6th Grade Science - Life Science

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Rachel Williamson
Jessica Harwood
Douglas Wilkin, Ph.D.
Ken Vicknair

next generation textbooks

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AUTHORS
Rachel Williamson
Jessica Harwood
Douglas Wilkin, Ph.D.
Ken Vicknair

EDITOR
Douglas Wilkin, Ph.D.

CONTRIBUTORS
Doris Kraus, Ph.D.
Niamh Gray-Wilson
Jean Brainard, Ph.D.
Sarah Johnson
Jane Willan
Corliss Karasov

Contents

CONCEPT 1 Basic and Applied Science

- Define basic science and applied science.
- Distinguish between basic science and applied science.

Why should we study the rainforest?

Some scientists study problems that seem to have very little impact on our lives. For example, scientists are working to describe every type of plant and animal in the rainforest. What is the purpose? Many of our medicines come from plants and animals of the rainforest. So what medicines have not yet been discovered? There might be new cures to diseases yet to be identified. This is an example of how science can be applied to our lives.

Basic and Applied Science

Science can be "basic" or "applied." The goal of **basic science** is to understand how things work—whether it is a single **cell**, an organism made of trillions of cells, or a whole **ecosystem**. Scientists working on basic science questions are simply looking to increase human knowledge of nature and the world around us. The knowledge obtained through the study of the subspecialties of the life sciences is mostly basic science.

Basic science is the source of most **scientific theories**. For example, a scientist that tries to figure out how the body makes cholesterol, or what causes a particular disease, is performing basic science. This is also known as **basic research**. Additional examples of basic research would be investigating how glucose is turned into cellular energy or determining how elevated blood glucose levels can be harmful. The study of the cell (cell biology), the study of inheritance (genetics), the study of molecules (molecular biology), the study of microorganisms and viruses (microbiology and virology), the study of tissues and organs (physiology) are all types of basic research, and have all generated lots of information that is applied to humans and human health.

Applied science is using scientific discoveries, such as those from basic research, to solve practical problems. For example, medicine, and all that is known about how to treat patients, is applied science based on basic research

(**Figure** 1.1). A doctor administering a drug to lower a person's cholesterol is an example of applied science. Applied science also creates new technologies based on basic science. For example, designing windmills to capture wind energy is applied science (**Figure** 1.2). This technology relies, however, on basic science. Studies of wind patterns and bird migration routes help determine the best placement for the windmills.

FIGURE 1.1
Surgeons operating on a person, an example of applied science.

FIGURE 1.2
Windmills capturing energy, an example of applied science.

Summary

- Basic science, such as understanding how cells work, is research aimed at understanding fundamental problems.
- Applied science, such as the medical field, is the application of basic scientific knowledge to solve practical problems.
- Applied science uses and applies information obtained through basic science.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Basic vs. Applied Research** at http://www.sjsu.edu/people/fred.prochaska/courses/ScWk170/s0/Basic-vs.-Applied-Research.pdf .

1. What is basic research? Give two examples of basic research.
2. What is applied research? Give two examples of applied research.
3. What is the relationship between basic research and applied science?
4. Why do some scientists believe more emphasis needs to be placed on applied science?

Explore More II

- **Reinvesting in Basic Research** at http://www.youtube.com/watch?v=NHjrMtECVo0 (3:58)

MEDIA

Click image to the left or use the URL below.

URL: https://www.ck12.org/flx/render/embeddedobject/57477

1. How could basic biomedical research lead to better physicians?
2. What is BMPER? Did its discovery come from basic or applied research? Explain your resoning fully.

Review

1. What is the difference between basic and applied science?
2. What is an example of applied science?

References

1. U.S. Department of Defense. Surgeons operating on a person, an example of applied science . Public Domain
2. Douglas Cataylo. Windmills capturing energy, an example of applied science . CC BY 2.0

Concept 2 Characteristics of Life

- Define what it means to be living.
- Know the five characteristics of living organisms.
- Describe the five characteristics shared by all living organisms.
- Identify the role of the five characteristics shared by all living organisms.
- Summarize in detail the role of each characteristic in life.

Is fire alive?

Fire can grow. Fire needs fuel and oxygen. But fire is not a form of life, although it shares a few traits with some living things. How can you distinguish between non-living and living things?

The Characteristics of Life

How do you define a living thing? What do mushrooms, daisies, cats, and bacteria have in common? All of these are living things, or **organisms**. It might seem hard to think of similarities among such different organisms, but they actually have many properties in common. Living organisms are similar to each other because all organisms evolved from the same common ancestor that lived billions of years ago.

All living organisms:

1. Need energy to carry out life processes.
2. Are composed of one or more cells.

3. Respond to their environment.
4. Grow and reproduce.
5. Maintain a stable internal environment.

Living Things Need Resources and Energy

Why do you eat everyday? To get energy. **Energy** is the ability to do work. Without energy, you could not do any "work." Though not doing any "work" may sound nice, the "work" fueled by energy includes everyday activities, such as walking, writing, and thinking. But you are not the only one who needs energy. In order to grow and reproduce and carry out the other process of life, all living organisms need energy. But where does this energy come from?

The source of energy differs for each type of living thing. In your body, the source of energy is the food you eat. Here is how animals, plants, and fungi obtain their energy:

- All animals must eat in order to obtain energy. Animals also eat to obtain building materials. Animals eat plants and other animals.
- Plants don't eat. Instead, they use energy from the sun to make their "food" through the process of **photosynthesis**.
- Mushrooms and other fungi obtain energy from other organisms. That's why you often see fungi growing on a fallen tree; the rotting tree is their source of energy (**Figure** 2.1).

Since plants harvest energy from the sun and other organisms get their energy from plants, nearly all the energy of living things initially comes from the sun.

FIGURE 2.1
Orange bracket fungi on a rotting log in the Oak Openings Preserve in Ohio. Fungi obtain energy from breaking down dead organisms, such as this rotting log.

Living Things Are Made of Cells

If you zoom in very close on a leaf of a plant, or on the skin on your hand, or a drop of blood, you will find cells, you will find cells (**Figure** 2.2). **Cells** are the smallest structural and functional unit of all living organisms. Most cells are so small that they are usually visible only through a microscope. Some organisms, like bacteria, plankton that live in the ocean, or the *Paramecium,* shown in **Figure** 2.3, are unicellular, made of just one cell. Other organisms have millions, billions, or trillions of cells.

All cells have at least some structures in common, such as **ribosomes,** which are the sites where proteins are made. All cells also have **DNA** and **proteins**. The **nucleus** is clearly visible in the blood cells (**Figure** 2.2). The nucleus can be described as the "information center," containing the instructions (DNA) for making all the proteins in a cell, as well as how much of each protein to make. The nucleus is also the main distinguishing feature between the two general categories of cell, with cells known as prokaryotic lacking a nucleus.

Although the cells of different organisms are built differently, they all have certain general functions. Every cell must get energy from food, be able to grow and divide, and respond to its environment. More about cell structure and function will be discussed in additional concepts.

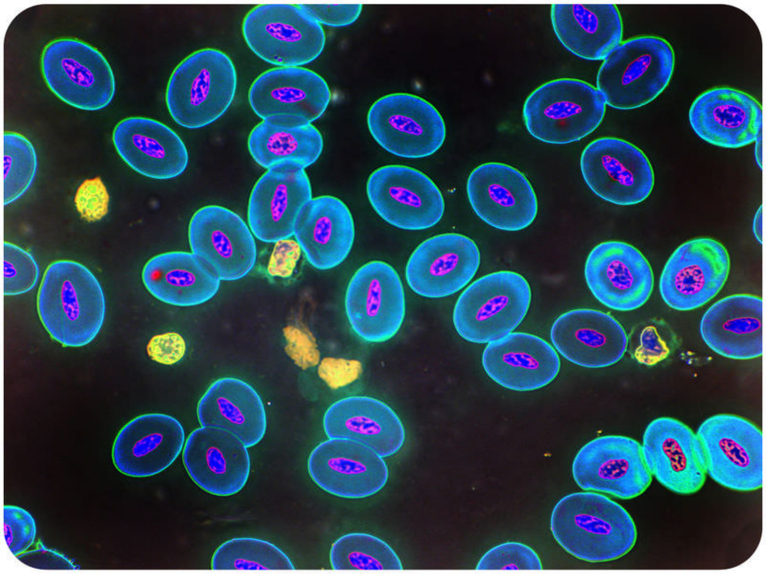


FIGURE 2.2
These cells show the characteristic nucleus. A few smaller cells are also visible. This image has been magnified 1000 times its real size.

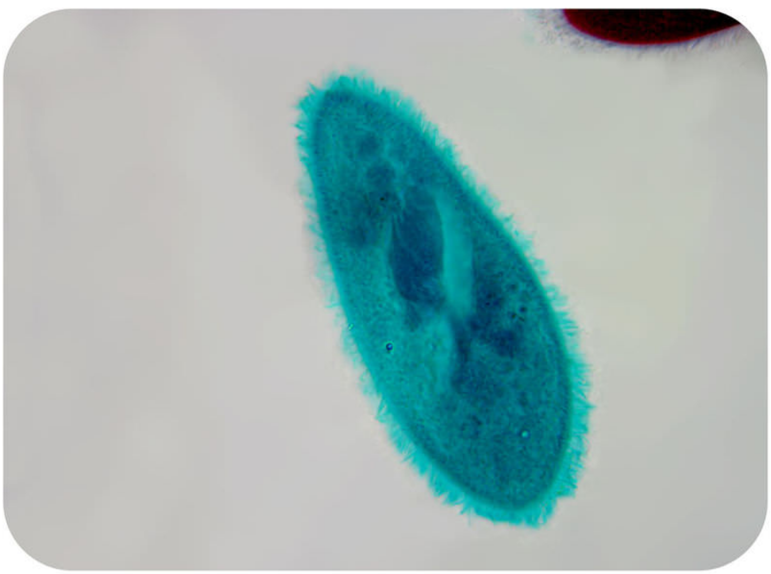


FIGURE 2.3
This *Paramecium* is a single-celled organism.

Living Organisms Respond to their Environment

All living organisms are able to react to something important or interesting in their external environment. For example, living organisms constantly respond to their environment. They respond to changes in light, heat, sound, and chemical and mechanical contact. Organisms have means for receiving information, such as eyes, ears, taste buds, or other structures.

Living Things Grow and Reproduce

All living things **reproduce** to make the next generation. Organisms that do not reproduce will go extinct. As a result, there are no species that do not reproduce (**Figure** 2.4). Some organisms reproduce asexually (**asexual**

reproduction), especially single-celled organisms, and make identical copies (or clones) of themselves. Other organisms reproduce sexually (**sexual reproduction**), combining genetic information from two parents to make genetically unique offspring.

FIGURE 2.4
Like all living things, cats reproduce to make a new generation of cats.

Living Things Maintain Stable Internal Conditions

When you are cold, what does your body do to keep warm? You shiver to warm up your body. When you are too warm, you sweat to release heat. When any living organism gets thrown off balance, its body or cells help it return to normal. In other words, living organisms have the ability to keep a stable internal environment. Maintaining a balance inside the body or cells of organisms is known as **homeostasis**. Like us, many animals have evolved behaviors that control their internal temperature. A lizard may stretch out on a sunny rock to increase its internal temperature, and a bird may fluff its feathers to stay warm (**Figure** 2.5).

FIGURE 2.5
A bird fluffs its feathers to stay warm and to maintain homeostasis.

Summary

- Living things are called organisms.
- All living organisms need energy to carry out life processes, are composed of one or more cells, respond to their environment, grow, reproduce, and maintain a stable internal environment.

Explore More

Use the resource below to answer the questions that follow.

- **Characteristics of Life** at http://www.youtube.com/watch?v=gJd65_Xrxs4 (3:15)

1. What are cell products? Do you think they should be included in characteristics of life? Why or why not?
2. Are all responses to the environment immediately obvious? Be specific and explain your reasoning.
3. Explain the concept of homeostasis. Give an example.
4. At what level does life evolve?

Review

1. Is a crystal alive? Why or why not?
2. What is a cell?
3. What is homeostasis?
4. What are the two forms of reproduction? Describe the examples in your response.

References

1. Benny Mazur. Fungi breaking down a rotting log . CC BY 2.0
2. Image copyright Jubal Harshaw, 2014. Nuclei of reptilian blood cells . Used under license from Shutterstock.com
3. Image copyright Jubal Harshaw, 2014. Picture of a paramecium, a single-celled organism . Used under license from Shutterstock.com
4. Charles Nadeau. Like all living things, cats reproduce to make a new generation of cats . CC BY 2.0
5. Tony Hisgett. A bird fluffs its feathers to stay warm and to maintain homeostasis . CC BY 2.0

CONCEPT 3 Fields in the Life Sciences

- Define life science.
- Describe the major fields within the life sciences.
- Explain what is studied in cell biology, genetics, and evolution.

What kind of scientist studies dolphins?

Dolphins are living organisms, so studying them is part of the life sciences. The life sciences, however, are broken down into many fields. Scientists that study dolphins and other life in the ocean are called marine biologists.

Fields in the Life Sciences

The **life sciences** are the study of living organisms. They deal with every aspect of living organisms, from the biology of **cells**, to the biology of individual organisms, to how these organisms interact with other organisms and their environment.

The life sciences are so complex that most scientists focus on just one or two subspecialties. If you want to study insects, what would you be called? An entomologist. If you want to study the tiny things that give us the flu, then you need to enter the field of **virology**, the study of viruses. If you want to study the nervous system, which life science field is right for you (**Table** 3.1, **Table** 3.2, and **Table** 3.3)?

TABLE 3.1: Subspecialties That Focus on One Type of Organism

Field	Focus
Botany	Plants
Zoology	Animals
Marine biology	Organisms living in oceans

TABLE 3.1: (continued)

Field	Focus
Freshwater biology	Organisms living in and around freshwater lakes, streams, rivers, ponds, etc.
Microbiology	Microorganisms
Bacteriology	Bacteria
Virology	Viruses
Entomology	Insects
Taxonomy	The classification of organisms

TABLE 3.2: Subspecialties That Examine the Structure, Function, Growth, Development, and/or Evolution of Living Organisms

Field	Focus
Cell biology	Cells and their structures/functions
Anatomy	Structures of animals
Morphology	Form and structure of living organisms
Physiology	Physical and chemical functions of tissues and organs
Immunology	Mechanisms inside organisms that protect them from disease and infection
Neuroscience	The nervous system
Developmental biology and embryology	Growth and development of plants and animals
Genetics	Genetic makeup of living organisms and heredity
Biochemistry	Chemistry of living organisms
Molecular biology	Nucleic acids and proteins
Epidemiology	How diseases arise and spread
Evolution	The changing of species over time

TABLE 3.3: Fields of Biology That Examine the Distribution and Environments of Organisms

Field	Focus
Ecology	How various organisms interact with their environments
Biogeography	Distribution of living organisms
Population biology	The biodiversity, evolution, and environmental biology of populations of organisms

During the study of the life sciences, you will study **cell biology**, **genetics**, **molecular biology**, **botany**, **microbiology**, **zoology**, **evolution**, **ecology**, and **physiology**. Cell biology is the study of cellular structure and function (**Figure** 3.1). Genetics is the study of **heredity**, which is the passing of traits (and **genes**) from one generation to the next. Molecular biology is the study of molecules, such as DNA and proteins. Ecologists study **ecosystems**, which are made of both living and nonliving parts of the environment. A botanist may work in a botanical garden, where plant life can be studied. What will you study with the other subspecialties?

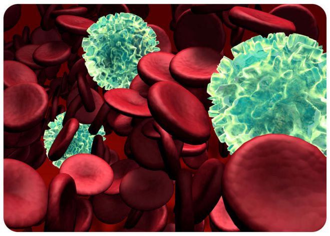


FIGURE 3.1
This illustration shows a virus among red blood cells. Which fields study red blood cells and viruses? (Keep in mind that viruses are actually much smaller than cells.)

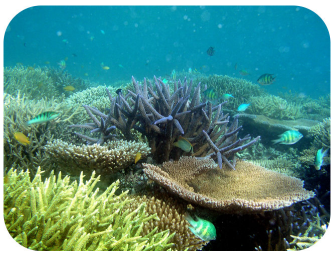


FIGURE 3.2
Other life science subspecialties include biogeography, which is the study of where organisms live and at what abundance.

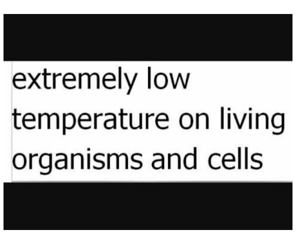
Summary

- There are several subspecialties within the life sciences that focus on one type of organism, such as virology and bacteriology.
- There are several fields of the life sciences that examine interactions between organisms and their environments, such as ecology.

Explore More

Use the resource below to answer the questions that follow.

- **Branches of Biology** at http://www.youtube.com/watch?v=OrlOOJ0Tm_E (3:28)



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1. What is the study of reptiles and amphibians?
2. What is the study of prehistoric life by means of fossils?
3. What is the study of mollusks?
4. What is the study of cells?
5. What is the study of fungi?
6. What is ecology?

Review

1. What is name of the field of the life sciences that studies insects?
2. What is name of the field of the life sciences that studies the nervous system?
3. What are cell biology, genetics, and molecular biology?

References

1. Image copyright Jiri Flogel, 2014. Drawing of viruses among red blood cells . Used under license from Shutterstock.com
2. Rocky Mountain Research Station/U.S. Department of Agriculture. Biogeography of a coral reef . Public Domain

Concept 4 Safety in the Life Sciences

- Recognize the types of hazards that a scientist faces.
- Describe laboratory safety guidelines that minimize potential risks.

What does this sign mean?

If a substance is corrosive, it can eat through objects. Many scientists have to work with chemicals that are corrosive or otherwise dangerous. That's one reason that following safety precautions in the laboratory or field is very important.

Safety in the Life Sciences

There can be some very serious safety risks in scientific research. If researchers are not careful, they could poison themselves or contract a deadly illness. The kinds of risks that scientists face depend on the kind of research they perform. For example, a scientist working with bacteria in a laboratory faces different risks than a scientist studying the behavior of lions in Africa, but both scientists must still follow safety guidelines. Safety practices must be followed when working with the hazardous things such as parasites, radiation and radioactive materials, toxins, and wild animals. Also, **carcinogens**, which are chemical that cause cancer, **pathogens**, which are disease-causing virus, bacteria or fungi, and **teratogens**, which are chemical that cause deformities in developing embryos, are extremely hazardous, and extreme care must be used when working with these items as well. For example, scientists studying dangerous organisms such as *Yersinia pestis*, the cause of bubonic plague, use special equipment that helps keep the organism from escaping the lab.

A **biohazard** is any biological material that could make someone sick, including disease-causing organisms. Therefore, a used needle is a biohazard because it could harbor blood contaminated with a disease-causing organism. Bacteria grown in a laboratory are also biohazards if they could potentially cause disease.

FIGURE 4.1

Science laboratory safety and chemical hazard signs.

Laboratory Safety

If you perform an experiment in your classroom, your teacher will explain how to be safe. Professional scientists follow safety rules as well, especially for the study of dangerous organisms like the bacteria that cause bubonic plague (**Figure** 4.2).

Sharp objects, chemicals, heat, and electricity are all used at times in laboratories. Below is a list of safety guidelines that you should follow when in the laboratory:

- Be sure to obey all safety guidelines given in lab instructions and by your teacher.
- Follow directions carefully.
- Tie back long hair.
- Wear closed toe shoes with flat heels and shirts with no hanging sleeves, hoods, or drawstrings.
- Use gloves, goggles, or safety aprons when instructed to do so.
- Broken glass should only be cleaned up with a dust pan and broom. Never touch broken glass with your bare hands.
- Never eat or drink anything in the science lab. Table tops and counters could have dangerous substances on them.

- Be sure to completely clean materials like test tubes and beakers. Leftover substances could interact with other substances in future experiments.
- If you are using flames or heat plates, be careful when you reach. Be sure your arms and hair are kept far away from heat.
- Alert your teacher immediately if anything out of the ordinary occurs. An accident report may be required if someone is hurt. Also, the teacher must know if any materials are damaged or discarded.

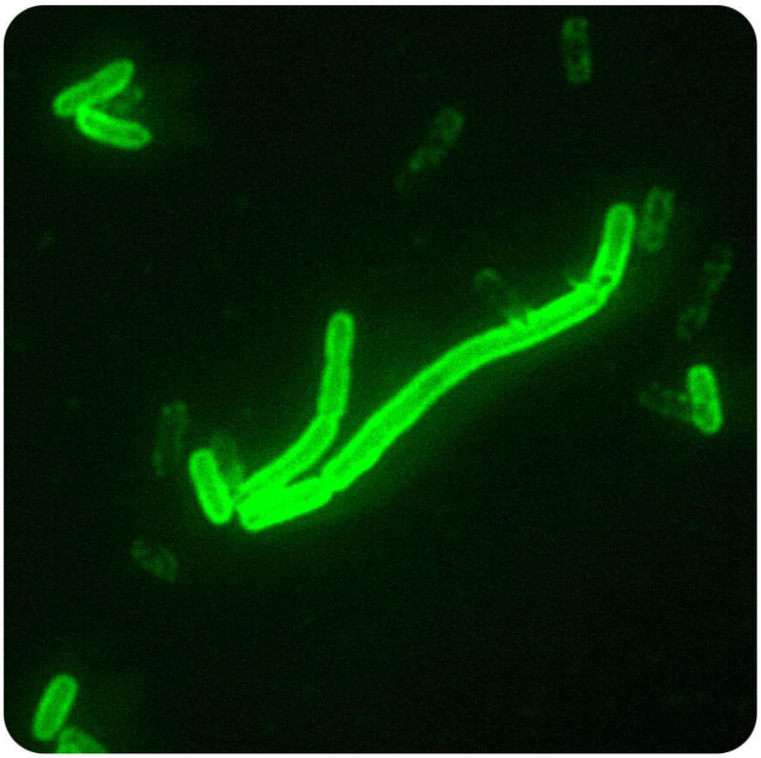


FIGURE 4.2

Scientists studying dangerous organisms such as *Yersinia pestis*, the cause of bubonic plague, use special equipment that helps keep the organism from escaping the lab.

Field Research Safety

A **field scientist** studies an organism in a natural setting, which is not usually an indoor laboratory. Scientists who work outdoors are also required to follow safety regulations. These safety regulations are designed to prevent harm to themselves, other humans, animals, and the environment. If scientists work outside the country, they are required to learn about and follow the laws and restrictions of the country in which they are doing research. For example, entomologists following monarch butterfly (**Figure** 4.3) migrations between the United States and Mexico must follow regulations in both countries. Before biologists can study protected wildlife or plant species, they must apply for permission to do so, usually from the government. This is important to protect these fragile species. For example, if scientists collect rare butterflies, they must first get a permit. They must also be careful to not disturb the habitat.

Summary

- There are serious risks in scientific research, including carcinogens, biohazards, and toxins.
- You need to carefully follow all safety rules while working in the laboratory.

FIGURE 4.3
A monarch butterfly.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **FSU Chemistry Lab Safety** at http://www.youtube.com/watch?v=hv9imJzZWrY (6:51)

MEDIA
Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/57465

1. Is applying cosmetics in a lab allowed?
2. What should you do if there is an accident?
3. How should you dispose of waste?

Explore More II

- **Science Lab Safety Rules** at http://www.youtube.com/watch?v=yclOrqEv7kw (2:24)

MEDIA
Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/57466

1. List five lab safety rules covered in the video.
2. What kind of clothing should you wear in a science lab?
3. What should you wear in a science lab that you would not wear usually outside a science lab?

Review

1. What is a biohazard?
2. List three hazards found in scientific research.
3. List three safety guidelines that you should follow in the laboratory.

References

1. . Science laboratory safety and chemical hazard signs . Public Domain
2. Larry Stauffer/Oregon State Public Health Laboratory/CDC. Image of Yersina pestis, the cause of the buboni c plague . Public Domain
3. William Warby. A monarch butterfly on a flower . CC BY 2.0

CONCEPT 5 Microscopes

- Describe how microscopes are used in the life sciences.
- Identify how cells were first identified.

How can we see the details of bacteria?

With the naked eye, bacteria just look like a slimy smear on a petri dish. How can we study them in more detail? The invention of the microscope has allowed us to see bacteria, cells, and other things too small to be seen with the naked eye.

The Microscope

Microscopes, tools that you may get to use in your class, are some of the most important tools in biology (**Figure** 5.1). A **microscope** is a tool used to make things that are too small to be seen by the human eye look bigger. **Microscopy** is the study of small objects using microscopes. Look at your fingertips. Before microscopes were invented in 1595, the smallest things you could see on yourself were the tiny lines in your skin. But what else is hidden in your skin?

Invention of the Microscope

Over four hundred years ago, two Dutch spectacle makers, Zaccharias Janssen and his son Hans, were experimenting with several lenses in a tube. They discovered that nearby objects appeared greatly enlarged, or **magnified**. This was the forerunner of the compound microscope and of the telescope.

In 1665, Robert Hooke, an English natural scientist, used a microscope to zoom in on a piece of cork - the stuff that makes up the stoppers in wine bottles, which is made from tree bark. Inside of cork, he discovered tiny structures, which he called **cells.** It turns out that cells are the smallest structural unit of living organisms. This finding eventually led to the development of the theory that *all living things are made of cells.* Without microscopes, this discovery would not have been possible, and the **cell theor**y would not have been developed.

FIGURE 5.1
Basic light microscopes opened up a new world to curious people.

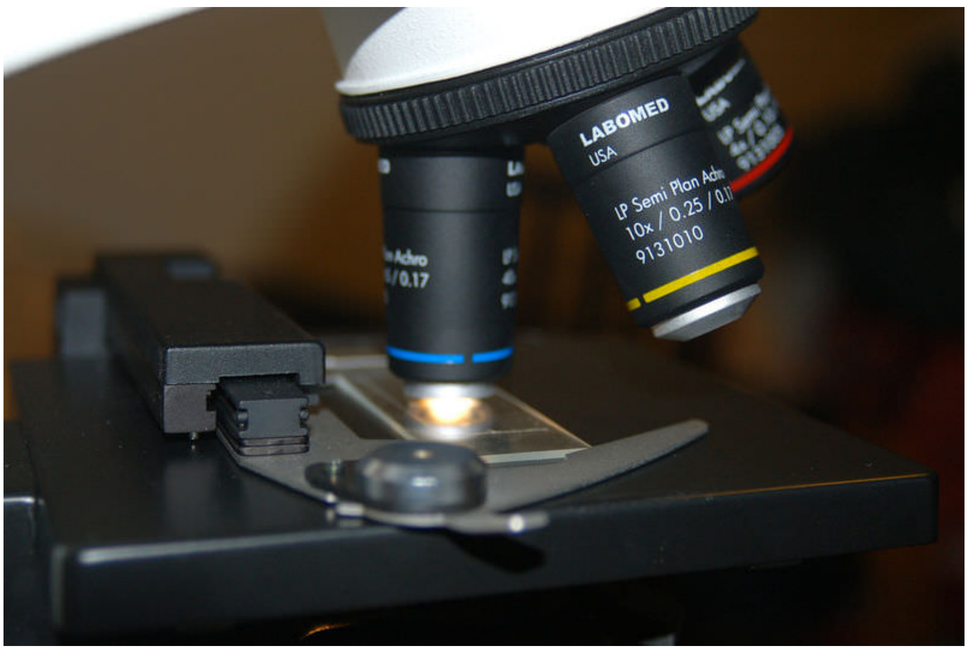
Hooke's discovery of the cell set the stage for other scientists to discover other types of organisms. After Hooke, the "father of microscopy," Dutch scientist Antoine van Leeuwenhoek (**Figure** 5.2) taught himself to make one of the first microscopes. In one of his early experiments, van Leeuwenhoek took a sample of scum from his own teeth and used his microscope to discover **bacteria**, the smallest living organism on the planet. Using microscopes, van Leeuwenhoek also discovered one-celled **protists** and sperm cells.

Today, microscopes are used by all types of scientists, including cell biologists, microbiologists, virologists, forensic scientists, entomologists, taxonomists, and many other types.

FIGURE 5.2

Antoine van Leeuwenhoek, a Dutch cloth merchant with a passion for microscopy.

Types of Microscopes



Some modern microscopes use light, as Hooke's and van Leeuwenhoek's did. Others may use electron beams or sound waves. Researchers now use these four types of microscopes:

1. **Light microscopes** allow biologists to see small details of a specimen. Most of the microscopes used in schools and laboratories are light microscopes. Light microscopes use lenses, typically made of glass or plastic, to focus light either into the eye, a camera, or some other light detector. The most powerful light microscopes can make images up to 2,000 times larger.
2. **Transmission electron microscopes (TEM)** focus a beam of electrons through an object and can make an image up to two million times bigger, with a very clear image.
3. **Scanning electron microscopes (SEM)** allow scientists to find the shape and surface texture of extremely small objects, including a paperclip, a bedbug, or even an atom. These microscopes slide a beam of electrons across the surface of a specimen, producing detailed maps of the surface of objects. Magnification in a SEM can be controlled over a range from about 10 to 500,000 times.
4. **Scanning acoustic microscopes** use sound waves to scan a specimen. These microscopes are useful in biology and medical research.

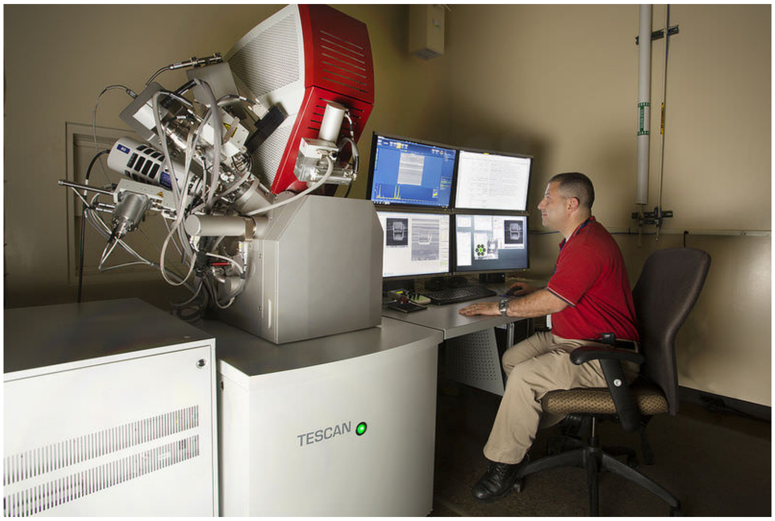


FIGURE 5.3
A scanning electron microscope.

Summary

- A microscope is a tool used to make things that are too small to be seen by the naked eye look bigger.
- Types of microscopes include light microscopes, transmission electron microscopes (TEM), scanning electron microscopes (SEM), and scanning acoustic microscopes.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Using a microscope** at http://www.youtube.com/watch?v=bGBgABLEV4g (4:01)

MEDIA
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1. How should you carry a compound optical microscope?
2. What procedure should you use when seeking to use the most powerful optical lenses?

Explore More II

- **Dissecting Microscope** at http://www.youtube.com/watch?v=JoqOwzLyMIA (5:05)

MEDIA

Click image to the left or use the URL below.

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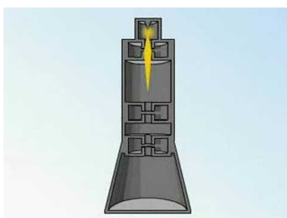
1. What light sources can you use with a dissecting microscope?
2. Why is it important to have a fixed ocular lens and an adjustable ocular lens?
3. What happens to your field of view as you increase magnification? Can you explain why this happens?

Explore More III

- **Structure and Function of the Electron Microscope** at http://www.youtube.com/watch?v=fToTFjwUc5M (1:49)



MEDIA

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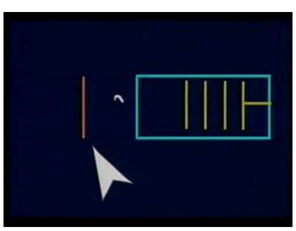
URL: https://www.ck12.org/flx/render/embeddedobject/57473

1. How does an electron microscope differ from a light microscope? List all the differences you can think of.
2. How should you carry an electron microscope?

Explore More IV

- **Scanning Electron Microscope** at http://www.youtube.com/watch?v=lrXMIghANbg (5:04)



MEDIA

Click image to the left or use the URL below.

URL: https://www.ck12.org/flx/render/embeddedobject/57474

1. How is the electron beam focused?
2. What part of a specimen does a scanning electron microscope look at?
3. Why is it important that a specimen for an electron microscope be placed in a vacuum? Why is this step unnecessary for a light microscope?

Review

1. What is the purpose of a microscope?
2. What were the findings of Hooke and van Leeuwenhoek?
3. What are the differences between a light microscope and a scanning electron microscope?

References

1. George Hodan. Picture of a light microscope . Public Domain
2. J. Verkolje. Antoine van Leeuwenhoek, inventor of the microscope . Public Domain
3. Idaho National Laboratory. A Scanning Electron Microscope . CC BY 2.0

CONCEPT 6 Organization of Living Things

- Explain the main contribution of Carolus (Carl) Linnaeus.
- Define binomial nomenclature.
- Summarize modern classification of living organisms.
- Define a species.

How would you classify a horse?

It's easy enough to classify the horse in the animal kingdom. That's one level of classification. But what other groups does the horse belong to? Horses also belong to a class—the mammals. These animals all have fur and nurse their young.

Classification of Life

When you see an organism that you have never seen before, you probably put it into a group without even thinking. If it is green and leafy, you probably call it a plant. If it is long and slithers, you probably call it as a snake. How do you make these decisions? You look at the physical features of the organism and think about what it has in common with other organisms.

Scientists do the same thing when they **classify**, or put into categories, living things. Scientists classify organisms not only by their physical features, but also by how closely related they are. Lions and tigers look like each other more than they look like bears, but are lions and tigers related? Evolutionarily speaking, yes. **Evolution** is the change in a species over time. Lions and tigers both evolved from a common ancestor. So it turns out that the two cats are actually more closely related to each other than to bears. How an organism looks and how it is related to other organisms determines how it is classified.

Linnaean System of Classification

People have been concerned with classifying organisms for thousands of years. Over 2,000 years ago, the Greek philosopher Aristotle developed a classification system that divided living things into several groups that we still use today, including mammals, insects, and reptiles.

Carolus (Carl) Linnaeus (1707-1778) (**Figure** 6.1) built on Aristotle's work to create his own classification system. He invented the way we name organisms today, with each organism having a two word name. Linnaeus is considered the inventor of modern **taxonomy**, the science of naming and grouping organisms.

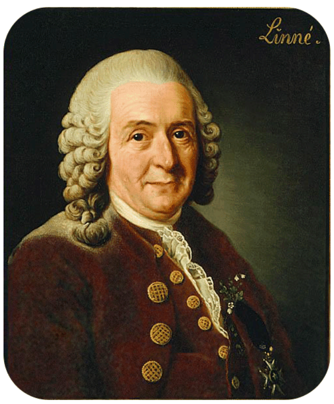


FIGURE 6.1

In the 18th century, Carl Linnaeus invented the two-name system of naming organisms (genus and species) and introduced the most complete classification system then known.

Linnaeus developed **binomial nomenclature**, a way to give a scientific name to every organism. In this system, each organism receives a two-part name in which the first word is the **genus** (a group of species), and the second word refers to one species in that genus. For example, a coyote's species name is *Canis latrans*. *Latrans* is the species and *Canis* is the genus, a larger group that includes dogs, wolves, and other dog-like animals. Here is another example: the red maple, *Acer rubra*, and the sugar maple, *Acer saccharum*, are both in the same genus and they look similar (**Figure** 6.2). Notice that the genus is capitalized and the species is not, and that the whole scientific name is in italics. Tigers *(Panthera tigris)* and lions *(Panthera leo)* have the same genus name, but are obviously different species. The names may seem strange, but the names are written in a language called Latin.

FIGURE 6.2

These leaves are from two different species of trees in the *Acer*, or maple, genus. The green leaf (*far left*) is from the sugar maple, and the red leaf (*center*) are from the red maple. One of the characteristics of the maple genus is winged seeds (*far right*).

Modern Classification

Modern taxonomists have reordered many groups of organisms since Linnaeus. The main categories that biologists use are listed here from the most specific to the least specific category (**Figure** 6.3). All organisms can be classified into one of three **domains**, the least specific grouping. The three domains are Bacteria, Archaea, and Eukarya. The Kingdom is the next category after the Domain. All life is divided among six kingdoms: Kingdom Bacteria, Kingdom Archaea, Kingdom Protista, Kingdom Plantae, Kingdom Fungi, and Kingdom Animalia.

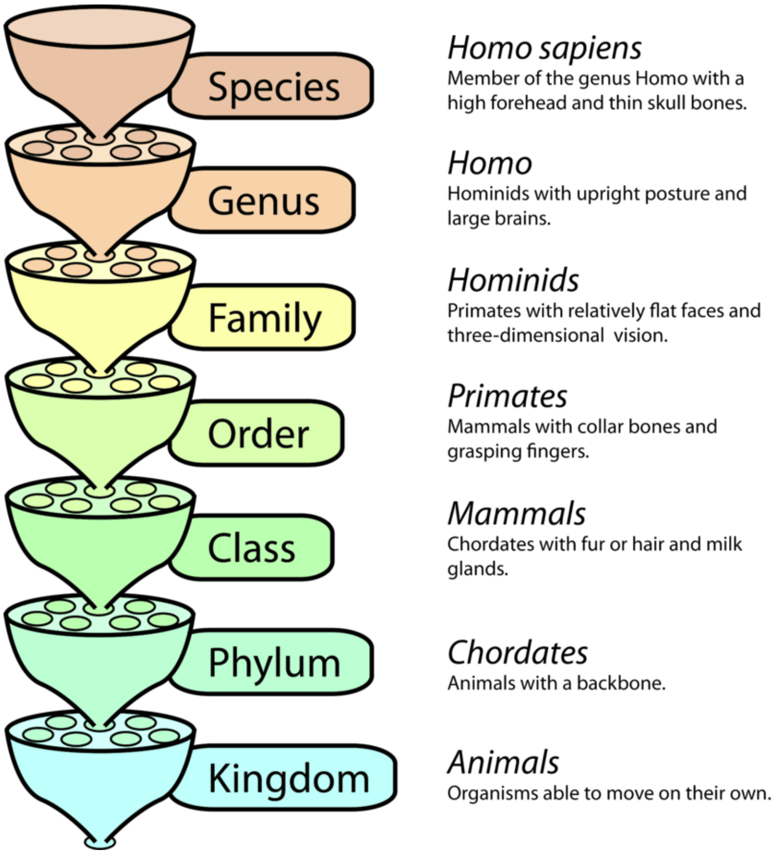


FIGURE 6.3

This diagram illustrates the classification categories for organisms, with the broadest category (kingdom) at the bottom, and the most specific category (species) at the top. We are *Homo sapiens. Homo* is the genus of great apes that includes modern humans and closely related species, and *sapiens* is the only living species of the genus.

Defining a Species

Even though naming species is straightforward, deciding if two organisms are the same species can sometimes be difficult. Linnaeus defined each species by the distinctive physical characteristics shared by these organisms. But two members of the same species may look quite different. For example, people from different parts of the world sometimes look very different, but we are all the same species (**Figure** 6.4).

So how is a species defined? A **species** is defined as a group of similar individuals that can interbreed with one another and produce fertile offspring. A species does not produce fertile offspring with other species.

Summary

- Scientists have defined several major categories for classifying organisms: domain, kingdom, phylum, class, order, family, genus, and species.
- The scientific name of an organism consists of its genus and species.

FIGURE 6.4
These children are all members of the same species, *Homo sapiens*.

Explore More

Use the resources below to answer the following questions.

Explore More I

- **Taxonomy - Shape of Life** at http://shapeoflife.org/video/other-topics/taxonomy (2:52)

MEDIA
Click image to the left or use the URL below.
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1. What do taxonomists study? How does their work help other scientists?
2. Who was the first person we know of who developed a system to categorize things? How was this done? Is his system still used today?
3. What contribution to taxonomy did Carolus Linnaeus make?

Explore More II

Use the below activity to see specific examples of how organisms are categorized. Make sure you go through all three types of organisms so you can gain a good understanding of the level at which different types of organisms separate from each other.

- **Nova: Classifying Life** at http://www.pbs.org/wgbh/nova/nature/classifying-life.html

Review

1. Who is the inventor of the modern classification system?

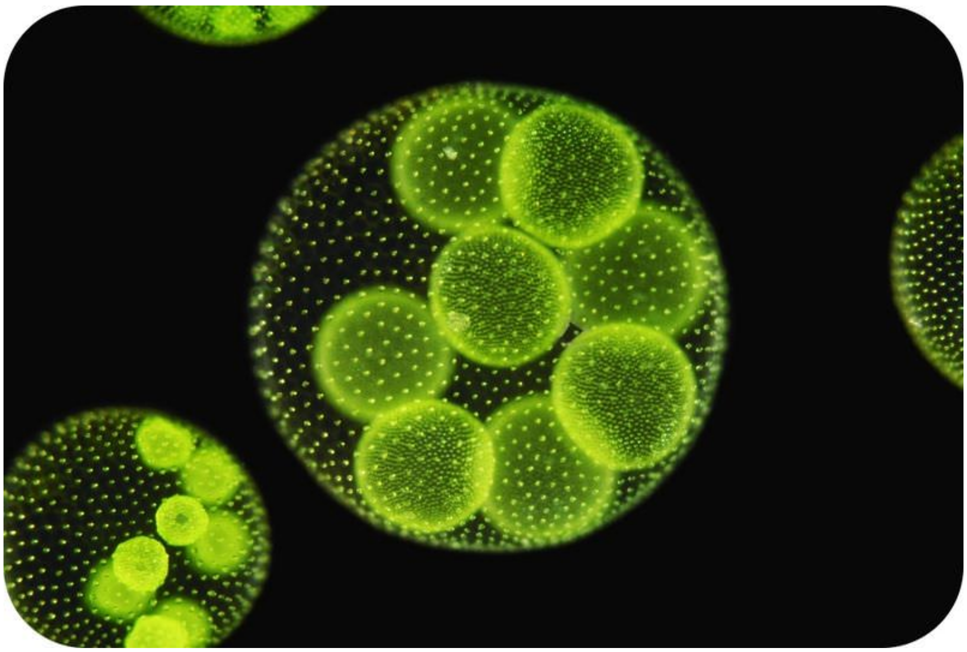
2. List the classification categories for organisms from the broadest category to the most specific.
3. What is meant by binomial nomenclature?
4. Define a species.

References

1. Alexander Roslin. Portrait of Carl Linnaeus, the inventor of modern taxonomy . Public Domain
2. Left to right: Evelyn Fitzgerald; Liz West; Flickr:DaraKero_F. Leaves from the green and red maple tree, and a maple seed . CC BY 2.0
3. Peter Halasz, modified by CK-12 Foundation. Diagram of the classification categories for organisms . CC BY-NC 3.0
4. Image copyright Monkey Business Images, 2014. This group of children are all members of the same species . Used under license from Shutterstock.com

CONCEPT 7 Light Reactions of Photosynthesis

- Describe the structure of a chloroplast.
- Write the chemical reaction of photosynthesis.
- Name the reactants and products of photosynthesis.
- Summarize the process of photosynthesis.



Are plants the only organisms that perform photosynthesis?

Although we generally discuss plants when learning about photosynthesis, keep in mind that plants are not the only organisms that can make their own food. Some bacteria and some protists, such as the algae pictured here, also perform photosynthesis. This alga has chloroplasts and photosynthesizes just like a plant.

The Process of Photosynthesis

In the Presence of Sunlight, Carbon Dioxide

Photosynthesis takes place in the organelle of the plant cell known as the chloroplasts. **Chloroplasts** are one of the main differences between plant and animal cells. Animal cells do not have chloroplasts, so they cannot photosynthesize. Photosynthesis occurs in two stages. During the first stage, the energy from sunlight is absorbed by the chloroplast. Water is used, and oxygen is produced during this part of the process. During the second stage, carbon dioxide is used, and glucose is produced.

Chloroplasts contain stacks of **thylakoids**, which are flattened sacs of membrane. Energy from sunlight is absorbed by the pigment **chlorophyll** in the thylakoid membrane. There are two separate parts of a chloroplast: the space inside the chloroplast itself, and the space inside the thylakoids (**Figure** 7.1).

- The inner compartments inside the thylakoids are called the thylakoid space (or lumen). This is the site of the first part of photosynthesis.

- The interior space that surrounds the thylakoids is filled with a fluid called **stroma**. This is where carbon dioxide is used to produce glucose, the second part of photosynthesis.

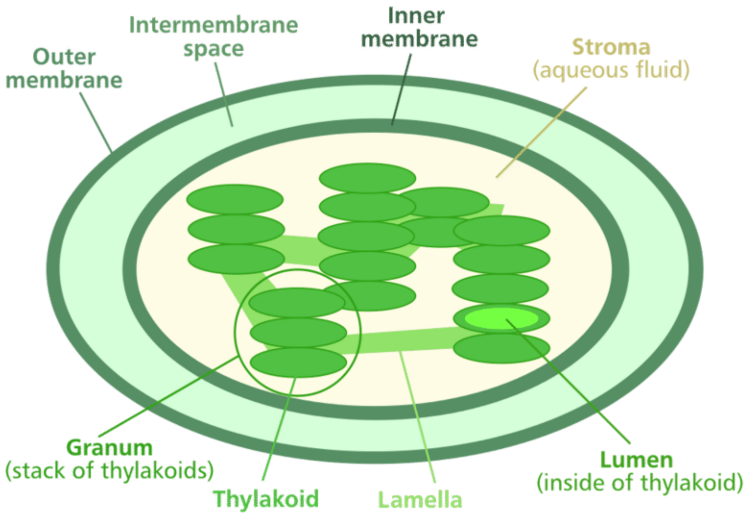


FIGURE 7.1
The chloroplast is the photosynthesis factory of the plant.

The Reactants

What goes into the plant cell to start photosynthesis? The **reactants** of photosynthesis are carbon dioxide and water. These are the molecules necessary to begin the process. But one more item is necessary, and that is sunlight. All three components, carbon dioxide, water, and the sun's energy are necessary for photosynthesis to occur. These three components must meet in the chloroplast of the leaf cell for photosynthesis to occur. How do these three components get to the cells in the leaf?

- Chlorophyll is the green pigment in leaves that captures energy from the sun. Chlorophyll molecules are located in the thylakoid membranes inside chloroplasts.
- The *veins* in a plant carry water from the roots to the leaves.
- Carbon dioxide enters the leaf from the air through special openings called **stomata** (**Figure** 7.2).

The Products

What is produced by the plant cell during photosynthesis? The **products** of photosynthesis are glucose and oxygen. This means they are produced at the end of photosynthesis. **Glucose**, the food of plants, can be used to store energy in the form of large carbohydrate molecules. Glucose is a simple sugar molecule which can be combined with other glucose molecules to form large carbohydrates, such as starch. Oxygen is a waste product of photosynthesis. It is released into the atmosphere through the stomata. As you know, animals need oxygen to live. Without photosynthetic organisms like plants, there would not be enough oxygen in the atmosphere for animals to survive.

The Chemical Reaction

The overall chemical reaction for photosynthesis is 6 molecules of carbon dioxide (CO_2) and 6 molecules of water (H_2O), with the addition of solar energy. This produces 1 molecule of glucose ($C_6H_{12}O_6$) and 6 molecules of oxygen

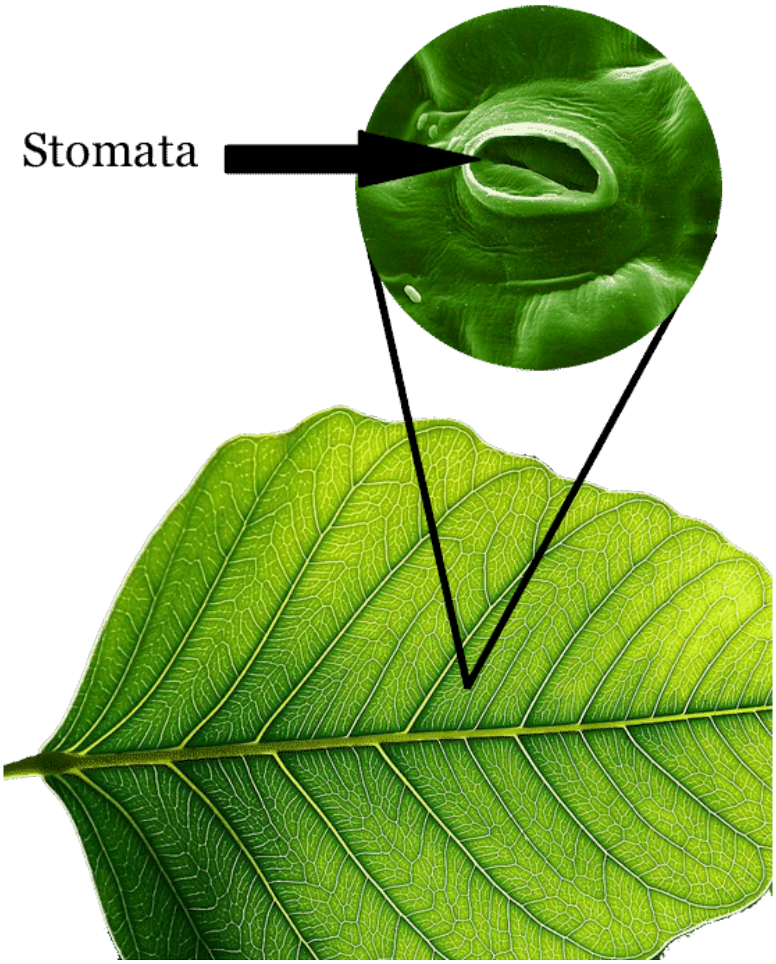


FIGURE 7.2
Stomata are special pores that allow gasses to enter and exit the leaf.

(O_2). Using chemical symbols, the equation is represented as follows: $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$. Though this equation may not seem that complicated, photosynthesis is a series of chemical reactions divided into two stages, the light reactions and the Calvin cycle (**Figure** 7.3).

The Light Reactions

Photosynthesis begins with the **light reactions.** It is during these reactions that the energy from sunlight is absorbed by the pigment chlorophyll in the thylakoid membranes of the chloroplast. The energy is then temporarily transferred to two molecules, ATP and NADPH, which are used in the second stage of photosynthesis. ATP and NADPH are generated by two **electron transport chains**. During the light reactions, water is used and oxygen is produced. These reactions can only occur during daylight as the process needs sunlight to begin.

The Calvin Cycle

The second stage of photosynthesis is the production of glucose from carbon dioxide. This process occurs in a continuous cycle, named after its discover, Melvin Calvin. The **Calvin cycle** uses CO_2 and the energy temporarily stored in ATP and NADPH to make the sugar glucose.

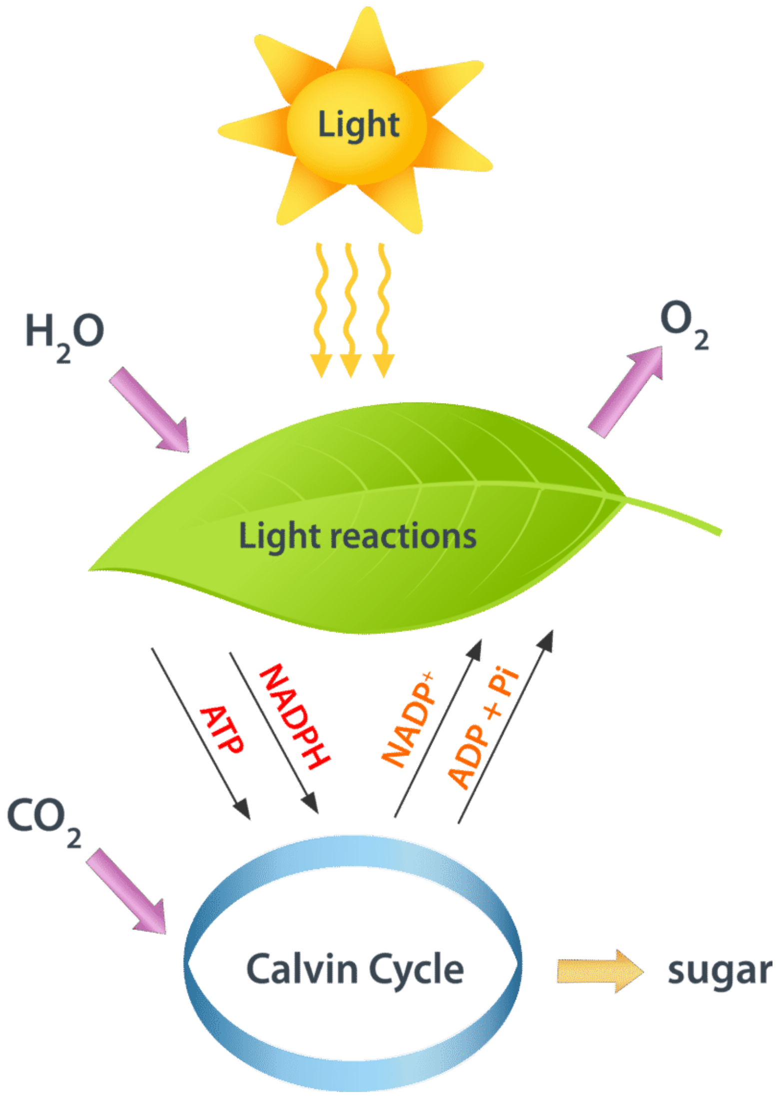


FIGURE 7.3

Photosynthesis is a two stage process. As is depicted here, the energy from sunlight is needed to start photosynthesis. The initial stage is called the light reactions as they occur only in the presence of light. During these initial reactions, water is used and oxygen is released. The energy from sunlight is converted into a small amount of ATP and an energy carrier called NADPH. Together with carbon dioxide, these are used to make glucose (sugar) through a process called the Calvin Cycle. $NADP^+$ and ADP (and Pi, inorganic phosphate) are regenerated to complete the process.

Summary

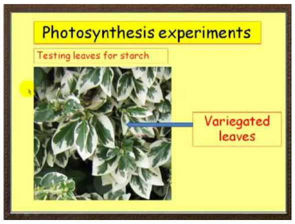
- Photosynthesis occurs in the chloroplast of the plant cell.
- Carbon dioxide, water, and the sun's energy are necessary for the chemical reactions of photosynthesis.
- The products of photosynthesis are glucose and oxygen.

Explore More

Use the resources below to answer the following questions.

Explore More I

- **Photosynthesis** at http://www.youtube.com/watch?v=RNufj-64OO0 (7:08)



MEDIA

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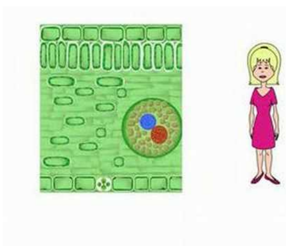
1. How do autotrophs differ from heterotrophs? How are they the same?
2. What do plants do with most of the sugar they produce during photosynthesis?
3. How do decreasing levels of CO_2 affect plants? How do you think increasing levels of CO_2 affect plants?

Explore More II

- **Photosynthesis** at http://www.youtube.com/watch?v=mpPwmvtDjWw (2:41)



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1. Where do plants get the raw materials for photosynthesis?
2. What do plants take up through their roots? Which of these substances are used for photosynthesis?
3. Where does the chemical reactions of photosynthesis take place?

Review

1. Describe the structures of the chloroplast where photosynthesis takes place.
2. What would happen if the stomata of a plant leaf were glued shut? Would that plant be able to perform photosynthesis? Why or why not?
3. What are the reactants needed to perform photosynthesis? The products?
4. What happens to the products of photosynthesis?

References

1. Ollin. Diagram of a chloroplast . Public Domain
2. Dartmouth Electron Microscope Facility; Jon Sullivan. Picture showing the stomata in a leaf . Public Domain
3. Hana Zavadska. Diagram of the steps of photosynthesis . CC BY-NC 3.0

CONCEPT 8 Levels of Ecological Organization

- Define population, community, and biosphere.
- Describe the levels of organization in ecology.
- Explain the components of an ecosystem.

How is your school organized?

Your school is organized at several levels. Individual students and teachers are divided into classes. These classes are organized into an entire middle school. Your middle school and other nearby schools are organized into a school district. Just like schools are organized, ecosystems are also organized into several different levels, and an ecosystem can be studied at any one of the various levels of organization.

Levels of Ecological Organization

Ecosystems can be studied at small levels or at large levels. The levels of organization are described below from the smallest to the largest:

- A **species** is a group of individuals that are genetically related and can breed to produce fertile young. Individuals are not members of the same species if their members cannot produce offspring that can also have children. The second word in the two word name given to every organism is the species name. For example, in *Homo sapiens*, sapiens is the species name.
- A **population** is a group of organisms belonging to the same species that live in the same area and interact with one another.
- A **community** is all of the populations of different species that live in the same area and interact with one another. A community is composed of all of the biotic factors of an area.
- An **ecosystem** includes the living organisms (all the populations) in an area and the non-living aspects of the environment (**Figure** 8.1). An ecosystem is made of the biotic and abiotic factors in an area.

FIGURE 8.1
Satellite image of Australia's Great Barrier Reef, an example of a marine ecosystem.

- The **biosphere** is the part of the planet with living organisms (**Figure** 8.2). The biosphere includes most of Earth, including part of the oceans and the atmosphere.

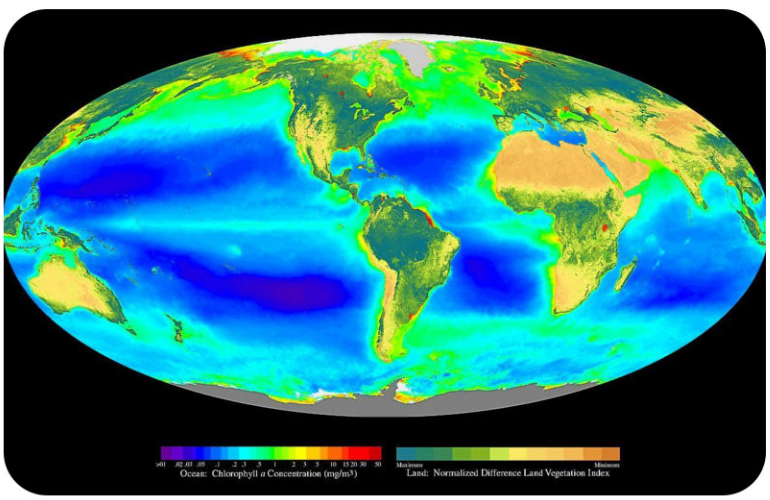


FIGURE 8.2
The global biosphere, which includes all areas that contain life, from the sea to the atmosphere.

Ecologists study ecosystems at every level, from the individual organism to the whole ecosystem and biosphere. They can ask different types of questions at each level. Examples of these questions are given in **Table** 8.1, using the zebra (*Equus zebra*) as an example.

TABLE 8.1: Ecological Questions

Ecosystem Level	Question
Individual	How do zebras keep water in their bodies?
Population	What causes the growth of a zebra populations?
Community	How does a disturbance, like a fire or predator, affect the number of mammal species in African grasslands?
Ecosystem	How does fire affect the amount of food available in grassland ecosystems?

TABLE 8.1: (continued)

Ecosystem Level	Question
Biosphere	How does carbon dioxide in the air affect global temperature?

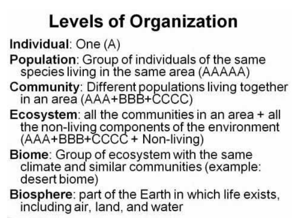
Summary

- Levels of organization in ecology include the population, community, ecosystem, and biosphere.
- An ecosystem is all the living things in an area interacting with all of the abiotic parts of the environment.

Explore More

Use the resource below to answer the questions that follow.

- **Ecology Levels and Populations** at http://www.youtube.com/watch?v=1JSS8XIYcgU (5:31)



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1. What is the relationship between an individual and a community?
2. What characteristics define a population?
3. Why is the distinction between a community and an ecosystem important to ecologists?

Review

1. Define species.
2. What is an ecosystem?
3. Define population. How is a population different from a community?

References

1. Courtesy of NASA. The Great Barrier Reef is an example of a marine ecosystem . Public Domain
2. SeaWiFS Project, NASA/Goddard Space Flight Center and ORBIMAGE. The global biosphere includes all areas that contain life . Public Domain

CONCEPT 9 Ecosystems

- Define and describe an ecosystem.
- Give examples of biotic and abiotic factors.
- Explain the relationship between producers and consumers.
- Summarize the importance of biogeochemical cycles.

What nonliving things are essential for life?

Living organisms cannot exist without the nonliving aspects of the environment. For example: air, water, and sunlight, which are all nonliving, are all essential to living organisms. Both nonliving and living things make up an ecosystem.

What is an Ecosystem?

Ecology is the study of ecosystems. That is, ecology is the study of how living organisms interact with each other and with the nonliving part of their environment. An **ecosystem** consists of all the nonliving factors and living organisms interacting in the same **habitat**. Recall that living organisms are **biotic factors**. The biotic factors of an ecosystem include all the **populations** in a habitat, such as all the species of plants, animals, and fungi, as well as all the micro-organisms. Also recall that the nonliving factors are called **abiotic factors**. Abiotic factors include temperature, water, soil, and air.

You can find an ecosystem in a large body of fresh water or in a small aquarium. You can find an ecosystem in a large thriving forest or in a small piece of dead wood. Examples of ecosystems are as diverse as the rainforest, the savanna, the tundra, or the desert (**Figure** 9.1). The differences in the abiotic factors, such as differences in temperature, rainfall, and soil quality, found in these areas greatly contribute to the differences seen in these ecosystems. Ecosystems can include well known sites, such as the Great Barrier Reef off the coast of Australia and the Greater Yellowstone Ecosystem of Yellowstone National Park, which actually includes a few different ecosystems, some with geothermal features, such as Old Faithful geyser.

FIGURE 9.1
Desert Botanical Gardens in Phoenix, Arizona.

Ecosystems need energy. Many ecosystems get their energy in the form of sunlight, which enters the ecosystem through **photosynthesis**. This energy then flows through the ecosystem, passed from **producers** to **consumers**. Plants are producers in many ecosystems. Energy flows from plants to the herbivores that eat the plants, and then to carnivores that eat the herbivores. The flow of energy depicts interactions of organisms within an ecosystem.

Matter is also recycled in ecosystems. **Biogeochemical cycles** recycle nutrients, like carbon and nitrogen, so they are always available. These nutrients are used over and over again by organisms. Water is also continuously recycled. The flow of energy and the recycling of nutrients and water are examples of the interactions between organisms and the interactions between the biotic and abiotic factors of an ecosystem.

Summary

- An ecosystem consists of all the living things and nonliving things interacting in the same area.
- Matter is also recycled in ecosystems; recycling of nutrients is important so they can always be available

Explore More

Use the resource below to answer the questions that follow.

- **How Ecosystems Work** at http://www.youtube.com/watch?v=o_RBHfjZsUQ (3:24)

MEDIA
Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/1497

1. How do land plants generate the energy they need for their metabolic energy? What do they do with excess energy?

2. Where do scavengers in an ecosystem obtain their energy from? How can scavenging be a beneficial strategy for an organism?
3. What is the role of decomposers?
4. What kind of problems can you foresee if every speck of carbon were turned into biomass? Why?
5. Complete this statement: Energy ___________ through an ecosystem, whereas nutrients are ____________.

Review

1. Define an ecosystem.
2. Distinguish between abiotic and biotic factors. Give examples of each.
3. Where does the energy come from for many ecosystems?
4. Name two nutrients that are recycled through an ecosystem.

References

1. Kevin Dooley. The Baja desert is an example of an ecosystem . CC BY 2.0

CONCEPT 10 Food Webs

- Distinguish a food chain from a food web.
- Be able to draw and interpret a food web.
- Summarize the roles of producers, herbivores, and carnivores in a food web.

How do the grasshopper and the grass interact?

Grasshoppers don't just hop on the grass. They also eat the grass. Other organisms also eat the grass, and some animals even eat the grasshopper. These interactions can be visualized by drawing a food web.

Food Webs

Energy must constantly flow through an ecosystem for the system to remain stable. What exactly does this mean? Essentially, it means that organisms must eat other organisms. **Food chains** (**Figure** 10.1) show the eating patterns in an ecosystem. Food energy flows from one organism to another. Arrows are used to show the feeding relationship between the animals. The arrow points from the organism being eaten to the organism that eats it. For example, an arrow from a plant to a grasshopper shows that the grasshopper eats the leaves. Energy and nutrients are moving from the plant to the grasshopper. Next, a bird might prey on the grasshopper, a snake may eat the bird, and then an owl might eat the snake. The food chain would be:

plant → grasshopper → bird → snake → owl.

A food chain cannot continue to go on and on. For example the food chain could not be:

plant → grasshopper → spider → frog → lizard → fox → hawk.

Food chains only have 4 or 5 total levels. Therefore, a chain has only 3 or 4 levels for energy transfer.

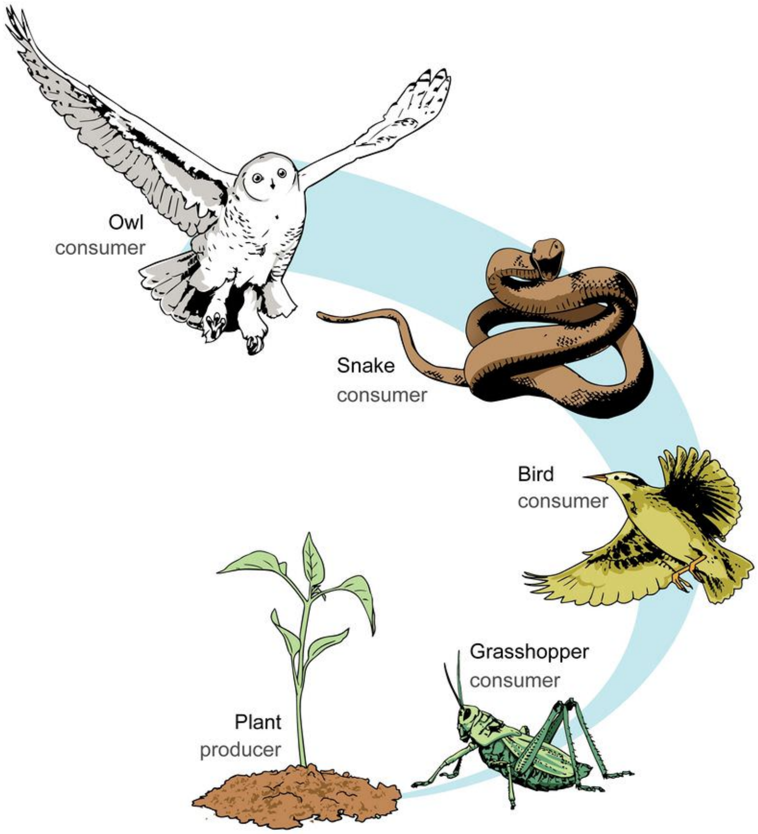


FIGURE 10.1
This food chain includes producers and consumers. How could you add decomposers to the food chain?

In an ocean ecosystem, one possible food chain might look like this: phytoplankton → krill → fish → shark. The **producers** are always at the beginning of the food chain, bringing energy into the ecosystem. Through photosynthesis, the producers create their own food in the form of glucose, but also create the food for the other organisms in the ecosystem. The **herbivores** come next, then the **carnivores**. When these **consumers** eat other organisms, they use the glucose in those organisms for energy. In this example, phytoplankton are eaten by krill, which are tiny, shrimp-like animals. The krill are eaten by fish, which are then eaten by sharks. Could **decomposers** be added to a food chain?

Each organism can eat and be eaten by many different types of organisms, so simple food chains are rare in nature. There are also many different species of fish and sharks. So a food chain cannot end with a shark; it must end with a distinct species of shark. A food chain does not contain the general category of "fish," it will contain specific species of fish. In ecosystems, there are many food chains.

Since feeding relationships are so complicated, we can combine food chains together to create a more accurate flow of energy within an ecosystem. A **food web** (**Figure** 10.2) shows the feeding relationships between many organisms in an ecosystem. If you expand our original example of a food chain, you could add deer that eat clover and foxes that hunt chipmunks. A food web shows many more arrows, but still shows the flow of energy. A complete food web may show hundreds of different feeding relationships.

For more information on food chains, see *A Million Sharks* at https://www.youtube.com/watch?v=QXMTzXaWJyk .

Summary

- A food chain is a diagram that shows feeding interactions in an ecosystem through a single pathway.

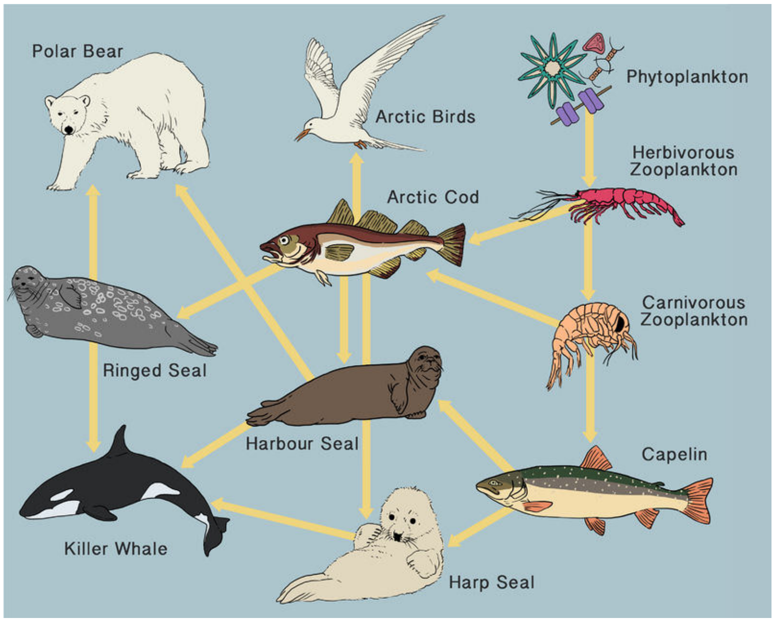


FIGURE 10.2
Food web in the Arctic Ocean.

- A food web is a diagram that shows feeding interactions between many organisms in an ecosystem through multiple intersecting pathways.

Explore More

Use the resource below to answer the questions that follow.

- **Build A Food Web** at http://www.sciencesource2.ca/resources/SS_active_art/active_art/SEinteractive_gr09_ch01_pg31/index.html

1. What do the Loons and Arctic Tern have in common in the food web?
2. What do the Beluga and the sea duck have in common in the food web?
3. What species in the food web feed on zooplankton (animal plankton)?
4. When you build your own food web what must it contain to be healthy? How many healthy food webs could you build?

Review

1. What is the difference between a food chain and a food web?
2. Food chains always begin with what type of organism? Why?
3. What is the herbivore in the following food chain: algae $\rightarrow$ fish $\rightarrow$ herons?

References

1. Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation. This food chain includes both producers and consumers, but not decomposers . CC BY-NC 3.0
2. Laura Guerin. This food web displays some feeding relationships found in the Arctic Ocean . CC BY-NC 3.0

CONCEPT 11 Energy Pyramids

- Define energy and energy pyramid.
- Explain the flow of energy through an ecosystem using an energy pyramid.
- Describe a trophic level.
- Explain the maximum number of trophic levels in an ecosystem.

How much energy could be gained from the warthog?

If the cheetah is successful in capturing the warthog, it would gain some energy by eating it. But would the cheetah gain as much energy as the warthog has ever consumed? No, the warthog has used up some of the energy it has consumed for its own needs. The cheetah will only gain a fraction of the energy that the warthog has consumed throughout its lifetime.

Energy Pyramids

When an herbivore eats a plant, the **energy** in the plant tissues is used by the herbivore. But how much of that energy is transferred to the herbivore? Remember that plants are **producers**, bringing the energy into the ecosystem by converting sunlight into glucose. Does the plant use some of the energy for its own needs? Recall the energy is the ability to do work, and the plant has plenty or "work" to do. So of course it needs and uses energy. It converts the glucose it makes into **ATP** through **cellular respiration** just like other organisms. After the plant uses the energy from glucose for its own needs, the excess energy is available to the organism that eats the plant.

The herbivore uses the energy from the plant to power its own life processes and to build more body tissues. However, only about 10% of the total energy from the plant gets stored in the herbivore's body as extra body tissue. The rest of the energy is used by the herbivore and released as heat. The next consumer on the food chain that eats the herbivore will only store about 10% of the total energy from the herbivore in its own body. This means the carnivore will store only about 1% of the total energy that was originally in the plant. In other words, only about 10% of energy of one step in a food chain is stored in the next step in the food chain. The majority of the energy is used by the organism or released to the environment.

Every time energy is transferred from one organism to another, there is a loss of energy. This loss of energy can be shown in an **energy pyramid**. An example of an energy pyramid is pictured below (**Figure** 11.1). Since there is energy loss at each step in a food chain, it takes many producers to support just a few carnivores in a community.

Each step of the food chain in the energy pyramid is called a **trophic level**. Plants or other photosynthetic organisms (**autotrophs**) are found on the first trophic level, at the bottom of the pyramid. The next level will be the herbivores, and then the carnivores that eat the herbivores. The energy pyramid (**Figure** 11.1) shows four levels of a food chain, from producers to carnivores. Because of the high rate of energy loss in food chains, there are usually only 4 or 5 trophic levels in the food chain or energy pyramid. There just is not enough energy to support any additional trophic levels. **Heterotrophs** are found in all levels of an energy pyramid other than the first level.

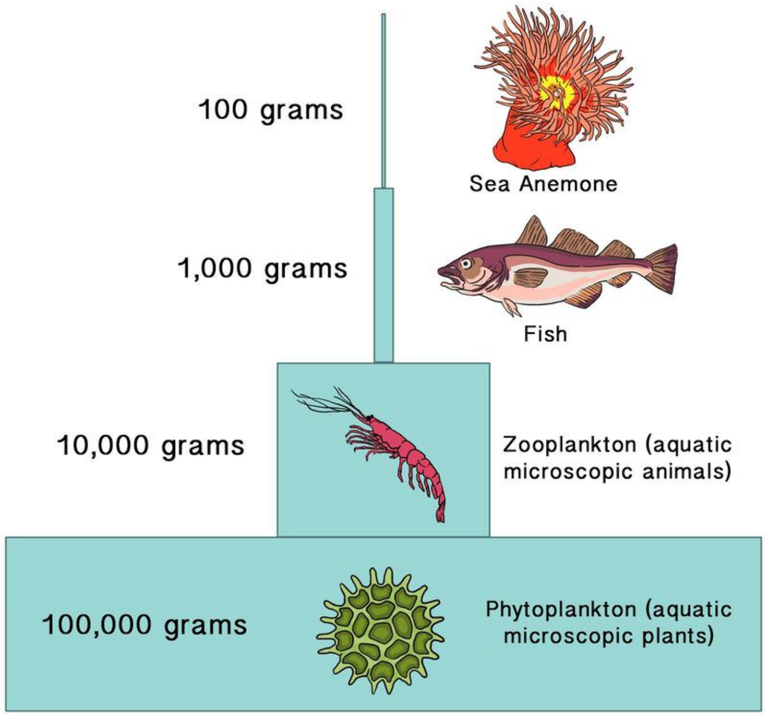


FIGURE 11.1

As illustrated by this ecological pyramid, it takes a lot of phytoplankton to support the carnivores of the oceans. This energy pyramid has four trophic levels, which signify the organisms place in the food chain from the original source of energy.

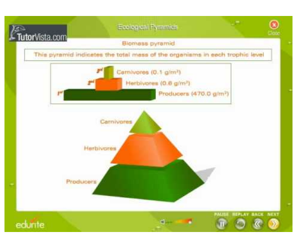
Summary

- As energy is transferred along a food chain, energy is lost as heat.
- Only about 10% of energy of one step in a food chain is stored in the next step in the food chain.

Explore More

Use the resource below to answer the questions that follow.

- **Ecological Pyramids** at http://www.youtube.com/watch?v=NJplkrliUEg (4:03)



MEDIA

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1. What are three types of ecological pyramids? How do their shapes compare?

2. Do you think it would be possible to construct a pyramid where the number of carnivores was more than the number of herbivores? Why or why not?
3. Do you think it would be possible to construct a pyramid where the biomass of carnivores was more than the biomass of herbivores? How does this compare to a numbers pyramid.
4. What consumes energy at each trophic level? How does this contribute to energy loss between trophic levels?

Review

1. When an herbivore eats a plant, what happens to 90% of the energy obtained from that plant?
2. What is a trophic level?
3. Why are the number of trophic levels limited?
4. In a forest community, caterpillars eat leaves, and birds eat caterpillars. Draw an energy pyramid using this information.

References

1. Laura Guerin. This energy pyramid illustrates that many organisms on the bottom are needed to support the top carnivores . CC BY-NC 3.0

CONCEPT 12 Producers

- Explain where all the energy in an ecosystem originates.
- Define photosynthesis and chemosynthesis.
- Describe how energy enters an ecosystem.
- Explain the role of a producer.

Where does all the bear's energy come from?

Bears get their energy from their food. Brown bears eat a varied diet, from nuts and berries to fish and other animals. When bears eat a berry, they are obtaining energy that the plant originally captured from the sun. Even when a bear eats another animal, the energy in that animal ultimately came from eating a producer that captured the sun's energy.

Producers

Energy is the ability to do work. In organisms, this work can be physical work, like walking or jumping, or it can be the work used to carry out the chemical processes in their cells. Every biochemical reaction that occurs in an organism's cells needs energy. All organisms need a constant supply of energy to stay alive.

Some organisms can get the energy directly from the sun. Other organisms get their energy from other organisms. Through **predator-prey relationships**, the energy of one organism is passed on to another. Energy is constantly flowing through a community. With just a few exceptions, all life on Earth depends on the sun's energy for survival.

The energy of the sun is first captured by **producers** (**Figure** 12.1), organisms that can make their own food. Many producers make their own food through the process of **photosynthesis**. The "food" the producers make is the sugar, **glucose**. Producers make food for the rest of the ecosystem. As energy is not recycled, energy must consistently be captured by producers. This energy is then passed on to the organisms that eat the producers, and then to the organisms that eat those organisms, and so on.

Recall that the only required ingredients needed for photosynthesis are sunlight, carbon dioxide (CO_2), and water (H_2O). From these simple inorganic ingredients, photosynthetic organisms produce the carbohydrate glucose ($C_6H_{12}O_6$), and other complex organic compounds. Essentially, these producers are changing the energy from the sunlight into a usable form of energy. They are also making the oxygen that we breathe. Oxygen is a waste product of photosynthesis.

The survival of every ecosystem is dependent on the producers. Without producers capturing the energy from the sun and turning it into glucose, an ecosystem could not exist. On land, plants are the dominant producers. **Phytoplankton**, tiny photosynthetic organisms, are the most common producers in the oceans and lakes. Algae, which is the green layer you might see floating on a pond, are an example of phytoplankton.

There are also bacteria that use chemical processes to produce food. They get their energy from sources other than the sun, but they are still called producers. This process is known as **chemosynthesis**, and is common in ecosystems without sunlight, such as certain marine ecosystems.

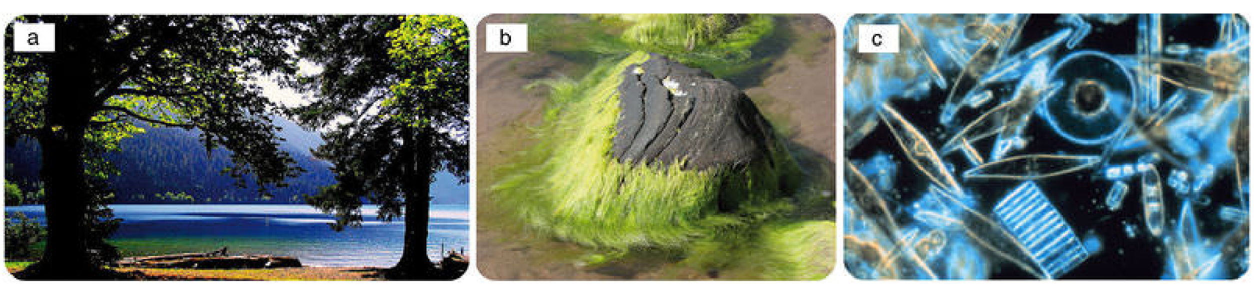


FIGURE 12.1

Producers include (a) plants, (b) algae, and (c) diatoms.

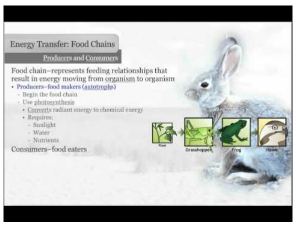
Summary

- With just a few exceptions, all life on Earth depends on the sun's energy for survival.
- Producers make food for the rest of the ecosystem through the process of photosynthesis, where the energy of the sun is used to convert carbon dioxide and water into glucose.

Explore More

Use the resource below to answer the questions that follow.

- **Producers and Consumers** at http://www.youtube.com/watch?v=P0a97kS_3SA (1:59)



MEDIA

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1. Can producers function without sunlight? Why or why not?
2. What are some examples of producers? Why are they called autotrophs?
3. How do some producers use sunlight to make "food"? What other resources do they require?

Review

1. Where does all the "food" in an ecosystem ultimately come from?
2. What is the most common method of producing energy for an ecosystem? What is the energy that is made?
3. What "ingredients" are needed for the process of photosynthesis?
4. Why are producers important to an ecosystem?

References

1. (a) Jan Tik; (b) Flickr:qorize; (c) Courtesy of Prof. Gordon T. Taylor, Stony Brook University/NSF Polar Programs. Producers include plants, algae, and diatoms . (a) CC BY 2.0; (b) CC BY 2.0; (c) Public Domain

Concept 13 Consumers and Decomposers

- Explain the roles of consumers and decomposers in an ecosystem.
- Distinguish herbivores from carnivores and omnivores.
- Classify organisms on the basis of how they obtain energy and describe examples of each.

What is breaking down this leaf?

Notice how this leaf is slowly being broken down. This process can be carried out by fungi and bacteria on the ground. Breaking down old leaves is an important process since it releases the nutrients in the dead leaves back into the soil for living plants to use.

Consumers and Decomposers

Recall that **producers** make their own food through photosynthesis. But many organisms are not producers and cannot make their own food. So how do these organisms obtain their energy? They must get their energy from other organisms. They must eat other organisms, or obtain their energy from these organisms some other way. The organisms that obtain their energy from other organisms are called **consumers**. All animals are consumers, and they eat other organisms. Fungi and many protists and bacteria are also consumers. But, whereas animals eat other organisms, fungi, protists, and bacteria "consume" organisms through different methods.

The consumers can be placed into different groups, depending on what they consume.

- **Herbivores** are animals that eat producers to get energy. For example, rabbits and deer are herbivores that eat plants. The caterpillar pictured below (**Figure** 13.1) is a herbivore. Animals that eat phytoplankton in aquatic environments are also herbivores.
- **Carnivores** feed on animals, either herbivores or other carnivores. Snakes that eat mice are carnivores. Hawks that eat snakes are also carnivores (**Figure** 13.1).

- **Omnivores** eat both producers and consumers. Most people are omnivores, since they eat fruits, vegetables, and grains from plants, and also meat and dairy products from animals. Dogs, bears, and raccoons are also omnivores.

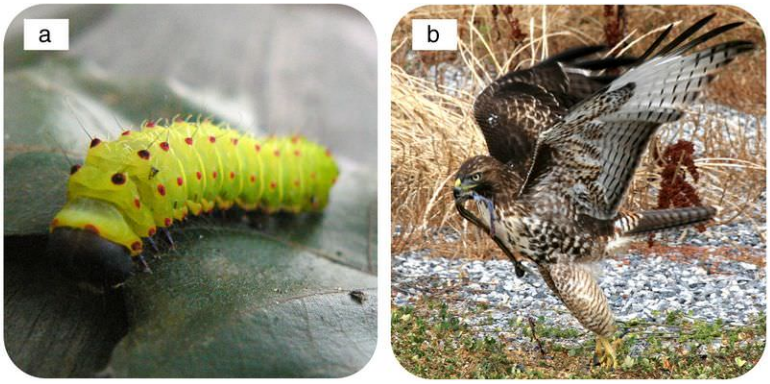

FIGURE 13.1
Examples of consumers are caterpillars (herbivores) and hawks (carnivore).

Decomposers and Stability

Decomposers (**Figure** 13.2) get nutrients and energy by breaking down dead organisms and animal wastes. Through this process, decomposers release nutrients, such as carbon and nitrogen, back into the environment. These nutrients are recycled back into the ecosystem so that the producers can use them. They are passed to other organisms when they are eaten or consumed. Many of these nutrients are recycled back into the soil, so they can be taken up by the roots of plants.

The stability of an ecosystem depends on the actions of the decomposers. Examples of decomposers include mushrooms on a decaying log. Bacteria in the soil are also decomposers. Imagine what would happen if there were no decomposers. Wastes and the remains of dead organisms would pile up and the nutrients within the waste and dead organisms would not be released back into the ecosystem. Producers would not have enough nutrients. The carbon and nitrogen necessary to build organic compounds, and then cells, allowing an organism to grow, would be insufficient. Other nutrients necessary for an organism to function properly would also not be sufficient. Essentially, many organisms could not exist.

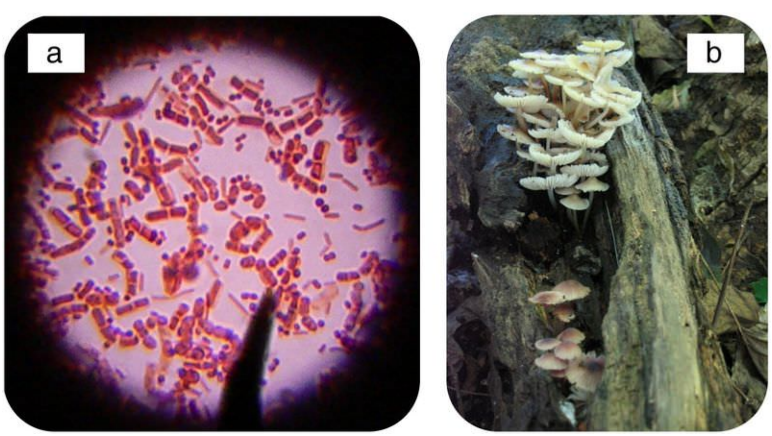

FIGURE 13.2
Examples of decomposers are (a) bacteria and (b) fungi.

Summary

- Consumers must obtain their nutrients and energy by eating other organisms.
- Decomposers break down animal remains and wastes to get energy.
- Decomposers are essential for the stability and survival of an ecosystem.

Explore More

Use the resource below to answer the questions that follow.

- **Decomposers** at http://www.youtube.com/watch?v=Z6V0a_7N1Mw (3:19)

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1. What is the role of decomposers in an ecosystem? What is the source of the matter which is decomposed?
2. How do the actions of earthworms improve soil quality? How does this impact the amount of biomass an ecosystem can support?
3. How do gastropods function as decomposers?

Review

1. What is a consumer?
2. What's the term for a consumer that eats both leaves and fish?
3. What are the different types of consumers?
4. Why are decomposers important in the ecosystem?

References

1. (a) Benny Mazur (Flickr: Benimoto); (b) Steve Jurvetson (Flickr: jurvetson). Both caterpillars and hawks are consumers . CC-BY 2.0
2. (a) Umberto Salvagnin (Flickr: kaibara87); (b) Flickr:takomabibelot. Bacteria and fungi are often decomposers . CC BY 2.0

CONCEPT 14 Predation

- Define predation.
- Explain the different types of predation.
- Describe how predation affects the community.
- Explain the advantages of camouflage and mimicry.

Can insects hunt for food?

When you think of an animal hunting for its food, large animals such as lions may come to mind. But many tiny animals also hunt for their food. For example, this praying mantis is eating a fly. To eat the fly, the praying mantis first had to catch the fly, which is a form of hunting.

Predation

Predation is another mechanism in which species interact with each other. Predation is when a predator organism feeds on another living organism or organisms, known as **prey**. The predator always lowers the prey's **fitness**. It does this by keeping the prey from surviving, reproducing, or both. **Predator-prey relationships** are essential to maintaining the balance of organisms in an ecosystem. Examples of predator-prey relationships include the lion and zebra, the bear and fish, and the fox and rabbit.

There are different types of predation, including:

- true predation.
- grazing.
- parasitism.

True predation is when a predator kills and eats its prey. Some predators of this type, such as jaguars, kill large prey. They tear it apart and chew it before eating it. Others, like bottlenose dolphins or snakes, may eat their prey whole. In some cases, the prey dies in the mouth or the digestive system of the predator. Baleen whales, for example,

FIGURE 14.1
This lion is an example of a predator on the hunt.

eat millions of plankton at once. The prey is digested afterward. True predators may hunt actively for prey, or they may sit and wait for prey to get within striking distance. Certain traits enable organisms to be effective hunters. These include camouflage, speed, and heightened senses. These traits also enable certain prey to avoid predators.

In **grazing**, the predator eats part of the prey but does not usually kill it. You may have seen cows grazing on grass. The grass they eat grows back, so there is no real effect on the population. In the ocean, kelp (a type of seaweed) can regrow after being eaten by fish.

Predators play an important role in an ecosystem. For example, if they did not exist, then a single species could become dominant over others. Grazers on a grassland keep grass from growing out of control. Predators can be **keystone species**. These are species that can have a large effect on the balance of organisms in an ecosystem. For example, if all of the wolves are removed from a population, then the population of deer or rabbits may increase. If there are too many deer, then they may decrease the amount of plants or grasses in the ecosystem. Decreased levels of **producers** may then have a detrimental effect on the whole ecosystem. In this example, the wolves would be a keystone species.

Prey also have adaptations for avoiding predators. Prey sometimes avoid detection by using camouflage (**Figure** 14.2). **Camouflage** means that species have an appearance (color, shape, or pattern) that helps them blend into the background. **Mimicry** is a related adaptation in which a species uses appearance to copy or mimic another species. For example, a non-poisonous dart frog may evolve to look like a poisonous dart frog. Why do you think this is an adaptation for the non-poisonous dart frog? Mimicry can be used by both predators and prey (**Figure** 14.3).

Parasitism is a type of **symbiotic** relationship and will be described in the *Symbiosis* concept.

FIGURE 14.2
Camouflage by the dead leaf mantis makes it less visible to both its predators and prey. If alarmed, it lies motionless on the rainforest floor of Madagascar, Africa, camouflaged among the actual dead leaves. It eats other animals up to the size of small lizards.

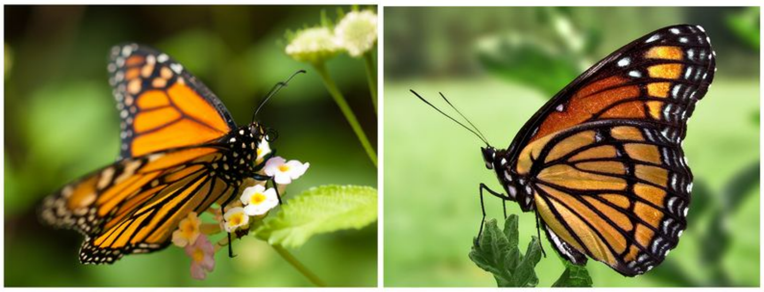

FIGURE 14.3
An example of mimicry, where the Viceroy butterfly (*right*) mimics the unpleasant Monarch butterfly (*left*). Both butterfly species are avoided by predators to a greater degree than either one would be without mimicry.

Summary

- Predation happens when a predator organism feeds on another living organism or organisms, known as prey.
- Predators can be keystone species, a species that can have a large effect on the balance of organisms in an ecosystem.

Explore More

Use the resource below to answer the questions that follow.

- **Best Disguised Predator Fish?** at http://video.nationalgeographic.com/video/stonefish-predation (1:18)

1. What allows the stone fish to sneak up on prey?
2. What does the stone fish eat?
3. Where does the stone fish hide?

Review

1. What is predation?
2. What's the difference between grazing and true predation?
3. What sorts of adaptations do prey have for avoiding predators?
4. Predators can be a keystone species. What does this mean?

References

1. Nick Jewell (Flickr:MacJewell). This lion is an example of a hunting predator . CC BY 2.0
2. Adrian Pingstone (Wikimedia: Arpingstone). This dead leaf mantis is camouflaged by the actual dead leaves . Public Domain
3. Viceroy: James D Rucker; Monarch: William Warby (Flickr:wwarby). The Viceroy butterfly mimics the unpleasant Monarch butterfly . CC BY 2.0

CONCEPT 15 Invasive Species

New To The Neighborhood?

FIGURE 15.1
The zebra mussel (Dreissena polymorpha) is one of the best known and most successful invasive species.

Where'd You Come From?

Invasive species are well known for the changes they cause in ecosystems. A few dramatic cases like the Cane Toad (*Bufo marinus*) in Australia or the Brown Tree Snake (*Boiga irregularis*) in Guam have greatly influenced people's opinion of invasive species, creating images of marauding invasive species callously driving native species to extinction. However, the real story is a bit different.

Every day up to 10,000 species are transported around the world into new ecosystems. Think about this for a second, 10,000 species per day. Have you heard of 10,000 invasive species? No, the truth is that ecosystems are both complex and resilient. Most species transported into ecosystems can't compete with the natives who grew up in that ecosystem. Natural selection gives the native species an edge. Make no mistake, there are exceptions, and their effects both ecologically and economically can be devastating, but they are the exception and not the rule. For a species to be a successful invader it needs to have an edge, like a chemical defense or life history trait which is unknown in the system it invades and allows it to dominate. Find out more about some species which have these traits, and what researchers are learning about them.

- **Invasive Species** from AMNH http://www.youtube.com/watch?v=ENhldZeyF6o

Explore More

Use the resources below to answer the following questions:

1. What is the difference between an exotic and native species?

2. What key trait of zebra mussels (*Dreissena polymorpha*) has given them a competitive edge over native mussels in the Great Lakes?
3. Have zebra mussels caused the extinction of native mussels? Have all the effects of zebra mussels been negative? How does this affect your view of invasive species?
4. How does the rate of movement and spacial scale currently seen with invasive species differ from simple range expansion of species? How does the rate of change affect a native species' ability to respond to a new competitor or predator?
5. How has international shipping affected the spread of species? Explain your answer as fully as you can. What steps would you take to control this situation?
6. How does the invasion of the Rusty Crayfish (*Orconectes rusticus*) into Sparkling Lake demonstrate that extinction is not the only or even the most common outcome of invasive species?

Resources Cited

- http://www.youtube.com/watch?v=ENhldZeyF6o
- http://www.glsc.usgs.gov/_files/factsheets/2000-6%20Zebra%20Mussels.pdf
- http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev3_015416.pdf
- http://www.publicaffairs.noaa.gov/pr96/mar96/noaa96-11.html
- http://currenttopicsinbiogeography.blogspot.com/2010/02/invasion-of-rusty-crayfish.html
- http://nsgl.gso.uri.edu/minnu/minnug99001.pdf
- http://anstaskforce.gov/spoc/rustycrayfish.php
- http://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=214
- http://www.issg.org/database/species/ecology.asp?si=217&fr=1&sts=sss

MEDIA

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References

1. . Zebra mussels.