UNIT 2

Ecosystems and Population Change

General Outcomes

In this unit, you will

- explain that the biosphere is composed of ecosystems, each with distinctive biotic and abiotic components
- explain the mechanisms involved in the change of populations with the passage of time

Unit Contents

Focussing Questions

1 What components make up the environment of a population of lawn dandelions in southern Alberta? How do these components compare with those that make up the environment of a population of lawn dandelions in northern Alberta?

2 Which factors could influence the rise and fall of populations of lawn dandelions in any environment?

3 How can changes in populations over thousands and millions of years be explained scientifically?

Unit PreQuiz

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For outdoor enthusiasts, the St. Mary Reservoir near Cardston in southern Alberta is a popular destination. For scientists, this reservoir is a gold mine for hiking into Alberta's past. University of Calgary archaeologist, Brian Kooyman, calls this site "one of the best preserved areas of ancient animal tracks in North America—possibly the world." Here, more than 10 000 years ago, as the ice sheets that covered much of Alberta receded, ancient animals—many of them now extinct—roamed. Mammoths, bison, camels, wolves, and pony-sized horses have left evidence of their existence, mainly in the form of fossilized bones and footprints. Scientists once thought that the North American horse (*Equus conversidens*) became extinct due to its inability to adjust to climate changes. They now have a different hypothesis, as a result of laboratory techniques used to identify blood proteins found on spear points: another animal—humans—hunted the horses, perhaps to extinction.

In this unit, you will learn how populations of plants, animals, and other organisms interact with one another and with their environment. You will also consider how changes in a population of organisms, as well as in a specific environment, occur with the passage of time.

UNIT 2 Preparation

Prerequisite Concepts

This unit builds on your knowledge of interactions of organisms within ecosystems from Unit 1, and it draws upon your knowledge of biological diversity and energy transfer in global systems from previous studies.

The Need for Reproduction

All species of organisms grow and produce offspring and, in so doing, pass on their hereditary information to succeeding generations. Thus, reproduction is essential to the survival of a species.

In order for multicellular organisms to grow, repair themselves, and reproduce, their cells undergo division. While many cells in your body, for instance, are growing and dividing, some are wearing out and dying. Cells reproduce through a continuous sequence of growth and division known as the cell cycle. The cell cycle consists of two main stages, the growth stage and the division stage. There are two types of cell division: *mitosis* and *meiosis*.

Mitosis

In mitosis, body cells (but not reproductive cells) divide to form two new cells, which are identical to the parent cell. Before a cell divides, the chromosomes first replicate (make copies of themselves). The cell then divides. The resulting two cells have the same number of chromosomes as the parent cell. (Chromosomes consist of DNA, the genetic information of a cell.) So, if a body cell has 46 chromosomes (as human cells do) after mitosis, the "daughter cells" also have 46 chromosomes.

Meiosis

Meiosis is a special type of cell division that occurs only in reproductive cells (sperm cells and egg cells). Meiosis

Table P2.1 Comparing Mitosis and Meiosis

Mitosis	Meiosis
one division	two divisions
two daughter cells	four daughter cells
daughter cells are genetically identical	daughter cells are genetically different
chromosome number in daughter cells same as in parent cell	chromosome number in daughter cells half that in parent cell
occurs in somatic (body) cells	occurs in reproductive cells (sperm and egg cells)
used for growth and repair of body cells (and in asexual reproduction in some organisms)	used for sexual reproduction, producing new genetic combinations in offspring from one generation to the next
	

produces reproductive cells called gametes. During meiosis, the nucleus of a gamete divides twice. The gametes, either egg or sperm, contain only one copy of each type of chromosome that the parent cell contains. So, in humans for example, the gametes from each parent contain only 23 chromosomes. Meiosis ensures that when a sperm fertilizes an egg, the resulting cell has the correct number of chromosomes. In humans, this is 46. (If the gametes did not go through meiosis before fertilization, there would be 92 chromosomes in humans.) Table P2.1 and Figure P2.1 compare meiosis with mitosis.

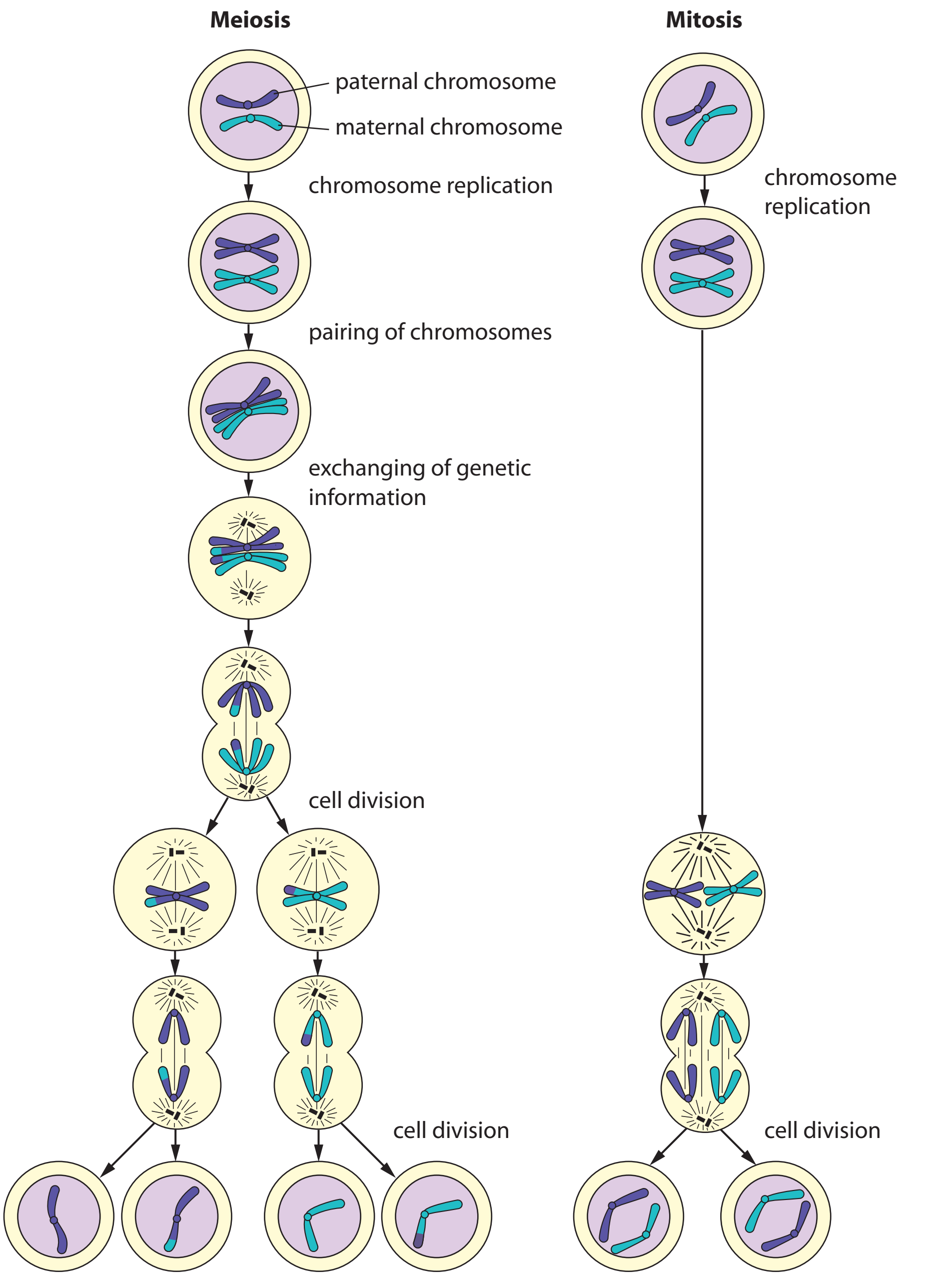
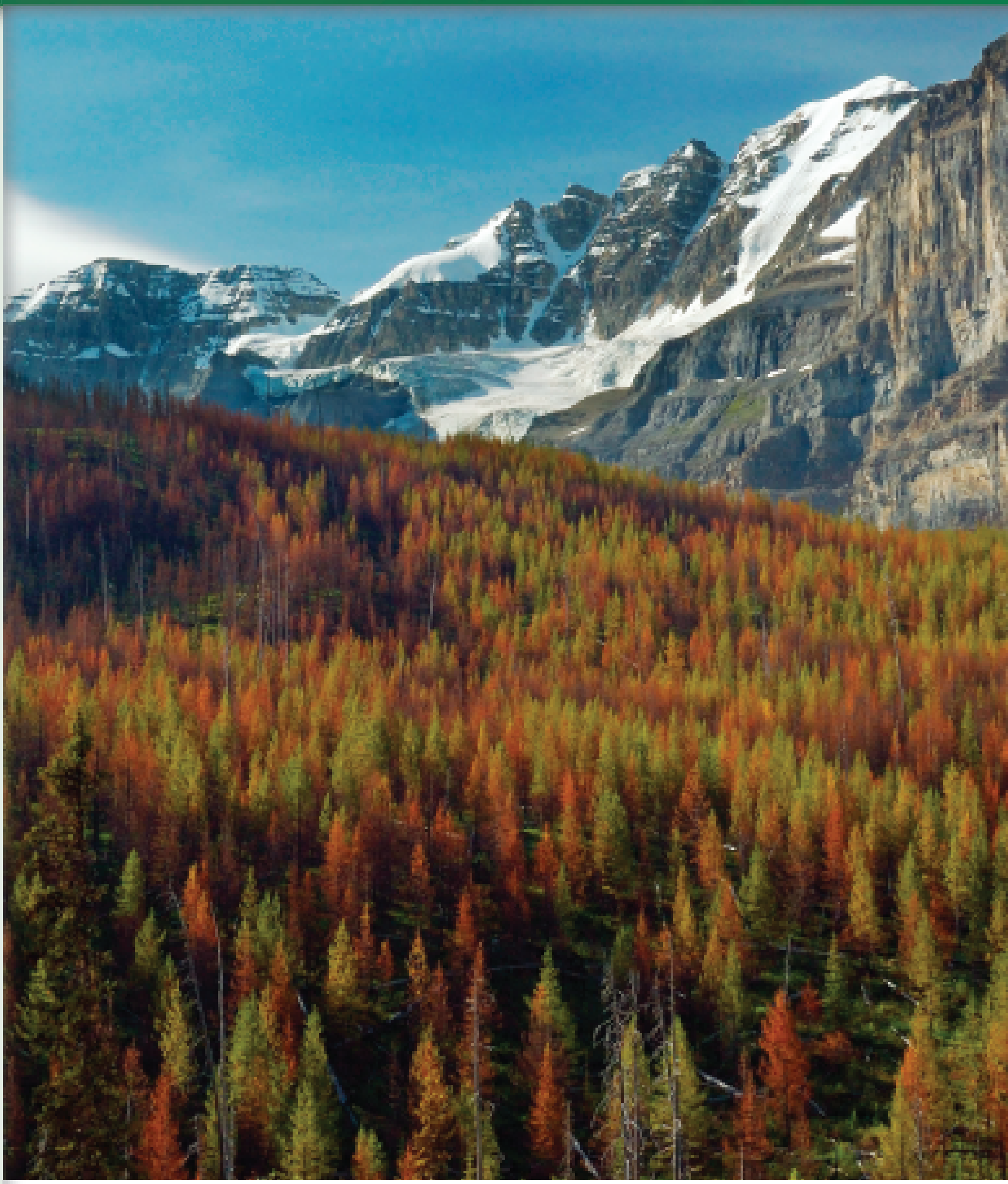


Figure P2.1 Meiosis involves two divisions of the nucleus with no replication of genetic material between them. Thus, it produces four daughter cells, each with half the original number of chromosomes. Mitosis involves a single division of the nucleus after chromosome replication. Thus, it produces two daughter cells, each containing the original number of chromosomes.

CHAPTER

3

Ecosystems and Their Diversity



Chapter Concepts

3.1 Individuals, Populations, and Communities in Ecosystems

- The distribution and abundance of organisms depend on interactions among organisms, and between individuals and their environments.
- An organism's environment includes abiotic and biotic components.
- Interactions between organisms and their environment can be categorized based on: individuals, populations, communities, and ecosystems.

3.2 Classifying and Naming Organisms

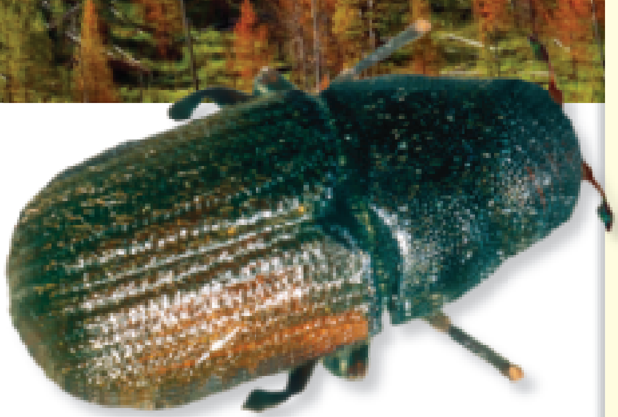
- Organisms are organized into groups (such as kingdoms), depending on shared biological characteristics.
- Internationally, scientists use a biological system of binomial nomenclature (two-word naming systems).
- Dichotomous keys are used to identify the two-word scientific name for individuals of a species.

3.3 Studying Organisms in Ecosystems

- Each biome has a particular mix of organisms that are adapted to living in its environmental conditions.
- Organisms have habitats, ranges, and ecological niches in ecosystems.
- Limiting factors influence the distribution, range, and abundance of organisms.
- Scientists take random samples to estimate population sizes.
- Sampling techniques include censuses, transects, and quadrats.

A healthy ecosystem is thick with populations of diverse organisms. The ecosystem shown here is characterized by some unhealthy populations. In the southern interior of British Columbia, one species—the mountain pine beetle—has been destroying large tracts of lodgepole pine, with consequences for all other organisms in the area. The mountain pine beetle infestation is an example of the failure of mechanisms that ensure the health of an ecosystem.

In this chapter you will see how organisms interact with their environment and other organisms, study the mechanisms that keep organisms and ecosystems healthy, and learn how scientists identify organisms and measure and record diversity. You'll practice using scientific tools to distinguish organisms and track and estimate populations of organisms within a local ecosystem.



The mountain pine beetle (*Dendroctonus ponderosae*) has devastated pine forests in British Columbia, and lodgepole pine trees (*Pinus contorta*) in Kakwa Wildland and Willmore Wilderness Parks in western Alberta have been treated for infestations. (Adult size 4 to 7.5 mm.)

Launch Lab

The Mountain Pine Beetle vs an Ecosystem

The lodgepole pine grows in the North American west, as far north as the Yukon. It tolerates most soil conditions; cold, wet winters; and warm, dry summers. Seed cones can withstand freezing temperatures and most insects. The trees have fairly thin bark and a shallow root system, making them susceptible to damage by fire and insects; however, the high temperatures of fires release the seeds to quickly regenerate trees after a forest fire. During the last hundred years, forest fires have been controlled and suppressed.

The mountain pine beetle is a common parasite of the lodgepole pine. Adult beetles bore through the thin bark to lay eggs and deposit a fungus carried on their bodies. The larvae live in and feed on the bark during the winter, as does the fungus. The bark damage usually kills the host tree, although sustained temperatures of –25 °C during the early fall or late spring or temperatures of –40 °C during winter can kill the larvae. Infestations usually last 5 to 7 years and happen in 20- to 40-year cycles.

The pine beetle infestation began in British Columbia in 1993, and over a decade later residents in affected areas are reporting:

- small mammals such as squirrels have disappeared
- song birds have left the area
- trap lines are increasingly empty
- cougars are coming to settled areas and preying on family pets
- devil's club, a plant used for Aboriginal medicine, is increasingly hard to find

Analysis

1. What biotic and abiotic components of the environment affect the life cycle of the lodgepole pine? What biotic and abiotic components of the environment affect the life cycle of the mountain pine beetle?

2. Can you suggest reasons why the current mountain pine beetle infestation has lasted longer than the usual 5 to 7 years?

3. What can you infer from the local reports about the impact of the loss of the trees on other organisms?

Extension

4. Choose one of the following roles and write or present a short paragraph on how the pine beetle infestation affects you as:

a) a local elder

b) a logger

c) a planner for the department of forests

d) a wilderness tour operator

SECTION 3.1

Individuals, Populations, and Communities in Ecosystems

Section Outcomes

In this section, you will
- **define** and **explain** the interrelationship among individual organisms, populations, communities, and ecosystems
- **recognize** different aspects of ecosystems that ecologists might study
- **plan** and **design** an investigation to study a local ecosystem

Key Terms

biotic
abiotic
species
population
community
ecosystem
biosphere

Figure 3.1 Pronghorn (*Antilocapra americana*) are found in southern Alberta. This is the northern extent of their distribution in North America. At one time, there were herds of close to 40 000 000 pronghorn in North America. Now there are fewer than 30 000. What factors might affect their distribution and abundance?

Among North American mammals, the pronghorn, shown in Figure 3.1 and once thought to be a North American relative of the African antelope because of its physical resemblance, is the swiftest, with a speed of up to 80 km/h. This speed, and the pronghorn's ability to sustain it over long distances, indicate that the pronghorn is well-adapted to living in the open plains environment. How does the pronghorn interact with its environment? What does the pronghorn eat, and what eats it? What physical and behavioural characteristics make the pronghorn well-suited for life in its environment? Why has the pronghorn survived on the open plain, while other organisms have not?

Organisms and Their Environment

The term "environment" refers to everything that affects an organism throughout its life, as well as everything that the organism affects. Throughout a pronghorn's life, it will come in contact with many different organisms: other pronghorns, insects, bacteria, foods such as grasses, other mammals it can co-exist with, and predators such as coyotes. These are what ecologists call the living—**biotic**—components of its environment. As well, a pronghorn will drink large amounts of water, breathe even larger quantities of air, and roam in hundreds of hectares of soil throughout the four seasons. Ecologists call these components of the environment, such as sunlight, water, and minerals, **abiotic**, or non-living.

Every organism on Earth—including you—affects, is affected by, and therefore interacts with the biotic and abiotic components of its environment.

1. Identify three biotic components and three abiotic components of a pronghorn's environment.
2. Identify three biotic components and three abiotic components of your environment.
3. Identify three biotic and three abiotic components of a starfish's environment.

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FYI
Western science has divided the physical world into living and non-living components in order to describe and explain organisms and their interactions. Other cultures do not make the same distinction. For example, Aboriginal people in North America consider all elements of the world to be living.

Figure 3.2 The starfish is an individual organism; it is shown here among a population of sea urchins. These organisms are living in a community of other organisms, or biotic components. The community is part of an ecosystem, which is also shown here. The ecosystem includes the biotic and abiotic elements *plus* their interactions.

Ecologists—scientists who study the interactions of organisms with one another and their environment—usually focus on a specific level of an environment, ranging from the smallest component to a more inclusive and complex picture. As highlighted in Figure 3.2, these levels include individual organisms, populations, communities, and ecosystems.

Individual Organisms

Ecologists who study individual organisms want to learn how the abiotic environment in which an individual lives affects its behaviour or physical features. For example, an ecologist might investigate the physical features of a species of alpine plant that allow it to live in an environment that is cold, dry, and windy. Another ecologist might study why a particular species of snail, the Banff Springs snail shown in Figure 3.3, only lives in seven thermal springs in Banff National Park and nowhere else in the world. Investigations like these help to explain the distribution of organisms—that is, why organisms are only present in certain locations. Abiotic conditions affect the distribution of organisms.

In the investigation on the next page, you will measure how the *morphology* (physical appearance) of an organism can change when abiotic conditions change.

Populations

Organisms that are able to breed with one another and produce fertile offspring are known collectively as a **species**. The concept of species is related to the next level of ecological organization: population. A **population** is a group of individuals of the same species living in a specific area at the same time. Population ecologists describe changes in the size of a population, its abundance, as time passes. For example, they may study how the population of lilies in the Bugaboo Mountains, shown in Figure 3.4 on the next page, increases, decreases, or remains the same during a period of time. They might also study the rate at which a population changes in size, and what factors determine the relative numbers of males and females (or young and old) in a population.

Population ecologists from Alberta are studying how populations of collared pika (see Figure 3.5A on page 81.) are changing. Pikas, which are related to rabbits, live among boulders in alpine

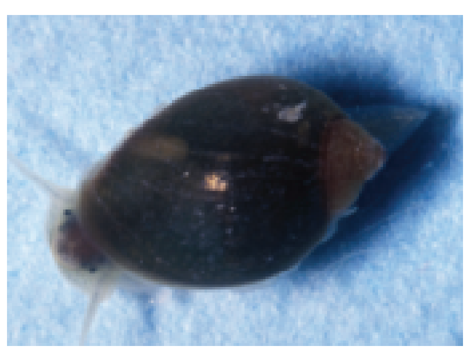

Figure 3.3 The adult Banff Springs snail (*Physella johnsoni*) has a shell length of about 5 mm. It is found in only a small number of hot springs in Banff National Park. What abiotic and biotic components allow it to live in water as hot as 36 °C?

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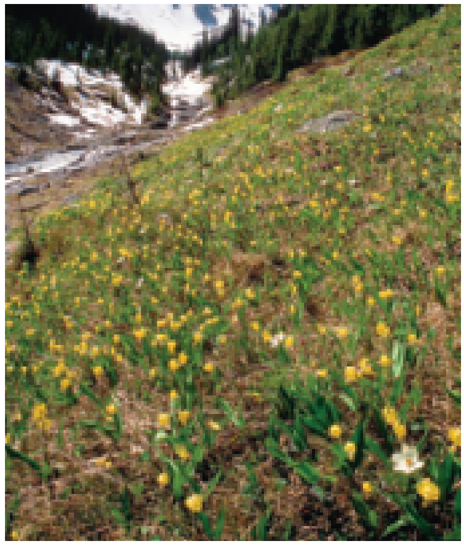
FYI

Antilocapra americana is often called an antelope, because it resembles animals that live in Africa and Asia. In fact, the pronghorn is the only modern, surviving member of a family called *Antilocapridae*, found only in North America. You will review the classification of organisms later in this chapter, in Section 3.2.

Figure 3.4 Each of these glacier lilies (*Erythronium grandiflorum*) is part of a population. How would you define this population? Can you identify its edges or boundaries? Why do you think it's a boundary?



regions. They forage on grasses and flowers, which they hoard in small "haystacks" in their tunnels for use in the winter. Studies, such as those carried out by ecologist Dr. David Hik of the University of Alberta, have shown that pikas are particularly vulnerable to changes in temperatures. After a series of warmer winters, starting in 1998, populations in one study area declined markedly, as shown in Figure 3.5B. The researchers hypothesize that rising temperatures associated with global warming have resulted in changes in vegetation, so the pikas have less to eat. As well, the lack of snow pack during warm winters may reduce the amount of snow that usually covers the pikas' rock-tunnel homes. Consequently, during cold spells, there may not be enough snow to provide the "insulative blanket" the pikas need to survive.

Communities

In nature, populations are rarely isolated. Instead, populations of different species interact with one another as part of a community. A **community** consists of all

INVESTIGATION 3.A

Target Skills

Measuring biotic characteristics of ecosystems and speculating on their relationship to abiotic characteristics

Working cooperatively to gather and share data

Observing Leaves

Changes in abiotic conditions, such as the amount of moisture or salt in soil or the amount of available sunlight, can result in changes in the morphology of a plant. In this investigation, the class will measure the leaves of a plant in two locations with different abiotic conditions to see how the different conditions affect a plant's morphology.

Materials

- ruler
- materials for recording data

Procedure

1. With your teacher, determine an area to study. You will be measuring the leaves of a plant species in two locations that have different abiotic conditions. For example, you could measure the leaves of a tree near a stream and a tree of the same species some distance away from the stream, dandelions in a field that is regularly mowed and dandelions in a field that is "wild," or a plant near a roadway and a plant of the same species in a nearby forested area.
2. Predict if there will be any differences in measurements for the plants in the two locations.
3. Working in pairs, measure the length at least 25 leaves on plants in each location and record the data. (If you are measuring leaves on a tree or shrub, use a larger sample size, such as 100 leaves. Take care not to endanger yourself or the plant during this activity.) Determine the average leaf length in each study area.

Analysis

1. Describe how the abiotic conditions in the two locations differ.
2. Was there a difference in average leaf size in the two locations?
3. If there was a difference, hypothesize why, making reference to abiotic conditions.

Figure 3.5A Yukon populations of collared pika (*Ochotona collaris*) declined dramatically between 1998 and 2000. Researchers acknowledge that they have much to learn about this species, but they hypothesize that rising global temperatures may be linked to the pika's decline.

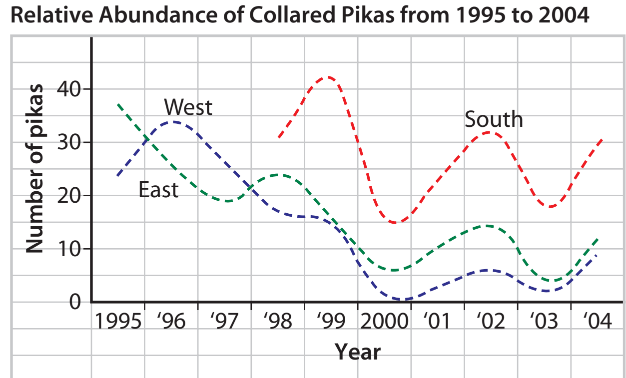


Figure 3.5B This graph shows how the number of collared pikas changed during a nine-year period on three slopes (east, west, and south) in the southwest Yukon study area of Ruby Range.

of the individuals in all of the interacting populations in a given area. Community ecologists typically study the interactions among the members of different populations. For example, they may be interested in why some communities are made up of many different species, while other communities contain only a few. In one study in Saskatchewan, for example, community ecologists compared the number of species of birds within sections of intact forest to the number of species in "forest fragments" (small stands of forest surrounded by agricultural land). They found that species that preferred to be in the interior of forests were more common in the larger, intact forests. Species that preferred the "edges" of forests, such as predatory birds, were more common in the smaller forest fragments.

Interactions that might influence the structure of a community include competition between individuals of the same species in different populations, as well as the relationship between predator and prey populations. Abiotic factors (such as how much moisture is present or the number of hours of sunlight) also have a strong influence on which and how many species live in a community. So, for example, a community ecologist might study how bird species compete for nesting habitat, or how prolonged droughts change the composition of plant species growing in a particular area.

Environments Change Over Time

Most communities are dynamic; they continue to change as abiotic conditions in the environment change (see Figure 3.6 on the next page). As the population level of one organism fluctuates, this affects the population levels of other organisms that may consume or be consumed by the organism. As well, as populations in a community interact with one another, they can modify the environment so that it becomes more suitable for other species. These other species then gradually take over and form a new community. For example, after a disturbance such as fire, an open area is created in a forest. The first organisms to establish themselves in this open area are members of species that do well in open, disturbed habitats. As these first organisms inhabit the area, they create shade, alter the soil, and, in various other ways, make the habitat less suitable for species like themselves and more suitable for other species.

Similar changes in communities occur whenever new habitat is available to support life. New habitat may be available after a rockslide, flood, or volcanic eruption, or after a glacier recedes. A century or more after ice has melted, a lush meadow (such as the one in Figure 3.6 on the next page) will grow,

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Try This
Alpine and arctic areas are some of the first places to show the effects of rising temperatures. Some plants, for example, are extending their range higher up mountainsides. As well, the loss of northern ice pack is changing the population size and reproductive success of polar bears and walrus. With a partner, discuss how other organisms might be affected as a result of these changes.

Figure 3.6 Communities that inhabit an area can change as time passes. When glacial ice first melted, populations of lichens and mosses were some of the first species to establish themselves in the area shown here. Eventually, soil was created and new plants began to grow. How might this meadow look in 200 years?

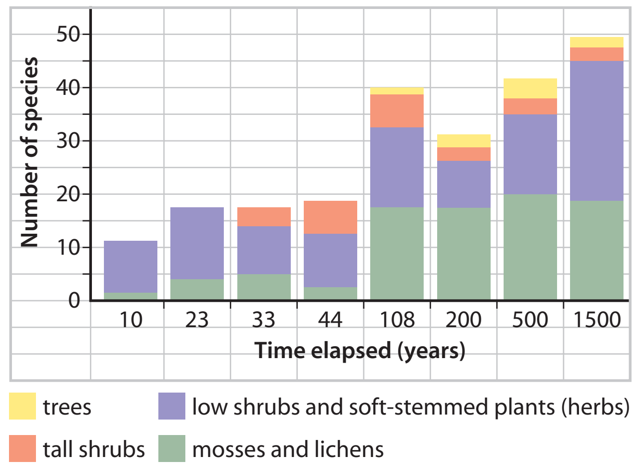

Figure 3.7 As time passed in this community, the number and type of species changed, growing on till that was exposed by a melting glacier. Why would you not expect to find evidence of trees growing until 100 years or more had passed?

with willows, wild flowers, grasses, and heathers. Several centuries later, a forest might cover this meadow. Figure 3.7 shows changes in a community as time passed after a glacier retreated in Glacier Bay, Alaska, United States.

Q 4 Describe an interaction that could occur between two organisms in a community.

Ecosystems

A community of populations, together with the abiotic factors that surround and affect it, is called an **ecosystem**. An ecosystem includes all of the non-living parts of the environment in a particular area and all the living organisms, as well as the interactions among them.

Although people often think of ecosystems as being quite large, they can be very small. In fact, the size of an ecosystem depends on what you are studying. There are small ecosystems within large ecosystems, which are within even larger ecosystems. For example, the lichen-covered boulder in Figure 3.8 could be considered an entire ecosystem. It contains a community of living things, together with abiotic components such as air, water, and minerals. This ecosystem interacts with, and is part of, a larger ecosystem that contains the community of organisms living in the scree slope, or avalanche chute, where the boulder might be found. Both of these ecosystems are part of an even larger ecosystem, which extends beyond the boundaries of the

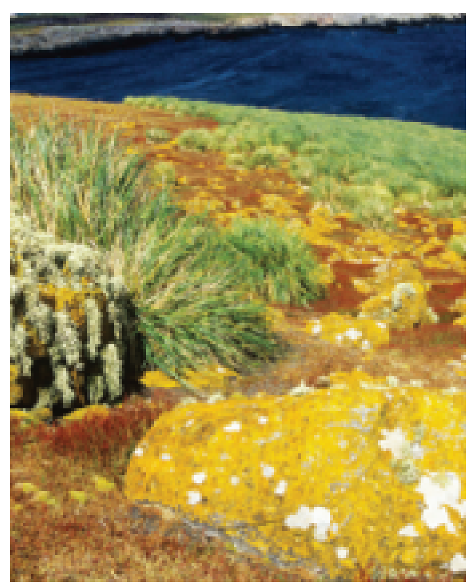

Figure 3.8 This boulder ecosystem is part of the larger ecosystem of organisms on the avalanche path. What bar of the graph shown in Figure 3.7 does it most closely resemble?

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Try This
Draw a diagram (either by hand or on a computer), or use a variety of coins or other small items you can manipulate, to compare and contrast the following ecological levels of organization: individuals, populations, communities, and ecosystems.

photograph. To prepare for your final investigation in this chapter, you will think about local ecosystems in the next Thought Lab.

The Bigger Picture: Earth's Biosphere

All the ecosystems in the world and their interactions make up the **biosphere**. You can think of the biosphere as the largest possible ecosystem. The biosphere includes all parts of Earth that are inhabitable by some type of life (in other words, all the land surfaces and bodies of water on Earth) and extends several kilometres into the atmosphere and several metres into the soil. All living things that inhabit these environments, as well as the abiotic components with which they interact, are part of the biosphere.

Populations are not randomly scattered throughout the biosphere, however. Each species has its own "place" in the biosphere. For example, mountain goats live in specific places in Canada, as shown by the range map in Figure 3.9. They do not live across the entire country. As you now know, the distribution of a species is related to the ways the biotic and abiotic components of an environment affect individual organisms and their ability to survive. In order to study distribution, however, ecologists must first be able to accurately identify the organisms they encounter. You will learn how to do this in Section 3.2.

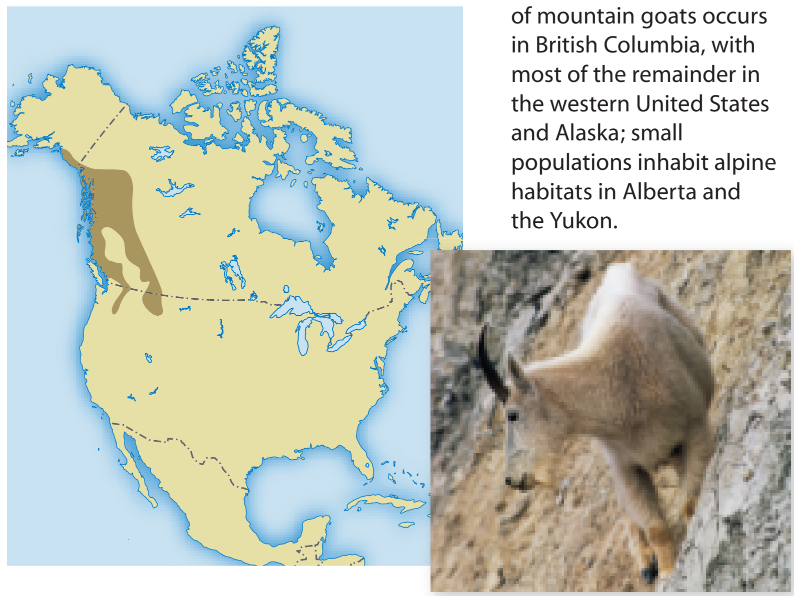


Figure 3.9 With their dense, insulative fur, powerful shoulder muscles, dexterous toes, and adhesive-like hoof pads, mountain goats (*Oreamnos americanus*) are able to live in the high mountain regions of western North America—the only places these animals are found naturally on Earth. About half the world population of mountain goats occurs in British Columbia, with most of the remainder in the western United States and Alaska; small populations inhabit alpine habitats in Alberta and the Yukon.

Thought Lab 3.1 Planning for Your Field Study

Target Skills

Planning a field study to compare biotic and abiotic components of two ecosystems

Working cooperatively to gather and begin organizing data for a field study

Selecting and **using** appropriate technologies to aid in effective communication

When Dr. David Hik set out to study the collared pika, he planned and carried out a field study. When staff at Alberta's Ministry of Sustainable Resources Development wanted to monitor the mountain pine beetle in Alberta's pine forests, they planned and carried out field studies. At the end of this chapter, you will take part in a field study to investigate and compare two ecosystems. Throughout this chapter, you and your group will be preparing for your field study. Here, you will begin your preparations by considering individuals, populations, and communities within two ecosystems.

Procedure

1. Read Investigation 3.D on page 106 so you can see what you will be doing in your field study.
2. As a group, brainstorm a list of possible local ecosystems that you could use as the focus for your field study. Recall that ecosystems can vary in size. Choose two ecosystems from your list. They should be similar types of ecosystems but in different locations. For example, one ecosystem could be a small pond in a forested area, and the other ecosystem could be a nearby water-filled ditch. Or one ecosystem could be a regularly mowed field, and the other ecosystem could be a nearby area that is not regularly mowed.
3. Decide on a method you will use to store and organize the information you gather during your field study. For example, you might use an electronic filing system.
4. Individually, choose one species that lives in both ecosystems you plan to study. From your experiences and observations, or after completing research, write a paragraph that explains how this species interacts with the abiotic and biotic components of its environment. For example, what eats this species, and what does it eat? What are its nutrient requirements?

Analysis

Describe the typical (a) population, (b) community, and (c) ecosystem of the species you chose in step 4.

Section 3.1 Summary

- An environment includes biotic and abiotic components.
- Ecologists divide the interactions between organisms and their environment into four levels: individual organisms, populations, communities, and ecosystems.
- Ecologists tend to specialize and focus on one level of an environment. They could be population ecologists, community ecologists, or they could spend their time studying an individual organism or an entire ecosystem.
- The study of an individual organism includes the effect of abiotic elements of its environment on physical features or behaviour.
- The study of a population includes all the members of the same species living in a specific area, plus their interactions with and the effects of the abiotic elements of their environment.
- The study of a community includes all individuals of all interacting populations in a specific area, and the effects of the abiotic elements of the environment.
- The study of an ecosystem includes all biotic and abiotic elements and their interactions.
- Most communities change over time because the abiotic elements change over time. Changing abiotic elements affect organisms and their interactions on all levels.

Section 3.1 Review

1. In ecological terms, describe the difference between a population and a community.
2. Define the term ecosystem and explain how a fallen tree in a forest could be regarded as an entire ecosystem.

Use the following information to answer the next question.

Limber Pine (*Pinus flexilis*)

The limber pine is described as a small, scrubby mountain tree with short twisted limbs, that usually grows to a height of only 5 m to 10 m. Its bark is silvery-grey on young trees, becoming very rough and almost black at maturity. The limber pine is an alpine tree that grows on high mountain slopes where it is cold, dry, and very windy.

3. Explain how the limber pine's physical characteristics can be a result of the abiotic conditions in its ecosystem.

Use the following information to answer the next questions.

Coyotes

Several families of coyote (*Canis latrans*) were found to be living within the boundaries of Waterton Lakes National Park in June 2006.

4. a) Identify the three components of a population as defined by ecologists.
   b) Describe why all of the coyotes in this park might be considered a single population.
   c) Describe why all of the coyotes in this park might not be considered a single population.
   d) Choose the argument from part (b) or part (c) that you think is more reasonable, and justify your choice.

Use the following information to answer the next question.

Northern Pike

The earliest fish to spawn in spring, northern pike (or Jackfish) inhabit Great Slave Lake. They have long, spotted, greenish brown bodies, and prominent snouts. Average weights for these fish run from 2 to 7 kg, but pike weighing 13 to 18 kg have been caught by people fishing in these waters.

5. In ecological terms, explain how the northern pike found in Great Slave Lake is not only part of a population but also part of a community and part of an ecosystem.
6. An ecologist is studying the plants that are eaten by Rocky Mountain bighorn sheep. Explain why the ecologist might measure soil nutrients, such as nitrates, as part of the study.
7. Identify at least four things that affect the pattern of distribution and the range of living things.
8. Describe the biosphere.

SECTION 3.2

Classifying and Naming Organisms

Section Outcomes

In this section, you will
- **explain** how organisms are classified in domains and kingdoms
- **explain** how organisms are named using a two-name system called binomial nomenclature
- **identify** species using a dichotomous key

Key Terms

taxonomy
kingdom
domain
binomial nomenclature
dichotomous key

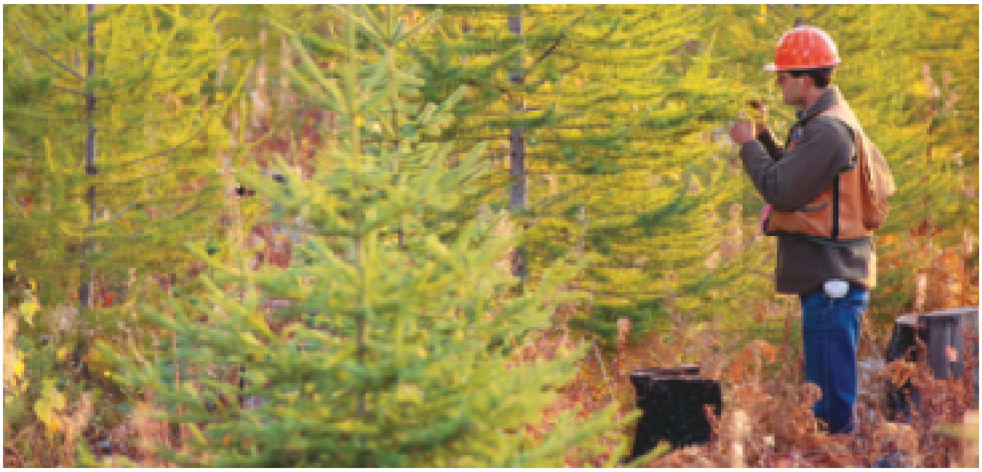


Figure 3.10 When forestry officials such as this one go into areas to check for pests like the mountain pine beetle (*Dendroctonus ponderosae*) how do they communicate their findings to the scientific community? A simple system for identifying and naming organisms has been in development since the 1700s. It is flexible enough to accommodate the discovery of new species and is still used by biologists all over the world.

Ecologists looking for the effects of the mountain pine beetle on the lodgepole pine community, as shown in Figure 3.10, need to be able to correctly identify the trees and the insects. They also need to be able to share information about their findings with colleagues elsewhere in the province, the country, and possibly around the world. Knowledge and practices developed in one part of the world to deal with a species can be more easily communicated to others if everyone can quickly agree on the identity of the organisms under discussion. Scientists can then pool their information to learn from each other's studies and more easily adapt and adopt successful practices.

The Classification of Organisms

The challenge of identifying, classifying, and naming the organisms that make up the diversity of life on Earth has existed since humans first began to observe the environment around them. The total number of species in the world is now estimated to be somewhere between 10 and 100 *million*.

Taxonomy is the practice of classifying living things. The continual development of more sophisticated tools for observation and analysis and resulting discovery of new species or reassessment of known ones means that taxonomy remains a practice in development. As you will see, the system is changing now and will continue to do so.

Early Classification Systems

One of the earliest attempts to classify life was made by the Greek philosopher Aristotle more than 2000 years ago. At that time, people had identified about 1000 different kinds of organisms. Aristotle put these organisms into two large groups: plants and animals. He called each group a **kingdom**, and the kingdoms later became known as Kingdom Plantae and Kingdom Animalia. Aristotle further categorized the animals based on their size and the way they moved on land, in water, and in air. He divided the plants into three categories based on differences in their stems.

Aristotle's classification system had its limitations, and over time it was changed. A student of Aristotle's, for example, grouped plants according to physical characteristics such as

Magnification: 1220 ×

Figure 3.11 The micro-organism *Euglena* can photosynthesize like plants do, but it can also move like animals do. How would you classify this organism?

reproductive structures and other types of external tissues. For the most part, however, this two-category system was used until the invention of rudimentary microscopes. The discovery of micro-organisms and cells forced scientists to reconsider their criteria for classification. Some micro-organisms have methods of locomotion and consume food like animals do. Others carry out photosynthesis like plants do. Still others, such as the *Euglena* in Figure 3.11, have characteristics of both plants *and* animals. *Euglena* is just one organism that scientists were having difficulty categorizing as either a plant or an animal. The German biologist Ernst Haeckel solved this problem, at least temporarily, in 1866. He proposed classifying micro-organisms that were neither animals nor plants in a third kingdom, which he named Protista.

Classification in Transition

Discoveries after Haeckel's time led to agreement that six kingdoms should be used to sort, organize, and identify organisms. However, the scientific community is once again debating the organization of organisms and is shifting to a grouping of a number of kingdoms within three domains.

The Six Kingdoms of Life

The six kingdoms of life are Archaea, Bacteria, Protista, Fungi, Plantae, and Animalia. Both Kingdom Archaea (or Archaebacteria) and Kingdom Bacteria (or Eubacteria) consist of single-celled organisms that lack a nucleus. The micro-organisms in Kingdom Bacteria are very diverse and can exist in a wide range of habitats. There is a special group of organisms, however, the Archaebacteria, that are capable of living in extreme environments, such as salt lakes, hot springs, and underwater thermal hot vents. As a result of advances in genetic analyses, which showed distinct differences between these species and other species of bacteria at the molecular level, biologists created a new kingdom to classify these micro-organisms during the 1990s.

All the organisms in Kingdoms Animalia, Plantae, Fungi, and Protista have cells that have nuclei and are called *eukaryotes*. These organisms can be unicellular or multicellular.

Organisms in Kingdom Protista, called protists, include both unicellular and multicellular organisms. Some protists photosynthesize (the autotrophs), while others (the heterotrophs) ingest their food. Still others obtain nutrients by decomposing and then absorbing their food much like fungi do. Protists include algae and protozoans such as *Euglena*.

Organisms in Kingdom Fungi obtain their food by secreting digestive enzymes onto their food source and then absorbing the molecules that are released by the enzymes. Fungi were once considered to be plants because they are *sessile* (do not move). Fungi do not have chloroplasts in their cells, however, and thus do not photosynthesize. There are both multicellular and unicellular fungi. Mushrooms, moulds, and yeasts are included in this kingdom.

Kingdom Plantae includes organisms that photosynthesize to make their own food. Most plants are sessile and multicellular, with relatively complex and specialized cells. Plants include mosses, ferns, coniferous trees, and flowering plants.

Organisms in Kingdom Animalia ingest their food, and most are motile. Like plants, they have complex and

Biology File

FYI

Within Domain Eukarya, the greatest diversity occurs in Kingdom Protista. Protists have lived on Earth for a much longer time than plants and animals, which has given them more opportunity to diversify. Many scientists feel that Kingdom Protista should be further divided into as many as seven different kingdoms.

specialized cells. Animals include insects (such as the mountain pine beetle), mammals (such as humans), and birds.

> **Q5** Explain why fungi are placed in a different kingdom than plants.

The Three Domains of Life

Dividing living things into strict categories and groups is often very difficult, particularly as new understanding of organisms emerges. The six-kingdom system is being amended to better explain the life forms modern research has been able to distinguish. There is now a level of classification above kingdoms, called **domains**, in common use. As shown in Figure 3.12, there are three domains: Bacteria, Archaea, and Eukarya.

These domains are based on the cellular composition of organisms. As mentioned previously, bacteria and archaea are the smallest and simplest types of cells, those without a nucleus. Their two former kingdoms are now the domains Bacteria and Archaea and contain the unicellular *prokaryotes* (*pro* means before, and *karya* means nucleus). When details of the molecular biology of these organisms were compared in 1996, it was clear that there were many striking differences. In fact, these two groups of organisms are as different from one another as they are from eukaryotes (protists, fungi, animals, and plants). As a result, archaea and bacteria were distinct enough from other another to warrant their own separate domains.

This domain-based classification system allows for an expanding list of kingdoms as research continues.

The Levels of Classification

A domain is the broadest category of classification. Scientists group organisms in a domain in a hierarchical fashion, through increasingly narrow, more precise categories, down to species. All animals, for example, belong to Kingdom Animalia, but there are many different types of animals. A bird, for example is more like a bat than a dragonfly, even though they all fly. (Both birds and bats have backbones; dragonflies do not.) As well, a bat is more like a whale than a bird. (Bats and whales are both mammals.)

BiologyFile

Try This
People sometimes use mnemonics (memory aids) to help them remember the order of the categories from domain through species. For example, **D**anish **K**ing **P**hilip **C**ame **O**ver **F**or **G**reen **S**pinach. Write your own mnemonic for biological classification.

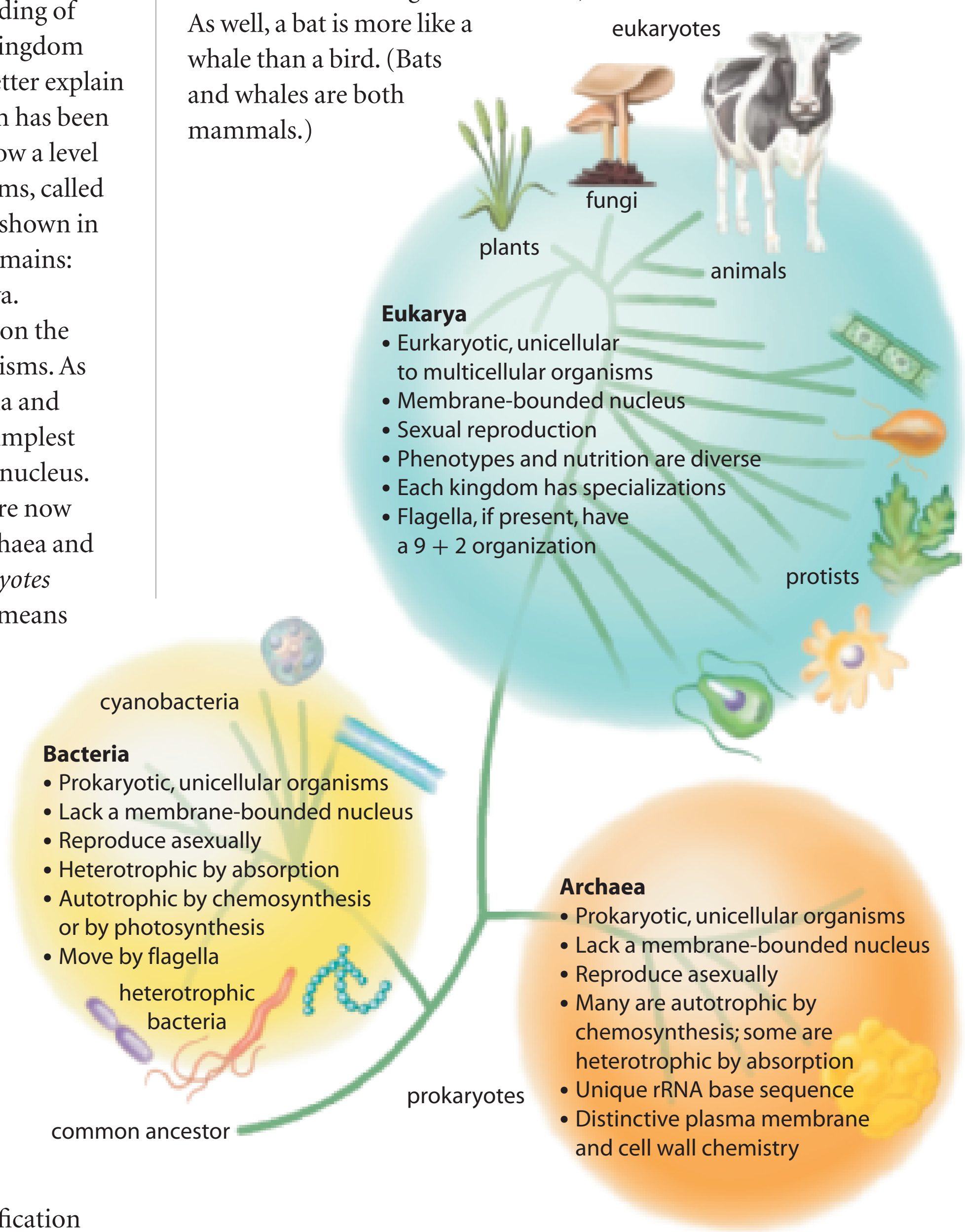


Figure 3.12 Adoption of the three-domain system of classification has given scientists even greater flexibility when it comes to classifying Earth's diversity. The former kingdoms of Archaea and Bacteria are now each in their own domain. The kingdoms Protista, Fungi, Plantae, and Animalia are grouped in the domain of Eukarya.

Table 3.1 Hierarchical Classification for the Bobcat, *Lynx rufus*

Group	Bobcat's classification	Organisms that can be included in this group
domain	Eukarya	euglena, mushrooms, lodgepole pines, earthworm, starfish, bee, shark, horse, oyster, frog, dog, cougar, lynx, house cat, bobcat
kingdom	Animalia	earthworm, starfish, bee, shark, horse, oyster, frog, dog, cougar, lynx, house cat, bobcat
phylum	Chordata	shark, horse, frog, dog, cougar, lynx, house cat, bobcat
class	Mammalia	horse, dog, cougar, lynx, house cat, bobcat
order	Carnivora	dog, cougar, lynx, house cat, bobcat
family	Felidae	cougar, lynx, house cat, bobcat
genus	*Lynx*	lynx, bobcat
species	*rufus*	bobcat

To distinguish among groups that have similarities, Swedish biologist Carolus Linnaeus (1707–1778) subdivided each kingdom into smaller and smaller groups of more and more similar organisms by using simple physical characteristics to categorize and describe organisms. After kingdom come phylum (plural "phyla"), class, order, family, genus (plural "genera"), and species. At each level, there are more similarities among members of the group. Table 3.1 illustrates the hierarchy and the increasingly narrow groupings, using the classification for the bobcat.

Naming Systems

The scientific names of organisms are based on their classification. Early scholars also grouped similar organisms and gave each group a Latin name. For example, they called bees *Apis*. Later, when they wanted to describe a particular species, they added a series of descriptive words. A variety of naming systems were tested. In one, the European honeybee had a name with 12 descriptive words! Linnaeus used his classification system to develop a much simpler naming system. He suggested a two-name, or binomial, naming system based on the last two categories of his classification system. The first word of an organism's scientific name is the genus, and the second word is the species. (In scientific naming, the first letter of the genus is always capitalized, but the species name is all lower case. Both the genus and species names are italicized, or when handwritten, underlined.) So, in Linaeus's system, the honeybee was *Apis mellifera*. (*Mellifera* means honey maker.)

Today, scientists still use the binomial system, called **binomial nomenclature**, devised by Linnaeus. To make the system universal, scientists agreed to use a language that is spoken by no country but forms the basis of many languages—Latin. When scientists discover and classify a new species, they give it a two-part Latin name based on its classification. (Greek root words are also often used.)

Using these two-part scientific names allows scientists from all around the world to be sure they are talking about the same species when they are communicating, regardless of whether they speak English, Spanish, or Chinese. Common names of organisms can vary from language to language, and even from region to region in a country. For example, a robin in England is an entirely different bird from a robin in Canada. In North America, the names "cougar," "panther," "puma," and "mountain lion" are all used for the same species of animal, *Puma concolor*. While the use of common names can be confusing, scientific names are universal.

Keep in mind, however, that scientific names can still change, particularly when new information is discovered. New technologies, such as DNA analysis, often lead to a more specific understanding of how various species are related. Skunks, for example, were previously categorized in a family with weasels, the Mustelidae. (*Mustela* is Latin for "weasel.") However, recent DNA analysis has shown that skunks are distinctive enough from weasels to be placed in their own family, the Mephitidae, with two species of Asian stink badger. (*Mephitis* is Latin for "foul odour.")

Biology File

FYI

Homo sapiens is the scientific name for human beings. The name is based on the following classification:

domain	Eukarya
kingdom	Animalia
phylum	Chordata
class	Mammalia
order	Primates
family	Hominidae
genus	Homo
species	sapiens

> **Q6** Why do scientists use an agreed-upon system of binomial nomenclature for naming organisms rather than common names?

Dichotomous Keys

Identification keys use observable characteristics to identify organisms. **Dichotomous keys** are arranged in steps, with two statements at each step. For example, if you are trying to identify a mite, such as the one in Figure 3.13, the first step in a dichotomous key gives two choices: red and not red (see Table 3.2). To use a dichotomous key, you always begin by choosing from the first pair of descriptions and then follow through the key from there. Since this mite is red, you would then proceed to step 2 and answer the questions there. This mite is the red velvet mite in the genus *Trombidium*.

Table 3.2 A Portion of a Key to Mites and Ticks of North America

1a. body colour red, go to 2

1b. body colour not red, go to 3

2a. body without hair; body globular and somewhat elongated; red freshwater mite, *Limnochares Americana*

2b. body with dense velvety hair; body oval to rounded rectangle; velvet mite, *Trombidium* genus

3a. body length 0.5 mm or less; two-spotted spider mite, *Tetranychus uriticae*

3b. body length more than 0.5 mm, go to 4

4a. etc.

The stepped comparisons in the keys can be very detailed, as shown in these examples from a key for identifying certain insects, or, more specifically, arthropods with six legs and well-developed wings. Therefore, the organism in question has already been described in a general way and placed in a phylum before an attempt is made to identify the class or order, as follows:

11a. Wings held flat over abdomen when at rest, last abdominal segment not enlarged, usually found in colonies: *Isoptera* (termites)

11b. Wings not held flat over abdomen when at rest, males with the last abdominal segment enlarged like a scorpion's stinger and held over the body, not found in colonies: *Mecoptera* (scorpion flies)

14a. Sucking mouthparts in the form of a rigid beak, front wings with clear tips, overlapping at rest, revealing a triangular panel on the back: *Heteroptera* (true bugs)

14b. Chewing mouthparts, front wings without clear tips. See step 15

Detailed dichotomous keys such as this one can fill several pages, and you may need a microscope to make some of the distinctions required to make an identification. Most important, you need to be a very keen observer and be able to sketch or photograph details to assist you in the process. Having a specimen on hand to help with identification is not always possible or desirable, depending on the type of organism, its habitat, and its abundance.

In the next investigation, you will create and use your own dichotomous key.

Figure 3.13 This mite is less than 1 mm in size. It has been magnified to make identification easier. What characteristics could you use to identify the genus or species of this mite?

INVESTIGATION 3.B

Target Skills

Compiling and **organizing** data to develop a dichotomous key for identifying organisms

Developing, **presenting**, and **justifying** a dichotomous key for identifying organisms

Creating a Dichotomous Key

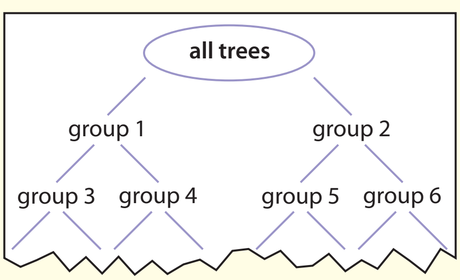
If you find a plant you have never seen before, how could you discover its identity? Many field guides help you match the characteristics of your specimen with those of similar organisms using a dichotomous key. As you have learned, a dichotomous key uses a series of paired comparisons to sort organisms into smaller and smaller groups. In this investigation, you will learn how to make your own dichotomous key.

Materials

- paper
- pencil
- sample dichotomous keys
- leaves and catkins or needles and cones of Alberta tree species (optional)

Procedure

1. Use this blank dichotomous key diagram as a model for your own dichotomous key. Note that your final key may not look exactly the same.



2. Study the 10 trees shown on the next page. (As an alternative, you could collect 10 or more plants from one or both of the ecosystems you chose for your field study.)
3. Select one characteristic. Sort the trees into two groups, based on whether they have this characteristic.
4. List each tree's number under either Group 1 or Group 2 on your key diagram.
5. Record the characteristic that identifies each group.
6. Select another characteristic for each subgroup, and repeat steps 4 and 5 for the next level down on your diagram.
7. Continue to subdivide the groups until you have 12 groups with one tree in each.
8. Using the characteristics in your diagram, construct a dichotomous key that someone could use to identify any tree in the given group. To do this, create a series of numbered steps, with the first step showing the first characteristic you used. At each step, offer two choices for classifying the tree based on a *single* characteristic. For example, you may have used the characteristics "have needles" as your first dividing characteristic. The first numbered step in your key would be
   1a. have needles
   1b. do not have needles
   Use the sample keys provided by your teacher to help you.
9. Exchange keys with a partner. Use your partner's key to classify a tree, and record all the characteristics of the species you chose.

Analysis

1. Is your partner's dichotomous key identical to yours? Explain why or why not.
2. **a)** Was your partner able to use your key successfully?
   b) How could you improve your key?
3. Which characteristics of trees were not useful for creating your key? Explain why not.

Conclusion

4. Why does a key offer only two choices at each step?

Extension

5. Non-native, invasive plants in Alberta, such as spotted knapweed (*Centaurea biebersteinii*), jeopardize ecosystems by out-competing native plant species. Examples of several other invasive plant species that pose problems in Alberta are purple loosestrife (*Lythrum salicaria*), creeping bellflower (*Campanula rapunculoides*), common tansy (*Tanacetum vulgare*), reed canary grass (*Phalaris arundinacea*), and common soapwort (*Saponaria officinalis*). Research the names of other invasive plant species in the province. Choose at least five of the species you researched, and design a key to identify them.

whitebark pine (*Pinus Albicaulis*)

jack pine (*Pinus banksiana*)

lodgepole pine (*Pinus contorta*)

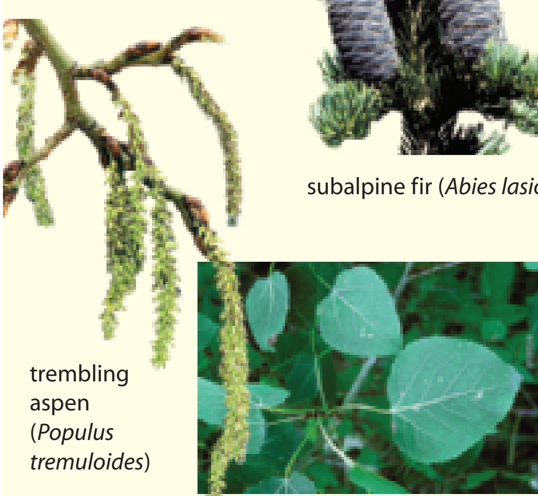
tamarack (*Larix laricina*)

white spruce (*Picea glauca*)

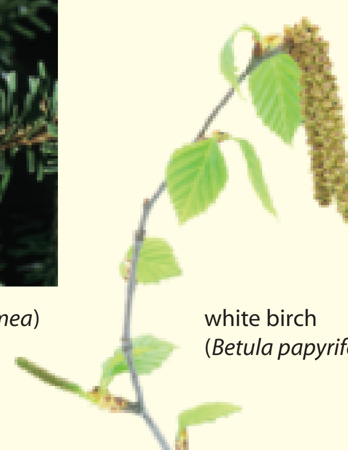
black spruce (*Picea mariana*)

subalpine fir (*Abies lasiocarpa*)

balsam fir (*Abies balsamea*)



trembling aspen (*Populus tremuloides*)



white birch (*Betula papyrifera*)

Section 3.2 Summary

- Organisms are sorted into a hierarchical system, starting with the broadest categories, domain and kingdom, and ending with the most specific category, species. The common classification levels are domain, kingdom, phylum, class, order, family, genus, and species.
- The classification system that is most commonly used today has three domains and a number of kingdoms. This system has been different in the past and may be different in the future.
- The three domains used to classify organisms are: Bacteria, Archaea, and Eukarya.
- The four kingdoms within the domain of Eukarya are: Protista, Fungi, Plantae, and Animalia.
- Scientists use binomial nomenclature to name organisms. The two-part scientific names use mostly Latin words and include the organism's genus and species.
- A dichotomous key is a branched or stepped process that can be used to identify organisms.

Section 3.2 Review

1. Explain why the categories into which organisms are grouped have changed over the past 2000 years, and why they will likely continue to change in the future.

2. Define the term taxonomy.

Use the following information to answer the next question.

3. Early scientists may have grouped the three animals shown above into a category called "flying animals." Use these three animals to explain why this category would not be particularly useful to biologists.

4. Use spreadsheet software to create a chart summarizing the main characteristics of the kingdoms of life identified in this textbook. Be sure to include an example of an organism found in each kingdom. ICT

5. a) Use the information in the dichotomous key shown opposite to classify the seven organisms pictured.

b) List the steps that you used in this key to explain how you determined that the lamprey eel is classified in the Class Agnatha.

6. Why is it useful and logical for all scientists to use the same system of classification?

Use the following information to answer the previous question.

Dichotomous Key to Classes of the Subphylum Vertebrata

Squirrel

Tufted Puffin

Lamprey Eel

Trout

Shark

Snake

Frog

1a. Hair present . . . . Class Mammalia
1b. Hair absent . . . . go to 2
2a. Feathers present . . . . Class Aves
2b. Feathers absent . . . . go to 3
3a. Jaws present . . . . go to 4
3b. Jaws absent . . . . Class Agnatha
4a. Paired fins present . . . . go to 5
4b. Paired fins absent . . . . go to 6
5a. Skeleton bony . . . . Class Osteichthyes
5b. Skeleton cartilagenous . . . . Class Chondrichthyes
6a. Skin scales present . . . . Class Reptilia
6b. Skin scales absent . . . . Class Amphibia