

FEATURES OF THIS BOOK

This book is just for you!

We've designed it to help you learn. Flip through the following pages to see the features that we've designed into this textbook to help you succeed in biology. In the back of the book you'll see appendixes, a glossary, and an index.

Opener—a short article that highlights issues and developments in biology that need to be examined from a biblical worldview

Extreme Life
We live on a planet that thrives with life to the extreme. Sometimes life takes hold in the most unexpected places—right on Earth with no sunlight or air, some with agonizingly hot or bitterly cold temperatures. Microbes have been found in the deepest ocean trenches, in acid lakes, and even buried deep under Antarctic ice.

Evolutionists look at these forms of life, called extremophiles, and wonder whether life like this exists outside of Earth. In fact, in 2012 NASA plans to send a probe to Europa, a moon of Jupiter with an ice surface. They suspect that this moon has liquid water beneath its icy surface and a rocky structure like Earth's. But what will they find? Will it change the way we think about life on our planet?

3.1 OUR LIVING PLANET
The Biosphere
The search for life originating outside our living planet has been a long one. From the space program to the probes for astrobiology, there is NASA's space program. The problems for astrobiologists is that they haven't found life that comes from anywhere other than Earth despite spending millions of dollars developing the finest technology. None at all! So why look for life in space when there is so much around us?
Scientists are looking to extend their beliefs about life on Earth to space. If life and everything in the universe is a product of chance and a big bang, why wouldn't we see life elsewhere in the universe? In their view of biology, evolution is life's design. The late Carl Sagan, famous professor and astronomer at Cornell University once said, "The universe is a green big place. If it's just so, we've hit an awful waste of space." Life should be easy to find wherever we look, but that's not what we observe.
God designed life, and He made Earth for life. We see life in the world, the water, and the stars, sun, and moon are all mentioned in direct connection to the living things that God created. The stars are mentioned about as an afterthought because life on this planet is the centerpiece of God's creation, though all of creation declares His glory (Ps. 18: 1; Rom. 1: 20). Earth is the shelter, the home, the base for God's precious, living creation in the heavens, earth, and sea. When we look around our living planet, we see the evidence of a God who cares and who provides for the needs of life on Earth, called the biosphere. **ASTROBIOLOGY'S** search for life in space is a new discovery and Earth's core. This life shall stand as in the only place we know of where life can occur.

Questions
How do ecologists categorize the living and nonliving parts of Earth?
How are living things affected by their environment?

Terms
Biosphere
ecology
biodiversity
biome
ecosystem
habitat
niche
abiotic factor
biotic factor
population

What makes Earth a good place for life?

biosphere.

Ecology 28

Italicized Terms—other important science terms

Essential Question—the "big question" that you will learn about in a section

Key Questions—the smaller questions that you can ask along the way through a section to help you answer the essential question

Bold-Faced Terms—vocabulary terms that you need to know

ETHICS

GENETICALLY MODIFIED FOODS



Scientists who wear personal protection equipment are usually required by federal regulations to do so when working with certain chemicals that are used with both GM and non-GM crops, including some organic crops.

ISSUE

Genetically modified foods, otherwise known as “GM foods,” have been the center of ethical debate for quite some time. Those who support modifying the genes of crops see value in altering foods to fit the needs of people and support a growing population. Others question the long-term effects on people and animals who consume GM foods. Many GM foods have been created with the intent of increasing a healthy food supply by reducing insects, pests, and diseases that are harmful to crops. They also have the benefits of adding nutritional value to foods and making produce more attractive.

When the first GM humans became available in 1994, the market for GM foods began to widen. The search companies began expanding their testing and new GM crops began popping up. Since that time, teams of researchers have studied the health effects of GM foods. Even with research suggesting that GM foods are safe to consume, people often wonder whether there has been enough testing and research done to truly understand the long-term effects. With all we know and don’t know about GM foods, should we eat them?

Work through this issue using the guiding questions from the biblical ethics trial.

1. What information can I get about this issue?
2. What does the Bible say about this issue?
3. What are the acceptable and unacceptable options of consuming GM foods?
4. What are the implications of the acceptable options?
5. What action should I take?

Use the ethics box to answer Question 33.

33. Using the biblical ethics trial 2 questions above, formulate an essay on the Christian position of consuming genetically modified foods. Be sure to address each leg of the road: biblical principles, biblical outcomes, and biblical applications.

Food Processes 281

Ethics Features—opportunities to apply a biblical worldview to ethical issues related to biology

MINI LAB

Starch and Fat Test

We have just learned about the properties and structures of organic compounds, but can we identify them in the foods we eat? Identifying whether foods have fats and starches can actually be quite an easy and fun task. Let’s take a look at different foods and try to see whether we can correctly identify them as fats or starches.

Materials

• 4 fat food samples • 4 starch food samples • water • large brown paper bag • small cups • permanent marker • iodine

PROCEDURE

Fat Test

1. Cut the brown paper bag so that you can spread it out and lay it on a flat, covered surface.
2. Using your permanent marker, divide the bag into sections according to the number of food items that you will be testing. Label each section with the name of the food sample being tested in that section. Be sure to include water as your control sample.
3. Place each fat food sample into its designated section on the paper. Some of the items will need to be spread onto the paper, while others can simply be placed into their sections. The samples will need to sit for about 15 minutes to allow them to dry. Use this time to make predictions as to whether these items will contain fat.
4. After the time is up, remove each food sample. Check whether any oily residue is left behind. An oily residue indicates that the food sample contains fat. Compare your predictions to the results from each trial.

1. Were your predictions correct? What results surprised you?

Starch Test

1. Place the small cups on a flat, covered surface according to the number of food samples that you will be using. Label each cup with the name of the sample being tested and place the samples in their respective cups. Be sure to include water in one cup as your control sample.
2. Make predictions as to whether the samples will contain starch.
3. Put three drops of iodine on each sample. If the sample contains starch, the iodine will turn blue-black. Be sure to record the results.

2. Were your predictions correct? What results surprised you?

GOING FURTHER

1. The substance amylose, present in starch, causes the color of iodine to change from yellow-brown to blue-black. What do you think causes this?



44 Chapter 2

Mini Labs—short hands-on exercises to get you thinking and working like a scientist

FEATURES OF THIS BOOK (continued)

Worldview Investigations—inquiry-based investigations that help you think through controversial areas of biology through the lens of Scripture

Case Studies—opportunities to investigate specific areas in biology to apply what you have learned in a chapter

SAILOR BUG

Crickets are the antithesis of the sea, and insects are the antithesis of the land, right? Don't tell that to the ocean stink bug, a member of the true bug family and one of the very few marine insects. Though it lives on the ocean, it doesn't swim—it walks on water! Ocean stink bugs eat plankton off the surface of the ocean. They have little air-breathing tubes on their legs that act as life jackets to keep them afloat. They eat better food out through! Sailors in the air and fishermen below the surface are constantly trying to keep them up.

Ocean stink bugs are getting an unexpected lift from the Great Pacific Garbage Patch, an area of sea surface debris suspended in the water column trapped in a circular current in the North Pacific Ocean. Some experts estimate the patch to be the size of Texas. Much of the garbage has been broken down into very small pieces after being continuously broken by ocean waves. Even though the particles are creating a problem for aquatic animals, they are providing a handy place for ocean stink bugs to lay their eggs on the open sea. Thanks to the garbage patch, ocean stink bugs are thriving.

Ecologists are concerned that the buoyancy of the ocean could be affected by all this artificial material in the ocean. And in another field, scientists are finding that the ocean stink bug acts as a storage vehicle for heavy metals present in the ocean, such as cadmium. This could give scientists some clues about how pollution and toxic metals spread in the oceans and what we can do to keep our waters and ocean populations safe.

17.3 SECTION REVIEW

1. List three ways that you can identify the walking stick insect before an insect.
2. How does an insect use its wings to maintain homeostasis?
3. How does an insect breathe?
4. How does the shape of an insect's mouthparts relate to its function?
5. How does an insect find a mate?
6. Does an insect reproduce sexually or asexually? Explain.
7. How does an insect change over its life?
8. What are some ways that we can control insects without using pesticides that could be harmful to the environment?
9. How do ocean stink bugs survive on the ocean?
10. How does floating debris in the water affect marine life?
11. Explain how studying ocean stink bugs may help scientists find new ways to keep our water clean.

188 Chapter 17

Review Questions—Questions at the end of each section and chapter will give you practice in applying what you've learned in a section or a chapter. Problem-solving and extra-thought questions are marked with a purple box—you may need to think a little harder or do some research to answer these questions.

worldview investigation

CREATURES AND CLIMATE CHANGE

Introduction

Several years ago it was reported that millions of bird babies were born off the coast of California were carrying anthrax in their beaks. Many wondered whether this was related to a change in climate that would have caused this odd behavior?

Task

Choose a migrating animal, such as a specific bird, butterfly, or sea creature, and try to determine whether there is a connection between the animal's behavior and climate change. Then decide whether humans should be part of the solution for helping to get back on its track.

Procedure

1. Once you've chosen an animal, research to find out the following information about it:
 - type of migration patterns, nesting habits, and habitat preferences
 - new or changing migration patterns, nesting habits, and habitat preferences
 - possible causes for the changing behaviors
 - ways that people are helping it recover
2. Pay attention to events such as wildfires, droughts, hurricanes, and pestilence. Many statistics that you'll find about the effect of climate change on animals may be projections into the future and not observed data.
3. Create a map that compares the animal's migration pattern in the past five to twenty years ago and its migration pattern now. Include on your map a summary of the research that you did.
4. Suggest a possible way that your animal can be helped. For example, there are some animal rescue groups in California that have help sea birds back to health and then release them. There are also some fishing restrictions to help increase the fish populations that sea birds like to eat.
5. Include a few sentences about how you think climate change might affect a person's interpretation of data. Use your evidence on the last questions below.
 - Why do many scientists believe that changing migration patterns are caused by humans?
 - What is the biblical view of people when it comes to helping the Creation Mandate?

Conclusion

It makes sense that as Earth's climate changes, animal populations change too. We should try to help struggling animals as much as we can because they are resources that are critical to our life. We should also keep in mind that the earth is the Lord's (Ps. 24:1) and that he is the creator of every change.

CHAPTER REVIEW

Chapter Summary

17.1 ARTHROPOD INTRODUCTION AND CHELICERATES

- Arthropods have open circulatory systems, compound or simple eyes, segmented bodies, nervous systems, jointed appendages, and exoskeletons.
- Chelicerates are arthropods with double appendages called chelicerae. Most have one or two body segments and four pairs of walking legs.
- Chelicerates use pedipalps to eat, mate, and sense their environment.
- Aquatic chelicerates reproduce sexually through external fertilization, but most chelicerates reproduce through internal fertilization.
- Some chelicerates may be parasites or predators. Some chelicerates serve as food for other animals, while some are used for the treatment of disease and infections.

Terms

arthropod • chelera • abdomen • cephalothorax • compound eye • pedipalp • antenna • chelera • pedipalp • book lung • arthropod

17.2 INSECTS

- Insects are arthropods that have three body segments, six legs, one pair of antennae, and one pair of compound eyes. Most insects have wings.
- Insects have mandibles used for grinding food. Ground-up food gets broken down further by saliva and travels through the digestive system.
- Insects release pheromones to attract a mate. These pheromones are also used to communicate danger or distress to a food source for other insects in a colony.
- Insects begin as a fertilized egg and undergo incomplete or complete metamorphosis to reach adulthood.
- Insects are useful to their colonies as pollinators. However, some are known to destroy crops and land. They are also used in medicine and forensic investigations.

Terms

mandible • tubicle • trachea • spiracle • glandular • metamorphosis • incomplete metamorphosis • nymph • complete metamorphosis • pupa

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Chapter Reviews—handy statements that sum up the big ideas in each section of a chapter along with a list of each section's key terms

2

THE CHEMISTRY OF LIVING THINGS

2.1 Matter, Energy, and Life

2.2 The Chemical Processes of Life

2.3 Biochemistry



Healing Poisons

Socrates put the cup to his lips, knowing that the poison hemlock that it contained would bring him certain death. Accused of corrupting the youth by not recognizing the Greek gods, he chose this punishment rather than exile. But how could a seemingly innocent plant bring on death with just a simple drink?

The odd thing is that the Greeks used this same poison as medicine to relieve nagging coughs, arthritis, and the discomfort of teething in babies! We still use poisons today to cure what ails us. Snake, spider, and scorpion venoms and poisonous plants contain amazing chemicals to fight cancer, cardiac arrest, and stroke.

2.1 MATTER, ENERGY, AND LIFE

Matter

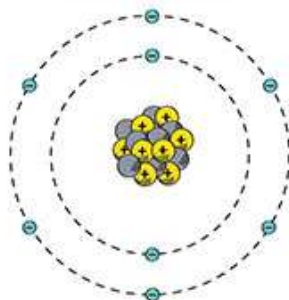
So what is the difference between a poison and a medicine? They are both chemicals that affect the way living things grow and operate. One of the most fruitful applications of studying life is to use chemicals from living things, like the poison from the hemlock, to develop medications that can save and improve people's lives. And lives matter because we are made in God's image.

Living things are deeply affected by matter and the changes that it undergoes. The study of matter and the changes that it experiences is called *chemistry*. **Matter** is anything that takes up space and has mass. We are made of matter and are breathing, using, and eating matter all the time! But we aren't the only ones. All living things—bees, banana trees, chimpanzees—interact with chemicals this way. There is a vital relationship between life and matter.

Atoms are the basic building blocks of matter. They are the smallest possible particles of an element. They have a nucleus that is heavy but extremely tiny compared to the rest of the atom. It is in the nucleus that positively charged *protons* and neutral *neutrons* are found. Whizzing around the nucleus is a cloud of negatively charged *electrons* that seem to occupy different levels, like the orbits of planets around the sun. Electrons in the outermost level are called *valence electrons*, and they are important for interacting with other atoms.

An atom with the same numbers of electrons and protons is electrically neutral. If these numbers are different, then the atom has an electrical charge, making it an *ion*. Extra electrons produce a negative ion, or *anion*. When there are fewer electrons than protons, the result is a *cation*, which has a net positive charge.

A neutral oxygen atom has 8 protons, 8 neutrons, and 8 electrons. There are 6 valence electrons in the outer level.



What is the difference between medicine and poison?

Questions

What is matter, and what is it made of?

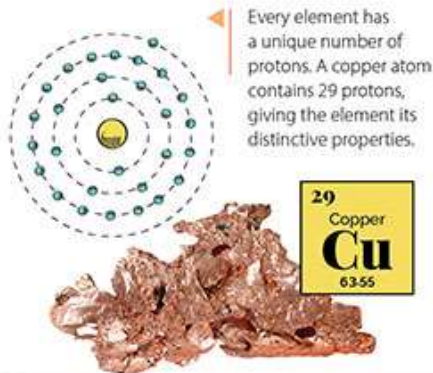
What is energy, and how do living things get it?

What is the difference between a physical and a chemical change?

Which kinds of chemical compounds are involved in living things?

Terms

matter
atom
element
energy
temperature
physical change
chemical change
bond
compound
molecule



Every element has a unique number of protons. A copper atom contains 29 protons, giving the element its distinctive properties.

The attraction of oppositely charged protons and electrons is the force that holds an atom together. Neutrons act like glue, keeping the protons in the nucleus from repelling each other. And it's a good thing, too, or living things would fly apart!

Not all atoms are the same. Atoms are classified as elements by the number of protons in their nuclei. **Elements** are pure substances made of only one kind of atom. For example, chlorine gas, copper nuggets, and hunks of yellow sulfur are each made of only one kind of atom. But living things are made of many different elements. The periodic table of elements shows the different kinds of elements that we know about, including the ones that are commonly found in living things.

Energy

Living things don't just have matter, like a blob just sitting there doing nothing. Living things also have energy. While matter is the material stuff of the universe, **energy** is the ability to do work. Without energy, nothing happens.

Bacteria move with little propellers, whales generate sounds, glowworms make light, and platypuses generate heat to incubate their eggs. These examples illustrate that there are different kinds of energy. When bacteria move, they show *mechanical energy*. When whales make sounds, they generate *acoustic energy*. When glowworms make light, they produce *light energy*. When platypuses generate heat, they produce *thermal energy*. Thermal energy comes from moving particles. The measure of the average speed at which these particles move is the **temperature** of a substance or organism, that is, its relative hotness or coldness. So when we have a fever, the average speed of the particles in our bodies is higher.

Living things need to get energy from somewhere before they can use it. Animals can't make their own energy—they get energy from their food. This energy is stored in the chemicals that make up food—we call it *chemical energy*. Plants, which also do not make their own energy, get energy by transforming energy from the sun. So we see that energy can be changed from one form to another. It's important to note that living things depend on these transformations.

Energy also tends to spread out. Plants concentrate energy in their stalks and leaves, and then other organisms eat the leaves. Plants also release energy as they emit water vapor and carbon dioxide, both of which disperse into the atmosphere. Living things depend on energy's tendency to disperse, a concept known as *entropy*.

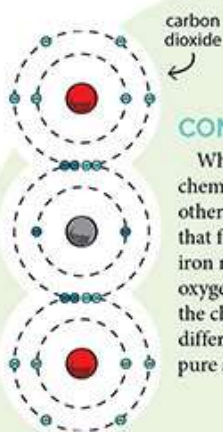


Changes in Matter

Just as energy can change from one form into another, so can matter. One of the basic laws of science is that the amount of matter and energy in the universe never changes. This is called the *law of conservation of mass and energy*. The conservation of energy is known as the *first law of thermodynamics*. Living things do not create new energy or matter, but matter can change from one form to another. That is why we observe cycles of matter in the environment, such as the water, nitrogen, and carbon cycles. We will learn more about these cycles in later chapters.



Changes that don't change a substance's identity are called **physical changes**. Icicles melting in the spring, water evaporating from the ocean and condensing to form clouds, and gas bubbles dissolving into a churning mountain stream are all examples of physical changes. Many physical changes can be reversed during other physical changes, but some are irreversible. For example, wheat can be ground into flour, but flour cannot be changed back to wheat.

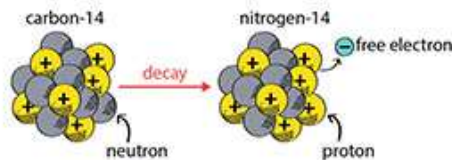


COMPOUNDS AND MOLECULES

When substances made of only one kind of element undergo a chemical change, their atoms react with the valence electrons from other atoms in a way that stores energy. An electrostatic attraction that forms between two atoms is called a **bond**. For example, when iron rusts, a chemical change occurs as the iron forms bonds with oxygen in the air to form rust. Iron and oxygen are also involved in the chemical process that allows our blood to carry oxygen to all the different parts of our bodies. Rust is an example of a **compound**, a pure substance made of two or more chemically combined elements.

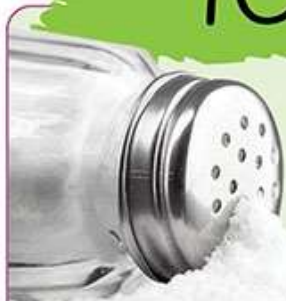
Sometimes matter changes in a way that completely transforms its identity. When iron rusts, for example, it undergoes a **chemical change**—a change that causes a substance to alter its chemical identity. In the case of the formation of rust, the change occurs as iron particles combine with oxygen particles. Not only is rust a new substance that is totally different from oxygen or iron, but it also has a different physical appearance. When a person digests food to produce glucose, the food undergoes a chemical change. When grass clippings decay to produce compost, a chemical change takes place. Sometimes chemical changes store chemical energy, such as during the digestion of food. Although many chemical changes can be reversed using other chemical changes, others are irreversible.

Another kind of chemical change is nuclear change. Nuclear changes are usually associated with substances that are radioactive. For example, carbon, one of the main elements associated with life, has six protons. But there are different forms, or isotopes, of carbon whose identities are determined by the number of neutrons each has. Carbon-12 is stable, but carbon-14 is radioactive. As carbon-14 undergoes radioactive decay, its atoms transform into nitrogen-14. This fact is what makes carbon-14 dating of fossils possible. We will learn more about this in Chapter 10.

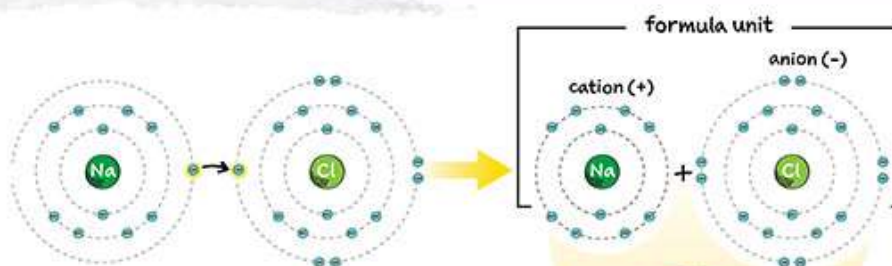


IONIC

COMPOUNDS



When atoms in the process of bonding give away or receive valence electrons, they transform into ions. One becomes a cation and the other an anion. These oppositely charged ions attract to form *ionic compounds*. The smallest part of an ionic compound is called a *formula unit*. Formula units build on each other to form crystals.



In this example of an ionic compound sodium donates a valence electron to chlorine to form a sodium chloride formula unit that combines with other formula units to form a table salt crystal.



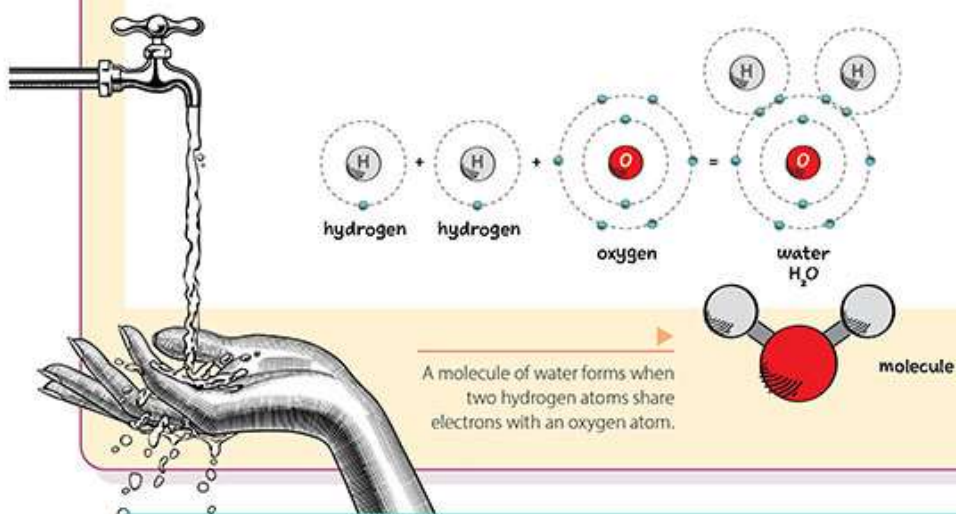
Ionic compounds are important to living things. We use toothpaste containing sodium fluoride (NaF) because our teeth are made of ionic compounds. We drink milk fortified with calcium phosphate [$\text{Ca}_3(\text{PO}_4)_2$] because our bones are made of ionic compounds. Many domesticated animals such as horses lick salt blocks because salt provides minerals necessary for their biological functions.



COVALENT COMPOUNDS

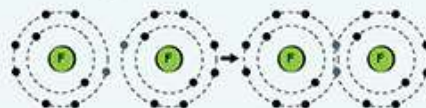
Sometimes atoms in the process of bonding share their valence electrons instead of donating them. An example is water, a chemical essential to life. Two hydrogen atoms each share an electron with a single oxygen atom to form a covalent compound. A particle consisting of two or more atoms covalently bonded together is called a **molecule**. Atoms in a covalent molecule typically don't form ions since the numbers of electrons and protons

in these atoms are equal. In covalent compounds pairs of shared electrons form the bonds that hold the atoms together. Molecules vary in complexity from simple molecules such as those made of only two oxygen atoms to the immensely complex macromolecules of proteins and DNA that contain hundreds of thousands of atoms. Some of the compounds most essential to life and its processes are mammoth—and some are minuscule.



2.1 SECTION REVIEW

1. What is the difference between a poison and a medicine? How can we use science to know the difference?
2. Write your own definition of the term *energy*.
3. Give an example of an energy transformation involving a living thing, and state the initial and final types of energy.
4. Create a table that compares physical and chemical changes, including definitions, observable changes, and examples.
5. List at least two differences between ionic and covalent compounds.
6. The illustration below shows the formation of a bond. What kind of compound is forming? How can you tell?



7. Create a chart that shows the relationships between matter, atoms, elements, protons, neutrons, electrons, compounds, and molecules.

2.2 THE CHEMICAL PROCESSES OF LIFE

How do chemical processes keep life going?



Questions

How does the nature of matter affect life?

What kinds of chemical reactions release or absorb energy?

What makes a chemical reaction speed up, slow down, or not even happen?

Terms

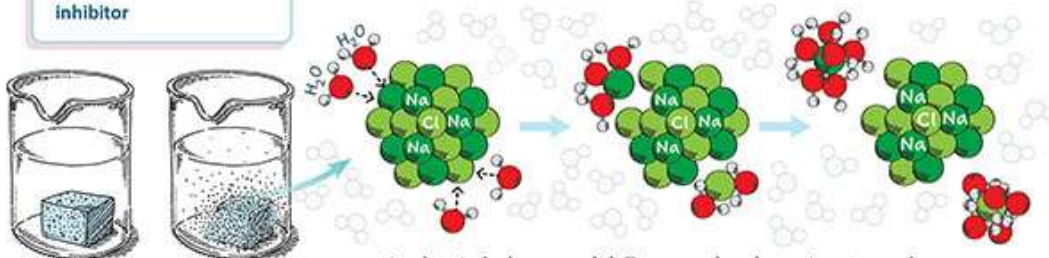
dissolving
acid
base
diffusion
reactant
product
catalyst
enzyme
inhibitor

Physical Changes

Break out your raincoat! It's a rainy day. A fine rain falls from a sky heavy with gray clouds onto a mountainside covered with balsam trees and mountain maples as you hike along a trail. The rain picks up. Water runs down the trail, sending insects scurrying, picking up soil particles, running over limestone rock faces, washing into streams that churn as they swell with rainfall. A rainy day demonstrates several physical changes. We've seen how a physical change alters matter in a way that doesn't change its identity. Let's look at some specific physical changes that are essential to keeping living things alive in this everyday example.

SOLUTIONS

When the water runs down the trail and picks up debris, it forms a mixture. We can see the bits of soil, pebbles, and twigs that get washed into the rainwater. When water runs over limestone deposits, some of the limestone will break up in the water so much that we can't see it. Limestone is the ionic compound calcium carbonate (CaCO_3), and it actually breaks up into calcium and carbonate ions mixed in with the water. This forms a solution. A solution is a uniform mixture. The process by which one substance (limestone) is broken up into smaller pieces, usually ions, by another substance (water) is called **dissolving** (illustrated below). The solution contains more water than limestone, so water is the *solvent*, and the limestone, the substance that is dissolved, is the *solute*. The amount of solute packed into a solvent is called the *concentration* of a solution.



Water molecules tear apart the salt crystal until it is completely dissolved in the solution.

A solute isn't always a solid. For example, when rainwater washes into churning mountain streams, some air dissolves in the water. This is very important for fish, salamanders, and other aquatic animals that rely on dissolved oxygen to breathe. In this case the oxygen is the solute.

Most rainfall is not pure water. It sometimes reacts with pollution, such as sulfuric acid or nitric acid in the air, to form acid rain. An **acid** is a substance that dissolves in water to form hydrogen ions (H^+). A **base** is a substance that dissolves in water to form hydroxide ions (OH^-) or other ions like chloride (Cl^-) or fluoride (F^-) that can accept hydrogen ions. When a strong acid and base react with each other, the hydrogen and hydroxide ions combine to form ... water! Acids and bases affect soil and water in the environment as well as digestion and even blood in living things.