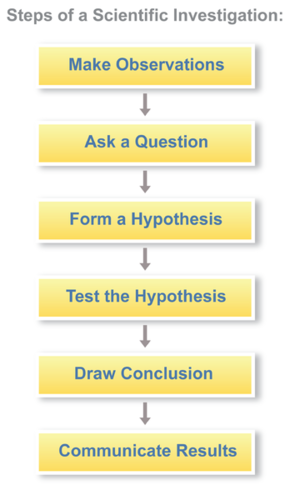
**Scientific Investigation**

* Describe how scientists study the natural world.

**Chances are you've heard of the scientific method. But what exactly is the scientific method?**

Is it a precise and exact way that all science must be done? Or is it a series of steps that most scientists generally follow, but may be modified for the benefit of an individual investigation?

**The Scientific Method**

"We also discovered that science is cool and fun because you get to do stuff that no one has ever done before." In the article *Blackawton bees,* published by eight to ten year old students: Biology Letters (2010) <http://rsbl.royalsocietypublishing.org/content/early/2010/12/18/rsbl.2010.1056.abstract>.

There are basic methods of gaining knowledge that are common to all of science. At the heart of science is the scientific investigation, which is done by following the **scientific method** . A **scientific investigation** is a plan for asking questions and testing possible answers. It generally follows the steps listed in **Figure** [below](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAxLTAyLVNjaWVudGlmaWMtSW52ZXN0aWdhdGlvbi0x) . See <http://www.youtube.com/watch?v=KZaCy5Z87FA>for an overview of the scientific method.

Steps of a Scientific Investigation. A scientific investigation typically has these steps.

**Making Observations**

A scientific investigation typically begins with observations. You make observations all the time. Let’s say you take a walk in the woods and observe a moth, like the one in **Figure** [beside](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QklPLTAxLTAzLU1vdGgtRXllLVNwb3Rz), resting on a tree trunk. You notice that the moth has spots on its wings that look like eyes. You think the eye spots make the moth look like the face of an owl.

Does this moth remind you of an owl?

**Asking a Question**

Observations often lead to questions. For example, you might ask yourself why the moth has eye spots that make it look like an owl’s face. What reason might there be for this observation?

**Forming a Hypothesis**

The next step in a scientific investigation is forming a hypothesis. A **hypothesis** is a possible answer to a scientific question, but it isn’t just any answer. A hypothesis must be based on scientific knowledge, and it must be logical. A hypothesis also must be falsifiable. In other words, it must be possible to make observations that would disprove the hypothesis if it really is false. Assume you know that some birds eat moths and that owls prey on other birds. From this knowledge, you reason that eye spots scare away birds that might eat the moth. This is your hypothesis.

**Testing the Hypothesis**

To test a hypothesis, you first need to make a prediction based on the hypothesis. A **prediction** is a statement that tells what will happen under certain conditions. It can be expressed in the form: If A occurs, then B will happen. Based on your hypothesis, you might make this prediction: If a moth has eye spots on its wings, then birds will avoid eating it.

Next, you must gather evidence to test your prediction. **Evidence** is any type of data that may either agree or disagree with a prediction, so it may either support or disprove a hypothesis. Evidence may be gathered by an **experiment**. Assume that you gather evidence by making more observations of moths with eye spots. Perhaps you observe that birds really do avoid eating moths with eye spots. This evidence agrees with your prediction.

**Drawing Conclusions**

Evidence that agrees with your prediction supports your hypothesis. Does such evidence prove that your hypothesis is true? No; a hypothesis cannot be proven conclusively to be true. This is because you can never examine all of the possible evidence, and someday evidence might be found that disproves the hypothesis. Nonetheless, the more evidence that supports a hypothesis, the more likely the hypothesis is to be true.

**Communicating Results**

The last step in a scientific investigation is communicating what you have learned with others. This is a very important step because it allows others to test your hypothesis. If other researchers get the same results as yours, they add support to the hypothesis. However, if they get different results, they may disprove the hypothesis. When scientists share their results, they should describe their methods and point out any possible problems with the investigation. For example, while you were observing moths, perhaps your presence scared birds away. This introduces an error into your investigation. You got the results you predicted (the birds avoided the moths while you were observing them), but not for the reason you hypothesized. Other researchers might be able to think of ways to avoid this error in future studies.

*The Scientific Method Made Easy* explains scientific method: <http://www.youtube.com/watch?v=zcavPAFiG14&feature=related>(9:55).

Go to <http://goo.gl/YJzuc9> for more information

As you view *The Scientific Method Made Easy,* focus on these concepts:

1. the relationship between evidence, conclusions and theories,
2. the "ground rules" of scientific research,
3. the steps in a scientific procedure,
4. the meaning of the "replication of results,"
5. the meaning of "falsifiable,"
6. the outcome when the scientific method is not followed.

**Summary**

* At the heart of science is the scientific investigation, which is done by following the scientific method. A scientific investigation is a plan for asking questions and testing possible answers.
* A scientific investigation typically begins with observations. Observations often lead to questions.
* A hypothesis is a possible logical answer to a scientific question, based on scientific knowledge.
* A prediction is a statement that tells what will happen under certain conditions.
* Evidence is any type of data that may either agree or disagree with a prediction, so it may either support or disprove a hypothesis. Conclusions may be formed from evidence.
* The last step in a scientific investigation is the communication of results with others.

**Practice I**

Use this resource to answer the questions that follow.

* <http://www.hippocampus.org/Biology>D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngBiology for AP\* D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngSearch: **How Do Biologists Study?**

1. Why is biology described as "a problem solving process"?
2. Define causation.
3. What is a high correlation? What was the example used to demonstrate a high correlation?
4. Does correlation equal causation? Why or why not?
5. Why is a cause and effect relationship important?

**Science Experiments**

* Explain the concept of an experiment.

**So what exactly is an experiment?**

At first you may picture a science laboratory with microscopes and chemicals and people in white lab coats. But do all experiments have to be done in a lab? And do all scientists have to wear lab coats?

**Experiments**

**Figure** [below](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAxLTA0LVBsYW50LUV4cGVyaW1lbnQ.) shows a laboratory experiment involving plants. An **experiment** is a special type of scientific investigation that is performed under controlled conditions, usually in a laboratory. Some experiments can be very simple, but even the simplest can contribute important evidence that helps scientists better understand the natural world. An example experiment can be seen here <http://www.youtube.com/watch?v=dVRBDRAsP6U>or here <http://www.youtube.com/watch?v=F10EyGwd57M>

The picture shows a laboratory experiment studying plant growth. What might this experiment involve?

**Medicine from the Ocean Floor**

Some experiments are much more sophisticated than those shown above. For example, scientists at the University of California, Santa Cruz are using robots to sort through thousands of marine chemicals in search of cures for diseases like cholera, breast cancer, and malaria. More info on the experiments can be found below:

<http://www.kqed.org/quest/blog/2009/03/20/reporters-notes-medicine-from-the-ocean-floor/>

<http://www.kqed.org/quest/radio/medicine-from-the-ocean-floor>

<http://science.kqed.org/quest/slideshow/web-extra-medicine-from-the-ocean-floor-slideshow/>

**Variables**

An experiment generally tests how one **variable** is affected by another. The affected variable is called the **dependent variable**. In the plant experiment shown above, the dependent variable is plant growth. The variable that affects the dependent variable is called the **independent variable**. In the plant experiment, the independent variable is fertilizer—some plants will get fertilizer, others will not. In any experiment, other factors that might affect the dependent variable must be controlled. In the plant experiment, what factors do you think should be controlled? (*Hint:* What other factors might affect plant growth?)

**Sample Size and Repetition**

The sample in an experiment or other investigation consists of the individuals or events that are studied, and the size of the sample (or **sample size**) directly affects the interpretation of the results. Typically, the sample is much smaller than all such individuals or events that exist in the world. Whether the results based on the sample are true in general cannot be known for certain. However, the larger the sample is, the more likely it is that the results are generally true.

Similarly, the more times that an experiment is repeated (which is known as **repetition**) and the same results obtained, the more likely the results are valid. This is why scientific experiments should always be repeated.

**Summary**

* An experiment is a special type of scientific investigation that is performed under controlled conditions, usually in a laboratory.
* An experiment generally tests how one variable is affected by another.
* The sample size in an experiment directly affects the interpretation of the results.
* Repetition is the repeating of an experiment, validating the results.

**Practice**

Use this resource to answer the questions that follow.

* <http://www.hippocampus.org/Biology>D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngBiology for AP\* D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngSearch: **How Do Biologists Study?**

1. What is a hypothesis?
2. What is a controlled scientific experiment?
3. What causes Lyme disease?
4. What is the relationship between the number of deer and Lyme disease?
5. Was the original hypothesis correct?
6. If the hypothesis is not correct, what must be done next?

**Scientific Theories**

* Explain what a scientific theory is.
* Name several well-known theories in biology.

**Theory vs. theory. Is a scientific *theory* different from the everyday use of the word *theory?***

A scientific theory is accepted as a scientific *truth*, supported by evidence collected by many scientists. The theory of evolution by natural selection is a classic scientific theory.

**Scientific Theories**

With repeated testing, some hypotheses may eventually become scientific theories. Keep in mind, a hypothesis is a possible answer to a scientific question. A **scientific theory** is a broad explanation for events that is widely accepted as true. To become a theory, a hypothesis must be tested over and over again, and it must be supported by a great deal of evidence.

People commonly use the word *theory* to describe a guess about how or why something happens. For example, you might say, “I think a woodchuck dug this hole in the ground, but it’s just a theory.” Using the word *theory* in this way is different from the way it is used in science. A scientific theory is more like a fact than a guess because it is so well-supported. There are several well-known theories in biology, including the theory of evolution, cell theory, and germ theory.

Two videos explaining scientific theories can be seen at <http://www.youtube.com/watch?v=S5YGhprR6KE>and <http://www.youtube.com/watch?v=jdWMcMW54fA>. Go to <http://goo.gl/Jn6dU9> for more content.

As you view *Know the Difference (Between Hypothesis and Theory)*, focus on these concepts:

1. the controversy surrounding the words "hypothesis" and "theory,"
2. the scientific use of the words "hypothesis" and "theory,"
3. the criteria for a "hypothesis,"
4. the National Academy of Sciences definition of "theory,"
5. the meaning of the statement, "theories are the bedrock of our understanding of nature."

**The Theory of Evolution**

**Evolution** is a change in the characteristics of living things over time. Evolution occurs by a process called **natural selection**. In natural selection, some living things produce more offspring than others, thus pass more genes to the next generation than others do. Over many generations, this can lead to major changes in the characteristics of living things. The theory of evolution by natural selection explains how living things are changing today and how modern life has descended from ancient life forms that no longer exist on Earth.

**The Cell Theory**

According to the **cell theory**, all living things are made up of cells, and living cells always come from other living cells.

**The Germ Theory**

The **germ theory** of disease, also called the pathogenic theory of medicine, is a theory that proposes that microorganisms are the cause of many diseases.

**Summary**

* With repeated testing, some hypotheses may eventually become scientific theories. A scientific theory is a broad explanation for events that is widely accepted as true.
* Evolution is a change species over time. Evolution occurs by natural selection.
* The cell theory states that all living things are made up of cells, and living cells always come from other living cells.
* The germ theory proposes that microorganisms are the cause of many diseases.

**Practice**

Use these resources to answer the questions that follow.

* **Darwinian Evolution** - *Science and Theory* at Non-Majors Biology: <http://www.hippocampus.org/Biology>.

1. How is the word "theory" used in common language?
2. How is the word "theory" used in science?
3. Provide a detailed definition for a "scientific theory."

* **Concepts and Methods in Biology** - *Theories and Laws* at Non-Majors Biology: <http://www.hippocampus.org/Biology>.

1. What is a scientific law?
2. What is a scientific theory?
3. Give an example of a scientific theory.
4. Why is a scientific theory different from the common use of the word "theory"?

**Characteristics of Life**

* List and describe the characteristics of life.

**What do a bacterium and a whale have in common?**

Do they share characteristics with us? All living organisms, from the smallest bacterium to the largest whale, share certain characteristics of life. Without these characteristics, there is no *life.*

**Characteristics of Life**

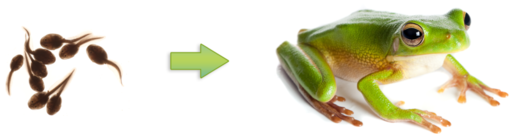
Look at the duck decoy in **Figure** [below](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAxLTA2LUR1Y2stZGVjb3k.). It looks very similar to a real duck. Of course, real ducks are living things. What about the decoy duck? It looks like a duck, but it is actually made of wood. The decoy duck doesn’t have all the characteristics of a living thing. What characteristics set the real ducks apart from the decoy duck? What are the characteristics of living things?

To be classified as a living thing, an object must have all six of the following characteristics:

1. It responds to the environment.
2. It grows and develops.
3. It produces offspring.
4. It maintains homeostasis.
5. It has complex chemistry.
6. It consists of cells.

**Response to the Environment**

All living things detect changes in their environment and respond to them. What happens if you step on a rock? Nothing; the rock doesn’t respond because it isn’t alive. But what if you think you are stepping on a rock and actually step on a turtle shell? The turtle is likely to respond by moving—it may even snap at you!

**Growth and Development**

All living things grow and develop. For example, a plant seed may look like a lifeless pebble, but under the right conditions it will grow and develop into a plant. Animals also grow and develop. Look at the animals in **Figure** [beside](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAxLTA3LUZyb2ctYW5kLVRhZHBvbGVz). How will the tadpoles change as they grow and develop into adult frogs? Tadpoles go through many changes to become adult frogs.

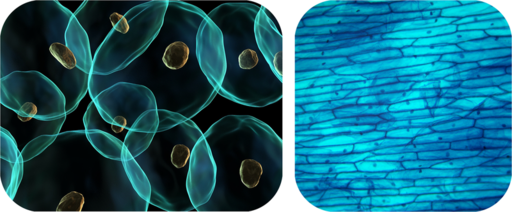
**Reproduction**

All living things are capable of reproduction. **Reproduction** is the process by which living things give rise to offspring. Reproducing may be as simple as a single cell dividing to form two daughter cells. Generally, however, it is much more complicated. Nonetheless, whether a living thing is a huge whale or a microscopic bacterium, it is capable of reproduction.

**Keeping Things Constant**

All living things are able to maintain a more-or-less constant internal environment. They keep things relatively stable on the inside regardless of the conditions around them. The process of maintaining a stable internal environment is called **homeostasis**. Human beings, for example, maintain a stable internal body temperature. If you go outside when the air temperature is below freezing, your body doesn’t freeze. Instead, by shivering and other means, it maintains a stable internal temperature.

**Complex Chemistry**

All living things—even the simplest life forms—have complex chemistry. Living things consist of large, complex molecules, and they also undergo many complicated chemical changes to stay alive. Complex chemistry is needed to carry out all the functions of life.

**Cells**

All forms of life are built of cells. A **cell** is the basic unit of the structure and function of living things. Living things may appear very different from one another on the outside, but their cells are very similar. Compare the human cells on the left in **Figure** [below](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAxLTA4LWh1bWFuLXZzLW9uaW9uLWNlbGxz) and onion cells on the right in **Figure** [below](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAxLTA4LWh1bWFuLXZzLW9uaW9uLWNlbGxz). How are they similar? If you click on the animation titled *Inside a Cell* at the link below, you can look inside a cell and see its internal structures. <http://bio-alive.com/animations/cell-biology.htm>

Human Cells (left). Onion Cells (right). If you looked at cells under a microscope, this is what you might see.

**Summary**

* All living things detect changes in their environment and respond to them.
* All living things grow and develop.
* All living things are capable of reproduction, the process by which living things give rise to offspring.
* All living things are able to maintain a constant internal environment through homeostasis.
* All living things have complex chemistry.
* All forms of life are built of cells. A cell is the basic unit of the structure and function of living things.

**Practice**

Use this resource to answer the questions that follow.

* <http://www.hippocampus.org/Biology>. D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngNon-Majors Biology D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngSearch: **Defining Biology**

1. What does "biology" encompass?
2. What characteristics define life?
3. Define metabolism.
4. Are viruses living? Explain your answer.

# Principles of Biology

* List and describe the four unifying principles of biology.

**Reproduction, homeostasis, evolution, metabolism, heredity. What controls characteristics of life?**

Characteristics of life are controlled by genes, which are passed from parents to offspring, and are located on chromosomes, like the one shown here, that are found in every cell. The gene theory is one of the unifying principles of biology.

### Unifying Principles of Biology

Four unifying principles form the basis of biology. Whether biologists are interested in ancient life, the life of bacteria, or how humans could live on the moon, they base their overall understanding of biology on these four principles:

1. cell theory
2. gene theory
3. homeostasis
4. evolution

#### D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_5_files\20130806214140962616.pngThe Cell Theory

According to the **cell theory**, all living things are made up of cells, and living cells always come from other living cells. In fact, each living thing begins life as a single cell. Some living things, such as bacteria, remain single-celled. Other living things, including plants and animals, grow and develop into many cells. Your own body is made up of an amazing 100 trillion cells! But even you—like all other living things—began life as a single cell.

Tiny diatoms and whale sharks are all made of cells. Diatoms are about 20 µm in diameter and are made up of one cell, whereas whale sharks can measure up to 12 meters in length and are made up of billions of cells.

#### The Gene Theory

The **gene theory** is the idea that the characteristics of living organisms are controlled by genes, which are passed from parents to their offspring. A **gene** is a segment of DNA that has the instructions to encode a protein. Genes are located on larger structures, called **chromosomes**, that are found inside every cell. Chromosomes, in turn, contain large molecules known as DNA (deoxyribonucleic acid). Molecules of DNA are encoded with instructions that tell cells what to do. To see how this happens, click on the animation titled Journey into DNA at the following link: <http://www.pbs.org/wgbh/nova/genome/dna.html>.

#### Homeostasis

**Homeostasis** , which is maintaining a stable internal environment or keeping things constant, is not just a characteristic of living things. It also applies to nature as a whole. Consider the concentration of oxygen in Earth’s atmosphere. Oxygen makes up 21% of the atmosphere, and this concentration is fairly constant. What keeps the concentration of oxygen constant? The answer is living things. Most living things need oxygen to survive, and when they breathe, they remove oxygen from the atmosphere. On the other hand, many living things, including plants, give off oxygen when they make food, and this adds oxygen to the atmosphere. The concentration of oxygen in the atmosphere is maintained mainly by the balance between these two processes. A quick overview of homeostasis can be viewed at <http://www.youtube.com/watch?v=DFyt7FJn-UM>.

#### Evolution

**Evolution** is a change in the characteristics of living things over time. Evolution occurs by a process called natural selection. In natural selection, some living things produce more offspring than others, so they pass more genes to the next generation than others do. Over many generations, this can lead to major changes in the characteristics of living things. Evolution explains how living things are changing today and how modern living things have descended from ancient life forms that no longer exist on Earth. As living things evolve, they generally become better suited for their environment. This is because they evolve adaptations. An **adaptation** is a characteristic that helps a living thing survive and reproduce in a given environment. Look at the mole in **Figure** [below](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAxLTA5LVN0YXItbm9zZWQtbW9sZQ..). It has tentacles around its nose that it uses to sense things by touch. The mole lives underground in the soil, where it is always dark. However, by using its touch organ, it can detect even tiny food items in the soil in total darkness. The touch organ is an adaptation because it helps the mole survive in its dark, underground environment.

This mole uses its star-shaped nose organ to sense food by touch in the dark. The mole’s very large front claws are also an adaptation for its life in the soil. Can you explain why?

### Summary

* The gene theory states that the characteristics of living things are controlled by genes.
* The cell theory states that all living things are made up of cells, and living cells always come from other living cells.
* Homeostasis is maintaining a constant environment.
* Evolution is a change in species over time.

### Practice

Use this resource to answer the questions that follow.

* <http://www.hippocampus.org/Biology>D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngNon-Majors Biology D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngSearch: **Cell Theory**

1. What is the cell theory?
2. What is one main tenet of the cell theory?
3. Describe the findings of Schwann, Schleiden, and Virchow.
4. What findings led to the refinement of the cell theory?
5. What is one main difference between the classic cell theory and the modern cell theory?

# D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_5_files\20130806214141202869.jpegInterdependence of Living Things

* Describe how living organisms interact.

**What other species do you need to survive?**

Species cannot live alone. All life needs other life to survive. Here surgeon fish are feeding on the algae growth on this turtle shell, a classic example of two species needing each other. This is an example of a symbiotic relationship.

### Interdependence of Living Things

All living things depend on their environment to supply them with what they need, including food, water, and shelter. Their environment consists of physical factors—such as soil, air, and temperature—and also of other organisms. An **organism** is an individual living thing. Many living things interact with other organisms in their environment. In fact, they may need other organisms in order to survive. This is known as **interdependence**. For example, living things that cannot make their own food must eat other organisms for food. Other interactions between living things include symbiosis and competition.

#### Symbiosis

**Symbiosis** is a close relationship between organisms of different species in which at least one of the organisms benefits. The other organism may also benefit, it may be unaffected by the relationship, or it may be harmed by the relationship. **Figure** [beside](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAxLTEwLVN5bWJpb3Npcw..) shows an example of symbiosis. The starlings in the picture are able to pick out parasites as food from the fur of the deer. The deer won't eat the birds. In fact, the deer knowingly lets the birds rest on it. What, if anything, do you think the deer gets out of the relationship?

#### D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_5_files\20130806214141276730.jpegCompetition

**Competition** is a relationship between living things that depend on the same resources. The resources may be food, water, or anything else they both need. Competition occurs whenever they both try to get the same resources in the same place and at the same time. The two organisms are likely to come into conflict, and the organism with better adaptations may win out over the other organism.

### Summary

* All living things depend on their environment to supply them with what they need, including food, water, and shelter.
* Symbiosis is a close relationship between organisms of different species in which at least one of the organisms benefits.
* Competition is a relationship between living things that depend on the same resources.

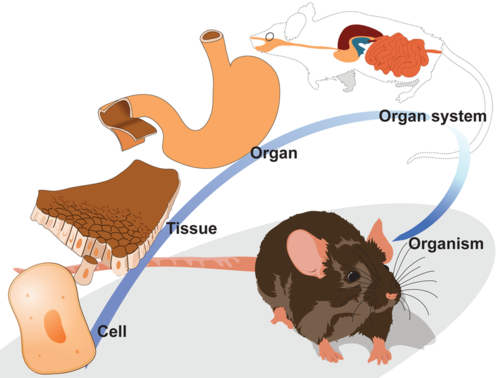
### Practice

Use this resource to answer the questions that follow.

* <http://www.hippocampus.org/Biology>D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngNon-Majors Biology D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngSearch: **Interactions Within Communities**

1. How do organisms within a community interact with each other?
2. Describe and give examples of the two types of competition.
3. How may predation benefit the prey population?
4. Describe the various types of symbiotic relationships.
5. Describe a type of mutualistic relationship involving humans.

# Organization of Living Things

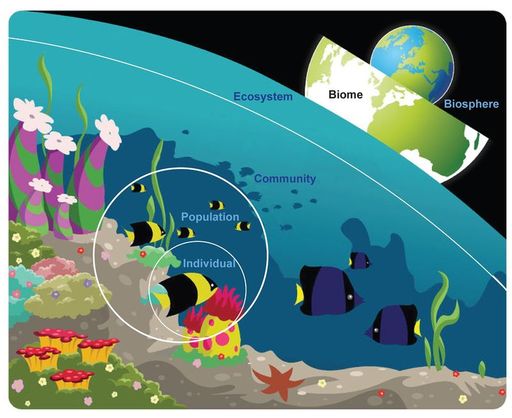
* Describe the organization of organisms.

**Organization of Living Things. What does this mean?**

We know it all starts with the cell. And for some species it ends with the cell. But for others, the cells come together to form tissues, tissues form organs, organs form organ systems, and organ systems combine to form an organism.

### Levels of Organization

The living world can be organized into different levels. For example, many individual organisms can be organized into the following levels:

* **Cell** : Basic unit of all living things.
* **Tissue** : Group of cells of the same kind.
* **Organ** : Structure composed of one or more types of tissues.
* **Organ system** : Group of organs that work together to do a certain job.
* **Organism** : Individual living thing that may be made up of one or more organ systems.

Examples of these levels of organization are shown in **Figure** [below](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAxLTExLU1vdXNl).

An individual mouse is made up of several organ systems. The system shown here is the digestive system, which breaks down food into a form that cells can use. One of the organs of the digestive system is the stomach. The stomach, in turn, consists of different types of tissues. Each type of tissue is made up of cells of the same type.

There are also levels of organization above the individual organism. These levels are illustrated in **Figure** [beside.](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAxLTEyLU9yZ2FuaXNtLXRvLWJpb3NwaGVyZQ..)

* Organisms of the same species that live in the same area make up a **population**. For example, all of the goldfish living in the same area make up a goldfish population.
* All of the populations that live in the same area make up a **community**. The community that includes the goldfish population also includes the populations of other fish, coral, and other organisms.
* An **ecosystem** consists of all the living things in a given area, together with the nonliving environment. The nonliving environment includes water, sunlight, and other physical factors.
* A group of similar ecosystems with the same general type of physical environment is called a **biome**.
* The **biosphere** is the part of Earth where all life exists, including all the land, water, and air where living things can be found. The biosphere consists of many different biomes.

#### D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_5_files\20130806214141699124.pngDiversity of Life

Life on Earth is very diverse. The diversity of living things is called **biodiversity**. A measure of Earth’s biodiversity is the number of different species of organisms that live on Earth. At least 10 million different species live on Earth today. They are commonly grouped into six different kingdoms. Examples of organisms within each kingdom are shown in **Figure** [beside](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAxLTEzLURpdmVyc2l0eS1vZi1MaWZl).

### Summary

* Many individual organisms can be organized into the following levels: cells, tissues, organs, and organs systems.
* An ecosystem consists of all the populations in a given area, together with the nonliving environment.
* The biosphere is the part of Earth where all life exists.
* The diversity of living things is called biodiversity.

### Practice

Use this resource to answer the questions that follow.

* <http://www.hippocampus.org/Biology>D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngBiology for AP\* D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngSearch: **Community Ecology: Overview**

1. What is the biological definition of a community?
2. What is species diversity?
3. What type of area may have high species diversity? What type of area may have low species diversity?
4. What are the major benefits of adaptive radiation?

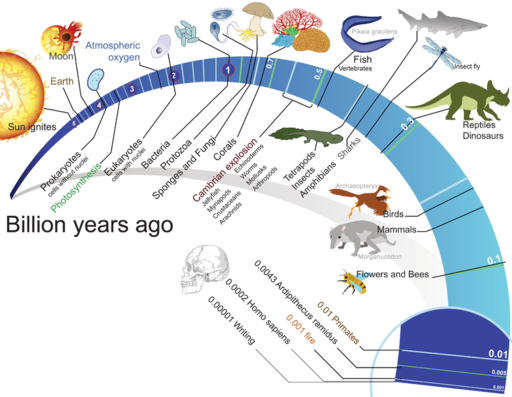
# D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_5_files\20130806214141822416.jpegEvolution of Life

* Explain how life on Earth evolves.

**Are dinosaurs evidence of past life forms?**

Evolution can be described as a change in species over time. Dinosaur fossils are significant evidence of evolution and of past life on Earth.

### Evolution of Life

The diversity of life on Earth today is the result of evolution. Life began on Earth at least 3.5 to 4 billion years ago, and it has been evolving ever since. At first, all living things on Earth were simple, single-celled organisms. Much later, the first multicellular organisms evolved, and after that, Earth’s biodiversity greatly increased. **Figure** [beside](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAxLTE0LUVhcnRoLVRpbWVsaW5l) shows a timeline of the history of life on Earth. You can also find an interactive timeline of the history of life at the link below. <http://www.johnkyrk.com/evolution.html>

This timeline shows the history of life on Earth. In the entire span of the time, humans are a relatively new addition.

Today, scientists accept the evolution of life on Earth as a fact. There is too much evidence supporting evolution to doubt it. However, that wasn’t always the case.

An introduction to evolution and natural selection can be viewed at <http://www.youtube.com/watch?v=GcjgWov7mTM>.

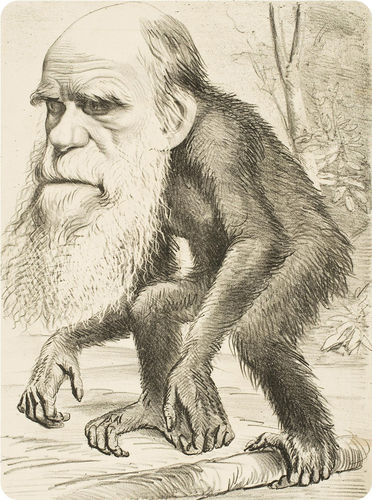
Go to <http://goo.gl/EbdEfo> for more content.

As you view Introduction to Evolution and Natural Selection, focus on these concepts:

1. the relationship between evolution and natural selection,
2. the relationship between natural selection and variation,
3. the evolution of the peppered moth.

#### Darwin and the Theory of Evolution

The idea of evolution has been around for centuries. In fact, it goes all the way back to the ancient Greek philosopher Aristotle. However, evolution is most often associated with Charles Darwin. Darwin published a book on evolution in 1859 titled On the Origin of Species. In the book, Darwin stated the theory of evolution by natural selection. He also presented a great deal of evidence that evolution occurs.

**Evolution** is a change in the characteristics of living things over time. As described by Darwin, evolution occurs by a process called **natural selection**. In natural selection, some members of a species produce more offspring than others, so they pass "advantageous traits" to their offspring. Over many generations, this can lead to major changes in the characteristics of the species. Evolution explains how living things are changing today and how modern living things have descended from ancient life forms that no longer exist on Earth. As living things evolve, they generally become better suited for their environment. This is because they evolve adaptations. An **adaptation** is a trait that helps an organism survive and reproduce in a given environment. Despite all the evidence Darwin presented, his theory was not well-received at first. Many people found it hard to accept the idea that humans had evolved from an ape-like ancestor, and they saw evolution as a challenge to their religious beliefs. Look at the cartoon in **Figure** [beside](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAxLTE1LURhcndpbi1jYXJ0b29u). Drawn in 1871, it depicts Darwin himself as an ape. The cartoon reflects how many people felt about Darwin and his theory during his own time. Darwin had actually expected this type of reaction to his theory and had waited a long time before publishing his book for this reason. It was only when another scientist, named Alfred Wallace, developed essentially the same theory of evolution that Darwin put his book into print.

Although Darwin presented a great deal of evidence for evolution in his book, he was unable to explain how evolution occurs. That’s because he knew nothing about genes. As a result, he didn’t know how characteristics are passed from parents to offspring, let alone how they could change over time.

#### Evolutionary Theory After Darwin

Since Darwin’s time, scientists have gathered even more evidence to support the theory of evolution. Some of the evidence comes from fossils, and some comes from studies that show how similar living things are to one another. By the 1930s, scientists had also learned about genes. As a result, they could finally explain how characteristics of organisms could pass from one generation to the next and change over time.

Using modern technology, scientists can now directly compare the genes of living species. The more genes different species share in common, the more closely related the species are presumed to be. Consider humans and chimpanzees. They share about 98% of their genes. This means that they shared a common ancestor in the not-too-distant past. This is just one of many pieces of evidence that show we are part of the evolution of life on Earth.

#### Misconceptions About Evolution

Today, evolution is still questioned by some people. Often, people who disagree with the theory of evolution do not really understand it. For example, some people think that the theory of evolution explains how life on Earth first began. In fact, the theory explains only how life changed after it first appeared. Some people think the theory of evolution means that humans evolved from modern apes. In fact, humans and modern apes have a common ancestor that lived several million years ago. These and other misconceptions about evolution contribute to the controversy that still surrounds this fundamental principle of biology.

### Summary

* Life began on Earth at least 3.5 to 4 billion years ago, and it has been evolving ever since.
* Darwin stated the theory of evolution by natural selection, presenting a great deal of evidence to support his theory.
* Evolution is a change in the characteristics of living things over time. Evolution occurs by natural selection.
* Characteristics of organisms are passed from one generation to the next through their genes.

### Practice

Use this resource to answer the questions that follow.

* <http://www.hippocampus.org/Biology>D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngNon-Majors Biology D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngSearch: **Darwinian Evolution**

1. Who was Charles Darwin?
2. What did Darwin conclude about homologous structures?
3. Why are some traits more likely to be passed to the next generation?
4. What is the outcome of natural selection?

# Significance of Carbon

* Explain why carbon is essential to life on Earth.

**Carbon. Element number six. Right in the middle of the first row of the Periodic Table. So what?**

Carbon is the most important element to life. Without this element, life as we know it would not exist. As you will see, carbon is the central element in compounds necessary for life.

### The Significance of Carbon

A compound found mainly in living things is known as an **organic compound**. Organic compounds make up the cells and other structures of organisms and carry out life processes. Carbon is the main element in organic compounds, so carbon is essential to life on Earth. Without carbon, life as we know it could not exist.

#### D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_5_files\20130806214142242596.pngCompounds

A **compound** is a substance that consists of two or more elements. A compound has a unique composition that is always the same. The smallest particle of a compound is called a molecule. Consider water as an example. A molecule of water always contains one atom of oxygen and two atoms of hydrogen. The composition of water is expressed by the chemical formula H 2 O. A model of a water molecule is shown in **Figure** [beside](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAyLTAyYS1XYXRlci1Nb2xlY3VsZQ..). Water is not an organic compound.

A water molecule always has this composition, one atom of oxygen and two atoms of hydrogen.

What causes the atoms of a water molecule to “stick” together? The answer is chemical bonds. A **chemical bond** is a force that holds molecules together. Chemical bonds form when substances react with one another. A **chemical reaction** is a process that changes some chemical substances into others. A chemical reaction is needed to form a compound. Another chemical reaction is needed to separate the substances in a compound.

#### Carbon

Why is carbon so basic to life? The reason is carbon’s ability to form stable bonds with many elements, including itself. This property allows carbon to form a huge variety of very large and complex molecules. In fact, there are nearly 10 million carbon-based compounds in living things! However, the millions of organic compounds can be grouped into just four major types: **carbohydrates**, **lipids**, **proteins**, and **nucleic acids**. You can compare the four types in **Table** [below](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-dGFibGU6b3JnYW5pYy1jb21wdW5kcw..). Each type is also described below.

| **Type of Compound** | **Examples** | **Elements** | **Functions** |
| --- | --- | --- | --- |
| Carbohydrates | sugars, starches | carbon, hydrogen, oxygen | provides energy to cells, stores energy, forms body structures |
| Lipids | fats, oils | carbon, hydrogen, oxygen | stores energy, forms cell membranes, carries messages |
| Proteins | enzymes, antibodies | carbon, hydrogen, oxygen, nitrogen, sulfur | helps cells keep their shape, makes up muscles, speeds up chemical reactions, carries messages and materials |
| Nucleic Acids | DNA, RNA | carbon, hydrogen, oxygen, nitrogen, phosphorus | contains instructions for proteins, passes instructions from parents to offspring, helps make proteins |

The Miracle of Life: Carbohydrates, Proteins, Lipids & Nucleic Acids video can be viewed at <http://www.youtube.com/watch?v=nMevuu0Hxuc>(3:28).

#### Energy From Carbon?

It may look like waste, but to some people it's green power. Find out how California dairy farms and white tablecloth restaurants are taking their leftover waste and transforming it into clean energy. See From Waste To Watts: Biofuel Bonanza at <http://www.kqed.org/quest/television/from-waste-to-watts-biofuel-bonanza>for further information.

### Summary

* Carbon is the main element in organic compounds.
* Carbon can form stable bonds with many elements, including itself.
* There are four major types of organic compounds: carbohydrates, lipids, proteins, and nucleic acids.

### Practice

Use this resource to answer the questions that follow.

* <http://www.hippocampus.org/Biology>D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngBiology for AP\* D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngSearch: **Organic Molecules: Overview**

1. What is an organic compound? Roughly how many organic compounds exist?
2. Describe the element carbon.
3. What is the chemical composition of aspirin? Is it a natural or synthetic compound?
4. Describe organic reactions.

# Carbohydrates

* Describe the structure and function of the four major types of organic compounds, focusing on carbohydrates.

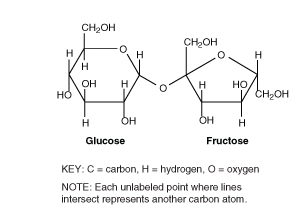
**Sugar. Does this look like biological energy?**

As a child, you may have been told that sugar is bad for you. Well, that's not exactly true. Essentially, carbohydrates are made of sugar, from a single sugar molecule to thousands of sugar molecules attached together. Why? One reason is to store energy. But that does not mean you should eat it by the spoonful.

### Carbohydrates

Carbohydrates are the most common type of organic compound. A **carbohydrate** is an organic compound such as sugar or starch, and is used to store energy. Like most organic compounds, carbohydrates are built of small, repeating units that form bonds with each other to make a larger molecule. In the case of carbohydrates, the small repeating units are called monosaccharides. Carbohydrates contain only carbon, hydrogen, and oxygen.

#### Monosaccharides and Disaccharides

A **monosaccharide** is a simple sugar such as fructose or glucose. Fructose is found in fruits, whereas glucose generally results from the digestion of other carbohydrates. **Glucose** (C6H12O6) is used for energy by the cells of most organisms, and is a product of photosynthesis.

The general formula for a **monosaccharide** is: (CH2 O) n

where n can be any number greater than two. For example, in glucose n is 6, and the formula is: C6 H12 O6

Another monosaccharide, fructose, has the same chemical formula as glucose, but the atoms are arranged differently. Molecules with the same chemical formula but with atoms in a different arrangement are called **isomers**. Compare the glucose and fructose molecules in **Figure** [above](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvMi0yLTE.). Can you identify their differences? The only differences are the positions of some of the atoms. These differences affect the properties of the two monosaccharides.

If two monosaccharides bond together, they form a carbohydrate called a **disaccharide**. An example of a disaccharide is sucrose (table sugar), which consists of the monosaccharides glucose and fructose (**Figure** [above](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvMi0yLTE.)). Monosaccharides and disaccharides are also called **simple sugars**. They provide the major source of energy to living cells.

#### Polysaccharides

A **polysaccharide** is a complex carbohydrate that forms when simple sugars bind together in a chain. Polysaccharides may contain just a few simple sugars or thousands of them. Complex carbohydrates have two main functions: storing energy and forming structures of living things. Some examples of complex carbohydrates and their functions are shown in **Table** [below](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-dGFibGU6Y29tcGxleC1jYXJicw..). Which type of complex carbohydrate does your own body use to store energy?

| **Name** | **Function** | **Example** |  |
| --- | --- | --- | --- |
| Starch | Used by plants to store energy. | D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_5_files\20130806214142755833.jpeg | A potato stores starch in underground tubers. |
| Glycogen | Used by animals to store energy. | D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_5_files\20130806214142837003.jpeg | A human stores glycogen in liver cells. |
| Cellulose | Used by plants to form rigid walls around cells. | D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_5_files\20130806214142921167.jpeg | Plants use cellulose for their cell walls. |
| Chitin | Used by some animals to form an external skeleton. | D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_5_files\20130806214143007391.jpeg | A housefly uses chitin for its exoskeleton. |

#### Biofuels: From Sugar to Energy

For years there's been buzz, both positive and negative, about generating ethanol fuel from corn. Is this a good idea? Is it necessary? These questions need to be discussed. However, the Bay Area of California is rapidly becoming a world center for the next generation of green fuel alternatives. The Joint BioEnergy Institute is developing methods to isolate biofeuls from the sugars in cellulose. See Biofuels: Beyond Ethanol at <http://www.kqed.org/quest/television/biofuels-beyond-ethanol>for further information.

Go to <http://goo.gl/sCA9Nk> for more content

As you view Biofuels: Beyond Ethanol, focus on these concepts:

1. the use of "cellulosic biomass,"
2. what is meant by "directed evolution."

### Summary

* Carbohydrates are organic compounds used to store energy.
* A monosaccharide is a simple sugar, such as fructose or glucose.
* Complex carbohydrates have two main functions: storing energy and forming structures of living things.

### Practice

Use these resources to answer the questions that follow.

* **Biomolecules - the Carbohydrates** at <http://www.wisc-online.com/Objects/ViewObject.aspx?ID=AP13104>.

1. What do carbohydrates provide to the cell?
2. Describe glucose.
3. What is an isomer? Give an example.
4. What is a disaccharide? Give an example.
5. What is the role of starch?

* <http://www.hippocampus.org/Biology>D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngBiology for AP\* D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngSearch: **Structure and Function of Polysaccharides**

1. How many monomers may make a polysaccharide?
2. What determines the function of a polysaccharide?
3. Describe 3 properties of cellulose.
4. What is the main function of starch?
5. What is the main structural difference between starch and glycogen?

# Lipids

* Describe the structure and function of the four major types of organic compounds, focusing on lipids.

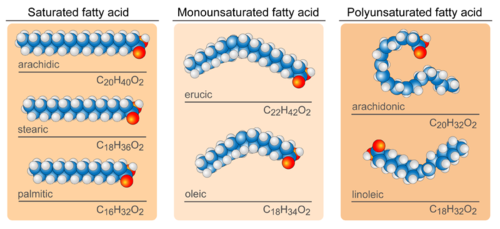
**Oil. Does it mix with water? No. Biologically, why is this important?**

Oil is a lipid. The property of chemically not being able to mix with water gives lipids some very important biological functions. Lipids form the outer membrane of cells. Why?

### Lipids

A **lipid** is an organic compound such as fat or oil. Organisms use lipids to store energy, but lipids have other important roles as well. Lipids consist of repeating units called fatty acids. **Fatty acids** are organic compounds that have the general formula CH 3 (CH 2 ) n COOH, where n usually ranges from 2 to 28 and is always an even number. There are two types of fatty acids: saturated fatty acids and unsaturated fatty acids.

#### Saturated Fatty Acids

In **saturated fatty acids**, carbon atoms are bonded to as many hydrogen atoms as possible. This causes the molecules to form straight chains, as shown in **Figure** [below](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAyLTAzYS1GYXR0eS1BY2lkcw..). The straight chains can be packed together very tightly, allowing them to store energy in a compact form. This explains why saturated fatty acids are solids at room temperature. Animals use saturated fatty acids to store energy.

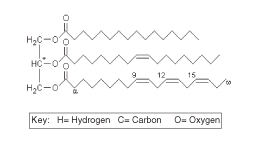
Fatty Acids. Saturated fatty acids have straight chains, like the three fatty acids shown in the upper left. Unsaturated fatty acids have bent chains, like all the other fatty acids in the figure.

#### Unsaturated Fatty Acids

In **unsaturated fatty acids**, some carbon atoms are not bonded to as many hydrogen atoms as possible. Instead, they are bonded to other groups of atoms. Wherever carbon binds with these other groups of atoms, it causes chains to bend (see **Figure** [above](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAyLTAzLUZhdHR5LUFjaWRz)). The bent chains cannot be packed together very tightly, so unsaturated fatty acids are liquids at room temperature. Plants use unsaturated fatty acids to store energy. Some examples are shown in **Figure** [beside](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAyLTA0LUhlYWx0aHktRmF0cw..).

#### D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_5_files\20130806214143348823.jpegTypes of Lipids

Lipids may consist of fatty acids alone, or they may contain other molecules as well. For example, some lipids contain alcohol or phosphate groups. They include

1. triglycerides: the main form of stored energy in animals.
2. phospholipids: the major components of cell membranes.
3. steroids: serve as chemical messengers and have other roles.

Triglyceride Molecule. The left part of this triglyceride molecule represents glycerol. Each of the three long chains on the right represents a different fatty acid. From top to bottom, the fatty acids are palmitic acid, oleic acid, and alpha-linolenic acid. The chemical formula for this triglyceride is C 55 H 98 O 6.

#### Lipids and Diet

Humans need lipids for many vital functions, such as storing energy and forming cell membranes. Lipids can also supply cells with energy. In fact, a gram of lipids supplies more than twice as much energy as a gram of carbohydrates or proteins. Lipids are necessary in the diet for most of these functions. Although the human body can manufacture most of the lipids it needs, there are others, called **essential fatty acids**, that must be consumed in food. Essential fatty acids include omega-3 and omega-6 fatty acids. Both of these fatty acids are needed for important biological processes, not just for energy.

Although some lipids in the diet are essential, excess dietary lipids can be harmful. Because lipids are very high in energy, eating too many may lead to unhealthy weight gain. A high-fat diet may also increase lipid levels in the blood. This, in turn, can increase the risk for health problems such as cardiovascular disease. The dietary lipids of most concern are saturated fatty acids, trans fats, and cholesterol. For example, cholesterol is the lipid mainly responsible for narrowing arteries and causing the disease atherosclerosis.

### Summary

* Organisms use lipids to store energy. There are two types of fatty acids: saturated and unsaturated.
* Animals use saturated fatty acids to store energy. Plants use unsaturated fatty acids to store energy.
* Phospholipids are the major components of cell membranes.
* Excess dietary lipids can be harmful.

### Practice

Use these resources to answer the questions that follow.

* **Biomolecules - The Lipids** at <http://www.wisc-online.com/Objects/ViewObject.aspx?ID=AP13204>.

1. What is the defining property of a lipid?
2. Give 3 examples of lipids.
3. What are the roles of natural fats?
4. Describe the structure of phospholipid molecules.
5. What are the functions of cholesterol?

* <http://www.hippocampus.org/Biology>D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngBiology for AP\* D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngSearch: **Structure and Function of Fats**

1. Describe the structure of triglyceride molecules.
2. What are the roles of triglycerides and phospholipids?
3. Which are non-polar molecules, triglycerides or phospholipids?
4. What determines a fat's function?

# Proteins

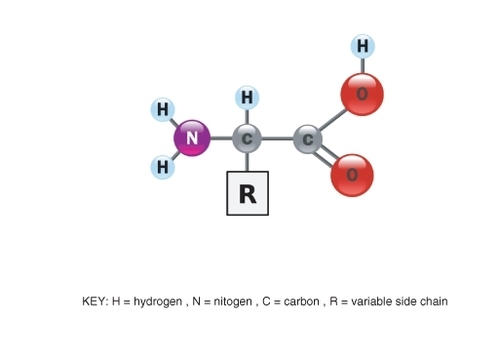
* Describe the structure and function of the four major types of organic compounds, focusing on proteins.

**You may have been told proteins are good for you. Do these look good to you?**

Proteins as food. To you, these may not look appetizing (or they might), but they do provide a nice supply of amino acids, the building blocks of proteins. Proteins have many important roles, from transporting, signaling, receiving, and catalyzing to storing, defending, and allowing for movement. Where do you get the amino acids needed so your cells can make their own proteins? If you cannot make it, you must eat it.

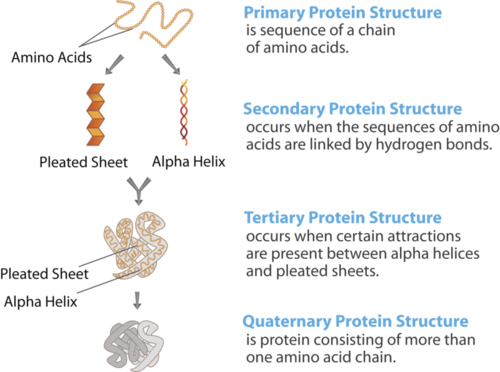
### Proteins

A **protein** is an organic compound made up of small molecules called **amino acids**. There are 20 different amino acids commonly found in the proteins of living organisms. Small proteins may contain just a few hundred amino acids, whereas large proteins may contain thousands of amino acids. The largest known proteins are the titins, found in muscle, which are composed from almost 27,000 amino acids.

General Structure of Amino Acids. This model shows the general structure of all amino acids. Only the side chain, R, varies from one amino acid to another. For example, in the amino acid glycine, the side chain is simply hydrogen (H). In glutamic acid, in contrast, the side chain is CH 2 CH 2 COOH. Variable side chains give amino acids different chemical properties. The order of amino acids, together with the properties of the amino acids, determines protein shape, and the protein shape determines the protein function. KEY: H = hydrogen, N = nitrogen, C = carbon, O = oxygen, R = variable side chain.

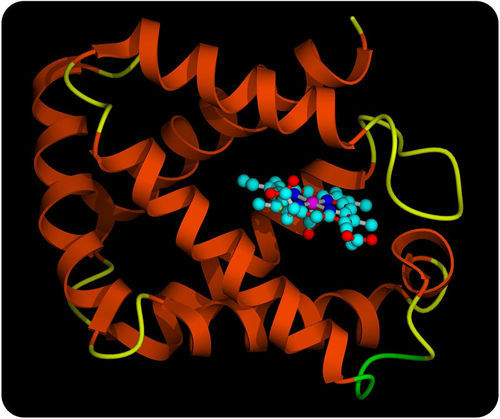
#### Protein Structure

When amino acids bind together, they form a long chain called a **polypeptide**. A protein consists of one or more polypeptide chains. A protein may have up to four levels of structure. The lowest level, a protein’s primary structure, is its sequence of amino acids. Higher levels of protein structure are described in **Figure** [beside](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAyLTA1LXByb3RlaW4tc3RydWN0dXJlcw..). The complex structures of different proteins give them unique properties, which they need to carry out their various jobs in living organisms. You can learn more about protein structure by watching the animation at the following link: <http://www.stolaf.edu/people/giannini/flashanimat/proteins/protein%20structure.swf>

Protein Structure. The structure of a protein starts with its sequence of amino acids. What determines the secondary structure of a protein? What are two types of secondary protein structure?

#### Functions of Proteins

Proteins play many important roles in living things. Some proteins help cells keep their shape, and some make up muscle tissues. **Enzymes** are proteins that speed up chemical reactions in cells. Other proteins are **antibodies**, which bind to foreign substances such as bacteria and target them for destruction. Still other proteins carry messages or materials. For example, human red blood cells contain a protein called **hemoglobin**, which binds with oxygen. Hemoglobin allows the blood to carry oxygen from the lungs to cells throughout the body. A model of the hemoglobin molecule is shown in **Figure** [below](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAyLTA2LWhlbW9nbG9iaW4.).

Hemoglobin Molecule. This model represents the protein hemoglobin. The red parts of the molecule contain iron. The iron binds with oxygen molecules.

A short video describing protein function can be viewed at <http://www.youtube.com/watch?v=T500B5yTy58&feature=related>(4:02).

Go to <http://goo.gl/0TbyvK> for more content.

As you view Protein Functions in the Body, focus on these concepts:

1. the amount of protein in each cell,
2. the roles of different types of proteins.

#### Proteins and Diet

Proteins in the diet are necessary for life. Dietary proteins are broken down into their component amino acids when food is digested. Cells can then use the components to build new proteins. Humans are able to synthesize all but eight of the twenty common amino acids. These eight amino acids, called **essential amino acids**, must be consumed in foods. Like dietary carbohydrates and lipids, dietary proteins can also be broken down to provide cells with energy.

### Summary

* Proteins are organic compounds made up of amino acids.
* A protein may have up to four levels of structure. The complex structures of different proteins give them unique properties.
* Enzymes are proteins that speed up biochemical reactions in cells. Antibodies are proteins that target pathogens for destruction.

### Practice

Use these resources to answer the questions that follow.

* **Biomolecules - The Proteins** at <http://www.wisc-online.com/Objects/ViewObject.aspx?ID=AP13304>.

1. Give 3 examples of proteins.
2. What determines the primary structure of a protein?
3. What determines the protein's function?
4. How can a protein's conformation be disrupted?

* **What is a Protein?** at <http://learn.genetics.utah.edu/content/begin/dna/>.

1. How many different proteins are in a cell?
2. What function do receptor proteins and structural proteins have in nerve cells?
3. What is the information used to make an individual protein?
4. What is the part of the cell where proteins are made?

* <http://www.hippocampus.org/Biology>D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngBiology for AP\* D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngSearch: **Structure and Function of Proteins**

1. How do amino acids link together?
2. What is a polypeptide?
3. What does "secondary structure" refer to? Describe examples of secondary structure.
4. Describe the hemoglobin protein.
5. What is the main difference between active sites and binding sites?
6. What is the main role of fibrous proteins?

# Nucleic Acids

* Describe the structure and function of the four major types of organic compounds, focusing on nucleic acids.

**You may have heard that something is "encoded in your DNA." What does that mean?**

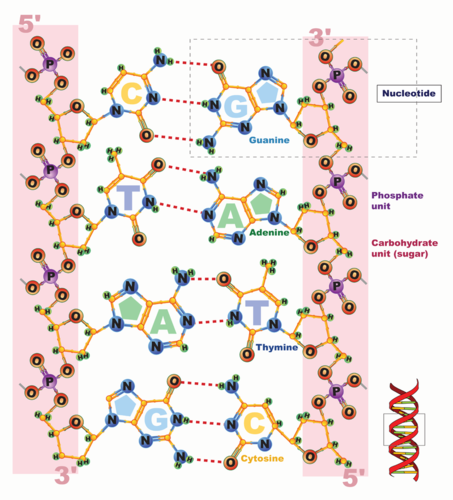
Nucleic acids. Essentially the "instructions" or "blueprints" of life. Deoxyribonucleic acid, or DNA, is the unique blueprints to make the proteins that give you your traits. Half of these blueprints come from your mother, and half from your father. Therefore, every person that has ever lived - except for identical twins - has his or her own unique set of blueprints - or instructions - or DNA.

### Nucleic Acids

A **nucleic acid** is an organic compound, such as DNA or RNA, that is built of small units called **nucleotides** . Many nucleotides bind together to form a chain called a **polynucleotide**. The nucleic acid **DNA** (deoxyribonucleic acid) consists of two polynucleotide chains. The nucleic acid **RNA** (ribonucleic acid) consists of just one polynucleotide chain.

An overview of DNA can be seen at <http://www.youtube.com/user/khanacademy#p/c/7A9646BC5110CF64/4/_-vZ_g7K6P0>(28:05).

Go to <http://goo.gl/erfcSs> for more content.

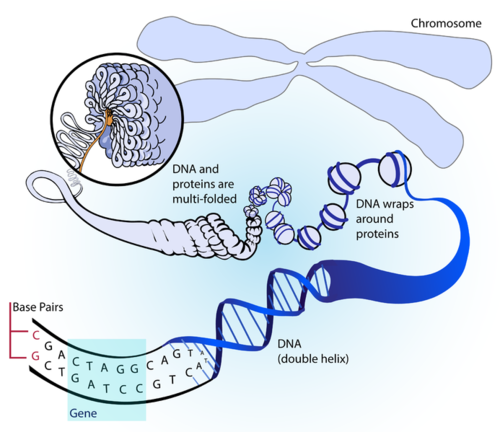
As you view DNA, focus on the following concept:

1. the structure and role of DNA.

#### Structure of Nucleic Acids

Each nucleotide consists of three smaller molecules:

1. sugar
2. phosphate group
3. nitrogen base

If you look at **Figure** [below](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAyLTA3LU51Y2xlaWMtYWNpZA..), you will see that the sugar of one nucleotide binds to the phosphate group of the next nucleotide. These two molecules alternate to form the backbone of the nucleotide chain. This backbone is known as the sugar-phosphate backbone. The nitrogen bases in a nucleic acid stick out from the backbone. There are four different types of bases: cytosine (C), adenine (A), guanine (G), and either thymine (T) in DNA, or uracil (U) in RNA. In DNA, bonds form between bases on the two nucleotide chains and hold the chains together. Each type of base binds with just one other type of base: cytosine always binds with guanine, and adenine always binds with thymine. These pairs of bases are called **complementary base pairs**.

Nucleic Acid. Sugars and phosphate groups form the backbone of a polynucleotide chain. Hydrogen bonds between complementary bases hold two polynucleotide chains together.

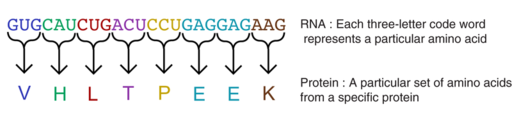
The binding of complementary bases allows DNA molecules to take their well-known shape, called a **double helix**, which is shown in **Figure** [beside](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-RE5BZm9sZGluZ0E.). A double helix is like a spiral staircase. The double helix shape forms naturally and is very strong, making the two polynucleotide chains difficult to break apart.

DNA Molecule. Bonds between complementary bases help form the double helix of a DNA molecule. The letters A, T, G, and C stand for the bases adenine, thymine, guanine, and cytosine. The sequence of these four bases in DNA is a code that carries instructions for making proteins. Shown is how the DNA winds into a chromosome.

An animation of DNA structure can be viewed at <http://www.youtube.com/watch?v=qy8dk5iS1f0&feature=related>.

#### Roles of Nucleic Acids

DNA is also known as the hereditary material or genetic information. It is found in genes, and its sequence of bases makes up a code. Between "starts" and "stops," the code carries instructions for the correct sequence of amino acids in a protein (see **Figure** [beside](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTIuMi4xMA..)). DNA and RNA have different functions relating to the genetic code and proteins. Like a set of blueprints, DNA contains the genetic instructions for the correct sequence of amino acids in proteins. RNA uses the information in DNA to assemble the correct amino acids and help make the protein. The information in DNA is passed from parent cells to daughter cells whenever cells divide. The information in DNA is also passed from parents to offspring when organisms reproduce. This is how inherited characteristics are passed from one generation to the next.



The letters G, U, C, and A stand for the bases in RNA. Each group of three bases makes up a code word, and each code word represents one amino acid (represented here by a single letter, such as V, H, or L). A string of code words specifies the sequence of amino acids in a protein.

### Summary

* DNA and RNA are nucleic acids. Nucleic acids are built of small units called nucleotides.
* The bases of DNA are adenine, guanine, cytosine and thymine. In RNA, thymine is replaced by uracil.
* In DNA, A always binds to T, and G always binds to C.
* The shape of the DNA molecule is known as a double helix.
* DNA contains the genetic instructions for the correct sequence of amino acids in proteins. RNA uses the information in DNA to assemble the correct amino acids and help make the protein.

### Practice

Use this resource to answer the questions that follow.

* **What is DNA?** at <http://learn.genetics.utah.edu/content/begin/dna/>.

1. Why is DNA referred to as the "instructions"?
2. Where is DNA located in the cell?
3. What do A, C, G and T refer to? How can only four letters tell the cell what to do?
4. What is a gene?

# D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_5_files\20130806214144771916.jpegBiochemical Reactions

* Describe what happens in chemical reactions.

**Understanding chemistry is essential to fully understand biology. Why?**

A general understanding of chemistry is necessary to understand biology. Essentially, our cells are just thousands of chemicals — made of elements like carbon, hydrogen, oxygen, nitrogen, phosphorus and sulfur — in just the right combinations. And these chemicals combine through chemical reactions.

### Chemical Reactions

The element chlorine (Cl) is a greenish poison. Would you eat chlorine? Of course not, but you often eat a compound containing chlorine. In fact, you probably eat this chlorine compound just about every day. Do you know what it is? It’s table salt. Table salt is sodium chloride (NaCl), which forms when chlorine and sodium (Na) combine in certain proportions. How does chlorine, a toxic green chemical, change into harmless white table salt? It happens in a chemical reaction.

A **chemical reaction** is a process that changes some chemical substances into others. A substance that starts a chemical reaction is called a **reactant**, and a substance that forms as a result of a chemical reaction is called a **product**. During a chemical reaction, the reactants are used up to create the products.

An example of a chemical reaction is the burning of methane. In this chemical reaction, the reactants are methane (CH4) and oxygen (O2), and the products are carbon dioxide (CO2) and water (H2O). A chemical reaction involves the breaking and forming of chemical bonds. When methane burns, bonds break in the methane and oxygen molecules, and new bonds form in the molecules of carbon dioxide and water.

#### Chemical Equations

A chemical reaction can be represented by a **chemical equation**. For example, the burning of methane can be represented by the chemical equation

CH4 + 2O2 → CO2 + 2H2O

The arrow in a chemical equation separates the reactants from the products and shows the direction in which the reaction proceeds. If the reaction could occur in the opposite direction as well, two arrows pointing in opposite directions would be used. The number 2 in front of O 2 and H 2 O shows that two oxygen molecules and two water molecules are involved in the reaction. (With no number in front of a chemical symbol, just one molecule is involved.)

#### Conservation of Matter

In a chemical reaction, the quantity of each element does not change; there is the same amount of each element in the products as there was in the reactants. This is because matter is always conserved. The conservation of matter is reflected in a reaction’s chemical equation. The same number of atoms of each element appears on each side of the arrow. For example, in the chemical equation above, there are four hydrogen atoms on each side of the arrow. Can you find all four of them on each side of the equation?

### Summary

* A chemical reaction is a process that changes some chemical substances into others. During a chemical reaction, the reactants are used up to create the products.
* In a chemical reaction, matter is always conserved.

### Practice

Use this resource to answer the questions that follow.

* <http://www.hippocampus.org/Biology>D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngBiology for AP\* D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngSearch: **Chemical Reactions**

1. What is a chemical reaction?
2. Why must chemical equations be balanced?
3. How can you tell if a reaction produces or consumes energy?

# Energy and Biochemical Reactions

* State the role of energy in chemical reactions.

**What is energy? Where does your energy come from? Can energy be recycled?**

This team of ants is breaking down a dead tree; a classic example of teamwork. And all that work takes energy. In fact, each chemical reaction - the chemical reactions that allow the cells in those ants to do the work - needs energy to get started. And all that energy comes from the food the ants eat. Whatever eats the ants gets their energy from the ants. Energy passes through an ecosystem in one direction only.

### Chemical Reactions and Energy

Chemical reactions always involve energy. **Energy** is a property of matter that is defined as the ability to do work. When methane burns, for example, it releases energy in the form of heat and light. Other chemical reactions absorb energy rather than release it.

#### Exothermic Reactions

A chemical reaction that releases energy (as heat) is called an **exothermic reaction**. This type of reaction can be represented by a general chemical equation:

Reactants → Products + Heat

In addition to methane burning, another example of an exothermic reaction is chlorine combining with sodium to form table salt. This reaction also releases energy.

#### Endothermic Reaction

A chemical reaction that absorbs energy is called an **endothermic reaction**. This type of reaction can also be represented by a general chemical equation:

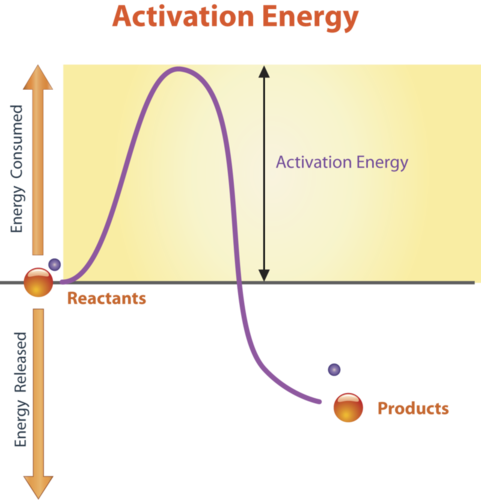
Reactants + Heat → Products

Did you ever use a chemical cold pack? The pack cools down because of an endothermic reaction. When a tube inside the pack is broken, it releases a chemical that reacts with water inside the pack. This reaction absorbs heat energy and quickly cools down the pack.

#### Activation Energy

All chemical reactions need energy to get started. Even reactions that release energy need a boost of energy in order to begin. The energy needed to start a chemical reaction is called **activation energy**. Activation energy is like the push a child needs to start going down a playground slide. The push gives the child enough energy to start moving, but once she starts, she keeps moving without being pushed again. Activation energy is illustrated in **Figure** [below](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAyLTExLWFjdGl2YXRpb24tZW5lcmd5).

Activation Energy. Activation energy provides the “push” needed to start a chemical reaction. Is the chemical reaction in this figure an exothermic or endothermic reaction?

Why do all chemical reactions need energy to get started? In order for reactions to begin, reactant molecules must bump into each other, so they must be moving, and movement requires energy. When reactant molecules bump together, they may repel each other because of intermolecular forces pushing them apart. Overcoming these forces so the molecules can come together and react also takes energy.

An overview of activation energy can be viewed at <http://www.youtube.com/watch?v=VbIaK6PLrRM&feature=related>(1:16).

Go to <http://goo.gl/jejl28> for more content

As you view Activation energy, focus on these concepts:

1. the role of activation energy,
2. what an energy diagram demonstrates.

### Summary

* Chemical reactions always involve energy. A chemical reaction that releases energy is an exothermic reaction, and a chemical reaction that absorbs energy is an endothermic reaction. The energy needed to start a chemical reaction is the activation energy.

### Practice

Use this resource to answer the questions that follow.

* <http://www.hippocampus.org/Biology>D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngNon-Majors Biology D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngSearch: **Energy**

1. What is energy?
2. Why do living organisms need energy?
3. What is the main difference between potential and kinetic energy?
4. What is the original source of most energy used by living organisms on Earth?

# D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_5_files\20130806214145123376.jpegTypes of Biochemical Reactions

* Describe what happens in biochemical reactions.

**What do you get when you cross biology and chemistry?**

Hummingbirds, with their tiny bodies and high levels of activity, have the highest metabolic rates of any animals — roughly a dozen times that of a pigeon and a hundred times that of an elephant. The metabolic rate, or rate of metabolism, has to do with the amount of energy the organism uses. And that energy is used to drive the chemical reactions in cells — or the biochemical reactions. And, of course, it is all the biochemical reactions that allow the cells function properly, and maintain life.

### Biochemical Reactions

**Biochemical reactions** are chemical reactions that take place inside the cells of living things. The field of **biochemistry** demonstrates that knowledge of chemistry as well as biology is needed to understand fully the life processes of organisms at the level of the cell. The sum of all the biochemical reactions in an organism is called **metabolism**. It includes both exothermic and endothermic reactions.

#### Types of Biochemical Reactions

Exothermic reactions in organisms are called **catabolic reactions**. These reactions break down molecules into smaller units and release energy. An example of a catabolic reaction is the breakdown of glucose, which releases energy that cells need to carry out life processes. Endothermic reactions in organisms are called **anabolic reactions**. These reactions build up bigger molecules from smaller ones. An example of an anabolic reaction is the joining of amino acids to form a protein. Which type of reactions—catabolic or anabolic—do you think occur when your body digests food?

### Summary

* Biochemical reactions are chemical reactions that take place inside the cells of organisms.

### Practice

Use this resource to answer the questions that follow.

* <http://www.hippocampus.org/Biology>D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngBiology for AP\* D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngSearch: **Enzymes and Metabolism: Overview**

1. What are kinetics and reaction rates?
2. What is an energy diagram?
3. Does a spontaneous reaction always result in products with a lower amount of free energy than the reactants?
4. Do all reactions need a certain amount of activation energy?
5. What lowers the amount of activation energy needed?

# Enzymes

* Explain the importance of enzymes to living organisms.

**What is a biological catalyst?**

This super-fast train can obviously reach great speeds. And there's a lot of technology that helps this train go fast. Speaking of helping things go fast brings us to enzymes. Life could not exist without enzymes. Essentially, enzymes are biological catalysts that speed up biochemical reactions.

### Enzymes

#### Enzymes and Biochemical Reactions

Most chemical reactions within organisms would be impossible under the conditions in cells. For example, the body temperature of most organisms is too low for reactions to occur quickly enough to carry out life processes. Reactants may also be present in such low concentrations that it is unlikely they will meet and collide. Therefore, the rate of most biochemical reactions must be increased by a catalyst. A **catalyst** is a chemical that speeds up chemical reactions. In organisms, catalysts are called **enzymes**. Essentially, enzymes are biological catalysts.

Like other catalysts, enzymes are not reactants in the reactions they control. They help the reactants interact but are not used up in the reactions. Instead, they may be used over and over again. Unlike other catalysts, enzymes are usually highly specific for particular chemical reactions. They generally catalyze only one or a few types of reactions.

Enzymes are extremely efficient in speeding up reactions. They can catalyze up to several million reactions per second. As a result, the difference in rates of biochemical reactions with and without enzymes may be enormous. A typical biochemical reaction might take hours or even days to occur under normal cellular conditions without an enzyme, but less than a second with an enzyme.

Enzymes, an overview of these proteins, can be viewed at <http://www.youtube.com/watch?v=E90D4BmaVJM&feature=related>(9:43).

Go to <http://goo.gl/xnMuVs> for more content

As you view Enzymes, focus on these concepts:

1. the role of enzymes in nature,
2. other uses of enzymes.

#### Importance of Enzymes

Enzymes are involved in most of the chemical reactions that take place in organisms. About 4,000 such reactions are known to be catalyzed by enzymes, but the number may be even higher.

In animals, an important function of enzymes is to help digest food. Digestive enzymes speed up reactions that break down large molecules of carbohydrates, proteins, and fats into smaller molecules the body can use. Without digestive enzymes, animals would not be able to break down food molecules quickly enough to provide the energy and nutrients they need to survive.

### Summary

* Enzymes are biological catalysts. They speed up biochemical reactions.
* Enzymes are involved in most of the chemical reactions that take place in organisms.

### Practice

Use this resource to answer the questions that follow.

* <http://www.hippocampus.org/Biology>D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngBiology for AP\* D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngSearch: **Enzymes as Catalysts**

1. What are enzymes?
2. What are substrates? What is the enzyme-substrate complex?
3. How do enzymes work?
4. What happens to the enzyme during a reaction?

# D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_5_files\20130806214145275994.jpeg

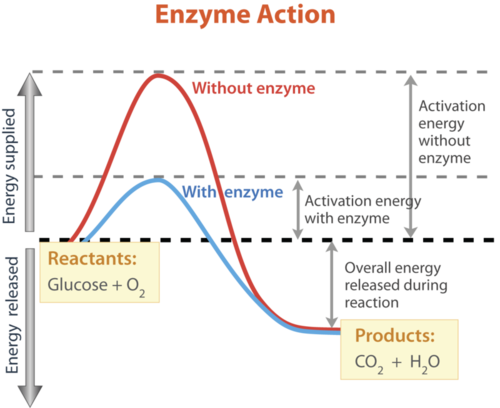
# Enzyme Function

* Explain the importance of enzymes to living organisms.
* Describe how enzymes function.

**Do cells have one enzyme with lots of functions, or many enzymes, each with just one function?**

Enzymes. Magical proteins necessary for life. So how do enzymes work? How do they catalyze just one specific biochemical reaction? In a puzzle, only two pieces will fit together properly. Understanding that is one of the main steps in understanding how enzymes work.

### Enzyme Function

How do **enzymes** speed up biochemical reactions so dramatically? Like all **catalysts**, enzymes work by lowering the **activation energy** of chemical reactions. Activation energy is the energy needed to start a chemical reaction. This is illustrated in **Figure** [below](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvMi0zLW41). The biochemical reaction shown in the figure requires about three times as much activation energy without the enzyme as it does with the enzyme.

An animation of how enzymes work is at <http://www.youtube.com/watch?v=CZD5xsOKres&feature=related>(2:02).

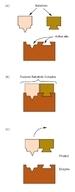
Go to <http://goo.gl/8mlh09> for more content

As you view Enzyme Animation, focus on this concept:

1. how enzymes function.

The reaction represented by this graph is a combustion reaction involving the reactants glucose (C6H12O6) and oxygen (O2). The products are carbon dioxide (CO2) and water (H2O). Energy is also released during the reaction. The enzyme speeds up the reaction by lowering the activation energy needed for the reaction to start. Compare the activation energy with and without the enzyme.

Enzymes generally lower activation energy by reducing the energy needed for reactants to come together and react. For example:

* Enzymes bring reactants together so they don’t have to expend energy moving about until they collide at random. Enzymes bind both reactant molecules (called the **substrate**), tightly and specifically, at a site on the enzyme molecule called the **active site** (**Figure** [below](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvMi0zLTQ.) ).
* By binding reactants at the active site, enzymes also position reactants correctly, so they do not have to overcome intermolecular forces that would otherwise push them apart. This allows the molecules to interact with less energy.
* Enzymes may also allow reactions to occur by different pathways that have lower activation energy.

The active site is specific for the reactants of the biochemical reaction the enzyme catalyzes. Similar to puzzle pieces fitting together, the active site can only bind certain substrates.

This enzyme molecule binds reactant molecules—called substrate—at its active site, forming an enzyme-substrate complex. This brings the reactants together and positions them correctly so the reaction can occur. After the reaction, the products are released from the enzyme’s active site. This frees up the enzyme so it can catalyze additional reactions.

The activities of enzymes also depend on the temperature and the pH of the surroundings. Some enzymes work best at acidic pHs, while others work best in neutral environments.

* Digestive enzymes secreted in the acidic environment (low pH) of the stomach help break down proteins into smaller molecules. The main digestive enzyme in the stomach is **pepsin**, which works best at a pH of about 1.5. These enzymes would not work optimally at other pHs. Trypsin is another enzyme in the digestive system, which breaks protein chains in food into smaller parts. Trypsin works in the small intestine, which is not an acidic environment. Trypsin's optimum pH is about 8.
* Biochemical reactions are optimal at physiological temperatures. For example, most biochemical reactions work best at the normal body temperature of 98.6˚F. Many enzymes lose function at lower and higher temperatures. At higher temperatures, an enzyme’s shape deteriorates. Only when the temperature comes back to normal does the enzyme regain its shape and normal activity.

### Summary

* Enzymes work by lowering the activation energy needed to start biochemical reactions.
* The activities of enzymes depend on the temperature, ionic conditions, and the pH of the surroundings.

### Practice I

Use this resource to answer the questions that follow.

* <http://www.hippocampus.org/Biology>D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngBiology for AP\* D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngSearch: **Enzymes as Catalysts**

1. What determines an enzyme's function?
2. What molecules react in a biochemical reaction?
3. How do enzymes lower activation energy?
4. What is a transition state?
5. How many substrates can an enzyme convert into products?

### Practice II

* **Enzyme Kinetics** at <http://www.kscience.co.uk/animations/model.swf>.

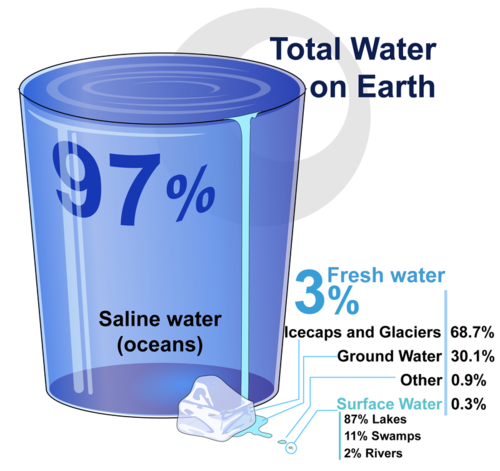
# Water and Life

* Describe the distribution of Earth’s water.
* Identify water’s structure and properties.
* Explain why water is essential for life.

**Dihydrogen oxide or dihydrogen monoxide. Does this chemical sound dangerous?**

Another name for this compound is…water. Water can create some absolutely beautiful sights. Iguassu Falls is the largest series of waterfalls on the planet, located in Brazil, Argentina, and Paraguay. And water is necessary for life. The importance of water to life cannot be emphasized enough. All life needs water. Life started in water. Essentially, without this simple three atom molecule, life would not exist.

### Water

Water, like carbon, has a special role in living things. It is needed by all known forms of life. Water is a simple molecule, containing just three atoms. Nonetheless, water’s structure gives it unique properties that help explain why it is vital to all living organisms.

#### Water, Water Everywhere

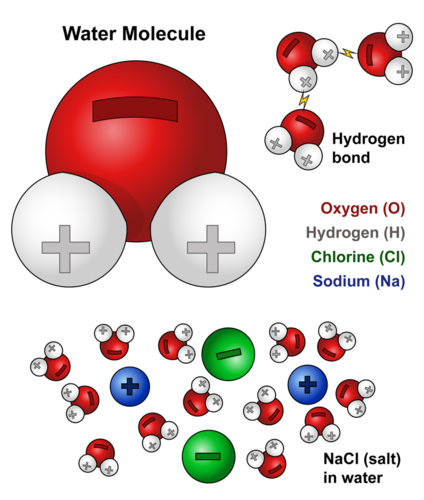
Water is a common chemical substance on planet Earth. In fact, Earth is sometimes called the "water planet" because almost 75% of its surface is covered with water. If you look at **Figure** [beside](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAyLTEzLXdhdGVyLWRpc3RyaWJ1dGlvbg..), you will see where Earth’s water is found. The term water generally refers to its liquid state, and water is a liquid over a wide range of temperatures on Earth. However, water also occurs on Earth as a solid (ice) and as a gas (water vapor).

Most of the water on Earth consists of saltwater in the oceans. What percent of Earth’s water is fresh water? Where is most of the fresh water found?

#### Structure and Properties of Water

No doubt, you are already aware of some of the properties of water. For example, you probably know that water is tasteless and odorless. You also probably know that water is transparent, which means that light can pass through it. This is important for organisms that live in the water, because some of them need sunlight to make food.

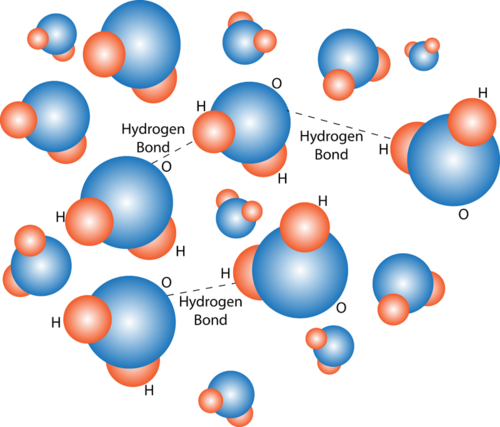
**Chemical Structure of Water**

To understand some of water’s properties, you need to know more about its chemical structure. As you have seen, each molecule of water consists of one atom of oxygen and two atoms of hydrogen. The oxygen atom in a water molecule attracts negatively-charged electrons more strongly than the hydrogen atoms do. As a result, the oxygen atom has a slightly negative charge, and the hydrogen atoms have a slightly positive charge. A difference in electrical charge between different parts of the same molecule is called **polarity**, making water a **polar molecule**. The diagram in **Figure** [beside](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-V2F0ZXJQb2xhcml0eS0wMQ..) shows water’s polarity.

Water Molecule. This diagram shows the positive and negative parts of a water molecule.

Opposites attract when it comes to charged molecules. In the case of water, the positive (hydrogen) end of one water molecule is attracted to the negative (oxygen) end of a nearby water molecule. Because of this attraction, weak bonds form between adjacent water molecules, as shown in **Figure** [below](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAyLTE1LWh5ZHJvZ2VuLWJvbmRpbmc.). The type of bond that forms between molecules is called a **hydrogen bond**. Bonds between molecules are not as strong as bonds within molecules, but in water they are strong enough to hold together nearby molecules.

Hydrogen Bonding in Water Molecules. Hydrogen bonds form between nearby water molecules. How do you think this might affect water’s properties?

**Properties of Water**

Hydrogen bonds between water molecules explain some of water’s properties. For example, hydrogen bonds explain why water molecules tend to stick together. Have you ever watched water drip from a leaky faucet or from a melting icicle? If you have, then you know that water always falls in drops rather than as separate molecules. The dew drops in **Figure** [below](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAyLTE2LWRldy1kcm9wcw..) are another example of water molecules sticking together.

Droplets of Dew. Drops of dew cling to a spider web in this picture. Can you think of other examples of water forming drops? (Hint: What happens when rain falls on a newly waxed car?)

Hydrogen bonds cause water to have a relatively high boiling point of 100°C (212°F). Because of its high boiling point, most water on Earth is in a liquid state rather than in a gaseous state. Water in its liquid state is needed by all living things. Hydrogen bonds also cause water to expand when it freezes. This, in turn, causes ice to have a lower density (mass/volume) than liquid water. The lower density of ice means that it floats on water. For example, in cold climates, ice floats on top of the water in lakes. This allows lake animals such as fish to survive the winter by staying in the water under the ice.

#### Water and Life

The human body is about 70% water (not counting the water in body fat, which varies from person to person). The body needs all this water to function normally. Just why is so much water required by human beings and other organisms? Water can dissolve many substances that organisms need, and it is necessary for many biochemical reactions. The examples below are among the most important biochemical processes that occur in living things, but they are just two of many ways that water is involved in biochemical reactions.

* Photosynthesis—In this process, cells use the energy in sunlight to change carbon dioxide and water to glucose and oxygen. The reactions of photosynthesis can be represented by the chemical equation

6CO 2 + 6H 2 O + Energy → C 6 H 12 O 6 + 6O 2

* Cellular respiration—In this process, cells break down glucose in the presence of oxygen and release carbon dioxide, water, and energy. The reactions of cellular respiration can be represented by the chemical equation

C 6 H 12 O 6 + 6O 2 → 6CO 2 + 6H 2 O + Energy

Water is involved in many other biochemical reactions. As a result, just about all life processes depend on water. Clearly, life as we know it could not exist without water.

### Summary

* Water is needed by all known forms of life.
* Due to the difference in the distribution of charge, water is a polar molecule.
* Hydrogen bonds hold adjacent water molecules together.
* Water is involved in many biochemical reactions. As a result, just about all life processes depend on water.

### Practice

Use these resources to answer the questions that follow.

* **Water** at <http://johnkyrk.com/H2O.html>.

1. How do hydrogen and oxygen bind to form water?
2. Why is water a polar molecule?
3. Describe the bond between water molecules.

* <http://www.hippocampus.org/Biology>D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngNon-Majors Biology D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_math_images_dir\b5a0de95678e94bcaab900992ee9b28b.pngSearch: **Properties of Water**

1. Describe two properties of water that make it important to life.
2. Why is the specific heat of water important?
3. Why does ice float?

# Acids and Bases in Biology

* Define acids, bases, and pH.

**Acids and bases. Why are these important in biology?**

It comes back to a number of biological processes. For example, enzymes work best at specific levels of acids or bases. Take your stomach, a very acidic environment. The enzymes that work in that environment could not work in your mouth. What would your food taste like if your mouth was also a very acidic environment?

### Acids and Bases

Water is the main ingredient of many solutions. A **solution** is a mixture of two or more substances that has the same composition throughout. Some solutions are acids and some are bases. To understand acids and bases, you need to know more about pure water. In pure water (such as distilled water), a tiny fraction of water molecules naturally breaks down to form ions. An **ion** is an electrically charged atom or molecule. The breakdown of water is represented by the chemical equation

2 H2O → H3O+ + OH -

The products of this reaction are a hydronium ion (H3O+) and a hydroxide ion (OH-). The hydroxide ion, which has a negative charge, forms when a water molecule gives up a positively charged hydrogen ion (H+). The hydronium ion, which has positive charge, forms when another water molecule accepts the hydrogen ion.

#### D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\ck12_5_files\20130806214146248204.pngAcidity and pH

The concentration of hydronium ions in a solution is known as **acidity**. In pure water, the concentration of hydronium ions is very low; only about 1 in 10 million water molecules naturally breaks down to form a hydronium ion. As a result, pure water is essentially neutral. Acidity is measured on a scale called **pH**, as shown in **Figure** [beside](file:///D:\LiberKey\Apps\Firefox\Data\profile\epub\17\OEBPS\5.html#x-ck12-QmlvLTAyLTE3LXBIU2NhbGVB). Pure water has a pH of 7, so the point of neutrality on the pH scale is 7.

**Acidity and the pH Scale** Water has a pH of 7, so this is the point of neutrality on the pH scale. Acids have a pH less than 7, and bases have a pH greater than 7. Approximate pHs of examples are shown.

#### Acids

If a solution has a higher concentration of hydronium ions than pure water, it has a pH lower than 7. A solution with a pH lower than 7 is called an **acid**. As the hydronium ion concentration increases, the pH value decreases. Therefore, the more acidic a solution is, the lower its pH value is. Did you ever taste vinegar? Like other acids, it tastes sour. Stronger acids can be harmful to organisms. For example, stomach acid would eat through the stomach if it were not lined with a layer of mucus. Strong acids can also damage materials, even hard materials such as glass.

#### Bases

If a solution has a lower concentration of hydronium ions than pure water, it has a pH higher than 7. A solution with a pH higher than 7 is called a **base**. Bases, such as baking soda, have a bitter taste. Like strong acids, strong bases can harm organisms and damage materials. For example, lye can burn the skin, and bleach can remove the color from clothing.

#### Acids and Bases in Organisms

Acids and bases are important in living things because most enzymes can do their job only at a certain level of acidity. Cells secrete acids and bases to maintain the proper pH for enzymes to work. For example, every time you digest food, acids and bases are at work in your digestive system. Consider the enzyme pepsin, which helps break down proteins in the stomach. Pepsin needs an acidic environment to do its job, and the stomach secretes a strong acid that allows pepsin to work. However, when stomach contents enter the small intestine, the acid must be neutralized. This is because enzymes in the small intestine need a basic environment in order to work. An organ called the pancreas secretes a strong base into the small intestine, and this base neutralizes the acid.

### Summary

* A solution is a mixture of two or more substances that has the same composition throughout. Some solutions are acids, some are bases.
* Pure water has a pH of 7, so the point of neutrality on the pH scale is 7.
* Acids have a higher concentration of hydronium ions than pure water, and a pH lower than 7.
* Bases have a lower concentration of hydronium ions than pure water, and a pH higher than 7.
* Acids and bases are important in living organisms because most enzymes function best at a specific pH.

### Practice I

Use this resource to answer the questions that follow.

* **pH** at <http://johnkyrk.com/pH.html>.

1. What is a strong acid?
2. What is the pH scale?
3. What is the pH range of most cellular processes?
4. Use the pH slider to find the pH of
   1. digestive juices.
   2. Windex.
   3. soapy water.
   4. sea water.
   5. beer.
   6. vinegar.

### Practice II

* **pH scale** at <http://phet.colorado.edu/en/simulation/ph-scale>.

## Summary

The scientific method is the process by which biological information, like that of all other sciences, has been identified. This has resulted in a number of important biological scientific theories, including the cell theory and the theory of evolution. All life is built around carbon, and four categories of organic compounds: carbohydrates, lipids, proteins, and nucleic acids. One particular type of protein, enzymes, are biological catalysts, allowing biochemical reactions to proceed at the rate necessary to maintain life. One other molecule, water, is also essential to life, though water is not an organic compound.