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

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

Italicized Terms—other important science terms

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

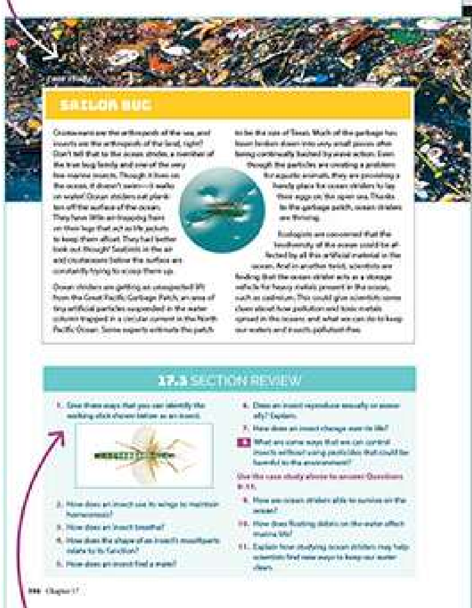
Ethics Features—opportunities to apply a biblical worldview to ethical issues related to biology

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

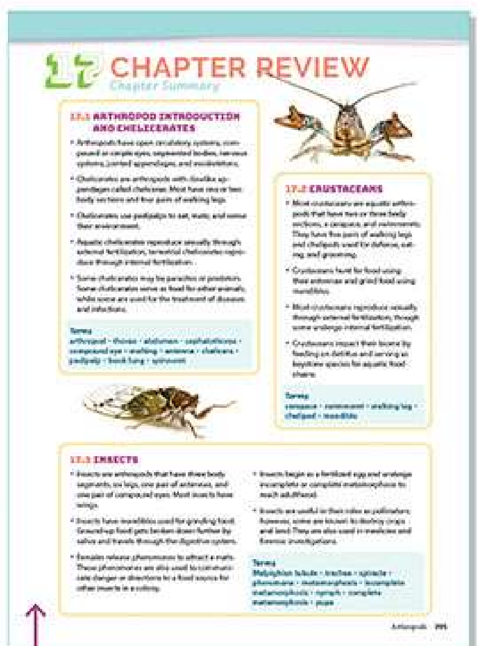
FEATURES OF THIS BOOK *(continued)*

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



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.



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

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

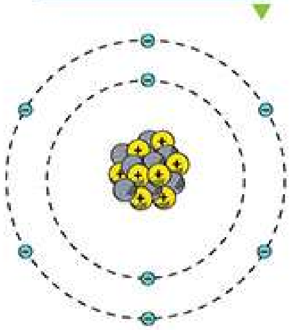
Matter

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.

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



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.

What is the difference between medicine and poison?

Questions

What is matter, and what is it made of?

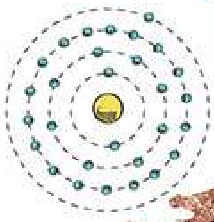
What is energy, and how do living things get it?

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*.

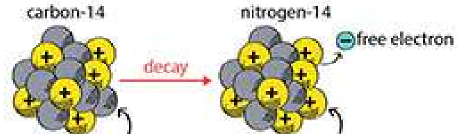
Changes in Matter

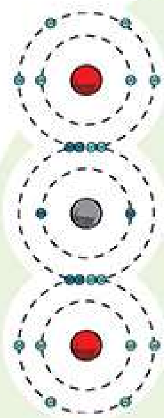
Just as energy can change from one form into another, so can matter. One of the basic laws of science is that the amount of matter and energy in the universe never changes. This is called the *law of conservation of mass and energy*. The conservation of energy is known as the *first law of thermodynamics*. 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.

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.

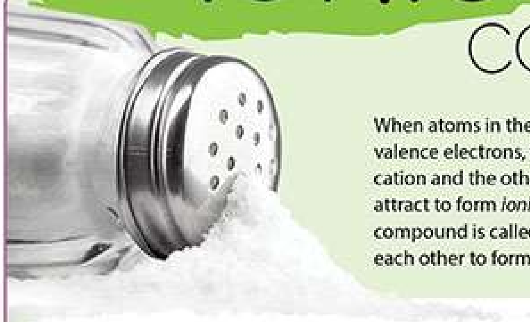




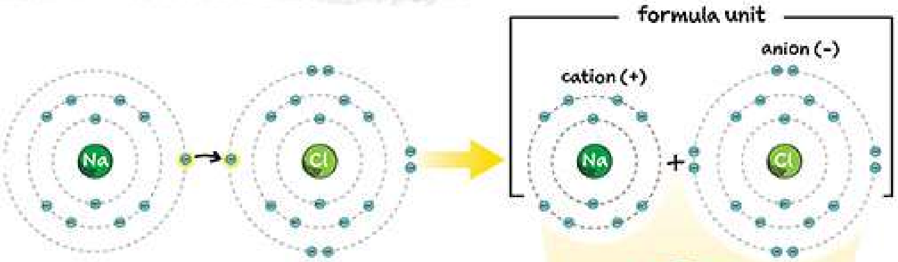
COMPOUNDS AND MOLECULES

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.

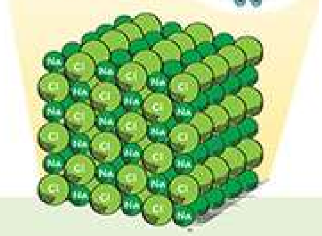
IONIC COMPOUNDS



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.



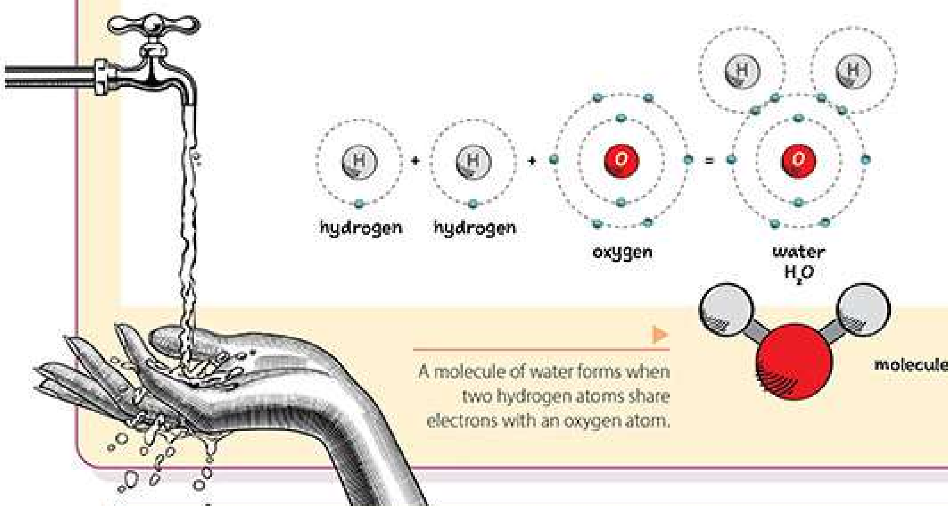
In this example of an ionic compound sodium donates a valence electron to chlorine to form a sodium chloride formula unit that combines with other formula units to form a table salt crystal.



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 $[Ca_3(PO_4)_2]$ 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

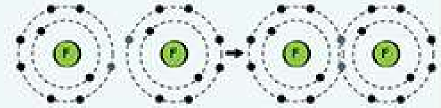
Sometimes atoms in the process of bonding share their valence electrons instead of donating them. An example is water, a chemical essential to life. Two hydrogen atoms each share an electron with a single oxygen atom to form a covalent compound. A particle consisting of two or more atoms covalently bonded 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.



A molecule of water forms when two hydrogen atoms share electrons with an oxygen atom.

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

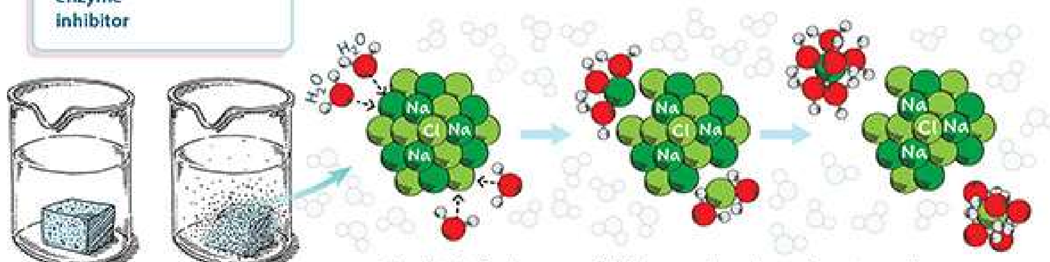
dissolving
acid
base
diffusion
reactant
product
catalyst
enzyme
inhibitor

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.