard plant over 4000 years ago in Europe and Asia, where the plant is a native species. The traits of the artificially selected varieties all differ from the wild plant, but they are members of the same species and can interbreed and produce fertile offspring. For example, you may have seen broccoflower in your grocery store, which is a cross between cauliflower and broccoli.

We breed food crops to resist drought, disease, or insect infestation. Artificial selection has its limits, though. If plants are bred to grow quickly, they may not tolerate poor soil conditions. Crop breeders now understand that selective breeding must be balanced to maintain genetic variation within the crops and the ability of the plants to respond to environmental change.



Strain	Kohlrabi	Kale	Broccoli	Brussels sprouts	Cabbage	Cauliflower
Modified trait	Stem	Leaves	Flower buds and stem	Lateral leaf buds	Terminal leaf bud	Flower buds

Figure 1.31 These six agricultural plants look very different from each other, but they carry much of the same genetic material as the wild mustard plant. The differences affect the formation of flowers, buds, stems, and leaves.

Activity

Selective Breeding

The original ancestor of corn was a small, weed-like grass called teosinte. Humans have selectively bred teosinte for so long that the characteristics of our modern, artificially selected corn bear almost no resemblance to the original corn ancestors. Compare the cob of wild teosinte and modern corn shown in the photo. What traits do you think early plant breeders selected for? Create a flowchart that shows a series of steps that may have been followed to produce modern corn from teosinte. Include the terms *variation*, *inherited*, and *selected* in your answer.

Consequences of Artificial Selection

Artificial selection has negative as well as positive consequences. For example, English bulldogs are selectively bred for different traits, such as their flat faces. This trait results in severe respiratory problems. German shepherds and many other breeds of dogs have been selectively bred for their large size. An unfortunate consequence of this is hip dysplasia, a disorder that leads to a loss of function of the hip joints.

One of the main goals of domestication is to produce organisms that are all similar. This means *reducing* genetic diversity. Plants are specialized through selective breeding to produce the specific qualities that growers want, so plants that have been selectively bred lack genetic diversity.

Figure 1.32 This monoculture shows the vast expanse that is covered by one crop (wheat), made up of plants that are artificially selected to be similar.

For example, most agriculture in the world is based on extensive plantings of the same varieties of a species over large expanses of land, like that shown in Figure 1.32. This practice is called **monoculture**. It is certainly easier to manage fields in which there is only one kind of plant growing. This is particularly true today when herbicides, insecticides, and fertilizers are manufactured specifically to meet the needs of specific crop species. However, with monoculture comes a significant risk. The lack of genetic diversity means that disease or environmental changes will affect all plants of the monoculture in the same way. As a result, the whole population—the whole crop—could be wiped out or severely damaged.

monoculture repeated planting of the same varieties of a species over large expanses of land

Extending the Connections

Food and Artificial Selection

All the major crops that we depend on for food have been domesticated over thousands of years. These crops include rice, wheat, varieties of squash, potatoes, and varieties of beans. Choose one of these crops, or a domesticated plant or animal of your choice, and research your selection using Internet and print resources. Sketch the original ancestor and the modern offspring. Compare the original and current forms. Describe at least three traits that humans appear to have selected for.

Before you leave this page . . .

1. What is artificial selection?
2. What are some benefits and risks associated with artificial selection of agricultural crops?

AT ISSUE

How can selection pressure lead to reverse speciation?

What's the Issue?

You have already learned that new species can form through adaptive radiation. However, recently scientists have been looking more closely at another way new species can form: through a process called reverse speciation. One example of reverse speciation occurred in Enos Lake on Vancouver Island.

For thousands of years two species of stickleback fish lived in the lake in harmony. These two species had a common ancestor and through natural selection and adaptive radiation, developed into two distinct species. One species lived close to the lakeshore and ate larval-stage insects. The other species lived in the middle of the lake and fed on zooplankton. The species did not interbreed and remained separate both physically in the lake and biologically as species.

Then, in the mid-1990s an invasive species of crayfish was introduced into the lake, most likely through human activity. Scientists think that the presence of the crayfish led to a change in the way the two species of sticklebacks interacted. Either the crayfish being there changed the way in which each fish species nested and bred, or the crayfish competed for food with lakeshore species, causing that species to move further into the lake, into the other fish species' territory.

Whatever the reason behind the change, selection pressure led the two species of sticklebacks to breed with each other and produce hybrid offspring. Between 1994 and 1997, both species of the sticklebacks, which were already endangered, became extinct in the lake and the new hybrid species remained. In reverse speciation, two species that previously diverged from a common ancestor become extinct and are replaced by a single species that has alleles and traits from both of the extinct species.

In the case of Enos Lake, the hybrid species has a phenotype that is a mix of traits from the two extinct species. It lives near the lakeshore but it eats larger insects compared to the now extinct stickleback that lived in the same area. Several changes to the lake ecosystem and surrounding terrestrial ecosystem have been noted by scientists since the reverse speciation occurred, including that leaves in the water take longer to decay and an increased number of smaller insects are hatching and reaching land.

This stickleback is the hybrid species that resulted from the interbreeding of two now extinct species of sticklebacks in Enos Lake.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. Scientists are finding that cases of reverse speciation are becoming more frequent. Research an example of reverse speciation. Describe the history of the species involved and the circumstances under which reverse speciation occurred. What role, if any, did humans play in the events? How did the reverse speciation affect the ecosystem and/or surrounding ecosystems? Did the reverse speciation have any economic or social effects? If so, explain. Present the results of your research in a manner of your choosing.
2. In small groups, discuss the effect of reverse speciation on biodiversity. In your discussion, include the contrasting idea of a new species forming while at the same time two or more species are becoming extinct. Have one person in the group record the main points and conclusions of your discussion. Share a summary of your discussion with other groups.
3. Research and describe how our increasing knowledge of DNA and genetics, including the use of biotechnology, plays a role in determining and documenting cases of reverse speciation.

TAKE a Stand

Make a Difference

Investigate Polycultures and other Sustainable Food Systems

The shift to mechanized agriculture and monocultures has greatly increased the amount of food that farmers can grow. To be sure, there are gains that result from growing food on such large scales. However, there are negative consequences as well. With respect to the environment, these include loss of topsoil, pollution of air and water, and an increased need for fertilizers and other synthetic chemicals. In economic terms, there are increasing costs of materials and energy. In social terms, consequences include lowered standards for living and working conditions for the people who work on the farm or in the production facilities.

Today, many people—First Peoples, politicians, scientists, business people, and citizens—believe that the current approaches to monoculture farming are not sustainable. People point, instead, to the need for sustainable agriculture methods. These involve growing and producing food in ways that meet the needs of the present while also enhancing the health of the land, human ecosystems, and natural ecosystems to meet the needs of future generations. Sustainable agriculture addresses environmental, economic, and social needs during the whole process of food production.

Polyculture

A key advantage to sustainable agriculture is its use of polycultures. Unlike the single, genetically limited crop of a monoculture, a polyculture contains a diversity of crops grown on the same plot of land. This practice mimics the biological and genetic diversity of natural ecosystems—not just for the crops planted, but also for the species that visit the crops. By mimicking nature, polycultures also help conserve topsoil, while at the same time reduce the need for water, fertilizers, and pesticides.

One of the studies of the benefits of this approach was done in China. In the two-year study, farmers grew a mixture of rice varieties in the same fields. Some of the varieties were naturally resistant to a fungus that spreads easily in rice plants. By mixing the disease-resistant rice with the types that are vulnerable to it, farmers increased crop yield by 89%. They also reduced infection from the fungus by 94% compared to rice plants grown in a monoculture. By the end of the study, farmers could grow rice in polycultures without any fungicide at all.

A type of polyculture that has been used for years, especially in local gardens, is companion planting. This involves planting two or more plant species close to each other to achieve a benefit. The benefit may be pest control, better absorption of nutrients, higher yield or a combination of these. One example developed by many First Peoples is the growing of the "three sisters": corn, beans, and squash. The corn provides a good structure on which the beans can grow up. The beans return nutrients (nitrogen compounds) to the soil, which benefits the squash. And the squash provides dense leaf cover and ground cover, which retains soil moisture and helps to prevent the growth of weeds.

Processing and Analyzing

1. UBC's Centre for Sustainable Food Systems at the UBC Farm is trail-blazing in many ways. In their own words, the farm "comprises a mosaic of cultivated annual crop fields, perennial hedgerows and orchards, pasture, teaching gardens, and forest stands." Find out about the unique Centre's guiding principles and programs. How, especially, do the Centre's indigenous initiatives support its vision?
2. Where else in B.C. are polycultures in active use, and how do they contribute to the well-being of the land and local community?

Evaluating and Communicating

2. How do polycultures and other environmentally responsible methods reflect the Centre for Sustainable Food Systems' principles and programs?
3. Based on your understanding of monoculture and polyculture systems, as well as any additional investigation you might conduct, develop an opinion piece, using a medium of your choice, that presents your views of the issue of food systems and sustainability.

Applying

3. Investigate the terms (and concepts of) food security and food sovereignty. How are they related? How are they different? How are both related to the issue of food systems and sustainability?

TAKE Action

Make a Difference

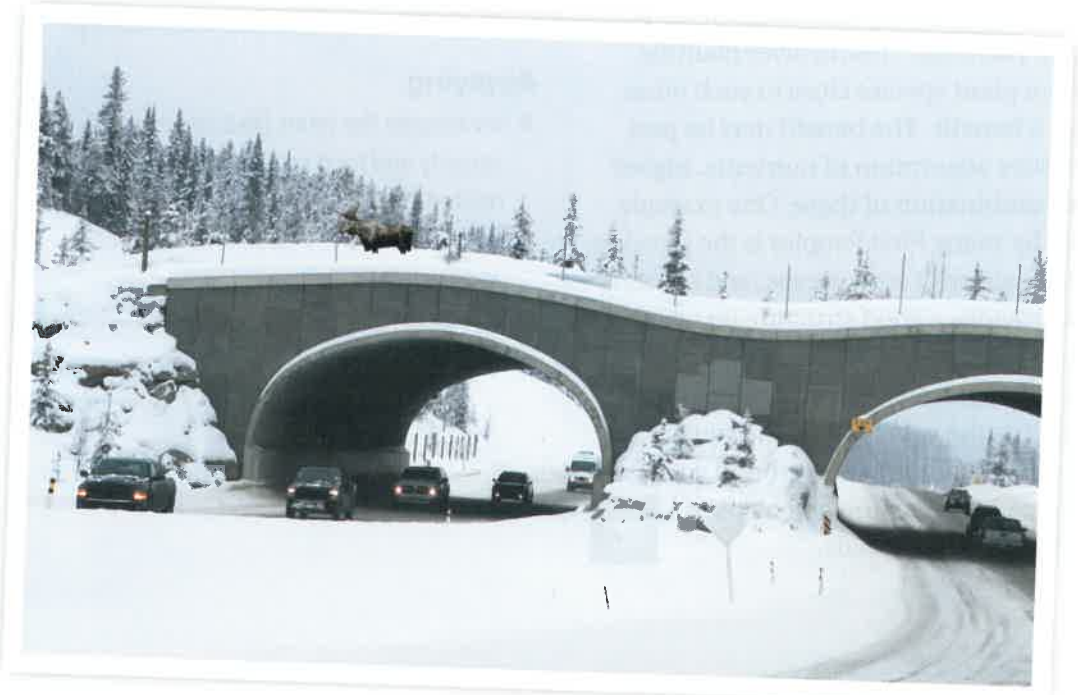
The Sixth Extinction

The five mass extinctions that have occurred during the past 500 million years were driven by natural events such as asteroid impacts and ice ages. Scientists warn that we are now on the brink of a sixth mass extinction. This time, however, we humans are the driving force. The degrading of the land through human activities—including habitat destruction and over-exploitation—is putting many species at risk of extinction. In March 2018, in advance of its complete report, the IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Service) released a summary document in which it states: "Combating land degradation and restoring degraded land is an urgent priority to protect the biodiversity and ecosystem services vital to all life on Earth and to ensure human well-being." (IPBES/6/L.9/Rev.1)

Choose a species at risk—locally, nationally, or internationally. Find out the current state of its populations. Evaluate the effectiveness of conservation efforts, and brainstorm other strategies that could work. Take action by developing a campaign to help protect and/or restore the species.

Evaluate, Apply, and Innovate

1. What resources do you need to run your campaign? Consider materials, people, and the timeframe. How will you measure the outcome of your campaign?
2. Write a report to outline your findings and proposed solutions. Evaluate how you could make improvements for future campaigns.
3. As a class, discuss specific actions that you, as individuals and as a community, can you take to prevent a sixth extinction.



Check Your Understanding of Topic 1.3

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Explain how mutations are a source of new alleles. PA

2. In a population of sparrows, most birds have a beak that is about 10 mm long. Some birds, however, have beaks that are slightly longer or slightly shorter than the average. Explain why this variation within the population is important in terms of survival of individual sparrows. PA C

3. Why does genetic variation make it possible for changes in populations to occur through natural selection? Explain your answer. E C

4. How does natural selection influence adaptation? PA

5. Explain how the ability of a population of insects to withstand the effects of an insecticide is an example of natural selection. C

6. Severe flooding results in a river changing course. Explain how a species of mouse that now lives on both sides of the river might eventually become two different species. What about a species of bird that now lives on both sides of the river? Explain. QP C

7. The Greater Antilles is a group of islands in the Caribbean. These islands include Cuba, the Dominican Republic, Haiti, Jamaica, and Puerto Rico. Each island is home to many lizard species that look very similar. DNA analysis shows that the similar-looking lizards from different islands are not alike genetically. Explain this. E C

8. Use a graphic organizer of your choice to identify and describe different types of mutagens and examples of each. C

9. Give an example of how people have used selective breeding to create a new variety of plant. Describe two possible consequences of the new variety. PA C

Connecting Ideas

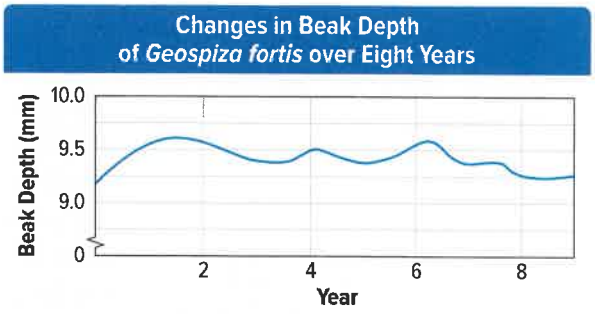
10. Many antibacterial soaps and sprays are available without a prescription. Why might your doctor suggest that you avoid using (or restrict your use of) these products? AI

Making New Connections

11. The medium ground finches (*Geospiza fortis*) of the Galapagos Islands use their strong beaks to crush seeds. They prefer the small seeds that are abundant during wet years. During dry years, fewer small seeds are produced. Therefore, the finches also have to eat larger seeds, which are more difficult to crush. Researchers have measured the depth (dimension from top to bottom) of the finches' beaks, which relates to strength. The deeper the beak, the stronger it is. Use the graph to answer these questions. PA E

    a) Years 1, 4, and 6 were drought years. Year 8 was wet. What do you notice about the average beak depth in the finch population during dry years compared with wet years?

    b) How do the data relate to selective pressure and natural selection?



INVESTIGATION

1-E

GUIDED INQUIRY

Variations Great and Small

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing Data
- Evaluating
- Communicating

Safety

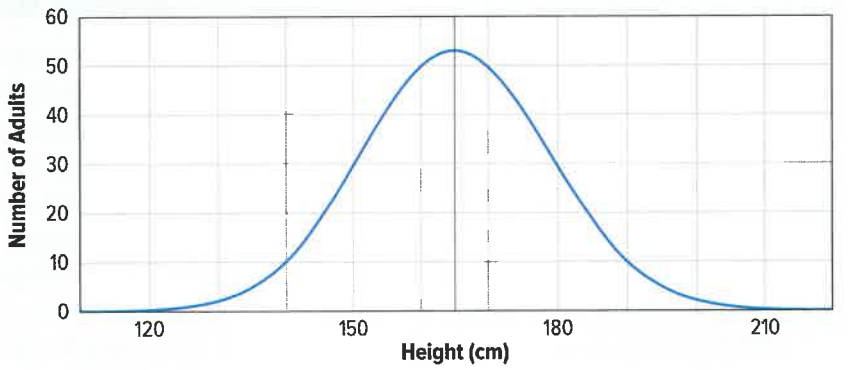
- Do not allow the seeds to fall on the floor. Someone could slip on them.

What You Need

- bean seeds or peas
- graph paper
- ruler
- computer with spreadsheet software (optional)
- triple beam or electronic balance

Diversity within a species can be monitored genetically, or it can be demonstrated by measuring individuals within a population. Most traits in a population vary in a continuous way from one extreme to the other. A plot of the distribution of the trait in a population often produces a bell-shaped curve. The curve shown below represents the distribution of height in a typical adult population. It consists of a group of adults from a variety of ethnic backgrounds. Most people have measurements in the centre of the curve—they are average height. Only a few are very tall or very short; thus, very high and very low measurements are at the sides of the curve.

Height in a Typical Adult Population



In this investigation, you will design an experiment to measure a particular characteristic in two populations: plant seeds and humans. These are very different characteristics in very different organisms. However, they are both determined by inherited genetic diversity, so they should follow the same patterns of distribution.

Question

Are there measurable differences among individuals of the same species?

Procedure – Part A: Variation in the Hand

1. With your group, design an investigation to determine the variation in the length of the human thumb or the width of a human hand. Choose a method to measure the characteristic, and ensure that it is standardized for every measurement you make. Make sure that the method you use is applied the same way for all measurements of that characteristic so you can compare the results fairly.

2. State and record a hypothesis for the investigation.

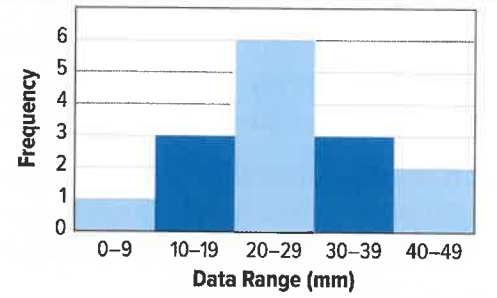
3. As a group, decide how you will make the appropriate measurements and how many samples you will need. Also, decide whether to pool your data with other groups. (Keep in mind that the larger the sample size, the more reliable the results are.)

4. Design a table like the one shown below to record your data for each investigation.

Sample Data

Data Range (mm)	Frequency
0–9	1
10–19	3
20–29	6
30–39	3
40–49	2

Sample Histogram



5. Identify the variables that you will control to ensure your data are reliable.

6. Show your experimental plan to your teacher. Then conduct your investigation and record your results.

7. A frequency histogram, such as the one shown here, is a representation of a frequency distribution. Draw or use spreadsheet software to construct a frequency histogram of the data you collect.

Procedure – Part B: Variation in Mass of Plant Seeds

8. With your group, design and carry out an investigation to determine the variation in the mass of plant seeds.

Process and Analyze

1. Identify the range of the data that you collected for each investigation.

Evaluate and Communicate

2. What can you conclude about the variations within a population? Is there a typical length or mass? Or is the frequency the same for each data range?

3. Would you get a greater or smaller variation in the range of data if all individuals sampled came from the same parents—for example, if all the seeds you measured originated from the same plant?

4. What advantage would size (either large size or small size) give to the population studied? (For example, what advantage would large size give to a seed?)

Apply and Innovate

5. Choose two different species (for example, one plant and one animal) from your neighbourhood. List at least two variable traits that you could measure for each species, and propose a method for measuring them. (Do not carry out your ideas without approval from your teacher.)

6. Choose one variable trait in human populations, and research to find the minimum, maximum, and average measurements. Is there an advantage or disadvantage with either of the upper or lower limits?

INVESTIGATION
1-F

GUIDED INQUIRY

Modelling Adaptation

In this activity, you will use different instruments to model bird beaks and find out whether small advantages can result in large gains for well-adapted individuals.

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing Data
- Evaluating
- Communicating

Safety

- The ends of some forceps and tweezers may be sharp.
- Do not allow the seeds to fall on the floor. Someone could slip on them.
- Tell your teacher if you have any food allergies.

What You Need

- sesame seeds (seed A)
- lentils (seed B)
- rice (seed C)
- tray with edges
- 3 forceps and/or tweezers, each a different size, length, and style
- graph paper or graphing software

Question

How can you model an adaptation?

Procedure

1. Read the steps below. Then design a table to record your data.
2. Mix about 30 to 40 of each type of seed together in a tray. Make sure you have an equal number of each type of seed.
3. Choose one style of forceps, and record its characteristics in your table. Pick up seeds (of all three types) for 30 s. Record the number of seeds picked up by type of seed.
4. Return the seeds to the container. Repeat the trial two more times, and determine the average number of seeds gathered.
5. Repeat this procedure using two other styles of forceps or tweezers.
6. An environmental event such as a flood or drought has reduced the availability of seed A. To simulate this, leave only 10 percent of seed A in the tray. Repeat the trials and compare the results.
7. An environmental event that has reduced the number of seeds B and C and doubled the number of seed A. Leave only 10 percent of seeds B and C in the tray and double the original number of seed A. Repeat the trials and compare the results.

Analyze and Interpret

1. Graph your results from these trials.
2. Describe any correlation between the forceps and their ability to pick up certain types of seeds.

Conclude and Communicate

3. Describe what happened in Step 6. How might this affect later generations if the forceps were actually a type of bird beak?
4. Describe what happened in Step 7. Were any of the effects of the first trial reversed? Explain how this might happen in natural situations.

INVESTIGATION
1-G

GUIDED INQUIRY

Leopard Frogs—One Species or Eight?

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing Data
- Evaluating
- Communicating

What You Need

- computer with Internet access
- print resources

The songs of birds, the courtship rituals of elk, and the chemical signals of insects are factors that prevent interbreeding with closely related species. For example, the western meadowlark and the eastern meadowlark are nearly identical in shape, colours, and habitat. Their habitat ranges overlap. However, very little mating takes place between the two species. This is mostly due to the differences in the songs of the two species.

Western Meadowlark (*Sturnella neglecta*)

Eastern Meadowlark (*Sturnella magna*)

Leopard frogs were once thought to be a single, extremely variable species (*Rana pipiens*) that ranged across North America. By analyzing frog calls, biologists realized that more than a single species of leopard frog existed. At this time, biologists have identified at least eight different but related species.

Question

How can differences in their calls prevent species of leopard frogs from interbreeding?

Procedure

1. Listen to the calls of different species of leopard frogs supplied by your teacher. Discuss how you think they are different.

Analyze and Interpret

1. Leopard frogs in North America include the northern, southern, Rio Grande, plains, relict, Florida, Ramsey Canyon, and lowland leopard frogs. Research two of these species. Describe, in point form, the differences other than their calls that indicate the two are separate species.

Conclude and Communicate

2. Populations of amphibians, including frogs, are declining in North America. When it comes to conservation and monitoring of species, how could it be valuable to know that there are eight species of leopard frog rather than a single wide-ranging species?

INVESTIGATION
1-H

GUIDED INQUIRY

Islands and Species

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing Data
- Evaluating
- Communicating

What You Need

- paper
- computer with Internet access
- print resources
- coloured pencils

Suppose there is a small group of islands off the west coast of South America, just below the equator. They are volcanic and have existed for more than five million years. About half a million years ago, a pair of rats was washed off the main coast of South America. One rat was male and one was female, and both look like present-day rats. Clinging to a large tangle of logs, the rats drifted out to sea and came ashore on one of the islands. Over thousands of years, the offspring of those rats colonized all the islands in the group. In this investigation, you will design a rat that is adapted to one of the islands.

Question

What are the characteristics of the rat species living on your island, and how do those characteristics reflect natural selection and adaptation?

Island A

The island is fairly flat, with an occasional hill. The ground is soft dirt, and several species of shrubs grow toward the centre of the island. There is no animal life on land, but the water is teeming with fish. The island is surrounded by a coral reef, which keeps the predators out. The shore is sandy with no algal growth. Fresh water is available.

Island B

The island has a rocky shoreline. Many tidal pools dot the island along the shore where the wave action is somewhat sheltered by rock outcrops. The tidal pools host barnacles, chitons (primitive molluscs), abalone, sea urchins, and crabs. Algae grow all around the island, but growth is quite sparse in the tidal pools where the land and aquatic animals feed. The current is quite strong along the rocky outcrops where the algae grow best. Fresh water is available.

Island C

The island is somewhat barren. A few species of cactus thrive on the bare rocks. A species of large cactus-eating tortoises inhabits the island. A species of very large birds nests on the island annually. They build their nests on the rocks, and protect their eggs from the Sun by standing over the nests with outspread wings. The nests are always on the windy side of the island, which is cooled by offshore breezes. Fresh water is available.

Island D

The island is an extinct volcano. Vegetation on the island changes, depending on the altitude. Grasses grow at the base. On the lower slope of the volcano, the grasses give way to low shrubs. Halfway up, tropical plants and trees dominate the landscape. At this altitude, the island experiences frequent rain showers. Two species of birds inhabit the island. One is a raptor that preys on the smaller birds. The other fishes the waters approximately half a kilometre offshore. Both nest in trees. Fresh water is available.

Procedure

1. Learn about specific characteristics of rats, including their size, coloration, living and feeding habits, and predators. List the characteristics of a modern rat as your ancestor rat.

This photograph shows a modern-day brown rat.

2. Consider the features of the island that you have been assigned. List what types of food are available, what types of predators exist, and so on. Draw a sketch of your island, showing its geography and other features.
3. Draw your rat.
4. Present your rat and your island to the class along with your answers to the Analyze and Interpret questions.

Analyze and Interpret

1. How many adaptations to living on its island does your rat have, compared with the ancestral rat?
2. List the adaptations of your rat. Explain how each adaptation helps the rat survive the environment.
3. Choose one adaptation, and describe a possible path for natural selection.
4. Imagine your rat was washed away by the tide and landed on one of the other islands.
   a) Infer its chances for survival. Explain your answer.
   b) Could this rat's alleles be added to the already existing gene pool? Explain why or why not.

Conclude and Communicate

5. Compare and contrast your rat with the rat of another group. Explain the differences and similarities.

Apply and Innovate

6. Design a rat that is adapted to one of the other islands.
7. There are many small island chains in the world. Examples include the Cook, Canary, and Maldive Islands. Research one of these island chains, or another of your choosing. Describe some of the species that live on the islands. Are there obvious differences in species between islands?

TOPIC 1.4

How and why are the genes of organisms manipulated?

These two animals, named Pete and Webster, are not typical goats. A Canadian biotechnology company inserted a spider gene into their gametes, and now they produce spider silk protein in their milk. Spider silk has many possible uses, including as a component of tough, light-weight steel. Because spider silk is not rejected by the human body; this steel could be used to create durable, low-weight artificial limbs, tendons, and other replacement connective tissue for use in humans.

Key Concepts

- DNA of a living cell can be copied, modified, and inserted into another organism.
- DNA technology has many uses.
- The use of biotechnology has some risks and raises some ethical issues.

Curricular Competencies

- Communicate ideas, claims, information, and courses of action for specific purposes
- Transfer and apply learning to new situations.
- Consider the role of scientists in innovation.
- Connect scientific explorations to careers in science.

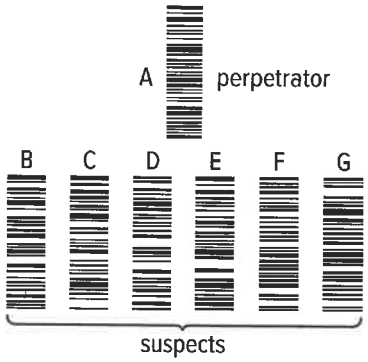
Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** The topic of biotechnology is often in the news. What do you think of when you hear the term? Are the associations you have positive, negative, or neutral? Why?

2. **Checking for Bias** One area of biotechnology includes developing ways to prevent certain types of inherited genetic disorders, especially those that are fatal. Do you think everyone should be tested for possible genetic disorders? Would you want to know if you had a genetic disease that may kill you before you turned 40? Reflect on your ideas in small groups or privately.

3. **Applying** A person can be identified from a single strand of hair. Except for identical twins, every person's body contains unique genetic information. Thus, your DNA is like your fingerprint. Police can use DNA fingerprinting to identify people based on samples such as a hair collected at a crime scene. Can you identify the perpetrator of this crime using DNA evidence shown on the right? Do you think this method is foolproof? Why or why not?



Sample A is the DNA fingerprint taken from a strand of hair. The hair was found on the victim, but it is not the victim's hair. Samples B though G are DNA fingerprints of hair taken from six suspects.

Key Terms

There are seven key terms that are highlighted in bold type in this Topic:

- biotechnology
- recombinant DNA
- in vitro fertilization (IVF)
- cloning
- artificial insemination
- gene therapy
- gene cloning

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meanings. Add other terms that you think are important and want to remember.

CONCEPT 1

DNA of a living cell can be copied, modified, and inserted into another organism.

Activity

Cloning—As easy as it is in science fiction?

You may have seen a science fiction film that had a character that had been cloned. Although a film may make it look easy to clone an organism, it is actually quite complicated to clone a single cell or even a piece of DNA within a cell. What do you think is needed to clone a gene, a cell, or a whole organism? What type of setting and equipment might be needed to clone something?

biotechnology the use of technology and organisms to produce useful products

cloning a process that produces identical copies of genes, cells, or organisms

gene cloning manipulating DNA to produce multiple copies of a gene or another segment of DNA in foreign cells

recombinant DNA a DNA molecule that includes genetic material from different sources

Over the last 60 years, the combination of science and technology has allowed us to learn more about DNA and about how to modify, or make changes to, genes. These techniques are often called **biotechnology**. One example of biotechnology is **cloning**. In general, cloning is defined as a process that produces identical copies of genes, cells, or organisms. However, the word *cloning* can mean very different things, depending on what is being copied. This book focusses on the process scientists use to clone a gene.

Gene Cloning

Gene cloning involves manipulating DNA to produce multiple copies of a gene or another segment of DNA in foreign cells. The cloned DNA can be used for further study or for mass producing the protein that the gene codes for. Proteins produced in this way have many commercial and medical applications. For example, insulin is a hormone that enables the body to use sugar; it is absent in people diagnosed with type I diabetes. Before gene cloning, people with diabetes used purified insulin from animal sources. Producing insulin this way was labour-intensive and expensive. Since the early 1980s, human insulin has been produced in bacteria through cloning of the insulin gene. The general experimental approach to gene cloning is described below. Refer also to Figure 1.33, which summarizes the steps in cloning a gene in bacteria.

1. Isolate the segment of DNA to clone, and choose a *vector* for cloning. Vectors act as carriers of the DNA to be cloned so that it can be copied in a foreign cell. One common vector for cloning in bacteria is called a *plasmid*. Plasmids are small, circular pieces of DNA that remain distinct from the bacterial chromosome.
2. Insert the chromosomal DNA into the vector. This relies on the use of enzymes that can cut DNA and help different pieces join together. The resulting DNA molecule, which includes genetic material from different sources, is called **recombinant DNA**.

3. Treat foreign cells, such as bacterial cells, so that they take in the recombinant DNA. This process is called *transformation*. Once the recombinant DNA plasmid is taken into the cell, many copies of the cloned gene or DNA fragment will be made by the host cell.

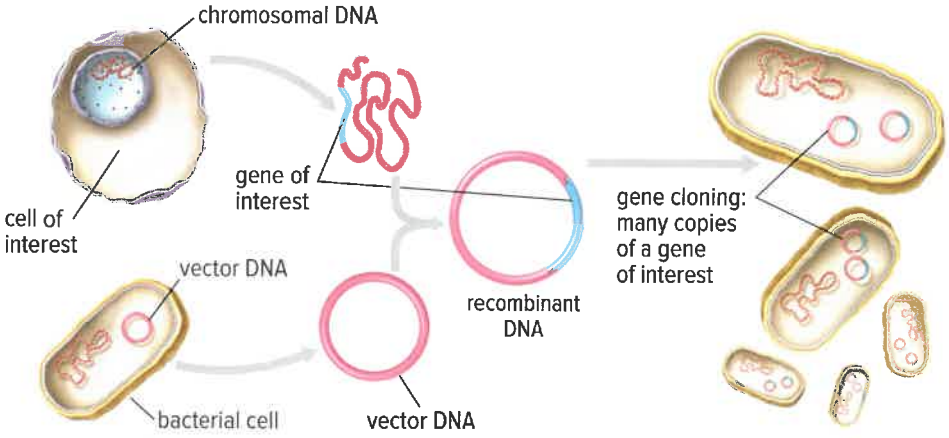


Figure 1.33 A gene or piece of DNA can be cloned. Many copies of it or the protein that the gene codes for can be produced and isolated. **Comparing: How does the recombinant DNA molecule differ from the vector DNA?**

Transgenic Organisms

Researchers have also developed techniques to investigate and alter the genetic material of many organisms. The process of specifically altering the genetic make-up of an organism is called *genetic engineering*. Genetic engineering involves making precise changes directed by the researcher (**Figure 1.34**). These include making specific changes to the sequence of DNA, such as introducing a mutation into a gene. Other kinds of changes are also possible. Genetic engineering involving the introduction of foreign DNA into an organism's genome, such as a gene from another species, results in a *transgenic organism*. Transgenic organisms are a type of genetically modified organism, or GMO.

Figure 1.34 This researcher is investigating ways to manipulate corn kernel traits such as starch and oil content.

Applications of Transgenic Plants

Transgenic crop plants account for more than half the corn and canola grown in North America. Many have been modified to increase their resistance to herbicides, insect pests, fungal infections, or viruses.

Transgenic Plants: Golden Rice

Scientists are also working to produce genetically modified plants with increased nutritional value. In many developing countries where rice is the main staple food, symptoms of iron and vitamin A deficiencies affect hundreds of thousands of people. In 2000, researchers in Switzerland developed a genetically modified strain of rice known as golden rice, shown in Figure 1.35. This rice has been genetically modified to increase its iron and vitamin A content. Golden rice is still in experimental stages, but it is considered to be the first GMO crop that was made to help reduce malnutrition.

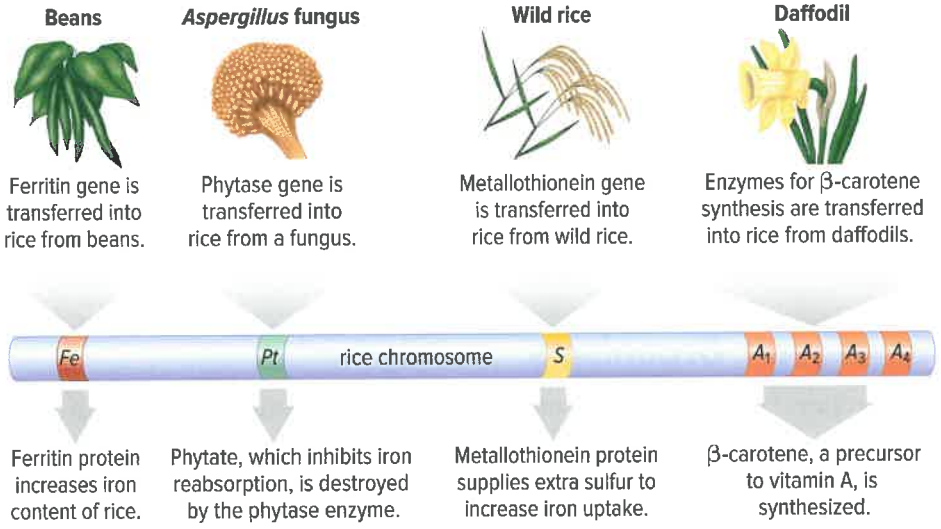


Figure 1.35 This transgenic product, golden rice, contains four different foreign genes. Three of these genes come from other plants, and one comes from a fungus. **Inferring: How could the development of such a disease-resistant plant be economically advantageous?**

Transgenic plants can also be used for medical purposes. In 2009, researchers used tobacco plants to produce virus-like particles that were used in vaccines against the A/H1N1 flu pandemic that hit the same year. Because the researchers used plants to produce the virus-like particles, they were able to develop a vaccine against the strain of virus causing the pandemic very quickly.

Activity

"Tough" Plants

One of Canada's most important crops is corn. European corn borers and corn earworms are insects that can destroy corn crops when they feed on them. A bacterium called *Bacillus thuringiensis*, makes a toxin that kills these insects when they ingest it. Scientists extracted the genes that control the production of the toxin from the bacteria and inserted them into the corn DNA. The genetically modified corn can now create the toxin. When the insects feed on the corn, they die shortly after being exposed to the toxin.

Many other crops, including soybean, potato, and strawberry, have been developed so they are resistant to diseases and insects. There is even a new apple that has been genetically modified so that its flesh does not turn brown if it is bruised or after it is cut or bitten into.

Suppose you are a transgenics scientist. Propose an idea for a genetically modified fruit or vegetable that most people eat. Write a paragraph explaining why you think you should look for a gene to alter that crop.

Applications of Transgenic Animals

Animals such as mice, fruit flies, and roundworms are widely used in research laboratories around the world to study diseases and ways to treat them. Transgenic milk-producing animals, such as goats, are being used to produce medical protein products that include human growth hormone and anti-clotting factors. **Figure 1.36** shows the main steps in creating a herd of goats that are genetically modified to secrete specific proteins in their milk. Recall also Pete and Webster in the opening to this Topic.

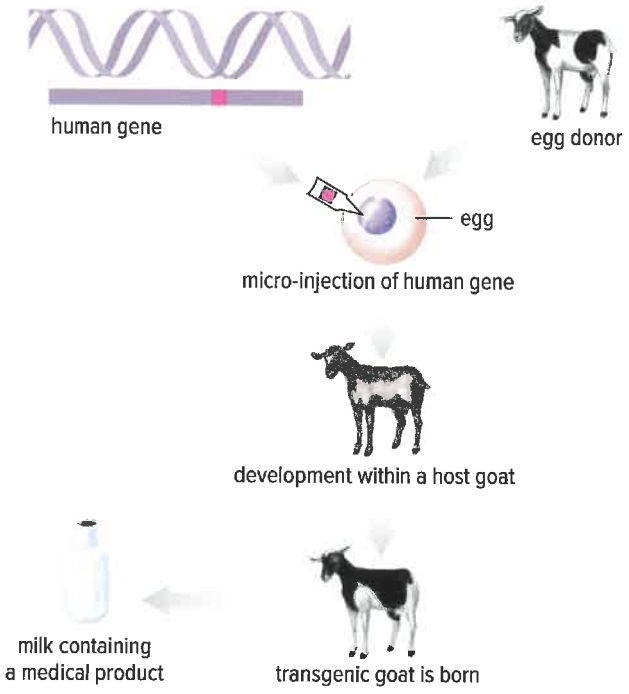


Figure 1.36 Genetic engineering can create transgenic animals that secrete human proteins or other substances in their milk. **Communicating: In your opinion, is it ethical to use animals in this way? Why or why not?**

Another area of research involves developing transgenic animals that can serve as organ donors for humans. Usually, transplanting organs from donor animals, such as pigs, into humans has very limited success because of tissue rejection. Some research teams are conducting work to develop transgenic pigs that are more compatible with human tissues. Research such as this also raises difficult issues, however. Some people are concerned about the risk of transferring diseases from pigs to humans. Other people ask whether it is ethical to create new kinds of animals purely for the purpose of harvesting their organs.

Before you leave this page . . .

1. What is the function of a vector in gene cloning?
2. Make a T-chart to list the different uses of transgenic plants and transgenic animals.

CONCEPT 2

DNA technology has many uses.

Advancements that have come from biotechnology can affect many aspects of our lives. Besides cloning and transgenic organisms, another example is a DNA profile, like the one shown in Figure 1.37A. A DNA profile determines the sequences of certain regions of a person's DNA that are unique to each individual. DNA profiles are used by law enforcement to try to match a person's DNA to a sample found at a crime scene. DNA profiles are also used to determine if people are related to each other.

Reproductive Technologies

Advancements in biotechnology and genetics also have touched one of the most basic biological activities—reproduction. These technologies have changed the way many people are conceiving children. They represent different options for people who want to have children but who are not able to conceive a child on their own.

In **artificial insemination**, sperm are collected and concentrated before being placed in the woman's uterus. This technique was originally developed to promote breeding success among domestic animals. Human couples have been using artificial insemination successfully for many years since it was first performed in the 1940s.

artificial insemination
a process that involves collecting and concentrating sperm, and then placing it in the female's uterus

in vitro fertilization (IVF)
a process that results in a female's eggs being fertilized by sperm outside of the body

Another example of the use of biotechnology to help people conceive children is **in vitro fertilization (IVF)**. In IVF, the woman's eggs are retrieved and combined with sperm in laboratory glassware. (*In vitro* is Latin for "in glass," and refers to the petri dish in which fertilization takes place.) After fertilization, one or more of the developing embryos are placed in the woman's uterus. Once an embryo becomes implanted, the pregnancy proceeds. In 1978, the birth of Louise Brown, the first baby born as a result of IVF, offered hope to many couples whose inability to conceive a child was due to the woman having blocked fallopian tubes. This prevents the sperm and egg from coming into contact for fertilization. A type of IVF technique, called intracytoplasmic sperm injection (ICSI) is shown in Figure 1.37B.

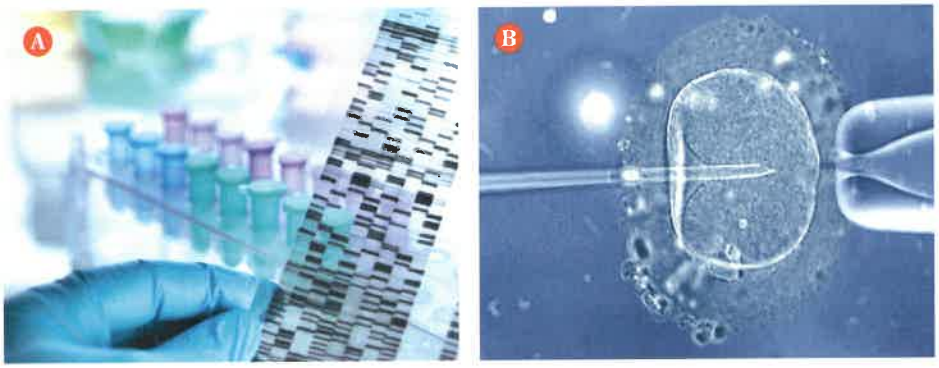


Figure 1.37 A DNA profiles are used by law enforcement to identify or eliminate perpetrators of crimes. B In a form of IVF called intracytoplasmic sperm injection (ICSI), the sperm is injected directly into the egg.

Gene Therapy

Understanding the role genes play in human diseases is an especially important part of biotechnology. This involves finding genes or genetic material that has been mutated in some way, and then identifying a link between those changes and a particular disease. Finding the genetic material that causes a disease enables doctors to make better diagnoses and to predict the likelihood of a person developing it.

gene therapy an experimental treatment to cure genetic disorders that involves inserting a healthy, normal form of a gene into the cells of tissues that are affected by a disorder

Gene therapy is an experimental treatment to cure genetic disorders. Its aim is to insert a healthy, normal form of a gene into the cells of tissues that are affected by a disorder. This gene can replace the mutated gene that causes the disorder. The approach to gene therapy for treating cystic fibrosis is shown in Figure 1.38. A normal gene is added to lung tissue, where it produces a normal protein. With a functioning protein, the thick mucus that builds up and harms people with cystic fibrosis is no longer produced, allowing them to breathe normally.

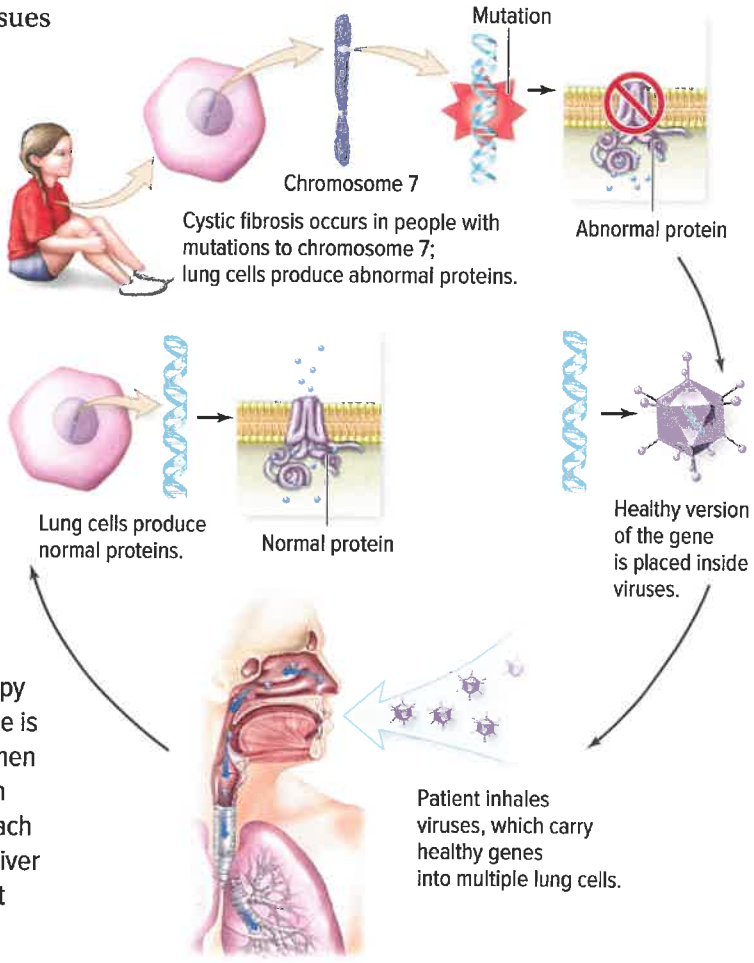


Figure 1.38 The strategy for using gene therapy to cure cystic fibrosis. A normal copy of the gene is taken up by cells in the lungs. These cells can then produce a normal protein from that gene, which can carry out its regular functions. In the approach shown, viruses act as vectors that carry and deliver the gene. The viruses have been treated so that they do not cause illness.

Extending the Connections

Gene Therapy for Donor Lungs

Scientists at the McEwen Centre for Regenerative Medicine in Toronto have developed a gene therapy technique to repair donor lungs before they are transplanted. The technique dramatically improves the success of transplants. As a result, more donor lungs are available to people who are waiting on transplant lists. Read the information provided by your teacher about this technique. Decide, from an ethics standpoint, whether this type of gene therapy is in the same category as treating the actual genetic material of an individual. Write a paragraph that summarizes your opinion, including supporting details.

Using DNA Technology in British Columbia

The use of DNA technology can benefit British Columbia both economically and ecologically. New DNA technologies are being used to help detect viruses in plants that are imported and exported to and from Canada. As well, biotechnology is applied to help fight invasive species in provincial forests.

Food Crops and Testing for Viruses

Exporting food crops is an important source of revenue for Canada. Exported strawberries bring in about $17 million per year, and tree fruits are worth over $240 million per year. As you might expect, when food crops are exported and imported to and from Canada they must be tested to make sure they are not carrying any viruses that could harm other crops. If food crops, such as those shown in **Figure 1.39**, are found to have viruses during testing, they are not accepted by the buyer. The loss of sales can be costly to growers. The earlier they can detect a virus in their plants, the better. Currently, the process of testing and quarantine can take up to three years. This can affect the speed with which products are traded, which can also cost growers.

Figure 1.39 Strawberries, blueberries, and cherries are just a few of the food crops grown in and exported from British Columbia.

In 2017, the Canadian Food Inspection Agency (CFIA) announced new projects that will use biotechnology to help reduce testing and quarantine time. In one project, scientists will use DNA-based technologies to test for all viruses normally associated with imported plants. This new testing process could reduce quarantine time to only six months. The second project specifically involves the testing of strawberry plants. The process will allow scientists to carry out a single test to check for multiple viruses in all exported strawberry plants. As with the first project, this will reduce the amount of time it takes for these plants to be sold.

Invasive Species and Forests of British Columbia

British Columbia's forests are important for many reasons. People use the forests for recreation and the trees and plants in the forests reduce soil erosion, filter water, and provide habitat. Timber is an important export for British Columbia and is a $33 billion industry across Canada.

When invasive species are introduced to forest ecosystems, they can cause great damage. An *invasive species* is a species that is not native to an ecosystem and causes harm to an ecosystem in which it is introduced. Examples of invasive species in B.C. forests include the Asian longhorned beetle, the Asian gypsy moth, and pathogens that cause sudden oak death and Dutch elm disease (**Figure 1.40**). Being able to identity the presence of an invasive species as early as possible can help reduce damage as well as reduce the risk that the exported timber will be rejected by the buyer.

Figure 1.40 As a caterpillar, the Asian gypsy moth eats the leaves of trees (left). Trees affected by sudden oak death (middle) develop cankers on their trunks. The leaves of trees with Dutch elm disease turn yellow, wilt, and then turn brown (right).

Scientists and CFIA agents can use a handheld device to test for invasive species. The device can extract DNA from samples of insect eggs or fungi. The DNA is then compared with a library of DNA from known invasive species and pathogens. This new device can reduce the time required to identify a sample from months to days. This device can also be used to test incoming wood and plant products for the presence of invasive species or infection. Early detection can prevent invasive species from entering B.C. ecosystems and reduce the damage they cause.

Activity

Asian Gypsy Moth

Your teacher will provide you with an information sheet about the Asian gypsy moth. Read the information, and then answer the questions on the worksheet provided by your teacher.

Before you leave this page . . .

1. Compare and contrast artificial insemination and in vitro fertilization.
2. Choose one of the uses of biotechnology discussed in the text and describe the benefits of its use. Do you think there are any disadvantages to its use? Explain.

CONCEPT 3

The use of biotechnology has some risks and raises some ethical issues.

Activity

Assessing the Use of Transgenic Plants

Different agencies oversee the development and use of transgenic products. These agencies consider criteria such as the potential social, economic, and environmental costs and benefits. Read the material provided by your teacher about a transgenic plant product or crop that has been approved for use in Canada. Describe the review process it has gone through for approval in Canada. What advantages does the product provide? Are there any negative consequences linked to its use?

Concerns about GMOs

The success in producing transgenic bacteria, plants, and animals has revolutionized health care and the ways that many plant crops are grown. However, there is controversy that surrounds making and using GMOs. Some of the risks and ethical issues are listed below.

Environmental threats

- The use of herbicide-resistant plants could encourage the use of stronger herbicides, which may get into the water or soil system and harm organisms that live there.
- There is evidence that genes can cross to other species, which may create "superweeds" and "superbugs" that cannot be controlled with pesticides.
- Another concern is that a GMO could out-compete or breed with species in the wild. This may endanger the natural populations.

Health effects

- Some scientists believe that not enough is known about the long-term effects of consuming genetically modified products such as food and medicine. Some people are concerned that GMOs are hazardous to our health or may produce allergic reactions in people. Some companies have chosen to make products that do not contain any GMO ingredients and are able to place a label on the product like the one shown in Figure 1.41.
- In Canada, up to 70% of processed foods could contain genetically modified ingredients. However, producers do not have to indicate this on their labels. Many international governments, including Canada's, continue to debate how to regulate the production, distribution, and labelling of GMOs and products that contain GMO ingredients.

Figure 1.41 Some products have a label that shows they do not contain any GMO ingredients.

Social and economic issues

- Although there are benefits to human health and reducing world hunger, the amount of money spent on genetics research may be greater than the overall benefits of the research.
- Some people wonder if private enterprise is having too much influence over the global food market.
- Other people question the ethics of using other species solely for human benefit.

Concerns about Gene Therapy

Scientists have carried out experimental treatments of genetic disorders aside from cystic fibrosis. These include treatments for sickle cell anemia (Figure 1.42) and some forms of inherited blindness. Although gene therapy has helped some people, others have experienced negative results. This caused most of the experimental treatments to be stopped until safer procedures could be developed. Nevertheless, gene therapy still holds great promise as a treatment for genetic disorders. As well, people are concerned about which genetic conditions should be considered "disorders" that deserve treatment.

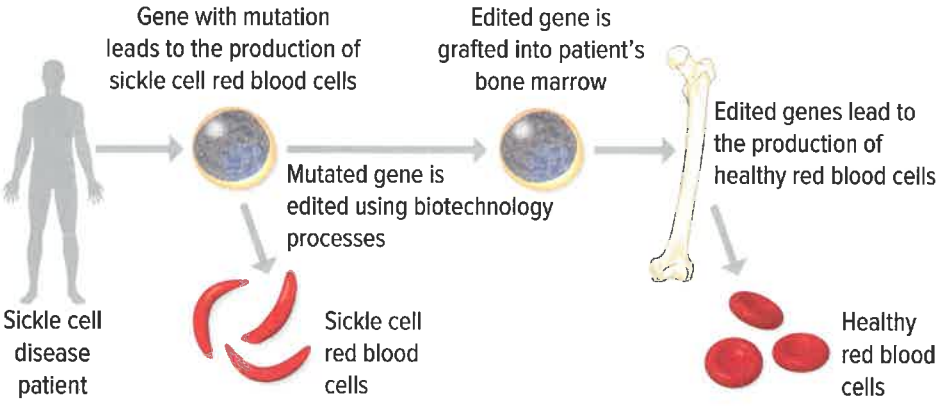


Figure 1.42 Gene therapy used to treat sickle cell anemia

Activity

Should we or shouldn't we?

Consider the scenario that has been presented by your teacher. In preparation for a debate, develop an argument for both sides of the issue. Your teacher will assign you a side to argue for in the debate. Carry out the debate according to the rules provided by your teacher.

Before you leave this page . . .

1. Why should environmental, social, and economic issues be considered when deciding how to use biotechnology?
2. Discuss one thing that concerns you about the use of biotechnology. Justify your concern with evidence collected from this concept.

AT ISSUE

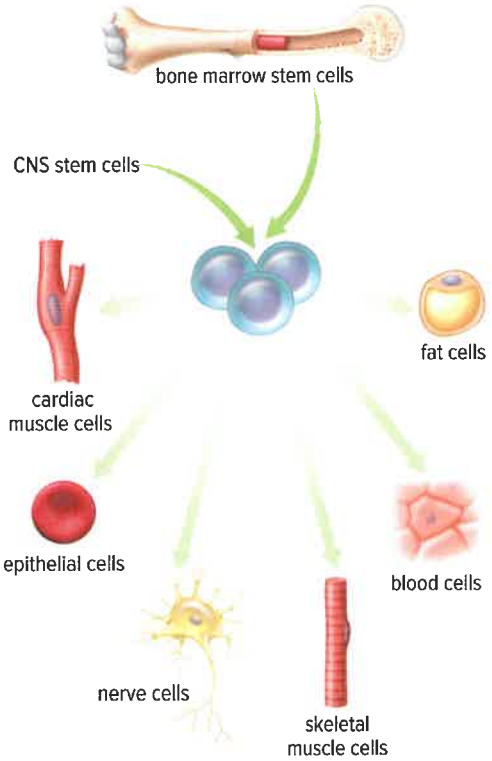
Stem Cells: Paralysis Cured

What's the Issue?

A race car driver is paralyzed in a crash. A teen is paralyzed after diving into shallow water. Until recently, these people would have little hope of regaining the full use of their bodies, but new research on adult stem cells shows promise for reversing paralysis.

What are stem cells? In animals, a cell that can differentiate into many different cell types is called a stem cell. A stem cell divides into two daughter cells through the processes of mitosis and cytokinesis. Each resulting daughter cell can develop into a different type of cell, based on which parts of its DNA are switched on. Stem cells generally occur in clumps that differentiate into different tissue layers, such as epithelial, muscle, and nerve tissues.

There are two types of stem cells. Embryonic stem cells can differentiate into any kind of cell. Adult stem cells exist within specialized tissue. They are only able to differentiate into certain types of cells. For example, tissue stem cells found in bone marrow can differentiate into white blood cells, red blood cells, or platelets.



Stem cells from bone marrow or the central nervous system (CNS) can be manipulated to generate many cell types that can then be transplanted to treat illness or repair damage.

How can stem cells be used? Scientists are trying to find ways to grow adult stem cells in cell cultures and manipulate them to generate specific cell types. For example, stem cells might be used to repair cardiac tissue after a heart attack, to restore vision in diseased or injured eyes, to treat diseases such as diabetes, or to repair spinal cells to reverse paralysis.

Stem Cells and Paralysis In Portugal, Dr. Carlos Lima and his team of researchers found that tissue taken from the nasal cavity is a rich source of adult stem cells. These stem cells become nerve cells when transplanted into the site of a spinal cord injury. The new nerve cells replace the cells that were damaged.

More than 40 people with paralysis due to accidents have undergone the Portuguese procedure. All have regained some sensation in paralyzed body areas. Most have regained some motor control. With intensive physical therapy, about 10 percent of them can now walk with the aid of supportive devices, such as walkers and braces. This is promising news to the many individuals facing illnesses or injuries that have robbed them of the full use of their bodies.

Stem Cells and the Future Scientists are eager to do the research necessary to make adult stem cell treatments a regular part of health care. Paralysis might not have to be permanent—stem cells could provide the cure.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. Create a pamphlet that explains the benefits to society of adult stem cell research. Conduct research in order to include information about the research methods, treatment, examples, cell physiology, and a brief history of adult stem cell research. Be sure to illustrate your pamphlet.
2. Legal, ethical, and social concerns surround human stem cell research. Investigate and summarize Canada's current guidelines on stem cell research.
3. Research the ethical arguments for and against stem cell research. Prepare an argument to present your opinion on this issue.

SCIENCE AT WORK

Biology Connections

Plant Pathologist

Bioinformatics Data Scientist

Fisheries Certification Manger

What kinds of jobs are there for people interested in the unity and diversity of life?

Soil Scientist

Animal Behaviourist

Bioethicist

If you like to ponder challenging issues, then keep reading. Bioethicists help researchers and healthcare workers make decisions about ethical dilemmas. They also help develop policies in hospitals and in research settings that involve human or other animal subjects.

Tree Breeder

Combine your interests in DNA and the great outdoors, and help manage and protect B.C.'s forests. Tree breeders help improve the growth, form, and health of trees to sustain forests for future generations.

Medical Illustrator

Where do you draw the line—literally? Medical illustrators use their knowledge of anatomy for advertising, textbooks, and other teaching tools. They work for medical schools, publishers, and companies that make pharmaceuticals and medical devices.

Questions

1. What other jobs and careers do you know or can you think of that involve biology?
2. Research a job or career related to Unit 1 that interests you. Explain what attracted you to it. What kinds of things do you have to know, do, and understand for this job or career?

Check Your Understanding of Topic 1.4

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Use a flowchart with diagrams to summarize gene cloning. PA C
2. What is the benefit of producing insulin from transgenic plants rather than transgenic bacteria? PA
3. A company has developed a transgenic carrot that secretes toxins that kill damaging insects and worms. AI C
   a) What are some of the risks and benefits that you think the Canadian government should consider when deciding whether to approve this plant for agricultural use?
   b) If approved, what advantages will this transgenic carrot offer to farmers? What are some of the potential drawbacks to farmers?
   c) Do you think that foods produced with genetically modified ingredients should be labelled so that consumers can make informed choices? List your arguments.
4. Explain the steps involved in in vitro fertilization. PA C
5. Use a graphic organizer of your choice to help explain how gene therapy works. PA C
6. Copy the following table into your notebook and complete it. PA C

Applications of Biotechnology

Application	Benefits	Risks/ Concerns
Cloning		
Genetically modified organisms		
Gene therapy		

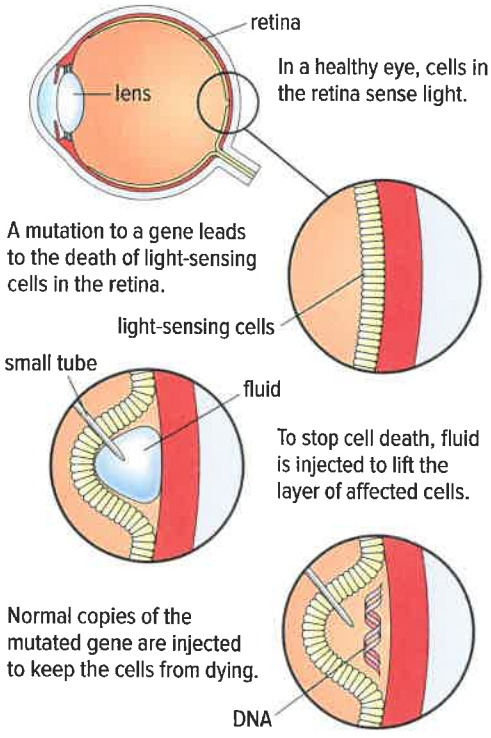
7. How can transgenic organisms help to achieve social, economic, or environmental goals? Give one example of a transgenic organism designed to meet one of these goals. E C

Connecting Ideas

8. Many people have life-threatening allergies to certain foods, such as nuts. Researchers are developing transgenic peanuts that will not produce allergic reactions. Do you think this is a good use of research money? Explain. E C

Making New Connections

9. Study the diagram below. What does it show? Explain your reasoning. PA C



INVESTIGATION 1-1

GUIDED INQUIRY

Owning and Controlling Genetic Information

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing Data
- Evaluating
- Communicating

What You Need

- access to online or print resources

As knowledge and technology related to genetic information continue to grow, more questions about how ownership and control of this information should be handled are being asked.

Question

How should ownership and control of genetic information be regulated?

Procedure

1. Work in small groups to conduct research on what laws or regulations different countries, such as Canada, the United States, and Great Britain, have regarding privacy of genetic information.
2. Why is privacy an issue of concern when it comes to personal genetic information? Research to find out how the privacy of genetic information relates to
   - potential employers
   - life insurance
   - medical drug plans
   - the health of family members
   - criminal cases
   - paternity testing
   - biobanks/stored DNA sequences
   - genetic research studies
3. Is a person's genetic information their own private property? Research to find different opinions about this issue.

Analyze and Interpret

1. Within your group, discuss whether there are any situations in which you think a person should be forced to share their genetic information. Defend your opinion.
2. Based on your research, how might someone be discriminated against because of his or her genetic profile? Include an example in your answer.
3. Why do you think the progress of government regulations is not able to keep up with scientific advancements in this area? What rules and policies would your group propose to deal with controlling genetic information?

Conclude and Communicate

4. As a group, present your list of rules and policies to the class.

INVESTIGATION
1-J

GUIDED INQUIRY

The Effects of Biotechnology

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing Data
- Evaluating
- Communicating

What You Need

- access to online or print resources

Despite successes, controversy still surrounds making and using GMOs. Most of the concerns are about the "unknowns"—potential dangers that may occur.

Question

What positive and negative effects do genetically modified organisms (GMOs) have on the environment?

Procedure

1. Use the questions below to guide your research.
   - What are three examples of GMOs that have been developed?
   - Why was each of these GMOs developed? What advantage does each provide?
   - Are there any reports of GMOs having negative impacts on the environment? If so, what is the source for each report?
   - How well do scientists understand the effects of GMOs on the environment? Are additional data and further studies necessary? If so, what kind?
2. Some of the following topic and key word suggestions may help guide your research:
   - BT corn
   - herbicide-resistant plants
   - genetically modified wheat, canola, or insects
   - GMO effects on biodiversity
   - effects on "non-target organisms"
   - development of superweeds

Analyze and Interpret

1. What information do regulators need when they are assessing the effects of GMOs on the environment?
2. How can you tell which reports about GMOs are based on credible evidence and which are based on misconceptions or opinions?

Conclude and Communicate

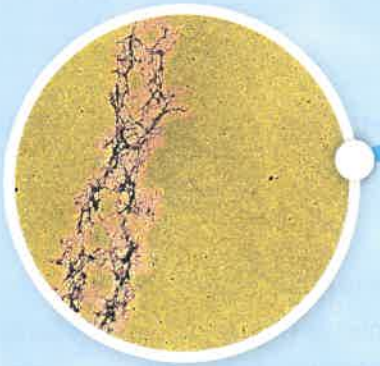
3. Create a table to summarize the positive and negative effects of GMOs on the environment. Do you think the benefits outweigh any negative effects?
4. Based on your research, do you think GMOs are safe to use? Create an informational poster to promote your point of view.

UNIT 1

Summary

ESSENTIAL QUESTION

How is DNA the foundation for unity and diversity of living things?



TOPIC 1.1:

How does an understanding of DNA help us investigate living things?

- The variation in living things we see around us is due to DNA.
- DNA is made of many nucleotides linked together in a specifc order.
- DNA exists in chromosomes, which contain thousands of genes.
- The structure of DNA is important to passing on genetic information.
- The different genetic make-up of organisms is reflected in the diversity of life.

Key Terms

DNA	nucleotide
protein	chromatin
chromosome	gene
allele	karyotype
species	population
nitrogenous bases	
complementary bases	
homologous chromosome	

TOPIC 1.2:

How is hereditary information passed from one generation to the next?

- Genes pass on inherited traits from parent to offspring.
- Punnett squares show the probability of offspring inheriting specific traits.
- Both alleles are expressed in codominance.
- In incomplete dominance, alleles are neither dominant nor recessive.
- Some inherited traits are due to alleles on the sex chromosomes.

Key Terms

genetics	traits	dominant
recessive	phenotype	genotype
homozygous	heterozygous	codominance
incomplete dominance		sex-linked traits

TOPIC 1.3:

How can natural and artificial selection influence changes in populations?

- DNA mutations produce genetic diversity within a population.
- Natural selection favours traits that make an organism better suited to its environment.
- Natural selection can lead to the formation of new species.
- Environmental factors can cause mutations.
- Humans select desired characteristics in organisms to be passed on to the next generation.

Key Terms

mutation	selective advantage	natural selection
adaptation	adaptive radiation	extinction
mutagen	carcinogen	artificial selection
monoculture		

TOPIC 1.4:

How and why are the genes of organisms manipulated?

- DNA of a living cell can be copied, modified, and inserted into another organism.
- DNA technology has many uses.
- The use of biotechnology has some risks and raises some ethical issues.

Key Terms

biotechnology	cloning
gene cloning	recombinant DNA
artificial insemination	in vitro fertilization (IVF)
gene therapy	

UNIT 1

Review

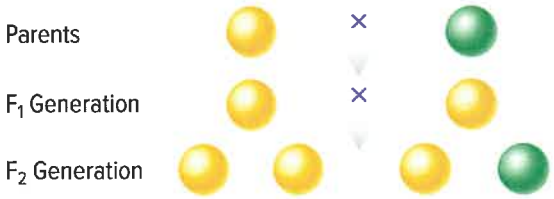
What Do You Know?
Connecting to Concepts

Visualizing Ideas

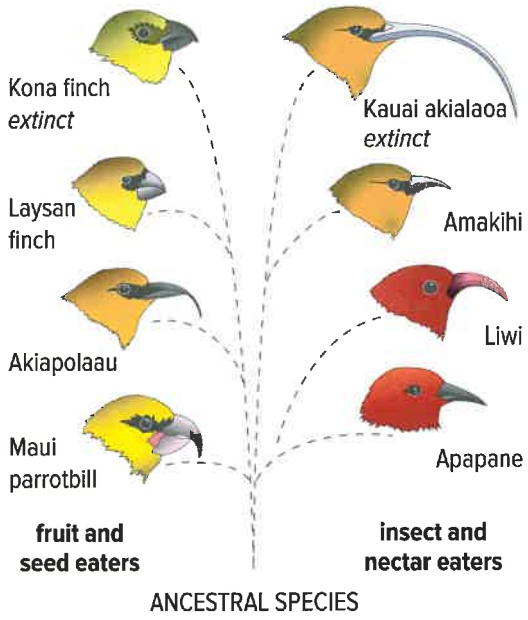
1. Study the photo here. How does DNA account for both the similarities and differences among the different varieties of apples?

2. Suppose you have to explain the concept of homologous chromosomes to a Grade 6 class. How could you use the diagram on the right as part of your explanation? What labels would you add?

3. The diagram below shows the results of two crosses. Explain the results and the genetic principle that is illustrated.



4. The image at the top of the next column shows what happened over time to a group of birds called honeycreepers after an ancestral species reached the Hawaiian Islands. Each island has different biotic and abiotic conditions. Identify and describe the concepts shown.



Using Key Terms

5. Create a table with three columns. In the first column, list all the key terms from this unit. In the second column, record a definition for each term, written in your own words. In the third column, sketch or draw a small picture that can help you remember the term and its meaning.

6. In a format of your choice, show how the term *DNA* relates to following terms from this unit:

- gene
- species
- population
- traits
- mutation
- natural selection
- adaptation
- adaptive radiation
- artificial selection
- monoculture
- biotechnology

Communicating Concepts

7. Scientists often describe the structure of DNA by comparing it to a ladder. Draw a DNA molecule and use the drawing to explain how DNA is similar to a ladder. Then explain the limitations of this comparison.

8. DNA sequences in a genome are compared to letters strung together in a book. Develop another analogy for how DNA, chromosomes, genes, and nucleotides are related.
9. Sketch a small section of DNA. Use the sketch to describe how DNA's complementary nature enables accurate replication.
10. "The sex chromosomes in a human are a homologous pair." Do you agree or disagree with this statement? Explain why.
11. Distinguish between the following pairs of terms using a definition and an example.
    a) homozygous and heterozygous
    b) dominant and recessive
12. Given the phenotype of an individual, can you determine its genotype? Explain.
13. Since Mendel performed his experiments with pea plants, scientists have discovered that there are more complex patterns of inheritance. Use examples and diagrams to illustrate the differences among the following mechanisms:
    - dominance
    - incomplete dominance
    - codominance
    - sex-linked inheritance
14. In a Venn diagram, compare and contrast natural selection and artificial selection.
15. Evolution is the process of biological change over time based on the relationships between species and their environments. Summarize how genetic variation is involved in biological change over time.
16. Make a table to show three examples of transgenic organisms and describe their practical application.
17. Make a flowchart to show the steps involved in gene cloning.
18. There are many benefits to biotechnology, but there are also ethical concerns. Use a concept map to illustrate some of the benefits and concerns that are associated with the biotechnology topics discussed in this unit.

What Do You Know? Connecting to Competencies

Developing Skills

19. A female fruit fly that is homozygous dominant for red eyes is crossed with a white-eyed male fruit fly. Use a Punnett square to predict the genotype(s) and phenotype(s) of their offspring.
20. Explain why there are varieties of houseflies that are not killed by a popular insecticide. Under what conditions is such resistance considered to be a selective advantage?
21. Outline a breeding program that would help you develop a cow that produces more milk.
22. Choose a species of animal, and describe two of its traits. Explain the adaptive value of both traits. Include a sketch with your explanation.
23. Research a drug or other form of medical treatment that was developed using recombinant DNA technology. Describe what it is, its use, and any risks or controversies that are associated with its use.

Thinking Critically and Creatively

24. Describe an experimental approach to determine which of two alleles for a gene is recessive.
25. Develop a plot for a movie or play that involves the use of gene therapy. Ensure that your ideas are scientifically plausible.

26. In radishes, colour is controlled by two alleles, one for red colour and one for white colour. Inheritance of these alleles shows incomplete dominance. The photographs below show the phenotype for each possible colour: red, purple, and white. What phenotypic ratio would you expect from crossing two heterozygous radish plants?

27. State whether each of the following examples demonstrates artificial selection. Explain why or why not.

- **a)** A person breeds long-furred Persian cats.
- **b)** A farmer increases the variability in the fat content of different plant species.
- **c)** Over time, plants develop chemical defences that deter herbivores.
- **d)** Crops are bred to be pest-resistant.

Understanding Big Ideas
Making New Connections

28. Imagine that you are a journalist writing an article for the magazine *Ethics in a Changing World*. You have been asked to research and explain the social and environmental implications of current genetics research. Suggested topics include gene cloning, transgenic crops to reduce hunger, in vitro fertilization, and gene therapy. Choose one topic and write an article on what you find.

Applying Your Understanding

29. A black-haired true-breeding guinea pig is crossed with a white-haired true-breeding guinea pig. All the offspring have black hair.

- **a)** Which hair colour is dominant?
- **b)** What are the genotypes and phenotypes of the parents?
- **c)** What are the genotypes and phenotypes of the offspring?

30. A yellow-haired rat is mated with a black-haired rat. Over time, the rats produce 45 black offspring and 52 yellow offspring. From these results, determine the *probable* genotypes of the parents and offspring. How could you determine the dominant allele?

31. Sickle cell anemia is an autosomal recessive disorder that results in the formation of abnormally shaped red blood cells. Write the genotypes for the following individuals:

- **a)** a person with sickle cell anemia
- **b)** a person carrying the sickle cell allele
- **c)** a homozygous person with a normal phenotype

32. Hemophilia is a disease that is due to an X-linked recessive allele. A man and woman who do not have hemophilia have a son who does have hemophilia. Explain how this can occur. If they have a daughter, could she have hemophilia? Explain.

Thinking Critically and Creatively

33. Sea stars eat clams by pulling apart the two halves of a clam's shell. Create a sequence of drawings to show how this could result in natural selection of muscle size in clams.

34. Adaptive radiation often occurs on islands. Would you expect to find more adaptive radiation on islands that are remote from the mainland, like small Pacific islands, or islands that are close to the mainland, like Vancouver Island? Explain your answer.

35. Explain the following observations from a scientific research study that involved finches (*Geospiza fortis*) on the Galapagos Islands.

- During a drought in 1977, a large percentage of *Geospiza fortis* finches died of starvation on the Galapagos island Daphne Major.
- The 90 bird survivors in 1978 had a beak depth from about 9.4 mm to about 10.2 mm, which was greater than the beak depth of the finches that did not survive.

36. Scientists at the University of Guelph produced genetically modified pigs. These pigs were given the name Enviropig™ because they were genetically altered so that less phosphorus was excreted in their waste. High levels of phosphorus in animal waste can enter streams and lakes and act as a pollutant.

a) What is one advantage of developing these pigs?

b) What is a potential risk of these pigs being produced?

c) These pigs were being considered as a source of food. Should genetically modified food that is to be consumed by people be labelled as such? Provide a supporting statement for your opinion.

Connect to Self and Society

37. In Canada, individual grizzly bears and populations of grizzly bears are being isolated as humans expand their use of land that was previously used by the bears.

a) If the grizzly bear were to become extinct, what might some of the economic, political, and social implications be for Canada?

b) How might wildlife corridors help the situation? (Wildlife corridors are routes designed to help animals cross busy highways safely in mountain parks.)

38. Indoor tanning beds work by exposing people to artificial ultraviolet light. Researcher have found that this increases a person's risk of developing a deadly form of skin cancer, called melanoma, by 20%.

a) What do you know about the link between ultraviolet light and cancer?

b) Several countries have passed laws to restrict the use of tanning beds by teenagers. What are the regulations in British Columbia for the use of indoor tanning beds? Do you think these regulations are strict enough, too strict, or not strict enough? Why?

39. Write a paragraph that summarizes how you think society has been affected by biotechnology and what the impact has been to date. In your paragraph be sure to include examples and information that support your opinion.

40. Choose a crop plant that is grown in British Columbia that has been genetically modified to be more resistant to disease. Research the economic and environmental impacts that growing this crop has had in B.C. Give your opinion as to whether the crop should continue to be grown in B.C. or not. Use evidence from your research to support your opinion.

41. With modern technologies, scientists can retrieve DNA from 5000 year old bones found in archeological digs. Recently some First Nations people have shared their DNA with scientists to see if there are connections with the DNA of people who lived in the same area thousands of years before. The results of these studies often show direct links between contemporary First Nations and their ancestors. In what ways does this research help to bring together Indigenous scientific knowledge and Western science?

Unit Assessment

How can we use our knowledge of DNA to learn more about the past and the future?

Black-footed ferrets were once plentiful in the prairies of North America. However, disease and the decline of their main food source left only 18 individuals by the mid-1980s. To save the species from extinction, they were captured as part of a zoo program using selective breeding and artificial insemination to reintroduce genetic diversity into the population. In 2009, 34 ferrets were released back to the wild—the program having been a success. The burrowing owl is another example of a species in which wild populations were increased due to a breeding program at the BC Wildlife Park (BCWP). After being locally extinct from British Columbia by 1980, the BCWP began a breeding program and, since 1991, over 2 500 burrowing owls have been released back into the wild. The BCWP is still working towards increasing the genetic diversity of local populations.

Work as part of a group to do the following.

STEP 1 ► Reflect on the three options, their photos, and the question asked for each option.

STEP 2 ► Brainstorm three more options and questions of your own about a situation that involves DNA and how our knowledge can be used to solve a problem or broaden our thinking.

STEP 3 ► Decide on one of the six options questions to investigate.

STEP 4 ► Plan and conduct a scientific inquiry to explore your question.

STEP 5 ► Organize and analyze the data and information that you find and collect.

STEP 6 ► Communicate the results of your inquiry in a suitable manner.

OPTION A

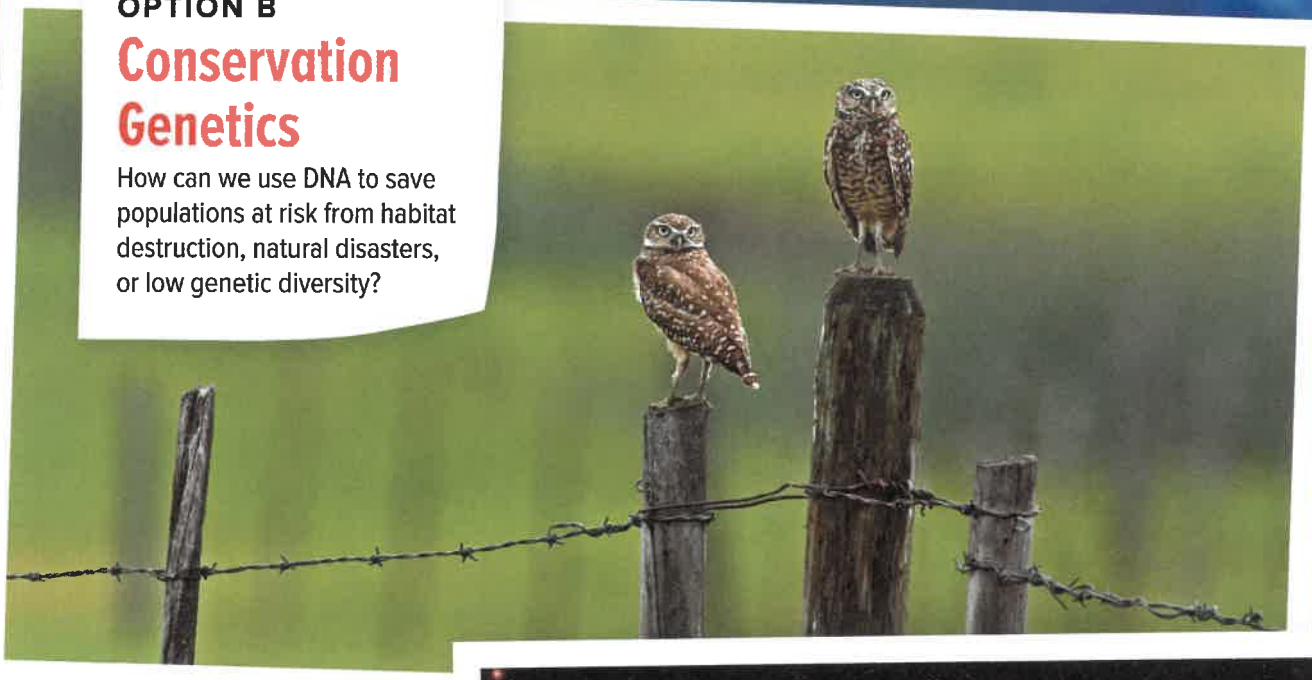
Evolutionary Relationships

What can we learn about evolutionary relationships among organisms by comparing DNA from fossils to that of modern organisms?

OPTION B

Conservation Genetics

How can we use DNA to save populations at risk from habitat destruction, natural disasters, or low genetic diversity?



OPTION C

XNA

Could other life in the universe have evolved without DNA or RNA?

Assessment Criteria

Did I and my group...

- Develop one or more questions that provided opportunities for rich investigation? QP
- Develop effective methods to collect and record reliable data and information? PC
- Apply different ways of knowing to analyze, reflect on, and draw meaningful conclusions that are consistent with evidence? PA
- Consider and demonstrate an awareness of bias, and social, ethical, and environmental implications over the whole process of our inquiry? E
- Propose alternative course of thought and/or action that contribute to care for self, others, community, and world? AI
- Construct evidence-based argument using language, conventions, and representations appropriate for a specific purpose and audience? C

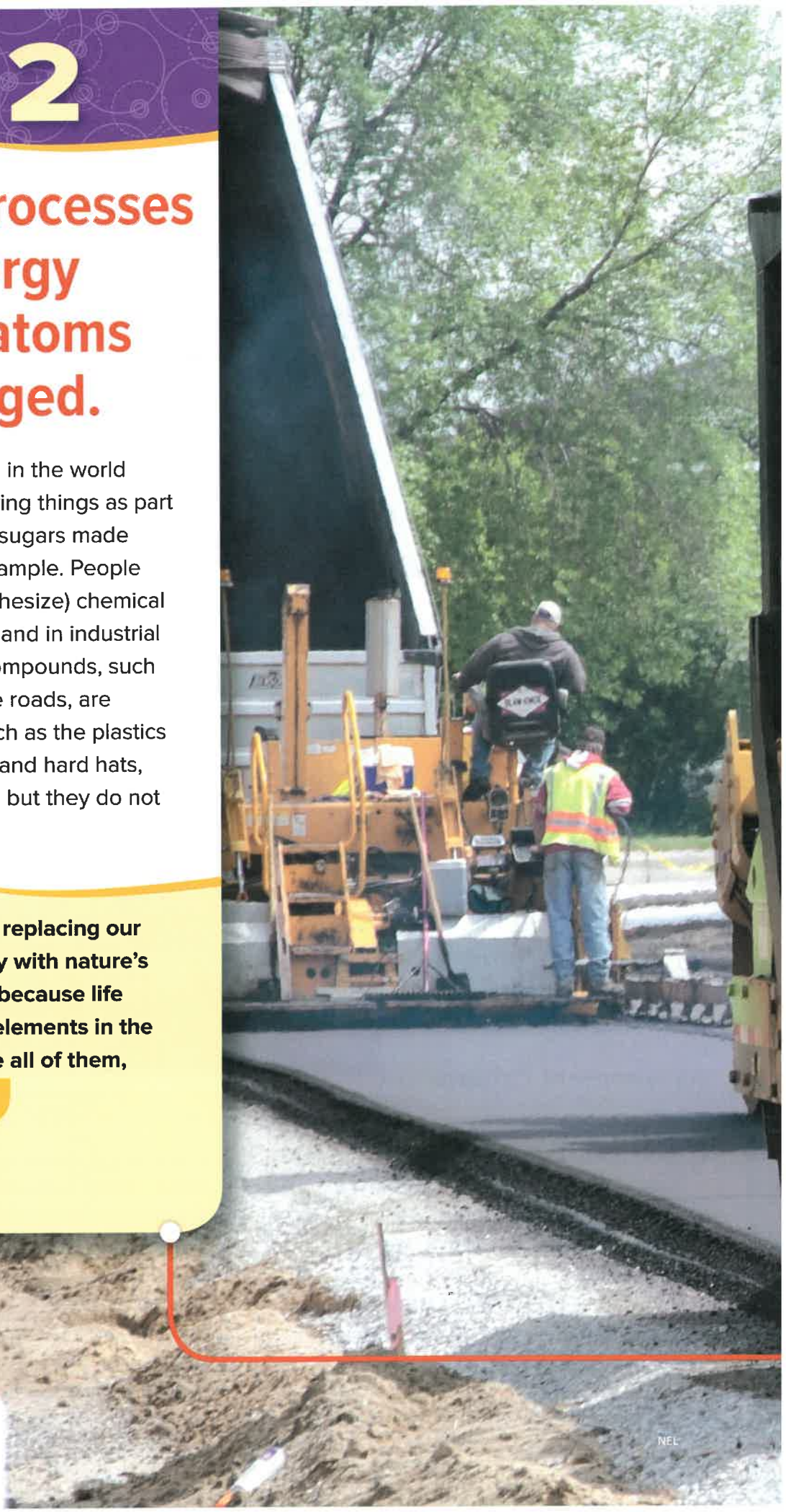
UNIT 2

Chemical processes require energy change as atoms are rearranged.

Many chemical compounds in the world around you are made by living things as part of their life processes. The sugars made by green plants are one example. People also isolate and make (synthesize) chemical compounds in laboratories and in industrial settings. Some synthetic compounds, such as the asphalt used to pave roads, are found in nature. Others, such as the plastics used to make traffic cones and hard hats, come from natural sources, but they do not exist in nature.

"Green chemistry is replacing our industrial chemistry with nature's recipe book. It's not easy, because life uses only a subset of the elements in the periodic table. And we use all of them, even the toxic ones."

Janine Benyus
Natural sciences author, innovation consultant



- What role does energy play in the production of chemical substances in nature and those we synthesize?
- What are the benefits and the costs of the chemical substances and products that we synthesize?
- What questions do you have about—this photo? the title of this unit? ...?

UNIT 2

At a Glance

You will demonstrate what you know, can do, and understand by being able to

- Perform investigations and use other investigative methods to explore properties and patterns involving elements and compounds
- Use scientific understandings to describe and explain the role of energy in chemical processes
- Seek patterns and connections to identify and describe types of chemical reactions
- Develop increasing facility to express ideas, attitudes, and actions in respectful and responsible ways

ESSENTIAL QUESTION

What happens to the energy and atoms of substances in chemical reactions?

TOPIC 2.1:

How are chemical processes part of our lives?

Some things you will do:

- demonstrate sustained intellectual curiosity about a topic or problem of personal interest
- ensure that safety and ethical guidelines are followed in investigations

Some things you will come to know:

- You live in a world filled with applications of chemistry.
- You have a responsibility to use chemicals and chemical knowledge safely.

TOPIC 2.2:
What happens to atoms in a chemical reaction?

Some things you will do:

- apply First Peoples perspectives and knowledge, other ways of knowing, and local knowledge as sources of information
- construct, analyze, and interpret models and diagrams
- transfer and apply learning to new situations

Some things you will come to know:

- The making and breaking of chemical bonds involves changes in energy.
- Writing chemical equations depends on the law of conservation of mass.

TOPIC 2.3:
How is energy involved in chemical processes?

Some things you will do:

- collaboratively and individually plan, select, and use appropriate investigation methods
- analyze cause-and-effect relationships
- contribute to care for self, others, community and world through individual and collaborative approaches

Some things you will come to know:

- Chemical reactions involve a transfer of energy between systems and their surroundings.
- Some chemical reactions absorb energy, and others release energy.

TOPIC 2.4:
How do atoms rearrange in different types of chemical reactions?

Some things you will do:

- seek and analyze patterns, trends, and connections in data
- communicate scientific ideas, claims, information, and courses of action for a specific purpose and audience

Some things you will come to know:

- The many kinds of chemical reactions can be grouped into a few main types based on how their atoms are rearranged.
- Acids and bases are common chemical substances in daily life.

UNIT 2

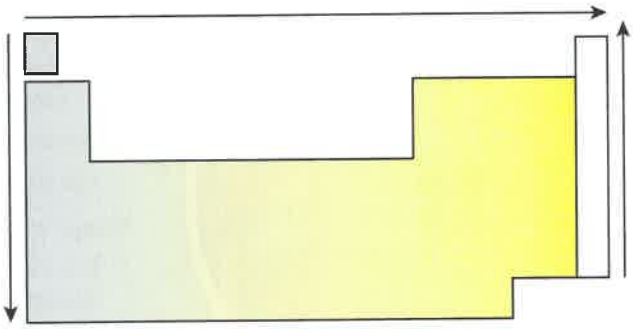
Connect To What You Already Know

This feature helps you reflect on what you know about some foundational ideas that you have learned in previous grades. Work alone or quietly in small groups to answer the questions. Reach out to your classmates to ask about things that you are unsure about or to offer assistance. Your teacher also can provide additional reinforcement materials to help you prepare for this unit.

Refer to **Figure 1** on the next page as well as the periodic table on the inside back cover of this textbook as you answer the following questions.

1. Look at the symbols and atomic numbers of the elements.
   - **a)** What is the atomic number of helium?
   - **b)** What is the atomic number of gold?
   - **c)** What is the symbol of the element with atomic number 22?
   - **d)** What is the symbol of the element with atomic number 33?
2. Look at the atomic masses of the elements.
   - **a)** What is the atomic mass of aluminum?
   - **b)** What is the atomic mass of silver?
   - **c)** What is the symbol of the element with atomic mass 40.1?
   - **d)** What is the symbol of the element with atomic mass 83.8?
3. What is the difference between an element's atomic number and its atomic mass? What is the significance of the atomic number in terms of the periodic table?

Figure 1



4. Copy the diagram below into your notebook, and use it to answer the following.
   - **a)** What physical properties do the grey-shaded elements have in common?
   - **b)** What physical properties do the yellow-shaded elements have in common?
   - **c)** What physical properties do the elements in the white column have in common?
   - **d)** One element appears on its own in the upper left corner of the periodic table. What makes this element unique in terms of many of its physical properties?
   - **e)** Identify the trends in physical and chemical properties represented by the arrows that surround **Figure 1**.
5. Elements 1, 3, 11, and 19 are in the first column of the periodic table.
   - **a)** What are the two terms used to identify columns of the periodic table?
   - **b)** Draw Bohr diagrams for these elements.
   - **c)** How is the electron arrangement in these elements similar?
   - **d)** How many electrons would you expect there to be in the outer energy shell of the elements Rb and Cs? Explain.
6. Look at elements 3 to 10.
   - **a)** Draw Bohr diagrams for these elements
   - **b)** Compare your diagrams. How are they the same? How are they different?
   - **c)** What period do these elements belong to?
   - **d)** What is the relationship between period number and occupied energy shells?

7. An element's reactivity is associated with how close it is to having a full valence shell.
   a) What elements have full valence shells? Are they the most or least reactive elements? Explain.
   b) Why are elements of Group 1 and 17 the most reactive elements?
   c) What is an ion? Using Bohr diagrams of representative elements, show how a negatively charged and a positively charged ion forms. Explain the formation of ions for these elements.

8. Elements in the same column of the periodic table have similar properties. Think of two examples in everyday life where similar substances could be substituted for each other. What other factors would you consider before making the substitutions?

9. a) Which elements on the periodic table do not occur naturally on Earth?
   b) Of these, which ones are synthetic (made only in the laboratory)?
   c) In both cases, what is it about the nature of these elements that accounts for the fact that they are not naturally occurring on Earth?

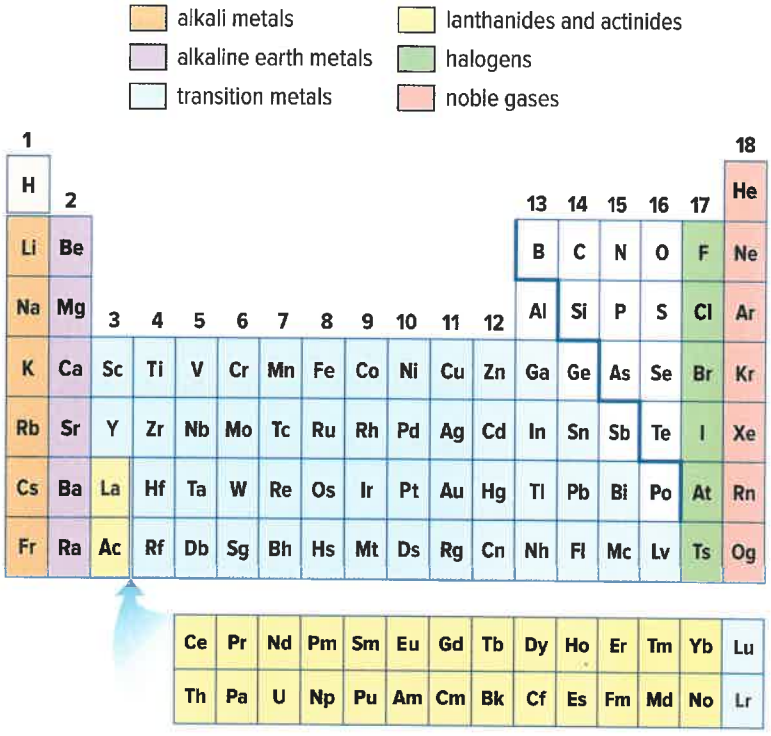
Figure 2

Elements are classified as metals, non-metals, and semi-metals based on their physical and chemical properties. The elements in groups 1, 2, and 13 to 18 are referred to as the main-group elements or representative elements. The elements in groups 3 to 12 are called the transition elements.

Most of the elements are metals. With the exception of mercury, metals are solid at room temperature. They are shiny when smooth and clean, and most are silver or grey in colour. They are good conductors of electric current and thermal energy. They are also malleable and ductile.

The non-metals, except for hydrogen, are found on the upper right side of the periodic table. Non-metals are general gases or brittle, dull-looking solids. They are poor conductors of electric current and thermal energy.

Semi-metals (also called metalloids) have physical and chemical properties of both metals and non-metals. For example, like metals, they are shiny solids at room temperature, but they are brittle and not ductile like non-metals. They also tend to be poor conductors of electric current and thermal energy.



TOPIC 2.1

How are chemical processes part of our lives?

Key Concepts

- Applications of chemistry are everywhere in the world around you.
- Knowing how to handle chemicals helps keep us and our environment safe.

Curricular Competencies

- Make observations aimed at identifying questions about the natural world.
- Ensure that safety and ethical guidelines are followed in investigations.
- Experience and interpret the local environment.
- Consider social, ethical, and environmental implications of findings.

The link between fireworks and celebration is more than 1000 years old. Its origins are in China, where the earliest fireworks had been invented centuries before. However, colourful displays like this one at Vancouver's annual Celebration of Light festival only became common less than 200 years ago. Before then, the only colours available were those you might see in a typical fire—orange, white, and yellow. Compounds of barium (which supply green hues) and strontium (which supply red) were not available until the elements themselves had been discovered. Strontium was discovered in 1790 and barium in 1808.

Many of today's fireworks use the ionic compound potassium perchlorate, $KClO_4$. When ignited by a lit fuse, this compound breaks apart and releases oxygen gas. Carbon and sulfur in the fireworks act as fuels. They react instantly with the oxygen, producing hot gases that provide some of the explosive force to propel the firework upward. The heat of the explosion causes metals and metal compounds in the firework to give off the coloured lights that we look forward to.