SBI3U-C

UNIT 5

Diversity of Living Things

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Introduction

There are an estimated 10 million species on earth, but only about two million have been classified and given names. The first step in understanding and managing the earth's biodiversity is recognizing the species. This unit begins with an overview of the six kingdoms of living things and the way all species are identified using the system of binomial nomenclature. You will also learn how to make and use classification keys as a tool for identification.

The unit continues with a more detailed examination of each of the kingdoms. You will learn to recognize the important defining features of each one, and study their role in natural ecosystems and human life. As human activities affect the diversity of life everywhere, you will analyze the consequences of human intervention, and examine the impact that climate change might have on diversity.

At the end of the unit there is a Practice Test. It will help you prepare for the Final Test. After you have studied your course materials and reviewed the Key Questions, you should try to answer all the questions in a two-hour period.

Practice Test Suggested Answers are provided so that you can mark it yourself. Instructions will be given at the end of Lesson 20.

Overall Expectations

After completing this unit, you will be able to

- analyze the effects of various human activities on the diversity of living things
- investigate, through activities, the principles of scientific classification, using appropriate sampling and classification techniques
- demonstrate an understanding of the diversity of living organisms in terms of the principles of taxonomy and phylogeny

SBI3U-C

Lesson 17

Taxonomy and Classification

Introduction

It is estimated that there are over 10 million species on earth. This incredible biodiversity is important for people and the planet. For example, fishing provides the livelihood and food security for over 200 million people, especially in the developing world. Globally, one in five people depend on fish as their primary source of protein. Yet, marine fish populations are in jeopardy all over the world due to over-fishing and environmental degradation. In fact, most biodiversity on the planet is under threat from human activities and environmental changes.

Biologists are racing to understand all of the biodiversity on earth in order to help save it. But first, biologists have to be able to recognize and classify species. Producing a catalogue of the world's biodiversity is important because it helps identify the species that may be the source of potential cures for disease, or the ones that are vital to keep ecosystems functioning, for example.

The science of classifying organisms is called taxonomy. In this lesson, you will learn how and why scientists classify organisms. You will also learn how to identify and classify unknown organisms using a classification tool called a dichotomous key. Finally, you will gain practical experience making and using your own dichotomous key.

Planning Your Study

You may find this time grid helpful in planning when and how you will work through this lesson.

Suggested Timing for This Lesson (hours)	
Taxonomy	½
Classifying Life on Earth	¾
Dichotomous Classification Keys	¾
Activity: Creating Your Own Dichotomous Key	1
Examples of Some Important Taxonomy Projects	½
Key Questions	1

What You Will Learn

After completing this lesson, you will be able to

- use appropriate terminology related to biodiversity, including genetic diversity, species diversity, and structural diversity
- create and apply a dichotomous key to identify and classify organisms from each of the kingdoms
- explain the fundamental principles of taxonomy and phylogeny by defining concepts of taxonomic rank and relationship such as genus, species, and taxon
- analyze the effects of various human activities on the diversity of living things
- demonstrate an understanding of the diversity of living organisms in terms of the principles of taxonomy and phylogeny

Taxonomy

Biologists have identified about two million different species, but they estimate the total number is closer to 10 million. The science of classifying and naming organisms is known as taxonomy, and the scientists who do this work are called taxonomists. Taxonomists also study the evolutionary relationships among species, and help determine when new species have evolved.

Why should biologists bother to name and classify organisms? Taxonomy is important for many practical reasons. For example, in genetics and medical research, it is important to know how closely related an experimental animal is to us. If we are closely related, then the new drugs being testing on the animal might work in a similar way in humans. In agriculture, knowing that a wild grass is a close relative to one of our important crop plants, like wheat, could help improve crop yields. We can study the genetics of the wild grass, and maybe borrow those genes to help make wheat more resistant to drought, frost, or disease. Taxonomy is also very important for ecologists, who need to know the identity of species in an ecosystem so they can predict how the ecosystem will respond to environmental changes.

Importance of Naming Species

Whenever you have studied a particular organism, you probably noticed it had a strange and complicated scientific name, like the bacterium *Escherichia coli*. Why do we need such complicated names, and how do scientists come up with them?

Why Do Species Need Scientific Names?

People have been giving the living things around them names for thousands of years. Chances are the same species will have many different common names around the world, or many different species will share the same name. For example, if a butterfly is known simply as "yellow butterfly," how would you know which yellow butterfly is being referred to? It would be like looking up a common name such as John Smith in Ottawa's telephone directory. Suppose over 200 John Smiths are found, but you only wanted to find one particular John Smith; it may take you a long time to find the right one.

Early biologists encountered a similar problem when trying to do research on species known only by their common names. How could they be sure that each biologist was actually working with the same species? For example, there are hundreds of varieties of spiders in Ontario. Imagine describing the spider as "the one found under the bush," or "the one that lives in the maple trees." This would not be very useful, especially for scientists outside Ontario. It would be much more practical to give a unique name to each of the hundreds of spiders, so you can tell them apart.

How do you come up with a unique name? You could make up a specific name for each spider such as "hairy-legged spider," or "red-striped spider," or "yellow-eyed spider." But scientists in another part of the world may come up with similar names for their spiders, which may have the same features, but are different species.

The main problem with using common names is the potential for confusion regarding which species is being discussed, since common names

- sometimes give the wrong impression of an organism; for example, ladybugs are actually beetles, and horned toads are really lizards;
- usually aren't the same from one language to another; for example, in French, cat is "chat," and dog is "chien";
- may describe several different organisms; for example, there are dozens of insect species around the world called "grasshopper."

How the Scientific Naming System Works

The problem of coming up with unique names for species was solved in the mid-1700s by Carl Linnaeus, whom you will recall from Lesson 1 of this course. He was a Swedish botanist who was also the first modern taxonomist. Linnaeus developed a system called binomial nomenclature, in which every species has a two-part name.

This naming system is based upon similarities that exist among organisms so that the most closely related organisms share the same first part of their name. The names are in ancient Greek or Latin because these languages are not spoken today, and therefore will not change over time. Binomial names are usually written in *italics* or are <u>underlined</u>.

In every binomial name, the first word (the genus) is always capitalized. The second word (the species) usually describes something about the organism, such as where it lives or the name of its discoverer, also translated into Latin or Greek. For example, in the name used for the redheaded woodpecker, *Melanerpes erythrocephalus*, "erythro" means "red" and "cephalus" means "head." The genus of the redheaded woodpecker is also descriptive: *Melanerpes*, which means "black creeper." This scientific name for this bird is used by scientists everywhere in the world, and no other organism has this exact scientific name. That is because there is a worldwide organization that controls the naming of new species to make sure that no two species are given the same scientific name by accident.

Linnaeus was able to use binomial nomenclature to name about 7700 plants and 4400 animals. Many of his original names are still used today. For example, the scientific name for humans is *Homo sapiens*, where "homo" means "man" and "sapiens" means "wise" in Latin. The binomial name for domestic cats is *Felis sylvestris*, and for dogs it is *Canis familiaris*.

Linnaeus did more than just find a way to name species. He also created a classification system for organizing all life. The first part of the name describes the genus of the organism. A genus is a relatively small group of closely related species. In the case of the redheaded woodpecker, the genus is *Melanerpes*. There can be many species in a genus. The second part of the name, *erythrocephalus*, is the species, and this name is used only once within a genus. But it could appear in another genus—so there could be another type of redheaded bird, maybe a duck, also called *erythrocephalus*, but the first part of its name would be different. That way, every binomial species name is unique.

Support Questions

Be sure to try the Support Questions on your own before looking at the suggested answers provided.

1. Explain why Linnaeus's system of binomial names helps us understand the relationships among species. Suggested answer
2. Based on their binomial names, are *Cornus canadensis* and *Tsuga canadensis* closely related to one another? Why? Suggested answer
3. Suppose every living organism on earth were known and classified. Do you think the study of taxonomy would end? Suggested answer

Classifying Life on Earth

The categories in the classification system developed by Linneaus represent major branches on the evolutionary tree of life. In this system, there are seven hierarchical levels or taxa (singular: taxon) used to arrange organisms with common characteristics. The top level is the kingdom, and the bottom level is the species. Table 17.1 shows how these seven levels are arranged with an example of how humans (*Homo sapiens*) are classified in this system.

Level of classification	Example: human
Kingdom	Animalia
Phylum	Chordata
Class	Mammalia
Order	Primates
Family	Hominidae
Genus	Homo
Species	Sapiens

Table 17.1: Hierarchy of levels in Linnaeus's classification system

You can see from Table 17.1 that humans are animals (kingdom Animalia) with backbones ("chordates," thus phylum Chordata) who are also mammals (class Mammalia). We are a particular type of mammal called a primate (order Primates) which means we are close relatives of other primates such as gorillas and chimpanzees. We are hominids (family Hominidae), which contains only human-like species. We are the only living species of hominid. Other hominids include our fossil relatives who lived millions of years ago. We are humans (genus Homo) and, finally, we are the only living example of a species in that genus (species Sapiens). Other groups of extinct humans in that genus include the Neanderthals, *Homo neanderthalensis*, who lived in ice-age Europe about 100 000 years ago.

The Six Kingdoms of Life

The largest taxon is the kingdom. When Linnaeus first created his system in the eighteenth century, he separated living organisms into two kingdoms: plants (Plantae) and animals (Animalia). However, since then, more kinds of organisms have been discovered, so that today biologists recognize six kingdoms: Archaea, Bacteria, Protista, Fungi, Plantae, and Animalia. You will learn the main identifying characteristics of each kingdom in this section, and then in more detail in the following lessons.

1. Kingdom Archaea

Kingdom Archaea contains the most ancient type of organisms. They are all unicellular, and look like bacteria; but, unlike bacteria, they have no nucleus and contain no organelles surrounded by a membrane. They are found today in harsh environments that are extremely salty and have low oxygen concentration. The earth's atmosphere billions of years ago was thought to be mainly like this. Archaea are found in salt pools, sulphur springs, volcanoes, and in oxygen-free environments such as swamps and marshes—environments that would kill most other organisms.

Figure 17.1, below, shows a species of Archaea in the genus *Halobacteria*, which is found in saline (salty) environments.

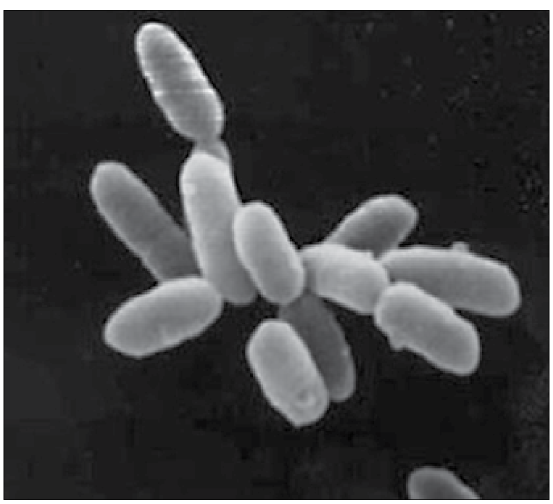


Figure 17.1: Microscope image of *Halobacteria sp.*

Source: Wikimedia Commons

2. Kingdom Bacteria

Biologists estimate that up to four million species of bacteria may exist; however, only about 4000 have been identified. Bacteria have been found everywhere in the world, and the task of classifying them all has only begun. Bacteria are prokaryotic, which means they do not contain membrane-bound organelles and are unicellular, though some can form colonies.

Some bacteria, such as cholera, cause disease in humans.

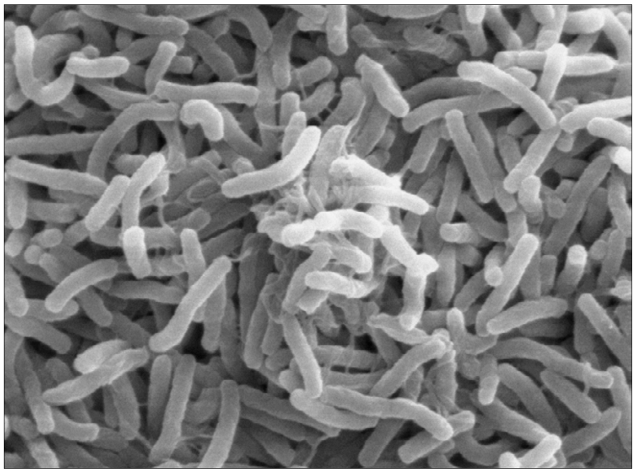


Figure 17.2: Microscope image of cholera bacteria

Source: Wikimedia Commons

3. Kingdom Protista

These organisms, called protists, are typically unicellular and eukaryotic, which means they contain a nucleus and other organelles surrounded by a membrane. Protists obtain their nutrition by absorption, ingestion, and photosynthesis. It is believed that protists evolved from prokaryotic bacteria. This kingdom is very diverse in nature; it contains all the eukaryotes that are not fungi, plants, or animals.

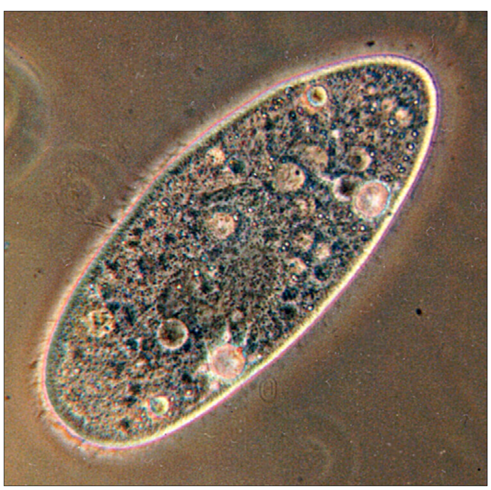


Figure 17.3: Microscope image of *Paramecium*, one of the best-known protists, which can be found in nearly every pond

Source: Wikimedia Commons

4. Kingdom Fungi

Fungi are multicellular eukaryotes that build cell walls similar to plants. However, plant cell walls contain the compound cellulose, whereas fungi cells do not. Some fungi are able to produce their own food through photosynthesis. Examples of fungi include mushrooms, moulds, and yeast.

Figure 17.4: Photograph of a type of mushroom co mmonly found in Southern Ontario in late summer

5. Kingdom Plantae

Plants are multicellular organisms that produce their own food (autotrophs) through photosynthesis. They have cell walls that contain cellulose. Examples of plants include mosses, ferns, and seed plants.

Figure 17.5: This picture of an Ontario landscape is dominated by plants. Here trees, grasses, shrubs, flowers, and aquatic plants (cattails) can all be seen growing close together.

6. Kingdom Animalia

Animals are multicellular organisms that must consume other organisms as food (heterotrophs), and have cell membranes without cell walls. They can be complex, with their cells organized into tissues, organs, and organ systems. The two main divisions of kingdom Animalia are the vertebrates (animals with backbones) and invertebrates (animals without backbones). Examples of animals include houseflies, fish, giraffes, jellyfish, and humans.

Figure 17.6: Photograph of two black rhinoceros. They are vertebrates, and are one of the world's most endangered animals.

Source: Wikimedia Commons

Support Questions

4. List, in order from the most inclusive to the least, the seven taxa or levels of classification into which organisms are arranged.

Suggested answer

5. To which kingdom do the following organisms belong?

Organism A: Multicellular, photosynthetic autotrophs, with cell walls that contain cellulose.

Organism B: Unicellular. Many live in some of the most extreme environments, and can survive only in the absence of oxygen.

Suggested answer

Dichotomous Classification Keys

Carolus Linnaeus grouped organisms into taxa based on their similarities. Species, the lowest level in the hierarchy, was the hardest taxon to define. For example, do individuals of different colours belong in the same species? Is that a big enough difference to define them as separate species? How do you know? Linnaeus categorized individuals that seemed similar in shape and features as belonging to the same species. He was right most of the time. Today, we define a species by saying that all members of the same species must be able to breed with each other to produce normal, fertile offspring. In addition, we now use genetic data to help us assign organisms to species.

It's not an easy task to identify and classify organisms. Sometimes the difference between two species is very slight. For example, two species of mice may differ only in the length of their tails or hind feet, or the markings on their teeth. Two families of beetles may differ only in the number of segments on their abdomen (five or six).

One tool used to help identify and classify organisms is the dichotomous classification key. Dichotomous classification keys include two choices for each characteristic ("dichotomous" means "dividing into two parts"). You can use ready-made dichotomous keys for a particular type of organism, or you can make your own. No two keys for the same set of items will necessarily be the same; a key only has to be able to separate all the organisms you are working with into their respective species.

Using a Dichotomous Key

The general procedure for using a dichotomous key to identify an unknown specimen is shown in Figure 17.7. You start at the top of the key, and work your way down by answering "yes" or "no" to each question until you reach the name of your specimen. Each numbered choice is based on certain identifying characteristics. Notice there are always two choices at each stage. Select the one that is most accurate for the organism, then follow that branch to the next stage and answer the question there. Repeat this process until you have reached a stage where only one species name appears. That is the name of your specimen.

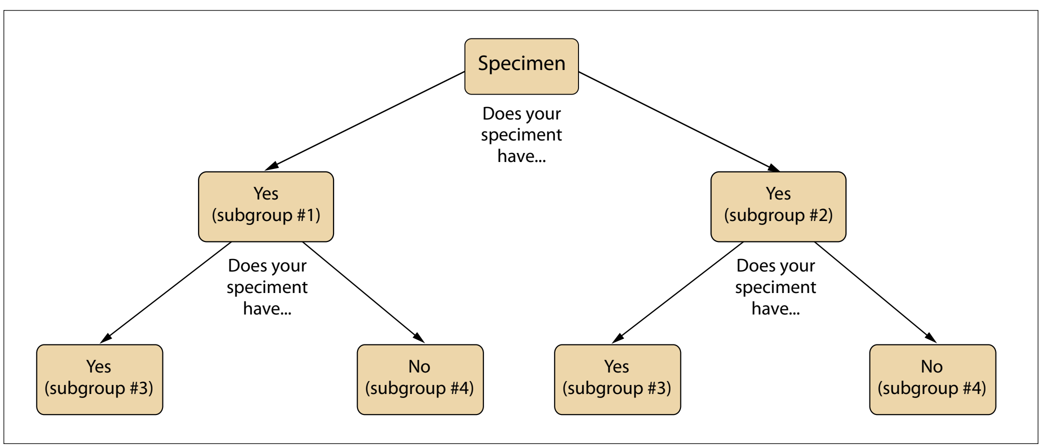


Figure 17.7: Diagram showing how to use a dichotomous key to identify an unknown specimen

The best way to learn is to try an example.

Example

Figure 17.8 on the next page shows drawings of nine insects. You need to determine the name of species F. You will identify it using the dichotomous key shown below the figure. The process of identifying a specimen using a dichotomous key is often called "keying out" the specimen.

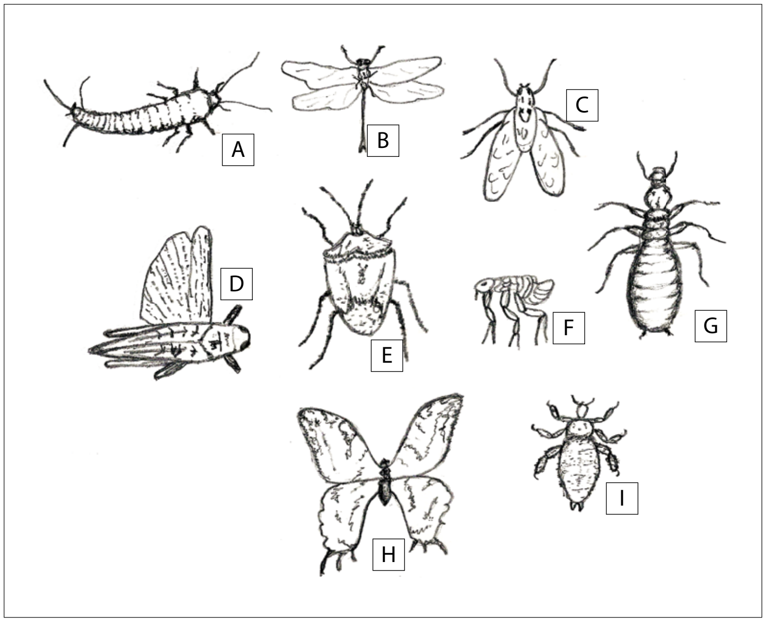


Figure 17.8: Nine unidentified insects to key out

Dichotomous Key for Insects A-I

1a.	Insect has visible wings	go to 2
1b.	Insect has no visible wings	go to 5
2a.	Only two wings visible in drawing	go to 3
2b.	Front and hind wings visible in drawing	go to 4
3a.	Both wings pointing backwards	Housefly
3b.	Both wings pointing upward	Cicada
4a.	Wings oval-shaped	Dragonfly
4b.	Wings not oval-shaped	Butterfly
5a.	Three long thin tails	Silverfish
5b.	No long thin tails	go to 6
6a.	All legs as long as the body	Flea
6b.	Not all legs as long as the body	go to 7
7a.	Head almost as wide as mid-point of the body	Termite

7b.	Head much narrower than mid-point of body	go to 8
8a.	Legs thick	Louse
8b.	Legs thin	Potato bug

Solution

To key out insect F, start at question 1.

1a.	Insect has visible wings	go to 2
1b.	Insect has no visible wings	go to 5

Since insect F does not have visible wings, go to question 5.

5a.	Three long thin tails	Silverfish
5b.	No long thin tails	go to 6

Since insect F does not have long thin tails, go to question 6.

6a.	All legs as long as the body	Flea
6b.	Not all legs as long as the body	go to 7

Since all the legs are as long as the body, insect F is a flea.

Support Questions

6. Using the key and insect pictures above, name the remaining eight insects in Figure 17.8.

Suggested answer

Activity: Creating Your Own Dichotomous Key

You can also create your own dichotomous key to categorize any group of objects. You will create one here to key out five grasshoppers into species. You will have to determine the stages used to distinguish each one of them as a separate species.

Suppose that you captured these five grasshoppers in a grasslands area of Ontario. You made the following drawings and observations of each of the five grasshoppers. Instead of giving the grasshoppers a species name, you have identified them by a letter (A, B, C, D, or E).

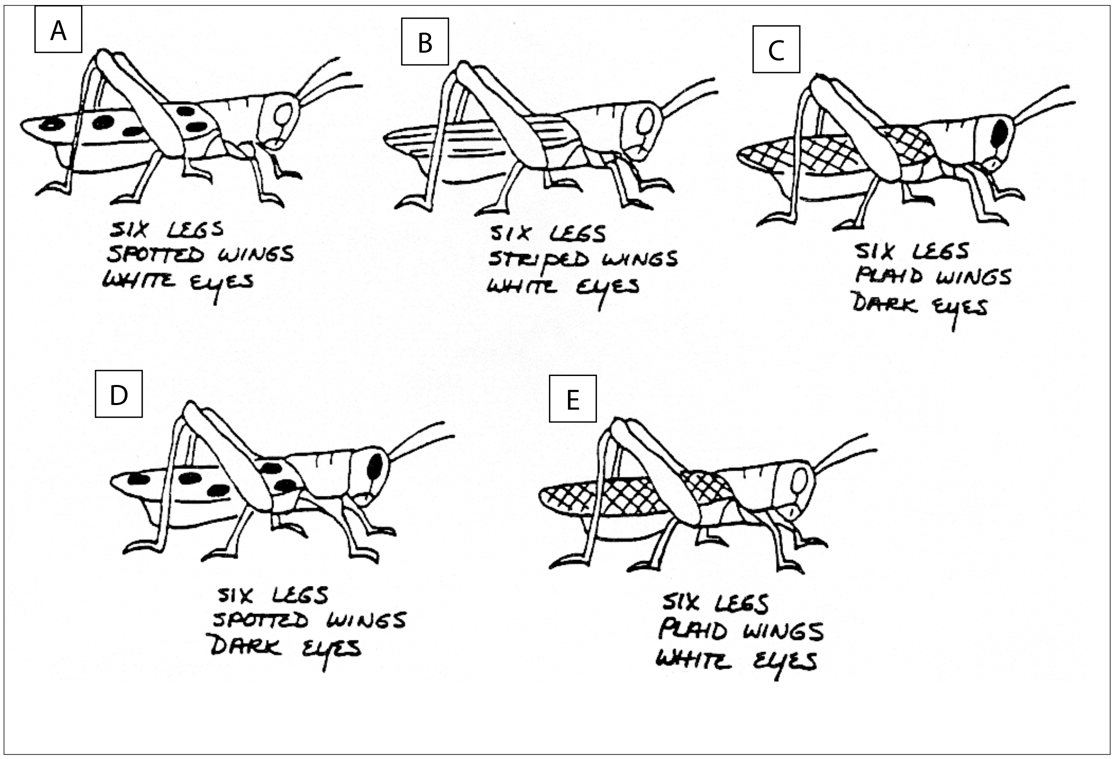


Figure 17.9: Five grasshoppers

How could you use your observations to make a dichotomous key for these grasshoppers? You need to separate the grasshoppers into two groups at every stage, until each grasshopper is in a category by itself. There are many ways to do this correctly. The right key is any one that works for you.

Choose criteria that will separate the organisms into two groups at each stage. Continue this process until each organism is in a group by itself. For example, the first stage might be:

1a. Grasshopper has white eyes	go to 2
1b. Grasshopper has dark eyes	go to 3

Support Questions

7. Write out your dichotomous key. Suggested answer

8. How many stages does it take to key out the five grasshoppers? Suggested answer

Examples of Important Taxonomy Projects

Operation Wallacea

Biologists are constantly monitoring population sizes and, in order to understand all of the biodiversity in aquatic and terrestrial ecosystems, ecologists have to be able to recognize and classify biotic factors in an ecosystem. Operation Wallacea, for example, is a series of research projects that operate in remote areas of the world. The projects aim to assess the need for protection of wildlife, and are thus primarily geared towards assessing wildlife population sizes. Their work has led to the discovery of over 30 new species, as well as the rediscovery of four species previously thought to be extinct. In order to fully understand the impact of human activity and other factors on important ecosystems, scientists need to identify the vast diversity of organisms living in them. This is possible through classification.

DNA Barcoding

There are an estimated 10 million species on earth. Recognizing all of them is impossible for any one person. Even experts in taxonomy may only be able to identify a few thousand species. For example, if you find a species of insect you don’t recognize in a sample from a rainforest, how can you identify it? Keys work to some extent, but not all species have been put into published keys, and it takes time to study all the features to create your own. A new genetic approach to solving this problem is called DNA barcoding. It uses a short sequence of DNA (usually under a thousand base pairs long) to identify a species, just like a product’s barcode identifies a product in a store.

Biologists are busy collecting genetic samples from all the known species in the world and putting them into a public DNA barcode database. Eventually, you will be able to take a sample of any known species from anywhere and, within a short time, match its DNA barcode against the database to determine its species. The hope is that one day anyone will be able to do this using a portable sampling device about the size of a cell phone. This will allow everyone everywhere to survey the biodiversity in their area, to help identify areas for conservation, or locate new sources of medicines, for example.

Applications of DNA barcoding include identifying plants when their flowers or fruit are not available, identifying the diet of an animal based on its stomach contents or feces, and identifying products made from organisms like foods, herbal supplements, wood, and leathers. How can you tell if the leather used to make a handbag came from an endangered or illegally caught species? Eventually, with DNA barcoding, you could walk into a store and have the answer within minutes.

Canadian researchers created the DNA barcoding project and are world leaders in gathering and analyzing species to go into the global barcode database. If interested, you can learn about the DNA barcoding work being done by evolutionary biologists and geneticists at the Canadian Museum of Nature in Ottawa, Ontario.

Now watch this video called Introduction to DNA Barcoding.

Tree of Life Project

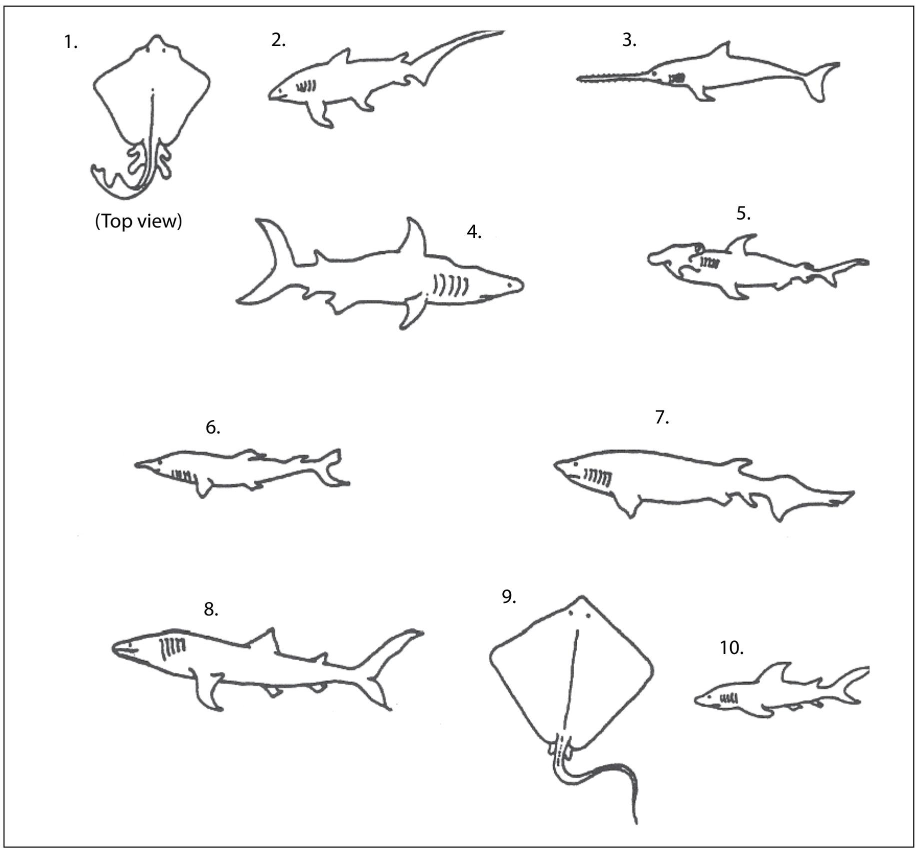
Scientists are using the Internet to build a catalogue of the world's diversity at the Tree of Life Web Project. This project is a collaboration of biologists and naturalists from around the world. It is freely available for anyone in the world to read and contribute to. For each species, the website provides information about its characteristics, evolutionary history, current conservation status, and links to more sources of information. This catalogue of diversity is growing every day as new species and more details are added. Eventually, combined with the DNA barcoding project, you will be able to pick up a piece of leaf or hair from the ground and, within minutes, know the scientific name of the species it came from and have access to everything known about that species.

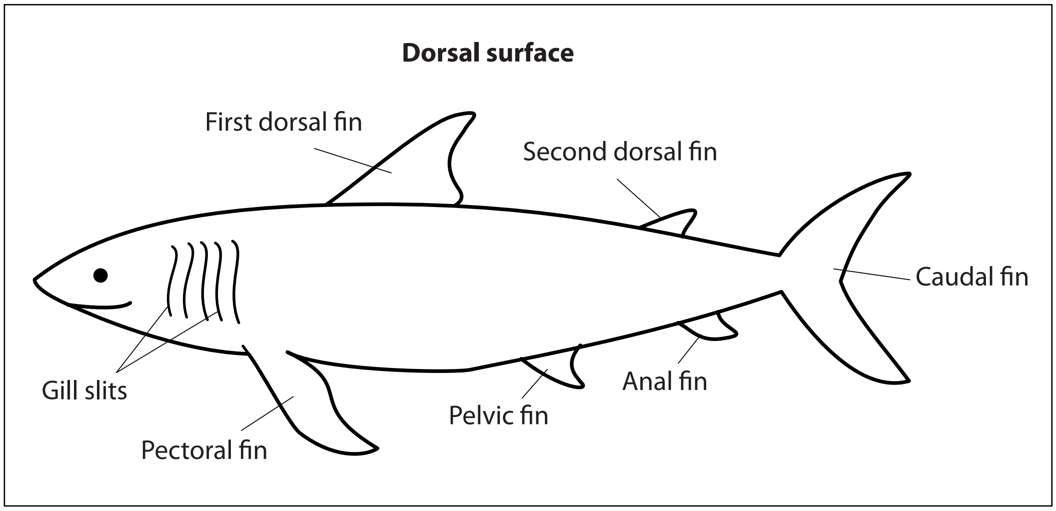
Key Questions

Now work on your Key Questions in the online submission tool. You may continue to work at this task over several sessions, but be sure to save your work each time. When you have answered all the unit's Key Questions, submit your work to the ILC.

(16 marks)

53. Using the shark anatomy picture and the key provided, classify the 10 sharks labelled 1–10 in the diagram below. **(10 marks)**





Anatomy of a shark. Use these terms to help you work through the key below.

Key

1a. Body, as seen from the top, shaped like a kite	go to 12
1b. Body, as seen from the top, not shaped like a kite	go to 2
2a. Pelvic fin absent	Pristiophoridae
2b. Pelvic fin present	go to 3
3a. Six gill slits	Hexanchidae
3b. Five gill slits	go to 4
4a. One dorsal fin	Scyliorhinidae
4b. Two dorsal fins	go to 5
5a. Mouth located at front of snout	Rhincodontidae
5b. Mouth located on underside of head	go to 6
6a. Head expanded, with eyes located at end of expansion	Sphrynidea
6b. Head not expanded	go to 7
7a. Top half of caudal fin same as bottom half	Isuridae
7b. Top half of caudal fin different than bottom half	go to 8
8a. First dorsal fin extremely long	Pseuodotriakidae
8b. First dorsal fin regular length	go to 9
9a. Caudal fin extremely long	Alopiidae
9b. Caudal fin regular length	go to 10

10a. A long point on end of snout	Scapanorhynchidae
10b. Snout without long point	go to 11
11a. Anal fin absent	Squalidae
11b. Anal fin present	Carcharhinidae
12a. Small dorsal fin present near tip of tail	Rajidae
12b. No dorsal fin near tip of tail	go to 13
13a. Front of animal with two hornlike appendages	Mobulidae
13b. No hornlike appendages	Dasyatidae

54. Explain what is meant by binomial nomenclature. **(2 marks)**

55. **a)** Which two of the following three species are more closely related: *Entamoeba histolytica*, *Escherichia coli*, *Entamoeba coli*? Explain. **(2 marks)**

b) Two organisms are in the same order, but not in the same family. From this information, can you determine whether they are in the same class? Explain. **(2 marks)**

Now go on to Lesson 18. Send your answers to the Key Questions to ILC when you have completed Unit 5 (Lessons 17 to 20).