

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?



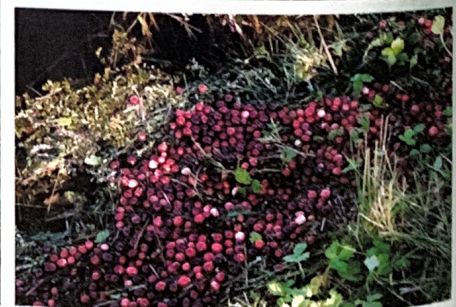
DNA deoxyribonucleic acid, a double-stranded nucleic acid that stores genetic information

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.

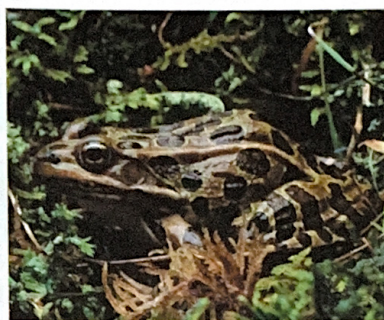
DNA (deoxyribonucleic acid) is genetic material that stores information. DNA is responsible for variation among all living things. Most cells of an organism contain genetic information that has an influence on its appearance and life processes. **Figure 1.1** shows some of the similarities and differences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

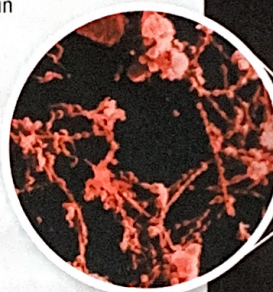
Plants have some form of roots, a stem, and leaves. Plants carry out photosynthesis to produce their own food. But differences in DNA result in variations in root systems, types of stems, and leaf shape that enable plants to live in ecosystems as diverse as temperate rainforests, alpine meadows, and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

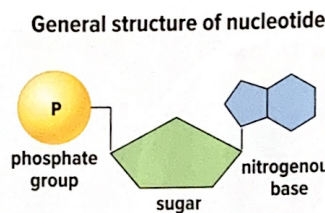
Activity

Follow the Instructions

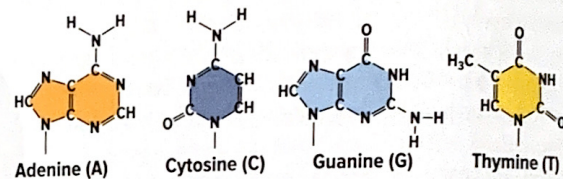
Think of something that has to be put together a certain way in order for it to function properly, such as a bicycle. Draw the basic steps needed to put together your example. Can your example be put together in any way? Why or why not?

Figure 1.2

Nucleotides are the basic building blocks of DNA and RNA.



Nitrogenous bases in DNA



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)

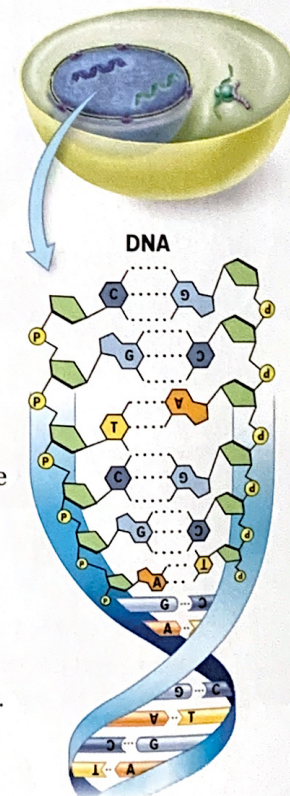
complementary bases nitrogenous bases that pair together in a specific way; A and T always pair together, and G and C always pair together

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).

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.

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.

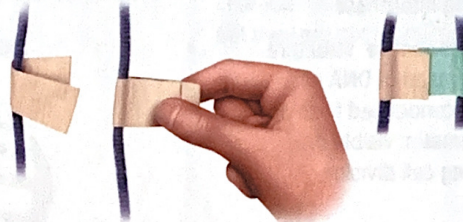
protein an organic chemical composed of a chain of building-block molecules called amino acids

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.
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

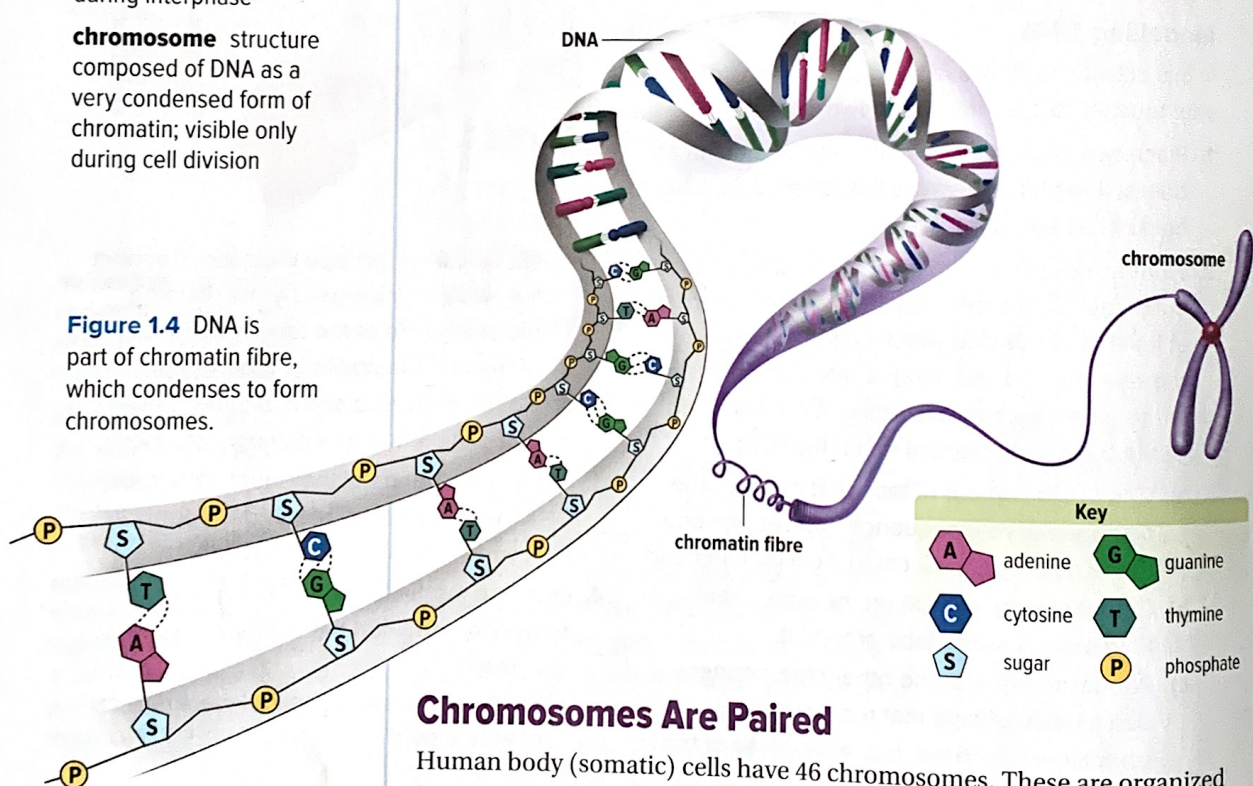
Recall the photo that began this Topic. Then examine the yarn and the box provided by your teacher. Can you get all the yarn to fit inside? How does this experience help you appreciate the structure of DNA and the complexity of life?



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.

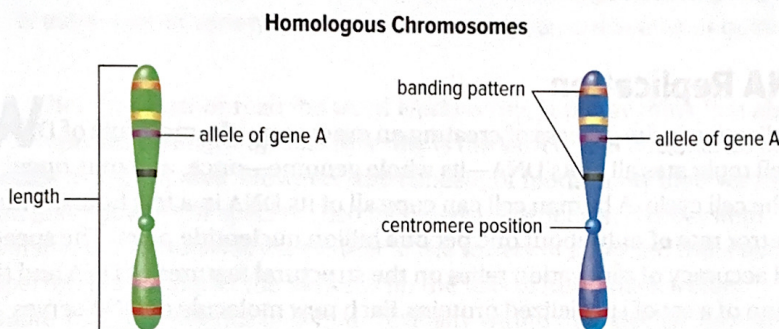


Chromosomes Are Paired

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.

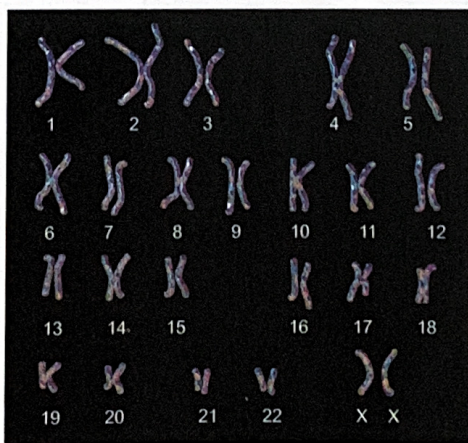
Homologous Chromosomes Contain Alleles

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.



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.



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.

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.

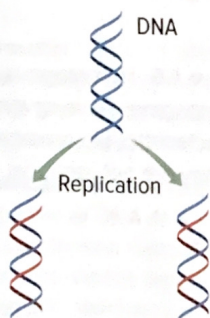
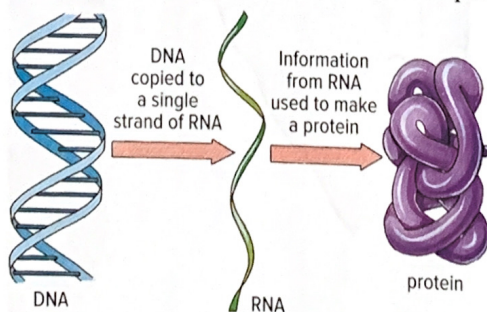


Figure 1.7 During DNA replication, two molecules of DNA are made from one. The resulting new molecules are identical to the original. Each new molecule contains one original strand of DNA (shown here in blue) and one new strand (shown in red).

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*.

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

Genetic Diversity

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.