1.1 Biodiversity—An Introduction

biodiversity the number and variety of species and ecosystems on Earth

Life on Earth is extraordinarily diverse. The variety and number of life forms on Earth is called biological diversity, or **biodiversity**. By 2010, the International Year of Biodiversity, over 1.7 million kinds of living things had been identified and described by scientists. This number continues to grow as new organisms are discovered daily. Among them are strange creatures from the depths of Earth's oceans (**Figure 1**), brightly coloured rainforest birds, and some peculiar organisms, such as tree kangaroos! Biologists believe that Earth may be home to as many as 15 million different kinds of living things.

Figure 1 Biologists continue to discover new organisms, such as the deep ocean Dumbo octopus.

In order to assess the diversity of life, scientists must observe and accurately describe each kind of living thing. Where do scientists begin? The first step is to choose a fundamental unit. In the case of living things, this unit is the *species*. However, defining and identifying this unit is not always easy.

What Is a Species?

species all organisms capable of breeding freely with each other under natural conditions

Most biologists define a **species** as a group whose members are able to freely breed among themselves under natural conditions. This definition is also referred to as the biological species concept. It is important to note that members of different species *usually* do not breed with one another. For example, under natural conditions lions breed only with lions, robins breed only with robins, and so on.

hybridization the cross-breeding of two different species

morphology the physical appearance and characteristics of an organism; also the science of the study of these physical characteristics

In many cases, the difference between species is obvious. For example, you would never mistake an elephant for a hippopotamus, or an ostrich for a turkey. Unfortunately, the traditional definition of species does not always hold true to all living things. Plants, for example, offer many exceptions. Two plants that appear to be distinct species may occasionally undergo **hybridization** under natural conditions, forming a cross between the two species. Although hybridization in nature does occur, it is relatively uncommon. Other plants, some fungi, and many microscopic organisms (micro-organisms) only reproduce asexually. For these organisms, the traditional species definition does not apply. When this is the case, species are defined based on a set of physical characteristics, or **morphology**. For example, dandelions (which reproduce asexually) are defined by their shared features rather than as members of a population of breeding individuals.

Individual Variability

Figure 2 Humans exhibit individual variability but are all members of the same species.

Atoms of an element or molecules of a compound are identical, but a species is composed of individuals with different traits. The individuals of any given species may show subtle differences (**Figure 2**). However, these individuals still belong to the same species and are members of the same breeding population.

As you will learn in the Genetic Processes unit, biologically inherited information (called genetic information) is a primary source of individual variability. The study of the diversity of living things focuses on distinctions among species, but individual variability is vital to both individuals and entire populations.

Variation over Time and Space

Species also change over time and space. They can evolve, or change, over many generations, and they can change across continents (**Figure 3**).

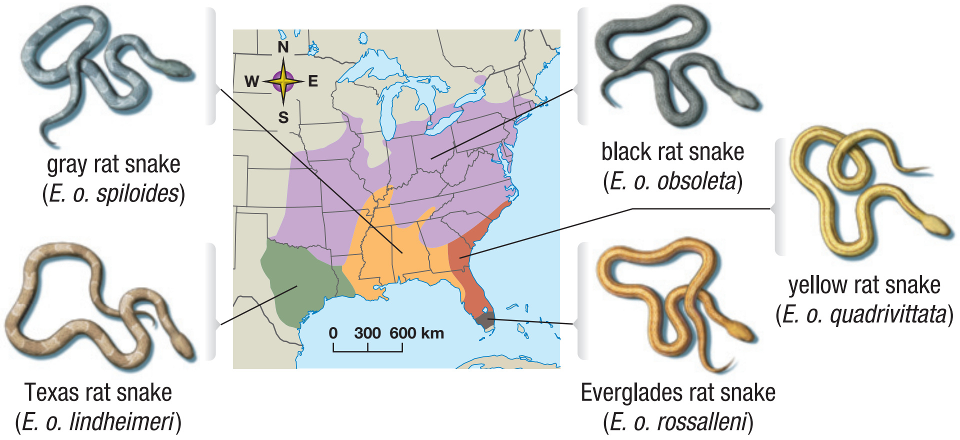


Figure 3 Five subspecies of rat snakes. These snakes are all considered members of the same species. They exhibit differences in colour and the presence or absence of stripes, depending on their geographic location.

The physical and behavioural changes that occur in entire populations of a species over time are referred to as **evolutionary changes**. Populations may separate and, over time, may form entirely new species. You will examine the factors influencing evolutionary changes in much greater detail in Unit 3.

evolutionary change a change that occurs in an entire population; usually occurs over a long period of time

Evolutionary changes usually occur over long periods of time and over long distances. However, in a particular location and at a particular time, species generally change little. For example, raccoons from Ontario may vary significantly from those in South America, but are much less variable within the Greater Toronto Area.

Biodiversity

Species come in all shapes and sizes—from microscopic organisms to massive marine mammals (**Figure 4**). Different species vary in their behaviours, habitats, ecological niches, and abundance. They also vary in their genetic makeup, referred to as **genetic diversity**. Individuals of a sexually reproducing species inherit unique combinations of genetic information from their parents. This produces genetic diversity. Examples of human genetic diversity are differences in hair, skin, and eye colour, as well as in facial features and adult height.

genetic diversity the genetic variability among organisms; usually referring to individuals of the same species

How do biologists make sense of this enormous array of diversity? What role does the diversity of life play in the functioning of ecosystems? Just how important is biodiversity? To begin to answer these questions, we will examine diversity in ecosystems.

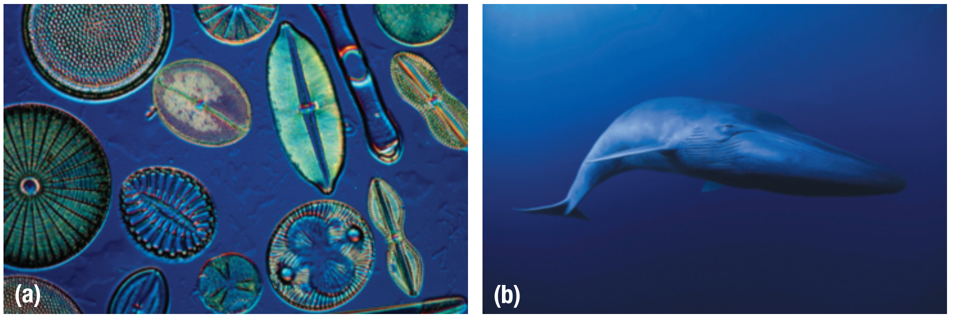


Figure 4 (a) This light microscope image shows several diatoms. Diatoms are a distinctive group of single-celled algae, characterized by their intricately patterned, glass-like cell walls. Diatoms form an important part of the plankton at the base of the marine and freshwater food chains. There are over 10 000 species of diatoms. (b) The blue whale is thought to be the largest animal that has ever lived. Its tongue alone weighs more than 2500 kg!

Diversity in Ecosystems

heterotroph an organism that obtains energy-rich nutrients by consuming living or dead organisms

autotroph an organism that uses sources of energy to produce nutrients from water, gases, and/or minerals

Ecosystems are made up of many different species and their physical environment. All these species depend on other species in some way for their own survival. For example, organisms that cannot make their own food, called **heterotrophs**, feed on other living or dead organisms. Even organisms that are able to make their own food, called **autotrophs**, are dependent on other organisms. Plants are examples of autotrophs. They depend on micro-organisms to recycle nitrogen, carbon, and other nutrients as part of biogeochemical cycles, and many depend on animals for pollination.

CAREER **LINK**

Ecologists

Ecologists are scientists who study ecosystems. To learn more about becoming an ecologist,

GO TO NELSON SCIENCE

Diversity of Interactions

The interdependence of one species on another goes far beyond simple food chains and biogeochemical cycles. For example, the important activities and processes of one species may depend entirely on another species for success (**Table 1**, next page).

Species support each other, and they also contribute to the stability and productivity of their ecosystems. Plant communities with a greater number of species are better able to withstand and recover from diseases, climate extremes, and pest infestations. They are also more biologically productive than plant communities with fewer species. For example, researchers have found that grasslands with mixed species are more than twice as productive as grasslands planted with a single species.

Of course, the larger the population of a species, the more interactions it will have. Diversity is therefore also influenced by the total number of individuals present in an ecosystem. An ecosystem with many large populations is considered more diverse than an ecosystem made up of smaller populations. For example, an ecosystem with 10 species—each with 500 individuals—is considered more biologically diverse than an ecosystem with 10 species—each with only 50 individuals.

species diversity a measure of diversity that takes into account the quantity of each species present, as well as the variety of different species present

The term **species diversity** describes both the variety of species in an ecosystem and the number of individuals within each of those species. The greatest species diversity exists in ecosystems with many different species that each have large populations.

Diversity of Habitats

structural diversity the range of physical shapes and sizes within a habitat or ecosystem

The range of physical sizes, shapes, and distribution of the individuals, as well as habitats and communities in an ecosystem, are together referred to as **structural diversity**. Structural diversity is critical for biodiversity because it creates microhabitats with a variety of abiotic conditions (**Figure 5**).

An ecosystem with greater structural diversity can support a greater diversity of species—it has greater biodiversity. This is why the biodiversity of a healthy rainforest is much greater than that of an even-aged tree plantation, in which all trees are the same height (**Figure 6(a)**). Aquatic ecosystems also exhibit a great range of structural diversity. Flat, smooth ocean bottoms offer little shelter for organisms, while irregular bottoms with rocks, reefs, logs, or even sunken ships enhance the range of microhabitats available for organisms (**Figure 6(b)**).

Figure 5 This mature forest has abundant structural diversity.

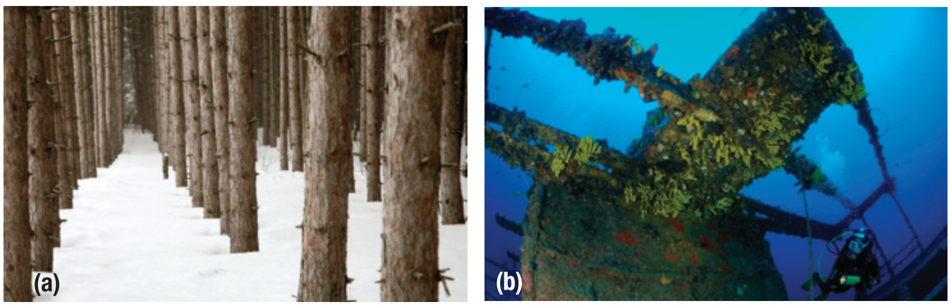
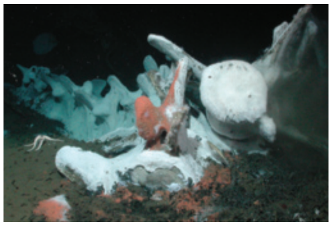
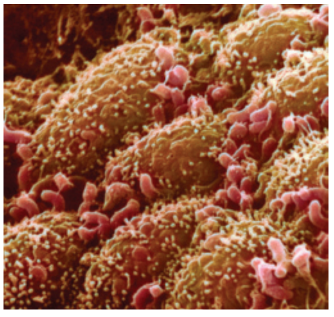


Figure 6 (a) Even-aged tree plantations, often established after clear-cutting, exhibit almost no structural diversity. (b) Artificial reefs made from sunken ships or aircraft increase the structural diversity of the ocean bottom.

All this variety challenges biologists to create methods of distinguishing and identifying species that resemble one another, and to name and categorize species in a systematic and consistent way.

Table 1 Species Interactions

Interaction	Examples (Organisms shown in the photos are bolded.)	
Food supply: Complex relationships exist between species and their food.	• **Boneworms feed exclusively on the bones of dead whales** that sink to the bottom of the ocean. • Photosynthetic micro-organisms live inside the bodies of giant clams and coral animals on reefs. They perform photosynthesis and supply the clams and corals with a steady supply of food.	
Protection: Many species depend on others for shelter and protection.	• Hermit crabs use the shells of dead snails for a protective home. • **Certain species of ants live within the trunks of *Cecropia* trees.** The trees provide shelter for the ants. The ants protect the tree by biting and stinging any herbivores that try to eat from it.	
Transportation: Many species move from place to place with the help of another species.	• Some flower mites climb onto the bills of hummingbirds moving from flower to flower feeding on nectar. • **Many seeds have hooks that allow them to stick to passing animals.** They can then be carried long distances before they fall off and begin growing.	
Reproduction: Many species depend on other species for their own successful reproduction.	• Trilliums produce seeds with fleshy tissues that attract ants. The seeds are then gathered and dispersed by the ants. If the ants do not feed on this outer seed tissue, the seeds cannot germinate. • Many bird species build their nests in the abandoned **tree cavities made by woodpeckers for their own nests.**	
Hygiene: Some species help maintain the health of another species.	• Coral reefs have "cleaning stations" where **large fish come to have external parasites removed by small fish and shrimp.** • The bacteria that naturally live on our own skin help protect us from other bacterial and fungal infections.	
Digestion: Species living within digestive tracts are essential for the digestion of food.	• Termites consume wood but are almost entirely incapable of digesting it themselves. Instead, a variety of bacteria and other micro-organisms living within the termites' guts do the digestion for them. • **Bacteria living in the large intestines of humans** produce vitamins that are absorbed into the circulatory system.	

Biodiversity at Risk

There is no doubt that all species depend on one another. Maintaining and enhancing biodiversity is essential for the health and sustainability of ecosystems. Although more than 10 000 new species are discovered each year, there is grave concern among the world's leading biologists that the diversity of life is declining rapidly.

The loss of biodiversity affects humans in many ways. Loss of biodiversity

- threatens our food supply when entire species and plant varieties are lost
- eliminates sources of natural medicines and potential new medicines
- has a significant economic impact on tourism and forestry when accompanied by habitat destruction
- has the potential to cause serious disruptions in biogeochemical cycles, including normal carbon uptake by natural ecosystems

Species extinction is a natural process. Some biologists estimate that a new species will, on average, become extinct after approximately one million years. Of course, extinction rates for species are variable and may be relatively low at times and relatively high at others.

The history of life on Earth includes a number of mass extinction events—relatively short time spans during which a large proportion of Earth's species became extinct. The most famous mass extinction event occurred approximately 65 million years ago and resulted in the extinction of most dinosaurs.

Past mass extinction events have been linked to large-scale disruptions in Earth's climate, caused by factors such as comet and meteor impacts, and volcanic activity. A change in climate may make conditions too hot or cold, or too wet or dry for species adapted to the original climatic conditions. In contrast, today's high rate of species extinction is tied directly to human activity. Human actions are resulting in a rapid loss of natural habitats due to agriculture, forestry, urban expansion, the introduction of invasive species, over-harvesting of wild populations, and serious air and water pollution. The production of greenhouse gases is also resulting in human-caused climate change. These human actions, among others, are now operating on a global scale and are increasing the rate of species extinction.

Many Canadian species, especially those living in the Arctic, are already feeling the impact of climate change. Caribou depend on lichens and small ground plants as a source of food. While a milder climate does not harm caribou directly, it is causing changes in Arctic vegetation. Smaller plants are being displaced by larger shrubs, reducing the available food supply for the caribou (**Figure 7**).

WEB LINK

To learn more about extinct species and species currently at risk,

GO TO NELSON SCIENCE

CAREER LINK

Conservation Biologists
Conservation biologists study the threats to species and their habitats. To learn more about this career,

GO TO NELSON SCIENCE

Figure 7 This healthy caribou is shedding the "velvet" from its set of large antlers. Unfortunately, caribou and other Arctic species are already starting to feel the impacts of climate change.

While it is not possible to know the precise rate of species extinction, Edward O. Wilson, one of the world's most eminent biologists and an authority on biodiversity, conservatively estimates losses at a rate of 27 000 species per year. He believes we are witnessing a new mass extinction event—one that we are causing.

1.1 Summary

- The biological species concept defines *species* as a population of individuals that are able to freely breed under natural conditions.
- Biologists have identified and described more than 1.7 million species.
- All species depend on other species in a variety of ways for their own survival.
- Species evolve over time and space.
- Biodiversity refers to the variety of species in an ecosystem but also includes structural diversity within ecosystems and individual variability within species.
- New species are still being discovered, but biodiversity is under threat from many human activities.

1.1 Questions

1. Suggest three examples of species that clearly fit the definition of a species based on the biological species concept. Explain your choices. K/U
2. Explain why some species must be defined based on their morphology rather than on reproductive behaviour. K/U
3. Different forms of a species—like the subspecies of eastern rat snakes—are associated with different geographic locations. Suggest a possible explanation for this. T/I
4. Distinguish between an autotroph and a heterotroph. Include examples. K/U
5. Species are involved in a diverse range of interactions. Provide a specific example of each of the following types of interactions. K/U A
   (a) One species removes parasites from another species.
   (b) One species needs help from another species in order to reproduce.
   (c) One species defends another species against attack.
   (d) One species transports the offspring of another species.
   (e) One species provides a place for another species to live.
6. Describe four ways in which one species may be dependent on another for its survival. Include an example for each. K/U A
7. What is meant by the following terms? K/U
   (a) biodiversity
   (b) structural diversity
   (c) genetic variability
8. Analyze some ways in which a loss of biodiversity might affect the following industries: T/I A
   (a) agriculture and forestry
   (b) tourism
   (c) healthcare
9. Conduct research and describe one or two methods scientists and organizations use to increase the biodiversity of damaged ecosystems. T/I
10. How could the structural diversity of the following environments be increased? K/U
    (a) a landowner who wants to increase the structural diversity of an even-aged tree plantation
    (b) a government agency that wants to increase the structural diversity of a new marine park
11. Consider the numbers of species known to exist on Earth, including the numbers that are being discovered and the numbers thought to be going extinct. What do these numbers suggest about biodiversity on Earth? T/I
12. At the current rate of extinction, approximately how many years will it take for one million species to become extinct? T/I
13. E.O. Wilson estimates that the current extinction rate may be as much as 10 000 times as great as it would be without humans. What are some of the primary human activities responsible for this increased rate of extinction? K/U
14. Using the Internet and other resources, research how climate change is affecting biodiversity in the Arctic. K/U T/I
    (a) What changes in the climate have been observed to date?
    (b) How is climate change affecting the structural diversity of Arctic ecosystems?
    (c) Why are changes in Arctic ecosystems significant for the rest of the world?
15. Consider an ecosystem that you are familiar with (for example, a park near your home or school.) K/U T/I A
    (a) Why is biodiversity important to that ecosystem?
    (b) Brainstorm how loss of biodiversity would affect your chosen ecosystem.

GO TO NELSON SCIENCE