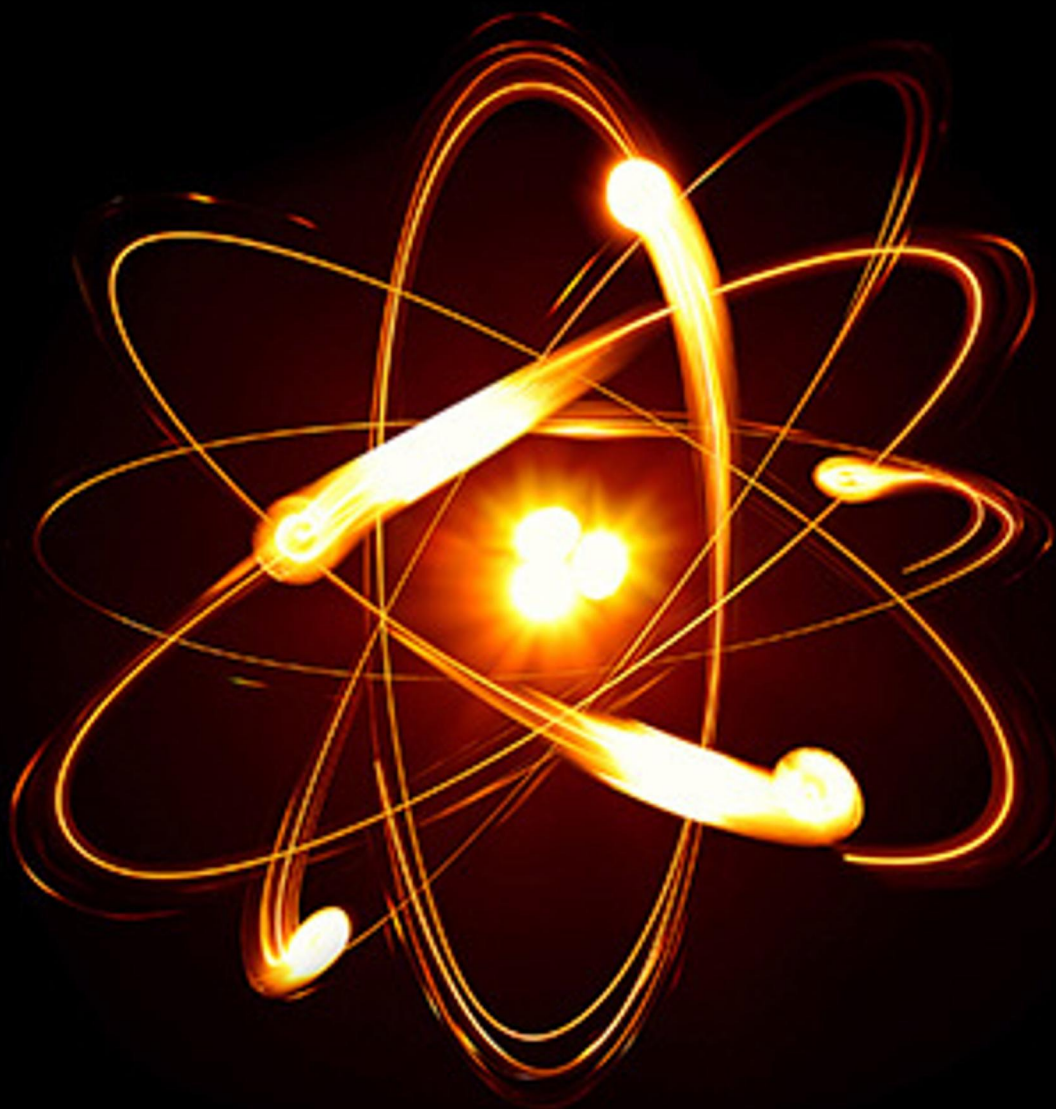


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Del Rio Middle School 8th Grade Science



SFDRCISD 8th Grade Science

Stephen Thomas
Kayla Thomas

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Contents

1	Chapter 1 - Science Safety & Procedures	1
1.1	Chapter 1 Guided Questions	2
1.2	Safety in Science	3
1.3	Safety Contract.docx	8
2	Chapter 2 - Atomic Structure	9
2.1	Chapter 2 Guided Questions	10
2.2	Atomic Structure	11
3	Chapter 3 - Periodic Table	29
3.1	Chapter 3 Guided Questions	30
3.2	Periodic Table	31
4	Chapter 4 - Chemical Formulas, Equations and Reactions	47
4.1	Chapter 4 Guided Questions	48
4.2	Endothermic or Exothermic Lab	49
4.3	Chemical Physical Foldable.docx	50
4.4	Chemical equations	51
4.5	Balanced or Not Practice	65
4.6	Slime Lab.docx	66
4.7	Caesin Lab - Chemical Reaction.docx	67
5	Chapter 5 - Motion and Force	68
5.1	Chapter 5 Guided Questions	69
5.2	Combining Forces.docx	70
5.3	Calculating Work.docx	74
5.4	Calculating Acceleration from Force and Mass.docx	77
5.5	Density Virtual Lab.docx	80
6	Chapter 6 - Newton's Laws	81
6.1	Chapter 6 Guided Questions	82
6.2	Newton's Laws 1, 2 & 3	83
7	Chapter 7 - Forces that Change the Earth	106
7.1	Chapter 7 Guided Questions	107
7.2	Theory of Plate Tectonics	108
7.3	Continental Drift	111
7.4	Earth's Tectonic Plates	114
7.5	Tectonic Plate Motions	119
7.6	Transform Plate Boundaries	122
7.7	Earthquakes at Transform Plate Boundaries	125
7.8	Divergent Plate Boundaries	128

7.9	Divergent Plate Boundaries in the Oceans	133
7.10	Continent-Continent Convergent Plate Boundaries	136
7.11	Earthquakes at Convergent Plate Boundaries	139
7.12	Volcanoes at Plate Boundaries	143
7.13	Ocean-Continent Convergent Plate Boundaries	148
7.14	Ocean-Ocean Convergent Plate Boundaries	153
7.15	Topographic Maps	156
7.16	References	161
8	Chapter 8 - Climate Interactions	163
8.1	Chapter 8 Guided Questions	164
8.2	How Ocean Currents Moderate Climate	165
8.3	Climate Interactions Ocean Currents Student notes	168
8.4	Climate Interactions Fronts Student Notes	171
8.5	Winds	176
8.6	Humidity and Air Masses Student Notes	182
8.7	How to read a weather map WS	184
8.8	Anemometer Lab	187
8.9	Climate Interaction Weather Symbols	189
8.10	References	191
9	Chapter 9 - Earth's Cycles	192
9.1	Chapter 9 Guided Questions	193
9.2	Rotation of Earth	194
9.3	Revolutions of Earth	197
9.4	Revolutions of Earth	199
9.5	Lunar Phases	204
9.6	Tides	207
9.7	Short-Term Climate Change	212
9.8	References	216
10	Chapter 10 - Light Years and Theories	217
10.1	Chapter 10 Guided Questions	218
10.2	Universe	219
10.3	Big Bang	222
10.4	Light Years (ly)	226
10.5	References	229
11	Chapter 11 - Characteristics of the Universe	230
11.1	Chapter 11 Guided Questions	231
11.2	The Hertzsprung-Russell Diagram (H-R)	232
11.3	Life Cycles of Stars	236
11.4	Galaxies	243
11.5	Electromagnetic Spectrum	248
11.6	References	251
12	Chapter 12 - Interdependence Among Living Systems	252
12.1	Chapter 12 Guided Questions	253
12.2	Autotrophs and Heterotrophs	254
12.3	Food Chains and Food Webs	259
12.4	Competition in Communities	263
12.5	Importance of the Oceans	266

12.6	Soil and Water Resources	269
12.7	References	273
13	Virtual Labs.docx	274

CHAPTER

1

Chapter 1 - Science Safety & Procedures

Chapter Outline

- 1.1 [CHAPTER 1 GUIDED QUESTIONS](#)
 - 1.2 [SAFETY IN SCIENCE](#)
 - 1.3 [SAFETY CONTRACT.DOCX](#)
-

1.1 Chapter 1 Guided Questions

Chapter 1: Guided Questions

- What are some lab safety rules that we must follow daily?
-
- How should we deal with chemicals in the lab?
-
- Why is lab safety so important?
-
- Describe some consequences that can occur when you do not follow lab safety rules.
-

1.2 Safety in Science

- Identify the meaning of lab safety symbols.
- List rules for staying safe in the lab.
- State what to do in case of accidents in the lab or field.



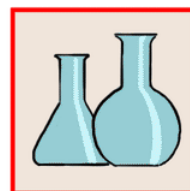
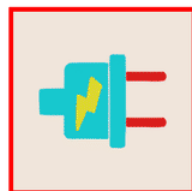
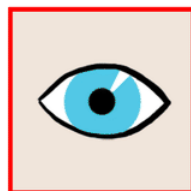
Research in physical science can be exciting, but it also has potential dangers. For example, the field scientist in this photo is collecting water samples from treatment ponds. There are many microorganisms in the water that could make him sick. The water and shore can also be strewn with dangerous objects such as sharp can lids and broken glass bottles that could cause serious injury. Whether in the field or in the lab, knowing how to stay safe in science is important.

Safety Symbols

Lab procedures and equipment may be labeled with safety symbols. These symbols warn of specific hazards, such as flames or broken glass. Learn the symbols so you will recognize the dangers. Then learn how to avoid them. Many common safety symbols are shown below.

ANIMAL
HAZARDSHARP INSTRUMENT
HAZARD

HEAT HAZARD

GLASSWARE
HAZARDCHEMICAL
HAZARDELECTRICAL
HAZARDEYE & FACE
HAZARDFIRE
HAZARD

BIOHAZARD

LASER RADIATION
HAZARDRADIOACTIVE
HAZARDEXPLOSIVE
HAZARD

Q: Do you know how you can avoid these hazards?

A: Wearing protective gear is one way to avoid many hazards in science. For example, to avoid being burned by hot objects, use hot mitts to protect your hands. To avoid eye hazards, such as harsh liquids splashed into the eyes, wear safety goggles. You can learn more about these and other lab hazards and how to avoid them at this URL: <http://www.angelfire.com/va3/chemclass/safety.html> .

Safety Rules

Following basic safety rules is another important way to stay safe in science. Safe practices help prevent accidents. Several lab safety rules are listed below. Different rules may apply when you work in the field. But in all cases, you should always follow your teacher's instructions.

Lab Safety Rules

- Wear long sleeves and shoes that completely cover your feet.
- If your hair is long, tie it back or cover it with a hair net.
- Protect your eyes, skin, and clothing by wearing safety goggles, an apron, and gloves.
- Use hot mitts to handle hot objects.
- Never work in the lab alone.
- Never engage in horseplay in the lab.
- Never eat or drink in the lab.
- Never do experiments without your teacher's approval.
- Always add acid to water, never the other way around, and add the acid slowly to avoid splashing.
- Take care to avoid knocking over Bunsen burners, and keep them away from flammable materials such as paper.

- Use your hand to fan vapors toward your nose rather than smelling substances directly.
- Never point the open end of a test tube toward anyone—including yourself!
- Clean up any spills immediately.
- Dispose of lab wastes according to your teacher’s instructions.
- Wash glassware and counters when you finish your work.
- Wash your hands with soap and water before leaving the lab.

In Case of Accident

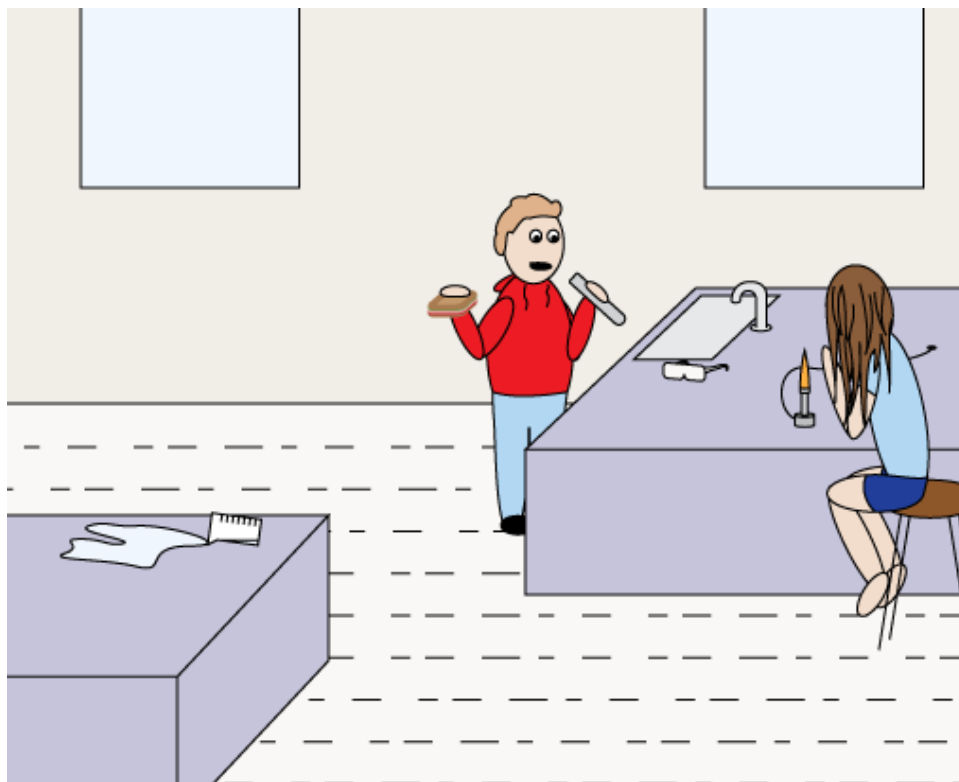
Even when you follow the rules, accidents can happen. Immediately alert your teacher if an accident occurs. Report all accidents, whether or not you think they are serious.

Summary

- Lab safety symbols warn of specific hazards, such as flames or broken glass. Knowing the symbols allows you to recognize and avoid the dangers.
- Following basic safety rules, such as wearing safety gear, helps prevent accidents in the lab and in the field.
- All accidents should be reported immediately.

Explore More

Examine this sketch of students working in a lab, and then answer the question below.



1. These students are breaking at least six lab safety rules. What are they doing that is unsafe?

Review

1. What hazard do think this safety symbol represents?



2. Identify three safety rules that help prevent accidents in the lab.
3. Create a safety poster to convey one of the three rules you listed in your answer to 2.

1.3 Safety Contract.docx



Student Safety Contract

School Name _____

Teacher _____

PURPOSE

Science is a hands-on laboratory class. However, science activities may have potential hazards. We will use some equipment and animals that may be dangerous if not handled properly. Safety in the science classroom is an important part of the scientific process. To ensure a safe classroom, a list of rules has been developed and is called the Science Safety Contract. These rules must be followed at all times. Additional safety instructions will be given for each activity.

No science student will be allowed to participate in science activities until this contract has been signed by both the student and a parent or guardian.

SAFETY RULES

1. Conduct yourself in a responsible manner at all times in the science room. Horseplay, practical jokes, and pranks will not be tolerated.
2. Follow all written and verbal instructions carefully. Ask your teacher questions if you do not understand the instructions.
3. Do not touch any equipment, supplies, animals, or other materials in the science room without permission from the teacher.
4. Perform only authorized and approved experiments. Do not conduct any experiments when the teacher is out of the room.
5. Never eat, drink, chew gum, or taste anything in the science room.
6. Keep hands away from face, eyes, and mouth while using science materials or when working with either chemicals or animals. Wash your hands with soap and water before leaving the science room.
7. Wear safety glasses or goggles when instructed. Never remove safety glasses or goggles during an experiment. There will be no exceptions to this rule!
8. Keep your work area and the science room neat and clean. Bring only your laboratory instructions, worksheets, and writing instruments to the work area.
9. Clean all work areas and equipment at the end of the experiment. Return all equipment clean and in working order to the proper storage area.
10. Follow your teacher's instructions to dispose of any waste materials generated in an experiment.
11. Report any accident (fire, spill, breakage, etc.), injury (cut, burn, etc.), or hazardous condition (broken equipment, etc.) to the teacher immediately.

12. Consider all chemicals used in the science room to be dangerous. Do not touch or smell any chemicals unless specifically instructed to do so.
13. Handle all animals with care and respect.
 - a. Open animal cages only with permission.
 - b. Never handle any animals when the teacher is out of the room.
 - c. Do not take animals out of the science room.
 - d. Do not tease or handle animals roughly.
 - e. Keep animals away from students' faces.
 - f. Wear gloves when handling animals.
 - g. Report any animal bite or scratch to the teacher immediately.
14. Always carry a microscope with both hands. Hold the arm with one hand; place the other hand under the base.
15. Treat all preserved specimens and dissecting supplies with care and respect.
 - a. Do not remove preserved specimens from the science room.
 - b. Use scalpels, scissors, and other sharp instruments only as instructed.
 - c. Never cut any material towards you—always cut away from your body.
 - d. Report any cut or scratch from sharp instruments to the teacher immediately.
16. Never open storage cabinets or enter the prep/storage room without permission from the teacher.
17. Do not remove chemicals, equipment, supplies, or animals from the science room without permission from the teacher.
18. Handle all glassware with care. Never pick up hot or broken glassware with your bare hands.
19. Use extreme caution when using matches, a burner, or hot plate. Only light burners when instructed and do not put anything into a flame unless specifically instructed to do so. Do not leave a lit burner unattended.
20. Dress properly—long hair must be tied back, no dangling jewelry, and no loose or baggy clothing. Wear aprons when instructed.
21. Learn where the safety equipment is located and how to use it. Know where the exits are located and what to do in case of an emergency or fire drill.

AGREEMENT

I, _____ (student's name) have read and understand each of the above safety rules set forth in this contract. I agree to follow them to ensure not only my own safety but also the safety of others in the science classroom or laboratory. I also agree to follow the general rules of appropriate behavior for a classroom at all times to avoid accidents and to provide a safe learning environment for everyone. I understand that if I do not follow all the rules and safety precautions, I will not be allowed to participate in science activities.

Student Signature _____

Date _____

Dear Parent or Guardian:

We feel that you should be informed of the school's effort to create and maintain a safe science classroom/laboratory environment. Please read the list of safety rules. No student will be permitted to perform science activities unless this contract is signed by both the student and parent/guardian and is on file with the teacher. Your signature on this contract indicates that you have read this Science Safety Contract, reviewed it with your child, and are aware of the measures taken to ensure the safety of your son/daughter in the science classroom.

Parent/Guardian Signature _____

Date _____

Important questions:

Does your child wear contact lenses?

Y or N

Is your child color blind?

Y or N

Does your child have any allergies?

Y or N

If so, please list:

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CHAPTER **2**

Chapter 2 - Atomic Structure

Chapter Outline

- 2.1 CHAPTER 2 GUIDED QUESTIONS
 - 2.2 ATOMIC STRUCTURE
-

2.1 Chapter 2 Guided Questions

Chapter 2: Guided Questions

- Create an analogy using the various parts of the atom.
-
- Describe the mass, electrical charge, and location of each part of an atom.
-
- Explain the structure of the atom.
-
- How is the electrical charge of the nucleus of an atom determined?

2.2 Atomic Structure

Lesson Objectives

Compare and contrast protons, neutrons, and electrons.

Describe the forces that hold the particles of atoms together.

Define atomic number and mass number.

Describe ions and isotopes

Identify the particles called quarks.

Vocabulary

atomic mass unit (amu)

atomic number

electron

ion

isotope

mass number

neutron

nucleus

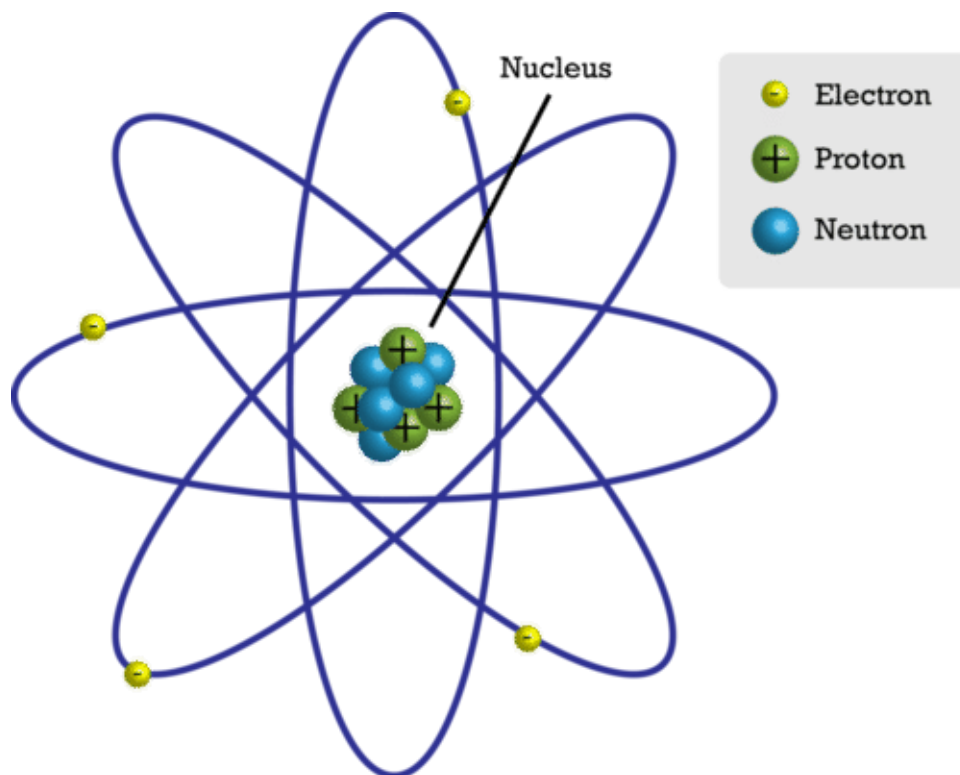
proton

Introduction

Atoms are the smallest particles of an element that still have the element's properties. They are the building blocks of all matter. Individual atoms are extremely small. In fact, they are so small that trillions of them would fit inside the period at the end of this sentence. Yet atoms, in turn, consist of even smaller particles.

Parts of the Atom

Figure below represents a simple model of an atom. You will learn about more complex models in later lessons, but this model is a good place to start. You can see similar, animated models of atoms at this URL: <http://web.jjay.cuny.edu/~acarpi/Natoms.htm>.



This simple atomic model shows the particles inside the atom.

The Nucleus

At the center of an atom is the **nucleus** (plural, nuclei). The nucleus contains most of the atom's mass. However, in size, it's just a tiny part of the atom. The model in **Figure above** is not to scale. If an atom were the size of a football stadium, the nucleus would be only about the size of a pea.

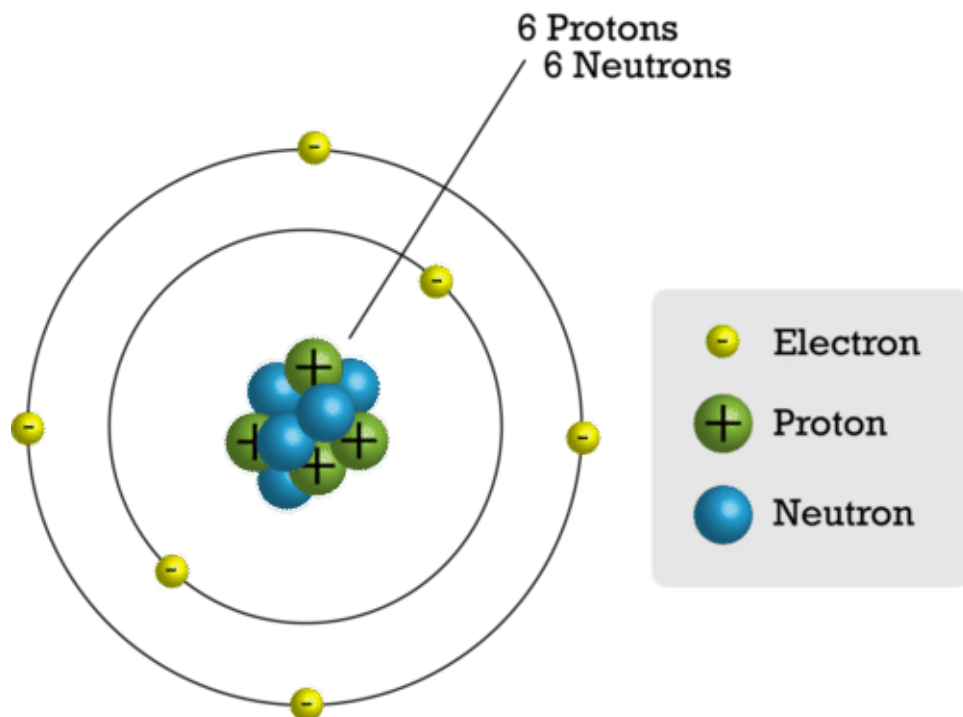
The nucleus, in turn, consists of two types of particles, called protons and neutrons. These particles are tightly packed inside the nucleus. Constantly moving about the nucleus are other particles called electrons. You can see a video about all three types of atomic particles at this URL: <https://www.youtube.com/watch?v=hbbqIJZ8wCM> (3:50).

Protons

A **proton** is a particle in the nucleus of an atom that has a positive electric charge. All protons are identical. It is the number of protons that gives atoms of different elements their unique properties. Atoms of each type of element have a characteristic number of protons. For example, each atom of carbon has six protons, as you can see in **Figure below**. No two elements have atoms with the same number of protons.

Neutrons

A **neutron** is a particle in the nucleus of an atom that has no electric charge. Atoms of an element often have the same number of neutrons as protons. For example, most carbon atoms have six neutrons as well as six protons. This is also shown in **Figure below**.



This model shows the particles that make up a carbon atom.

Electrons

An **electron** is a particle outside the nucleus of an atom that has a negative electric charge. The charge of an electron is opposite but equal to the charge of a proton. Atoms have the same number of electrons as protons. As a result, the negative and positive charges "cancel out." This makes atoms electrically neutral. For example, a carbon atom has six electrons that "cancel out" its six protons.

Atomic Number and Mass Number

Electrons have almost no mass. Instead, almost all the mass of an atom is in its protons and neutrons in the nucleus. The nucleus is very small, but it is densely packed with matter. The SI unit for the mass of an atom is the **atomic mass unit (amu)**. One atomic mass unit equals the mass of a proton, which is about 1.7×10^{-24} g. Each neutron also has a mass of 1 amu. Therefore, the sum of the protons and neutrons in an atom is about equal to the atom's total mass in atomic mass units.

Two numbers are commonly used to distinguish atoms: atomic number and mass number. **Figure below** shows how these numbers are usually written.



The symbol He stands for the element helium. Can you infer how many electrons a helium atom has?

The **atomic number** is the number of protons in an atom. This number is unique for atoms of each kind of element. For example, the atomic number of all helium atoms is 2.

The **mass number** is the number of protons plus the number of neutrons in an atom. For example, most atoms of helium have 2 neutrons, so their mass number is $2 + 2 = 4$. This mass number means that an atom of helium has a mass of about 4 amu.

Problem Solving

Problem: An atom has an atomic number of 12 and a mass number of 24. How many protons and neutrons does the atom have?

Solution: The number of protons is the same as the atomic number, or 12. The number of neutrons is equal to the mass number minus the atomic number, or $24 - 12 = 12$.

You Try It!

Problem: An atom has an atomic number of 8 and a mass number of 16. How many neutrons does it have? What is the atom's mass in atomic mass units?

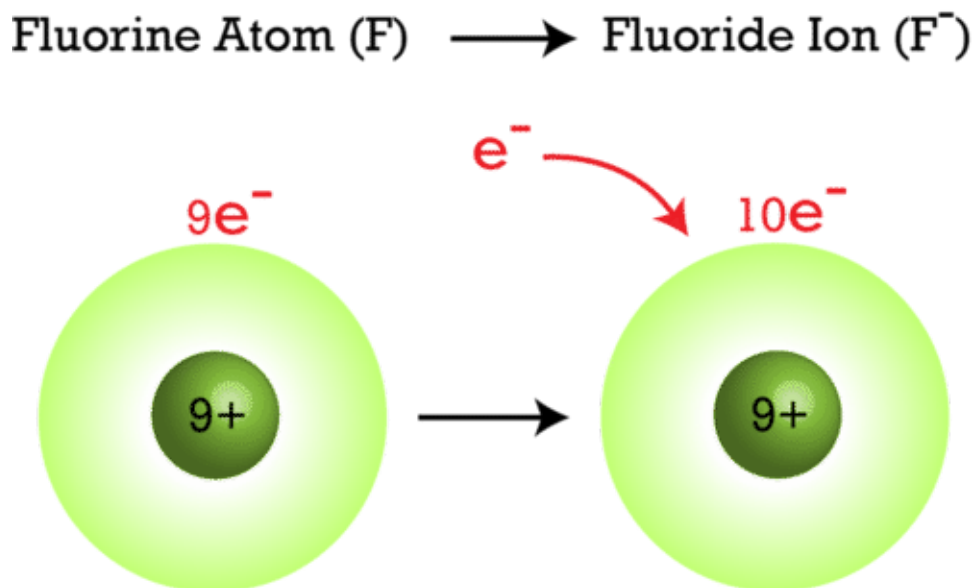
Ions and Isotopes

The number of protons per atom is always the same for a given element. However, the number of neutrons may vary, and the number of electrons can change.

Ions

Sometimes atoms lose or gain electrons. Then they become **ions**. Ions have a positive or negative charge. That's because they do not have the same number of electrons as protons. If atoms lose electrons, they become positive ions, or cations. If atoms gain electrons, they become negative ions, or anions.

Consider the example of fluorine in **Figure below**. A fluorine atom has nine protons and nine electrons, so it is electrically neutral. If a fluorine atom gains an electron, it becomes a fluoride ion with a negative charge of minus one.



When a fluorine atom gains an electron, it becomes a negative fluoride ion.

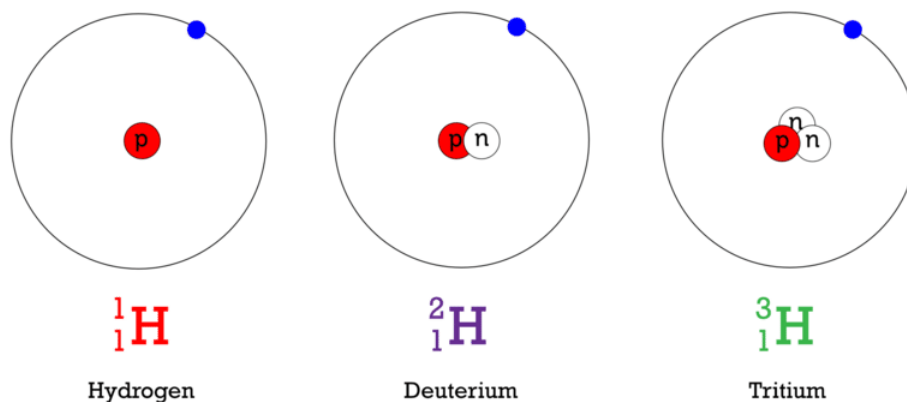
Isotopes of Atoms

Some atoms of the same element may have different numbers of neutrons. For example, some carbon atoms have seven or eight neutrons instead of the usual six. Atoms of the same element that differ in number of neutrons are called **isotopes**. Many isotopes occur naturally. Usually one or two isotopes of an element are the most stable and common. Different isotopes of an element generally have the same chemical properties. That's because

they have the same numbers of protons and electrons. For a video explanation of isotopes, go to this URL: <http://www.youtube.com/watch?v=6w7raarHNA8> (5:23).

An Example: Hydrogen Isotopes

Hydrogen is a good example of isotopes because it has the simplest atoms. Three isotopes of hydrogen are modeled in **Figure below**. Most hydrogen atoms have just one proton and one electron and lack a neutron. They are just called hydrogen. Some hydrogen atoms have one neutron. These atoms are the isotope named deuterium. Other hydrogen atoms have two neutrons. These atoms are the isotope named tritium.



All isotopes of a given element have the same number of protons (P), but they differ in the number of neutrons (N). What is the mass number of each isotope shown here?

Naming Isotopes

For most other elements, isotopes are named for their mass number. For example, carbon atoms with the usual 6 neutrons have a mass number of 12 (6 protons + 6 neutrons = 12), so they are called carbon-12. Carbon atoms with 7 neutrons have an atomic mass of 13 (6 protons + 7 neutrons = 13). These atoms are the isotope called carbon-13. Some carbon atoms have 8 neutrons. What is the name of this isotope of carbon? You can learn more about this isotope at the URL below. It is used by scientists to estimate the ages of rocks and fossils.

<http://www.khanacademy.org/video/carbon-14-dating-1?playlist=Chemistry>

Lesson Summary

The nucleus is at the center of the atom. It contains positive protons and neutral neutrons. Negative electrons constantly move about the nucleus.

Atomic number is the number of protons in an atom. It is unique for the atoms of each element. Mass number is the number of protons plus neutrons in an atom. It is about equal to the mass of the atom in atomic mass units (amu).

If atoms lose or gain electrons, they become positive or negative ions. Atoms of the same element that have different numbers of neutrons are called isotopes.

Lesson Review Questions

Recall

Describe the nucleus of an atom.

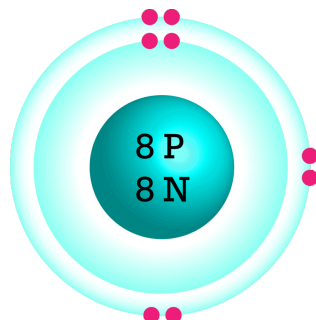
What does the atomic number of an atom represent?

Define isotope. Give an example.

Apply Concepts

- If an atom gains electrons, it becomes an ion. Is the ion positively or negatively charged? Explain your answer.

- What is the atomic mass (in atomic mass units) of the atom represented by the model below?



Think Critically

- Make a table comparing and contrasting protons, neutrons, and electrons. Include their location, mass, and electric charge.
- Explain why atoms are neutral in electric charge.

Points to Consider

In this lesson, you saw several simple models of atoms. Models are useful for representing things that are very small. Scientists have used models to represent atoms for more than 200 years. In the next lesson, "History of the Atom," you'll read about some of the earlier models.

How might scientists have modeled atoms before the particles inside atoms were discovered?

How do you think earlier models might have differed from the models in this lesson?

Lesson Objectives

State Democritus's ideas about the atom.

Outline Dalton's atomic theory.

Explain how Thomson discovered electrons.

Describe how Rutherford found the nucleus.

Introduction

Atoms are very tiny. They could not be seen before scanning tunneling microscopes were invented in 1981. However, the idea of atoms goes back to ancient Greece. That's where this brief history of the atom begins. You can watch a video about the history of the atom at this URL: <http://www.youtube.com/watch?v=sxQIzPejhO8>.

Democritus Introduces the Atom

The history of the atom begins around 450 B.C. with a Greek philosopher named Democritus (see **Figure below**). Democritus wondered what would happen if you cut a piece of matter, such as an apple, into smaller and smaller pieces. He thought that a point would be reached where matter could not be cut into still smaller pieces. He called these "uncuttable" pieces *atomos*. This is where the modern term atom comes from.



Democritus first introduced the idea of the atom almost 2500 years ago.

Democritus was an important philosopher. However, he was less influential than the Greek philosopher Aristotle, who lived about 100 years after Democritus. Aristotle rejected Democritus's idea of atoms. In fact, Aristotle thought the idea of atoms was ridiculous. Unfortunately, Aristotle's ideas were accepted for more than 2000 years. During that time, Democritus's ideas were more or less forgotten.

Dalton Brings Back the Atom

Around 1800, a British chemist named John Dalton revived Democritus's early ideas about the atom. Dalton is pictured in **Figure below**. He made a living by teaching and just did research in his spare time. Nonetheless, from his research results, he developed one of the most important theories in science.



John Dalton used evidence from experiments to show that atoms exist.

Dalton's Research

Dalton did many experiments that provided evidence for atoms. For example, he studied the pressure of gases. He concluded that gases must consist of tiny particles in constant motion. Dalton also researched the properties of compounds. He showed that a compound always consists of the same elements in the same ratio. On the other hand, different compounds always consist of different elements or ratios. This can happen, Dalton reasoned, only if elements are made of tiny particles that can combine in an endless variety of ways. From his research, Dalton developed a theory of the atom. You can learn more about Dalton and his research by watching the video at this URL: <http://www.youtube.com/watch?v=BhWgv0STLZs&feature=related> (9:03).

Dalton's Atomic Theory

The atomic theory Dalton developed consists of three ideas:

All substances are made of atoms. Atoms are the smallest particles of matter. They cannot be divided into smaller particles. They also cannot be created or destroyed.

All atoms of the same element are alike and have the same mass. Atoms of different elements are different and have different masses.

Atoms join together to form compounds. A given compound always consists of the same kinds of atoms in the same ratio.

Dalton's theory was soon widely accepted. Most of it is still accepted today. The only part that is no longer accepted is his idea that atoms are the smallest particles. Scientists now know that atoms consist of even smaller particles.

Dalton's Atomic Models

Dalton incorrectly thought that atoms are tiny solid particles of matter. He used solid wooden balls to model them. The sketch in the **Figure below** shows how Dalton's model atoms looked. He made holes in the balls so they could be joined together with hooks. In this way, the balls could be used to model compounds. When later scientists discovered subatomic particles (particles smaller than the atom itself), they realized that Dalton's models were too simple. They didn't show that atoms consist of even smaller particles. Models including these smaller particles were later developed.



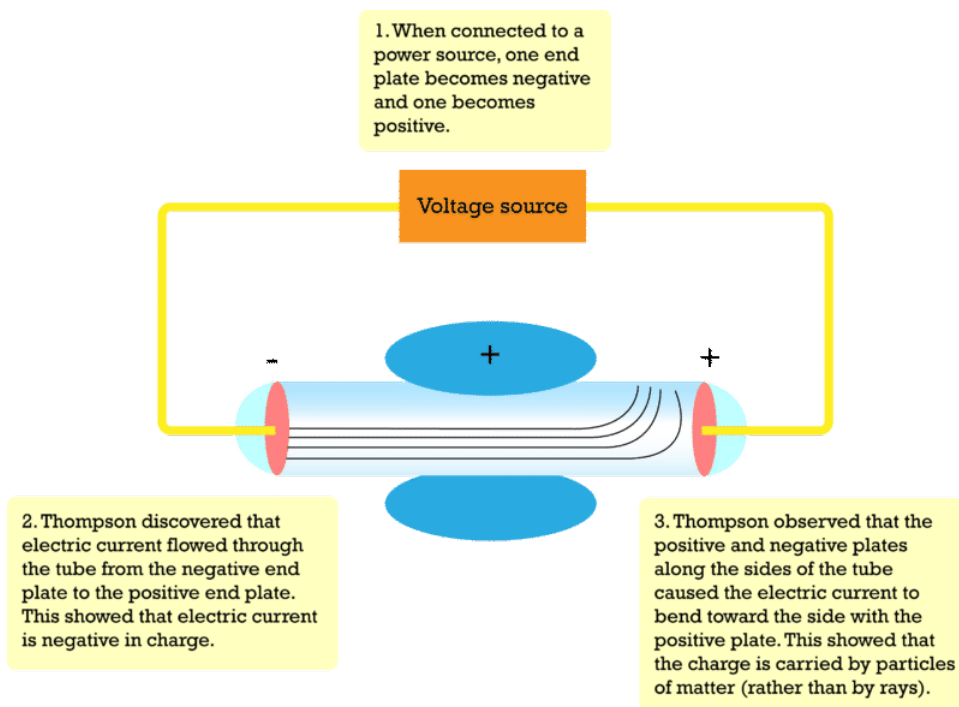
Dalton's model atoms were hard, solid balls. How do they differ from the atomic models you saw in the lesson "Inside the Atom" from earlier in the chapter?

Thomson Adds Electrons

The next major advance in the history of the atom was the discovery of electrons. These were the first subatomic particles to be identified. They were discovered in 1897 by a British physicist named J. J. Thomson. You can learn more about Thomson and his discovery at this online exhibit: <http://www.aip.org/history/electron/>.

Thomson's Vacuum Tube Experiments

Thomson was interested in electricity. He did experiments in which he passed an electric current through a vacuum tube. The experiments are described in **Figure below**.



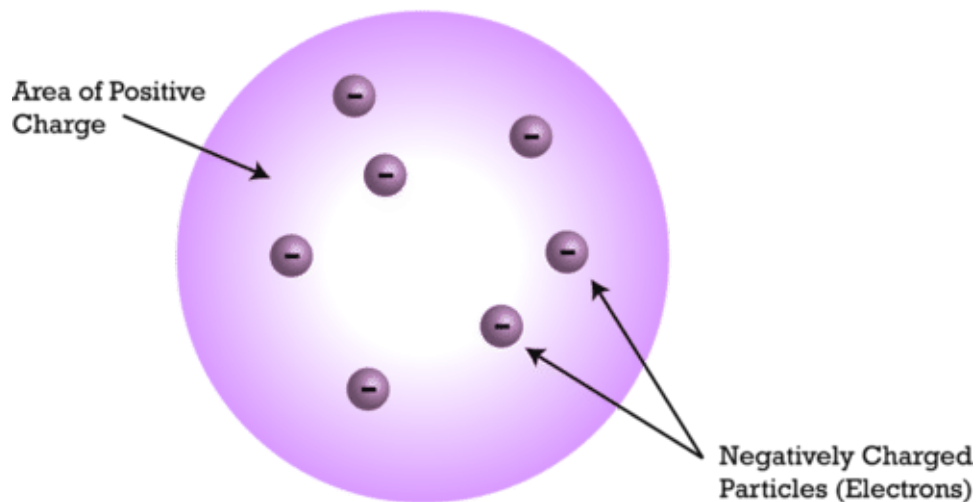
This sketch shows the basic set up of Thomson's experiments. The vacuum tube is a glass tube that contains very little air. It has metal plates at each end and along the sides.

Thomson's experiments showed that an electric current consists of flowing, negatively charged particles. Why was this discovery important? Many scientists of Thomson's time thought that electric current consists of rays, like rays of light, and that it is positive rather than negative. Thomson's experiments also showed that the negative particles are all alike and smaller than atoms. Thomson concluded that the negative particles couldn't be fundamental units of matter because they are all alike. Instead, they must be parts of atoms. The negative particles were later named electrons.

Thomson's Plum Pudding Model

Thomson knew that atoms are neutral in electric charge. So how could atoms contain negative particles? Thomson thought that the rest of the atom must be positive to cancel out the negative charge. He said that an atom is like a plum pudding, which has plums scattered through it. That's why Thomson's model of the atom is called the plum pudding model. You can see it in **Figure below**. It shows the atom as a sphere of positive charge (the pudding) with negative electrons (the plums) scattered through it.

The Plum Pudding Model of an Atom



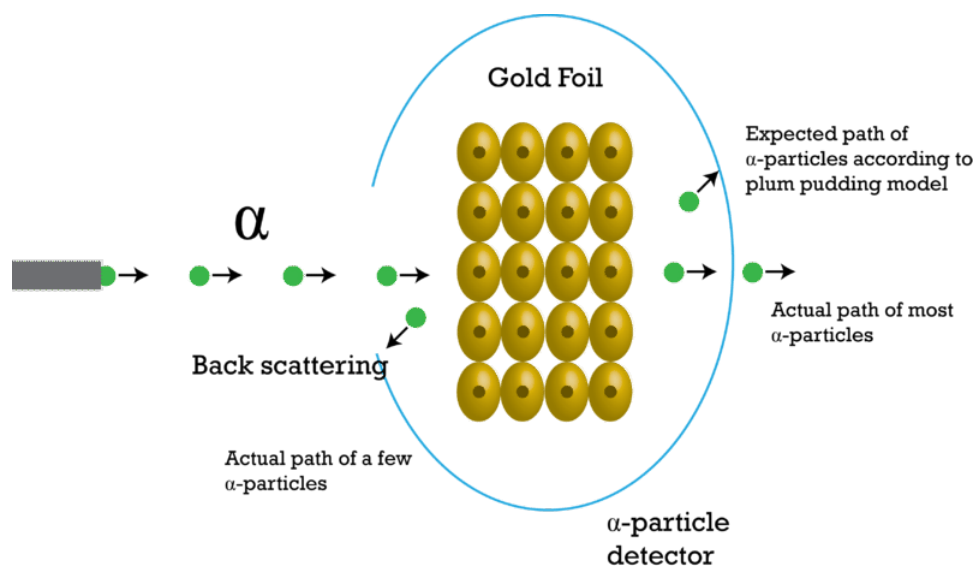
Thomson's atomic model includes negative electrons in a "sea" of positive charge.

Rutherford Finds the Nucleus

A physicist from New Zealand named Ernest Rutherford made the next major discovery about atoms. He discovered the nucleus. You can watch a video about Rutherford and his discovery at this URL: <http://www.youtube.com/watch?v=wzALbzT> (3:28).

Rutherford's Gold Foil Experiments

In 1899, Rutherford discovered that some elements give off positively charged particles. He named them alpha particles (α). In 1911, he used alpha particles to study atoms. He aimed a beam of alpha particles at a very thin sheet of gold foil. Outside the foil, he placed a screen of material that glowed when alpha particles struck it.



Rutherford shot a beam of positive alpha particles at thin gold foil.

If Thomson's plum pudding model were correct, the alpha particles should be deflected a little as they passed through the foil. Why? The positive "pudding" part of gold atoms would slightly repel the positive alpha particles. This would cause the alpha particles to change course. But Rutherford got a surprise. Most of the alpha particles

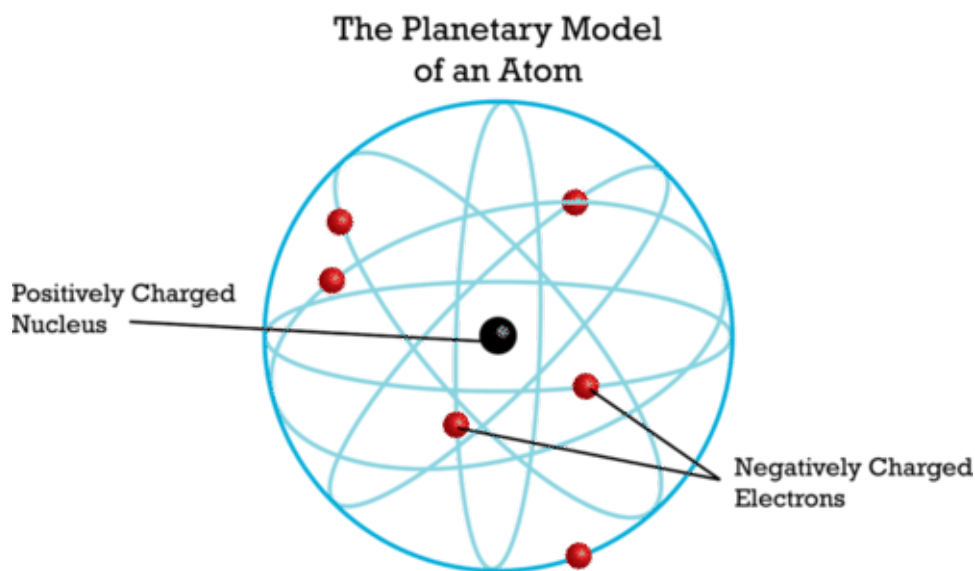
passed straight through the foil as though they were moving through empty space. Even more surprising, a few of the alpha particles bounced back from the foil as though they had struck a wall. This is called back scattering. It happened only in very small areas at the centers of the gold atoms.

The Nucleus and Its Particles

Based on his results, Rutherford concluded that all the positive charge of an atom is concentrated in a small central area. He called this area the nucleus. Rutherford later discovered that the nucleus contains positively charged particles. He named the positive particles protons. Rutherford also predicted the existence of neutrons in the nucleus. However, he failed to find them. One of his students, a physicist named James Chadwick, went on to discover neutrons in 1932. You learn how at this URL: <http://www.light-science.com/chadwick.html>.

Rutherford's Atomic Model

Rutherford's discoveries meant that Thomson's plum pudding model was incorrect. Positive charge is not spread out everywhere in an atom. It is all concentrated in the tiny nucleus. The rest of the atom is empty space, except for the electrons moving randomly through it. In Rutherford's model, electrons move around the nucleus in random orbits. He compared them to planets orbiting a star. That's why Rutherford's model is called the planetary model. You can see it in **Figure below**.



This model shows Rutherford's idea of the atom. How does it compare with Thomson's plum pudding model?

Lesson Summary

Around 450 B.C., the Greek philosopher Democritus introduced the idea of the atom. However, the idea was essentially forgotten for more than 2000 years.

In 1800, John Dalton re-introduced the atom. He provided evidence for atoms and developed atomic theory. His theory is essentially correct. However, he incorrectly thought that atoms are the smallest particles of matter.

In 1897, J.J. Thomson discovered electrons. He proposed the plum pudding model of the atom. In this model, negative electrons are scattered throughout a "sea" of positive charge.

In 1911, Ernest Rutherford discovered the nucleus. He later discovered protons as well. Rutherford thought that electrons randomly orbit the nucleus.

Lesson Review Questions

Recall

State Democritus's ideas about the atom.

What evidence did Dalton use to argue for the existence of atoms?

State Dalton's atomic theory.

Describe how Thomson discovered electrons.

Apply Concepts

Create sketches to compare and contrast Thomson's and Rutherford's models of the atom.

Think Critically

Based on Rutherford's work, use evidence and reasoning to argue for the existence of the nucleus.

Points to Consider

In this lesson, you read how models of the atom changed as scientists discovered the particles that make up atoms. In the next lesson, "Modern Atomic Theory," you will read how Rutherford's model was revised as scientists learned even more about electrons. For example, they discovered that electrons do not travel around the nucleus in random orbits as Rutherford thought.

Can you predict how electrons might move around the nucleus?

How might Rutherford's model be changed to show this?

Lesson Objectives

Define energy levels.

Describe the electron cloud and orbitals.

Vocabulary

electron cloud

energy level

orbital

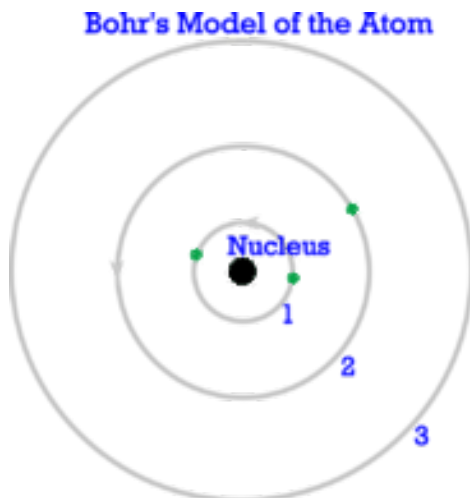
Introduction

Rutherford's model of the atom was better than earlier models. But it wasn't the last word. Danish physicist Niels Bohr created a more accurate and useful model. Bohr's model was an important step in the development of modern atomic theory. The video at the URL below is a good introduction to modern atomic theory. It also reviews important concepts from the previous two lessons, "Inside the Atom" and "History of the Atom."

<http://www.khanacademy.org/video/introduction-to-the-atom?playlist=Chemistry>

Bohr's Model of the Atom

Bohr's research focused on electrons. In 1913, he discovered evidence that the orbits of electrons are located at fixed distances from the nucleus. Remember, Rutherford thought that electrons orbit the nucleus at random. **Figure below** shows Bohr's model of the atom.



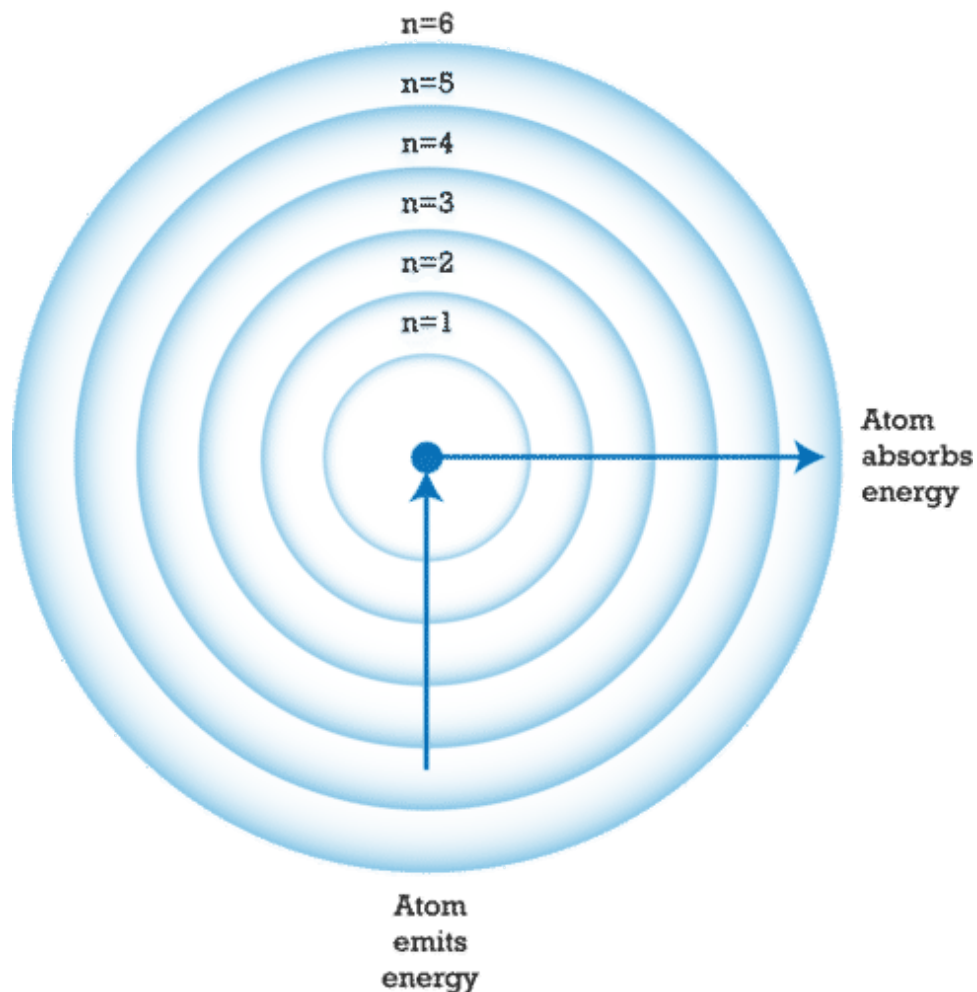
In Bohr's atomic model, electrons orbit at fixed distances from the nucleus. These distances are called energy levels.

Energy Levels

Basic to Bohr's model is the idea of energy levels. **Energy levels** are areas located at fixed distances from the nucleus of the atom. They are the only places where electrons can be found. Energy levels are a little like rungs on a ladder. You can stand on one rung or another but not between the rungs. The same goes for electrons. They can occupy one energy level or another but not the space between energy levels.

The model of an atom in **Figure below** has six energy levels. The level with the least energy is the one closest to the nucleus. As you go farther from the nucleus, the levels have more and more energy. Electrons can jump from one energy level to another. If an atom absorbs energy, some of its electrons can jump to a higher energy level. If electrons jump to a lower energy level, the atom emits, or gives off, energy. You can see an animation at this happening at the URL below.

<http://cas.sdss.org/dr6/en/proj/advanced/spectraltypes/energylevels.asp>



This model of an atom contains six energy levels ($n = 1$ to 6). Atoms absorb or emit energy when some of their electrons jump to a different energy level.

Energy Levels in Action

Bohr's idea of energy levels is still useful today. It helps explain how matter behaves. For example, when chemicals in fireworks explode, their atoms absorb energy. Some of their electrons jump to a higher energy level. When the electrons move back to their original energy level, they give off the energy as light. Different chemicals have different arrangements of electrons, so they give off light of different colors. This explains the blue- and purple-colored fireworks in **Figure below**.



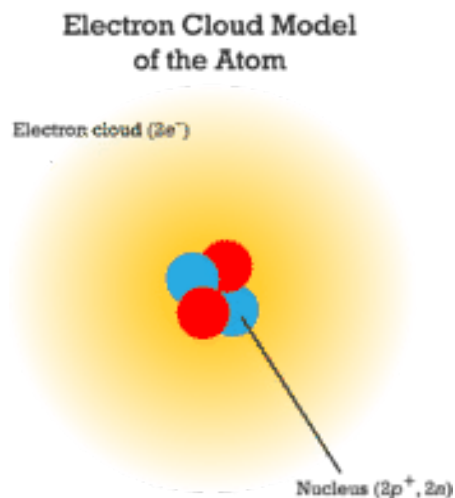
Atoms in fireworks give off light when their electrons jump back to a lower energy level.

Electron Cloud and Orbitals

In the 1920s, physicists discovered that electrons do not travel in fixed paths. In fact, they found that electrons only have a certain chance of being in any particular place. They could only describe where electrons are with mathematical formulas. That's because electrons have wave-like properties as well as properties of particles of matter. It is the "wave nature" of electrons that lets them exist only at certain distances from the nucleus. The negative electrons are attracted to the positive nucleus. However, because the electrons behave like waves, they bend around the nucleus instead of falling toward it. Electrons exist only where the wave is stable. These are the orbitals. They do not exist where the wave is not stable. These are the places between orbitals.

Electron Cloud Model

Today, these ideas about electrons are represented by the electron cloud model. The **electron cloud** is an area around the nucleus where electrons are likely to be. **Figure below** shows an electron cloud model for a helium atom.



This sketch represents the electron cloud model for helium. What does the electron cloud represent?

Orbitals

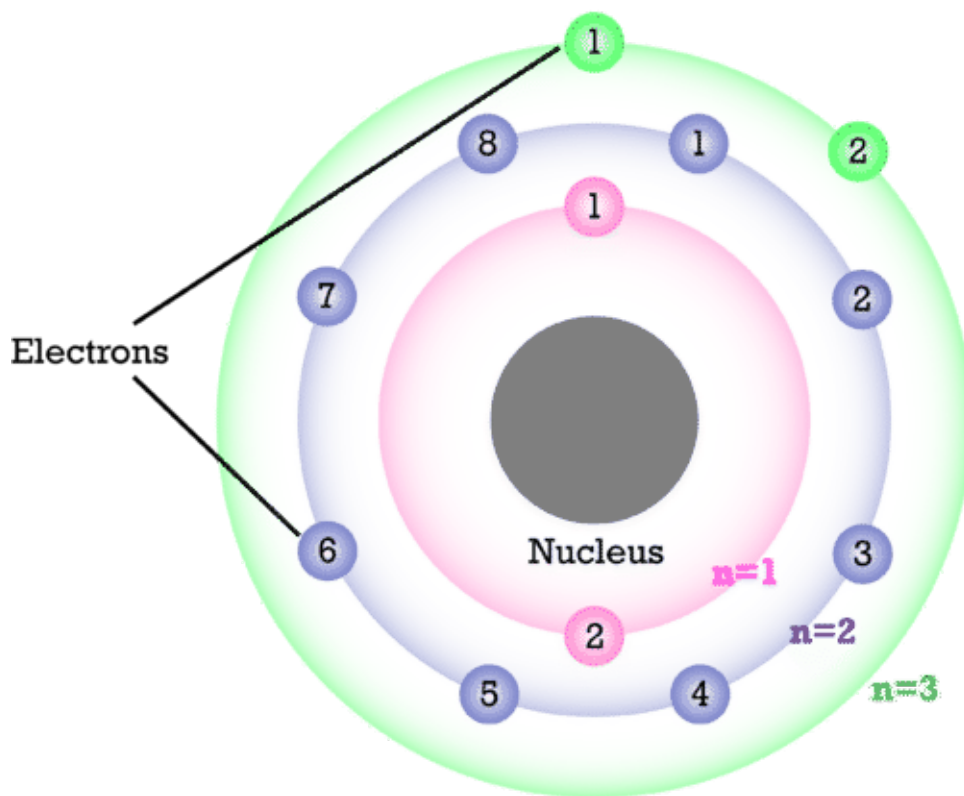
Some regions of the electron cloud are denser than others. The denser regions are areas where electrons are most likely to be. These regions are called **orbitals**. Each orbital has a maximum of just two electrons. Different energy levels in the cloud have different numbers of orbitals. Therefore, different energy levels have different maximum numbers of electrons. **Table below** lists the number of orbitals and electrons for the first four energy levels. Energy levels farther from the nucleus have more orbitals. Therefore, these levels can hold more electrons.

TABLE 2.1: short caption

First Four Energy Levels and Their Orbitals		
Energy Level	Number of Orbitals	Max. No. of Electrons (@ 2 per orbital)
1	1	2
2	4	8
3	9	18
4	16	32

Figure below shows the arrangement of electrons in an atom of magnesium as an example. The most stable arrangement of electrons occurs when electrons fill the orbitals at the lowest energy levels first before more are added at higher levels. You can learn more about orbitals and their electrons at the URL below: <http://www.khanacademy.org/video/orbitals>

Energy Levels and Electrons of Magnesium (Mg)



This model represents an atom of the element magnesium (Mg). How many electrons does the atom have at each energy level? What is the maximum number it could have at each level?

Lesson Summary

Bohr introduced the idea that electrons orbit the nucleus only at fixed distances, called energy levels. Electrons in energy levels farther from the nucleus have more energy.

Today, electrons are represented by an electron cloud model. Orbitals in the cloud show where electrons are most likely to be.

Lesson Review Questions

Recall

What are energy levels?

Which energy level has the smallest amount of energy?

Define orbitals.

How many electrons can be found in an orbital?

Apply Concepts

A change in energy caused an electron in an atom to jump from energy level 2 to energy level 3. Did the atom gain or lose energy? Explain.

Create a sketch to model the concept of the electron cloud.

Think Critically

Explain how orbitals are related to energy levels.

Points to Consider

In this chapter, you learned that atoms of each element have a unique number of protons. This is one way that each element differs from all other elements.

How could the number of protons be used to organize elements?

If one element has more protons than another element, how do their numbers of electrons compare?

CHAPTER

3

Chapter 3 - Periodic Table

Chapter Outline

3.1 CHAPTER 3 GUIDED QUESTIONS

3.2 PERIODIC TABLE

3.1 Chapter 3 Guided Questions

Chapter 3: Guided Questions

- What determines where an element is on the periodic table?
-
- Describe where the metals, nonmetals, and metalloids are located on the periodic table.
-
- Compare and contrast physical and chemical properties.
-
- Explain the difference between Groups and Periods.
-
- Describe Valence Electrons (location, role, charge).

3.2 Periodic Table

Objectives

Describe Mendeleev's periodic table of the elements.

Give an overview of the modern periodic table of the elements.

Vocabulary

group

period

periodic table

Introduction

Scientists first started looking for a way to organize the elements in the 1700s. They were trying to find a method to group together elements with similar properties. No one could come up with a good solution. It wasn't until the 1860s that a successful method was devised. It was developed by a Russian chemist named Dmitri Mendeleev. He is pictured in **Figure below**. You can learn more about him and his work at this URL: <http://videos.howstuffworks.com/science-channel/27862-100-greatest-discoveries-the-periodic-table-video.htm>.



Dmitri Mendeleev developed the first periodic table of the elements in 1869.

Mendeleev's Periodic Table of the Elements

Mendeleev was a teacher as well as a chemist. He was writing a chemistry textbook and needed a way to organize the elements so it would be easier for students to learn about them. He made a set of cards of the elements, similar to a deck of playing cards, with one element per card. On the card, he wrote the element's name, atomic mass, and known properties. He arranged and rearranged the cards in many different ways, looking for a pattern. He finally found it when he placed the elements in order by atomic mass.

A Repeating Pattern

You can see how Mendeleev organized the elements in **Figure below**. From left to right across each row, elements are arranged by increasing atomic mass. Mendeleev discovered that if he placed eight elements in each row and then continued on to the next row, the columns of the table would contain elements with similar properties. He called the

columns **groups**. They are sometimes called families, because elements within a group are similar but not identical to one another, like people in a family.

Reihen	Gruppe I. — R ¹ O	Gruppe II. — R ² O	Gruppe III. — R ³ O ³	Gruppe IV. RH ⁴ R ⁴ O ⁴	Gruppe V. RH ⁵ R ⁵ O ⁵	Gruppe VI. RH ⁶ R ⁶ O ⁶	Gruppe VII. RH R ⁷ O ⁷	Gruppe VIII. — R ⁸ O ⁸
1	II=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59, Ni=59, Cu=63.
5	(Cu=63)	Zn=65	—=68	—=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104, Pd=106, Ag=108.
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Co=140	—	—	—	—
9	(—)	—	—	—	—	—	—	—
10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=195, Ir=197, Pt=198, Au=199.
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	—
12	—	—	—	Th=231	—	U=240	—	—

Mendeleev's table of the elements organizes the elements by atomic mass. The table has a repeating pattern.

Mendeleev's table of the elements is called a **periodic table** because of its repeating pattern. Anything that keeps repeating is referred to as periodic. Other examples of things that are periodic include the monthly phases of the moon and the daily cycle of night and day. The term **period** refers to the interval between repetitions. In a periodic table, the periods are the rows of the table. In Mendeleev's table, each period contains eight elements, and then the pattern repeats in the next row.

Predicting Missing Elements

Did you notice the blanks in Mendeleev's table (**Figure above**)? They are spaces that Mendeleev left for elements that had not yet been discovered when he created his table. He predicted that these missing elements would eventually be discovered. Based on their position in the table, he could even predict their properties. For example, he predicted a missing element in row 5 of his group 3. He said it would have an atomic mass of about 68 and be a soft metal like other group 3 elements. Scientists searched for the missing element. They found it a few years later and named it gallium. Scientists searched for the other missing elements. Eventually, all of them were found.

An important measure of a good model is its ability to make accurate predictions. This makes it a useful model. Clearly, Mendeleev's periodic table was a useful model. It helped scientists discover new elements and make sense of those that were already known.

The Modern Periodic Table of the Elements

A periodic table is still used today to classify the elements. **Figure below** shows the modern periodic table. You can see an interactive version at this URL: <http://www.ptable.com/>.

The image shows a standard periodic table of elements. The elements are color-coded into three main categories: Metals (blue), Metalloids (orange), and Nonmetals (green). The table is organized into groups (columns) and periods (rows). The groups are labeled 1A through 8A, and the periods are labeled 1 through 7. The Lanthanides and Actinides are shown as separate rows below the main table. The elements are arranged in order of increasing atomic number from left to right and top to bottom.

The modern periodic table of the elements is a lot like Mendeleev's table. But the modern table is based on atomic number instead of atomic mass. It also has more than 110 elements. Mendeleev's table only had about 65 elements.

Basis of the Modern Periodic Table

In the modern periodic table, elements are organized by atomic number. The atomic number is the number of protons in an atom of an element. This number is unique for each element, so it seems like an obvious way to organize the elements. (Mendeleev used atomic mass instead of atomic number because protons had not yet been discovered when he made his table.) In the modern table, atomic number increases from left to right across each period. It also increases from top to bottom within each group. How is this like Mendeleev's table?

Reading the Table

Besides atomic number, the periodic table includes each element's chemical symbol and class. Some tables include other information as well.

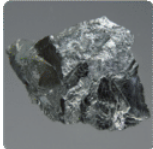
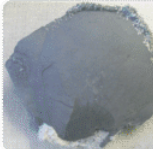

The chemical symbol consists of one or two letters that come from the chemical's name in English or another language. The first letter is always written in upper case. The second letter, if there is one, is always written in lower case. For example, the symbol for lead is Pb. It comes from the Latin word *plumbum*, which means "lead." Find lead in **Figure above**. What is its atomic number? You can access videos about lead and other elements in the modern periodic table at this URL: <http://www.periodicvideos.com/index.htm>.

The classes of elements are metals, metalloids, and nonmetals. They are color-coded in the table. Blue stands for metals, orange for metalloids, and green for nonmetals. You can read about each of these three classes of elements later in the chapter, in the lesson "Classes of Elements."

Periods

Rows of the modern table are called periods, as they are in Mendeleev's table. From left to right across a period, each element has one more proton than the element before it. In each period, elements change from metals on the left side of the table, to metalloids, and then to nonmetals on the right. **Figure below** shows this for period 4.

19 K 39.098 POTASSIUM	20 Ca 40.078 CALCIUM	21 Sc 44.956 SCANDIUM	22 Ti 47.887 TITANIUM	23 V 50.942 VANADIUM	24 Cr 51.996 CHROMIUM	25 Mn 54.938 MANGANESE	26 Fe 55.845 IRON	27 Co 58.933 COBALT	28 Ni 58.693 NICKEL	29 Cu 63.546 COPPER	30 Zn 65.38 ZINC	31 Ga 69.723 GALLIUM	32 Ge 72.630 GERMANIUM	33 As 74.922 ARSENIC	34 Se 78.96 SELENIUM	35 Br 79.904 BROMINE	36 Kr 83.801 KRYPTON
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	24 Cr 51.996 CHROMIUM		33 As 74.922 ARSENIC		36 Kr 83.801 KRYPTON
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Chromium (Cr) is a shiny, silver-colored metal. It is added to steel to make it harder.

Arsenic (As) is a poisonous metalloid. It is used in very small amounts in cell phones and other electronic products.

Krypton (Kr) is a gaseous nonmetal. It is used in fluorescent lights.

Like other periods, period 4 changes from metals on the left to metalloids and then nonmetals on the right.

Some periods in the modern periodic table are longer than others. For example, period 1 contains only two elements. Periods 6 and 7, in contrast, are so long that some of their elements are placed below the main part of the table. They are the elements starting with lanthanum (La) in period 6 and actinium (Ac) in period 7. Some elements in period 7 have not yet been named. They are represented by temporary symbols, such as Uub. Many of these elements have only recently been shown to exist. Elements 114 and 116 were added to the table in 2011. Four more elements (113, 115, 117, and 118) were approved for addition in December 2015 and will be named at some later date.

Groups

Columns of the modern table are called groups, as they are in Mendeleev's table. However, the modern table has many more groups — 18 to be exact. Elements in the same group have similar properties. For example, all elements in group 18 are colorless, odorless gases. You can read about the different groups of elements in this chapter's lesson on "Groups of Elements."

Lesson Summary

Mendeleev developed the first periodic table of the elements in 1869. He organized the elements by increasing atomic mass. He used his table to predict unknown elements. These were later discovered.

The modern periodic table is based on atomic number. Elements in each period go from metals on the left to metalloids and then nonmetals on the right. Within groups, elements have similar properties.

Lesson Review Questions

Recall

How did Mendeleev organize the elements?

How does the modern periodic table differ from Mendeleev's table?

What is a period in the periodic table?

What is a group in the periodic table?

Apply Concepts

An unknown element has an atomic number of 44. Identify the element's symbol and the symbols of two other elements that have similar properties.

Think Critically

Mendeleev's table and the modern periodic table organize the elements based on different information, yet most elements are in the same order in both tables. Explain why.

Points to Consider

Elements are classified as metals, metalloids, or nonmetals.

Do you know some examples of metals?

How do you think metals might differ from the other two classes of elements?

Lesson Objectives

Identify properties of metals.

List properties of nonmetals.

Describe metalloids.

Relate valence electrons to reactivity of elements by class.

Vocabulary

metal

metalloid

nonmetal

valence electron

Introduction

Elements in different groups are lumped together in one of three classes, depending on their properties. The classes are metals, nonmetals, and metalloids. Knowing the class of an element lets you predict many of its properties. The video at the URL below is a good introduction to the classes.

<http://www.youtube.com/watch?v=ZuQmionhkGU> (2:04)

Metals

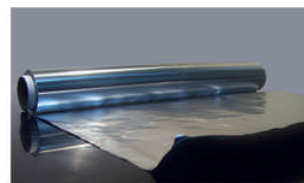
Metals are elements that are good conductors of electricity. They are the largest of the three classes of elements. In fact, most elements are metals. Look back at the modern periodic table (**Figure above**) in this chapter's lesson "How Elements Are Organized." Find the metals in the table. They are all the elements that are color-coded blue. Examples include sodium (Na), silver (Ag), and zinc (Zn).



Most metals are shiny. That's because they reflect a lot of light. This tray is made mainly of the metal silver (Ag).



Most metals are ductile. This means they can be pulled into long thin shapes, like these wires made of the metal copper (Cu).



Most metals are malleable. This means they can be formed into thin sheets without breaking, like this foil made of the metal aluminum (Al).

The three properties described here characterize most metals.

Metals have relatively high melting points, so almost all are solids at room temperature. The only exception is mercury (Hg), which is a liquid. Most metals are also good conductors of heat. That's why they are used for cooking pots and stovetops. Metals have other characteristic properties as well. Most are shiny, ductile, and malleable. These properties are illustrated in **Figure below**. You can dig deeper into the properties of metals at this URL: http://www.bbc.co.uk/schools/gcsebiteize/science/add_gateway/periodictable/metalsrev1.shtml.

Nonmetals

Nonmetals are elements that do not conduct electricity. They are the second largest class of elements. Find the nonmetals in **Figure above**. They are all the elements on the right side of the table that are color-coded green. Examples of nonmetals include helium (He), carbon (C), and oxygen (O).

Nonmetals generally have properties that are the opposite of those of metals. They also tend to vary more in their properties than metals do. For example, nonmetals have relatively low boiling points, so many of them are gases at room temperature. But several nonmetals are solids, including carbon and phosphorus (P). One nonmetal, bromine (Br), is a liquid at room temperature.

Generally, nonmetals are also poor conductors of heat. In fact, they may be used for insulation. For example, the down filling in a down jacket is mostly air, which consists mainly of nitrogen (N) and oxygen (O). These nonmetal gases are poor conductors of heat, so they keep body heat in and cold air out. Solid nonmetals are dull rather than shiny. They are also brittle rather than ductile or malleable. You can see examples of solid nonmetals in **Figure below**. You can learn more about specific nonmetals with the interactive table at this URL: <http://library.thinkquest.org/3659/pertable/nonmetal.html>.



These yellow piles of powder are sulfur (S), a nonmetal. Sulfur in rocks has been ground up to produce a powder. The powder has been heaped on a dock for shipment.



The "lead" in this pencil is actually graphite, a form of the nonmetal carbon (C). Graphite is brittle. It breaks easily if you put too much pressure on it.



These match heads are coated with the nonmetal phosphorus (P). Phosphorus is not malleable. If you tried to pound it flat, it would crumble into a powder.

Unlike metals, solid nonmetals are dull and brittle.

Metalloids

Metalloids are elements that fall between metals and nonmetals in the periodic table. Just seven elements are metalloids, so they are the smallest class of elements. In **Figure above**, they are color-coded orange. Examples of metalloids include boron (B), silicon (Si), and germanium (Ge).

Metalloids have some properties of metals and some properties of nonmetals. For example, many metalloids can conduct electricity but only at certain temperatures. These metalloids are called semiconductors. Silicon is an example. It is used in computer chips. It is also the most common metalloid on Earth. It is shiny like a metal but brittle like a nonmetal. You see a sample of silicon in **Figure below**. The figure also shows other examples of metalloids. You can learn more about the properties of metalloids at this URL: <http://library.thinkquest.org/3659/pertable/metalloid.html>.



Silicon (Si) is a metal that can conduct electricity but not as well as a metal. It is shiny but brittle. It chips easily, like glass.



Antimony (Sb) is a metalloid that is shiny like a metal but brittle like a nonmetal.



Boron (B) is a metalloid that is somewhat shiny. It also conducts electricity like a metal. However, it is brittle like a nonmetal.

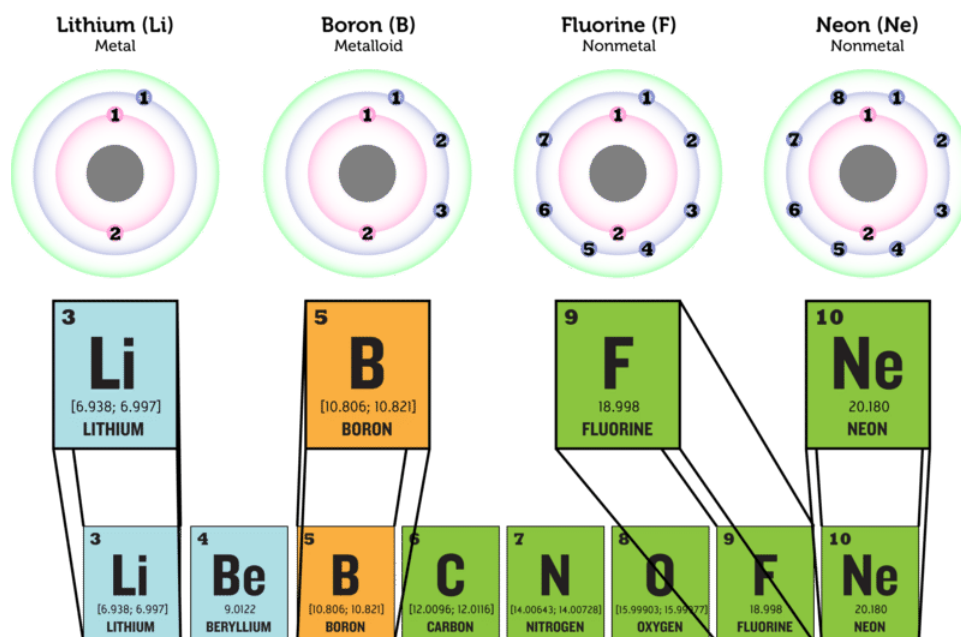
Metalloids share properties with both metals and nonmetals.

Classes of Elements and Electrons

From left to right across the periodic table, each element has one more proton than the element to its left. Because atoms are always electrically neutral, for each added proton, one electron is also added. Electrons are added first to the lowest energy level possible until that level is full. Only then are electrons added to the next higher energy level.

Electrons by Class

The increase in electrons across the periodic table explains why elements go from metals to metalloids and then to nonmetals from left to right across the table. Look at period 2 in **Figure below** as an example. Lithium (Li) is a metal, boron (B) a metalloid, and fluorine (F) and neon (Ne) are nonmetals. The inner energy level is full for all four elements. This level has just one orbital and can hold a maximum of two electrons. The outer energy level is a different story. This level has four orbitals and can hold a maximum of eight electrons. Lithium has just one electron in this level, boron has three, fluorine has seven, and neon has eight.



The number of electrons increases from left to right across each period in the periodic table. In period 2, lithium (Li) has the fewest electrons and neon (Ne) has the most. How do the numbers of electrons in their outer energy levels compare?

Valence Electrons and Reactivity

The electrons in the outer energy level of an atom are called **valence electrons**. It is valence electrons that are potentially involved in chemical reactions. The number of valence electrons determines an element's reactivity, or how likely the element is to react with other elements. The number of valence electrons also determines whether the element can conduct electric current. That's because electric current is the flow of electrons. **Table below** shows how these properties vary in elements from each class.

Metals such as lithium have an outer energy level that is almost empty. They "want" to give up their few valence electrons so they will have a full outer energy level. As a result, metals are very reactive and good conductors of electricity.

Metalloids such as boron have an outer energy level that is about half full. These elements need to gain or lose too many electrons for a full outer energy level to come about easily. As a result, these elements are not very reactive. They may be able to conduct electricity but not very well.

Some nonmetals, such as bromine, have an outer energy level that is almost full. They "want" to gain electrons so they will have a full outer energy level. As a result, these nonmetals are very reactive. Because they only accept electrons and do not give them up, they do not conduct electricity.

Other nonmetals, such as neon, have a completely full outer energy level. Their electrons are already in the most stable arrangement possible. They are unreactive and do not conduct electricity.

TABLE 3.1: short caption




These examples show the relative reactivity of elements in the three classes.	
Element	Description
Lithium 	Lithium (Li) is a highly reactive metal. It has just one electron in its outer energy level. Lithium reacts explosively with water (see picture). It can react with moisture on skin and cause serious burns.
Boron 	Boron (B) is a metalloid. It has three valence electrons and is less reactive than lithium. Boron compounds dissolved in water form boric acid. Dilute boric acid is weak enough to use as eye wash.
Bromine	Bromine (Br) is an extremely reactive nonmetal. In fact, reactions with fluorine are often explosive, as you can see in the URL below. http://www.youtube.com/watch?v=vtWp45Eewtw

TABLE 3.1: (continued)

These examples show the relative reactivity of elements in the three classes.	
<p>Neon</p> 	<p>Neon (Ne) is a nonmetal gas with a completely filled outer energy level. This makes it unreactive, so it doesn't combine with other elements. Neon is used for lighted signs like this one. You can learn why neon gives off light at this link: http://www.scientificamerican.com/article.cfm?id=how-do-neon-lights-work</p>

Lesson Summary

Metals are elements that are good conductors of electricity. They are the largest class of elements. Many metals are shiny, ductile, and malleable. They are also good conductors of heat. Almost all metals are solids at room temperature.

Nonmetals are elements that do not conduct electricity. They are the second largest class of elements. Nonmetals are also poor conductors of heat. The majority of nonmetals are gases. Solid nonmetals are dull and brittle.

Metalloids are elements that have properties of both metals and nonmetals. Some can conduct electricity but only at certain temperatures. They may be shiny but brittle. All metalloids are solids at room temperature.

Atoms of elements in different classes vary in their number of valence electrons. This explains their differences in reactivity and conductivity.

Lesson Review Questions

Recall

What are metals? Name one example.

Define nonmetal, and give an example.

State one way that metalloids may be like metals and one way they may be like nonmetals.

What are valence electrons?

Apply Concepts

A mystery element is a dull, gray solid. It is very reactive with other elements. Classify the mystery element as a metal, nonmetal, or metalloid. Explain your answer.

Think Critically

Create a Venn diagram for metals, metalloids, and nonmetals. The diagram should show which properties are different and which, if any, are shared among the three groups of elements.

Relate number of valence electrons to reactivity of classes of elements.

Points to Consider

The number of valence electrons increases from left to right across each period of the periodic table. By the end of the period, the outer energy level is full. Moving on to the next period of the table, electrons are added to the next higher energy level. This happens in each row of the periodic table.

How do you think the number of valence electrons compares in elements within the same column (group) of the periodic table?

How might this be reflected in the properties of elements within a group?

Image Attributions

Lesson Objectives

Identify hydrogen and alkali metals.

Describe alkaline Earth metals.

List properties of transition metals.

Identify groups containing metalloids.

Give properties of halogens.

Describe noble gases.

Vocabulary

alkali metal

alkaline Earth metal

halogen

noble gas

transition metal

Introduction

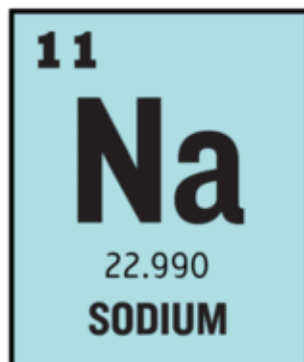
Elements in the same column, or group, of the periodic table have the same number of valence electrons in their outer energy level. This gives them many similar properties. The rest of this chapter describes properties of the different groups of elements. You can watch a video about the groups at this link: <http://www.khanacademy.org/video/groups-of-the-periodic-table?playlist=Chemistry>.

Group 1: Hydrogen and Alkali Metals

All the elements in group 1 have just one valence electron, so they are highly reactive. Group 1 is shown in **Figure below**. At the top of this group is hydrogen (H), which is a very reactive, gaseous nonmetal. It is the most common element in the universe.

All the other elements in group 1 are **alkali metals**. They are the most reactive of all metals, and along with the elements in group 17, the most reactive elements. Because alkali metals are so reactive, they are only found in nature combined with other elements. The alkali metals are soft. Most are soft enough to cut with a knife. They are also low in density. Some of them even float on water. All are solids at room temperature. You can see a video demonstrating the reactivity of alkali metals with water at this URL: <http://www.youtube.com/watch?v=uixxJtJPVXk> (2:22).

Sodium (Group 1)



1	H	1.00794, 1.00811	HYDROGEN
3	Li	6.938, 6.997	LITHIUM
11	Na	22.990	SODIUM
19	K	39.098	POTASSIUM
37	Rb	85.468	RUBIDIUM
55	Cs	132.905	CAESIUM
87	Fr	223.021	FRANCIUM

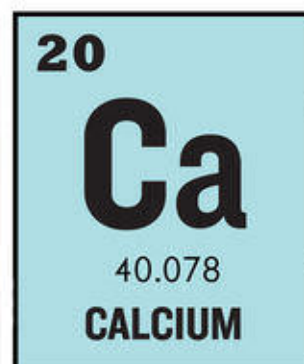
Sodium (Na) is an alkali metal. It is so reactive that it doesn't occur alone in nature. It is commonly found combined with chlorine (Cl) as sodium chloride (NaCl), which is table salt.

In group 1 of the periodic table, all the elements except hydrogen (H) are alkali metals.

Group 2: Alkaline Earth Metals

The **alkaline Earth metals** include all the elements in group 2 (see [Figure below](#)). These metals have just two valence electrons, so they are very reactive, although not quite as reactive as the alkali metals. In nature, they are always found combined with other elements. Alkaline Earth metals are silvery grey in color. They are harder and denser than the alkali metals. All are solids at room temperature.

Calcium (Group 2)



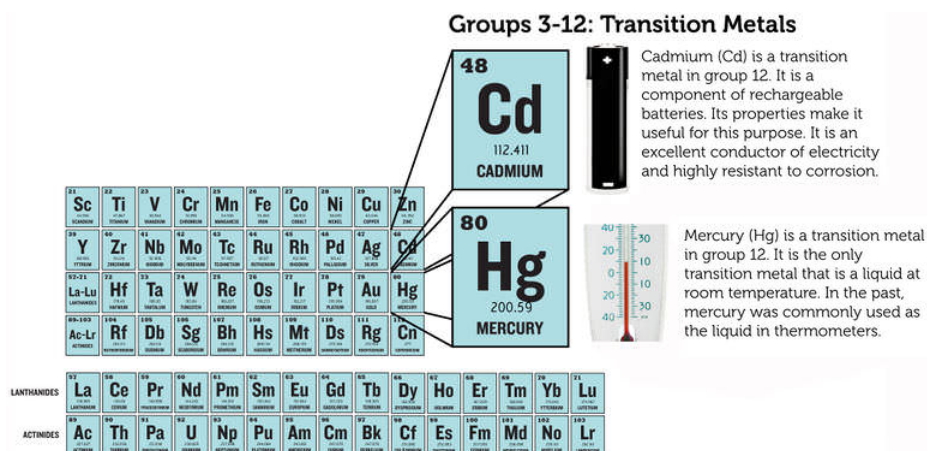
4	Be	9.012	BERYLLIUM
12	Mg	24.305	MAGNESIUM
20	Ca	40.078	CALCIUM
38	Sr	87.62	STRONTIUM
56	Ba	137.327	BARIUM
88	Ra	226.0254	RADIUM

Calcium (Ca) is an alkaline Earth metal. It is found in nature only in compounds with other elements. For example, it combines with carbon (C) and oxygen (O) to form calcium carbonate (CaCO₃). Chalk is made of calcium carbonate.

The alkaline Earth metals make up group 2 of the periodic table.

Groups 3-12: Transition Metals

Groups 3-12 of the periodic table contain **transition metals** (see **Figure below**). Transition metals have more valence electrons and are less reactive than metals in the first two metal groups. The transition metals are shiny. Many are silver colored. They tend to be very hard, with high melting and boiling points. All except mercury (Hg) are solids at room temperature.



All the elements in groups 3-12 are transition metals.

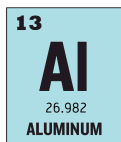
Transition metals include the elements that are placed below the periodic table. Those that follow lanthanum (La) are called lanthanides. They are all shiny, relatively reactive metals. Those that follow Actinium (Ac) are called actinides. They are all radioactive metals. This means they are unstable. They break down into different, more stable elements. You can read more about radioactive elements in the chapter *Nuclear Chemistry*. Many of the actinides do not occur in nature but are made in laboratories.

Groups 13-16: Groups Containing Metalloids

Groups 13-16 each contain one or more metalloids. These groups are shown in **Figure below**.

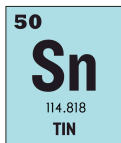
Groups 13-16: Metalloids

Aluminum (Group 13)



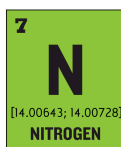
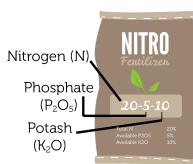
Aluminum (Al) is a shiny, low-density metal in group 13. It is durable, ductile, and malleable. Aluminum's properties make it a good choice for objects such as beverage cans, lawn furniture, and siding on homes.

Tin (Group 14)



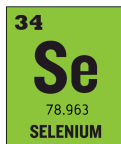
Tin (Sn) is a shiny, silver-colored metal in Group 14. The tin man in "The Wizard of Oz" was afraid of "rusting," but tin doesn't really rust (only iron rusts). In fact, tin is not very reactive with oxygen at all. That's one reason why it is used in food cans and for roofs.

Nitrogen (Group 15)



Nitrogen (N) is a gaseous nonmetal in group 15. It makes up 78% of Earth's atmosphere. Plants need nitrogen but are unable to use gaseous nitrogen in the air. Fertilizers supply nitrogen in a form plants can use.

Selenium (Group 16)



Selenium (Se) is a solid nonmetal in group 16. People need small amounts of selenium for good health. Nuts and fish are good food sources of selenium.

5 B [10.806; 10.821] BORON	6 C [12.0096; 12.0116] CARBON	7 N [14.00643; 14.00728] NITROGEN	8 O [15.99903; 15.99977] OXYGEN
13 Al 26.982 ALUMINUM	14 Si [28.086; 28.0866] SILICON	15 P 30.974 PHOSPHORUS	16 S [32.059; 32.076] SULFUR
31 Ga 69.723 GALLIUM	32 Ge 69.723 GERMANIUM	33 As 74.922 ARSENIC	34 Se 78.963 SELENIUM
49 In 114.818 INDIUM	50 Sn 114.818 TIN	51 Sb 121.760 ANTIMONY	52 Te 127.603 TELLURIUM
81 Tl [204.382; 204.385] THALLIUM	82 Pb 204.383 LEAD	83 Bi 208.980 BISMUTH	84 Po 208.982 POLONIUM

These groups each contain one or more metalloids.

Group 13 is called the boron group. The only metalloid in this group is boron (B). The other four elements are metals. All group 13 elements have three valence electrons and are fairly reactive. All are solids at room temperature.

Group 14 is called the carbon group. Carbon (C) is a nonmetal. The next two elements are metalloids, and the final two are metals. All the elements in the carbon group have four valence electrons. They are not very reactive. All are solids at room temperature.

Group 15 is called the nitrogen group. The first two elements in this group are nonmetals. These are followed by two metalloids and one metal. All the elements in the nitrogen group have five valence electrons, but they vary in their reactivity. Nitrogen (N) is not reactive at all. Phosphorus (P), in contrast, is quite reactive. In fact, it is found naturally only in combination with other substances. Nitrogen is a gas at room temperature. The other group 15 elements are solids.

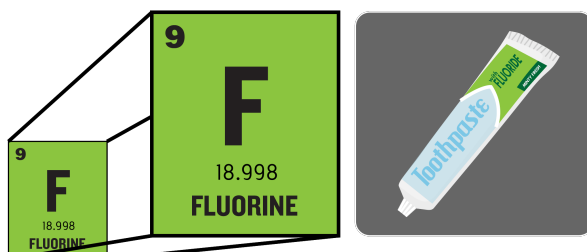
Group 16 is called the oxygen group. The first three elements in this group are nonmetals. They are followed by one metalloid and one metal. All the elements in the oxygen group have six valence electrons, and all are reactive. Oxygen (O), for example, readily reacts with metals to form compounds such as rust. Oxygen is a gas at room temperature. The other four elements in group 16 are solids.

Group 17: Halogens

Elements in group 17 are called **halogens** (see **Figure below**). They are highly reactive nonmetals with seven valence electrons. The halogens react violently with alkali metals, which have one valence electron. The two elements combine to form a salt. For example, the halogen chlorine (Cl) and the alkali metal sodium (Na) react to form table salt, or sodium chloride (NaCl). The halogen group includes gases, liquids, and solids. For example, chlorine is a gas at room temperature, bromine (Br) is a liquid, and iodine (I) is a solid. You can watch a video demonstrating the reactivity of halogens at this URL: http://www.youtube.com/watch?v=mY7o28-l_WU&feature=related.

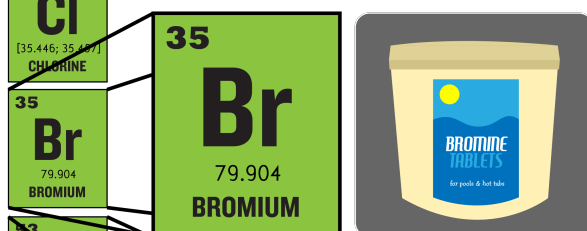
Group 17: Halogens

Fluorine (Group 17)



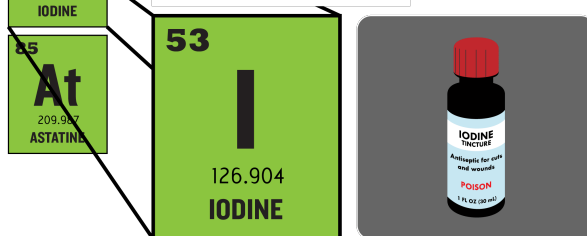
Fluorine (F) is a gaseous halogen. Evidence shows that fluorine helps prevent tooth decay. That's why it is added to toothpaste in the form of sodium fluoride. You can learn how it protects teeth at: http://www.animated-teeth.com/tooth_decay/t4_tooth_decay_fluoride.htm

Bromine (Group 17)



Bromine (Br) is the only liquid halogen. In tablet form, bromine is used to purify water in swimming pools and hot tubs. It reacts with bacteria and other germs and renders them harmless.

Iodine (Group 17)



Iodine (I) is a solid halogen. It is added to alcohol and used as an antiseptic. It reacts with germs on cuts and wounds. Small amounts of iodine are also needed for good health. In the U.S., iodine is added to table salt to prevent iodine deficiencies. Does the salt you use contain iodine?

Group 17 consists of the nonmetals called halogens.

Group 18: Noble Gases


Group 18 elements are nonmetals called **noble gases** (see [Figure below](#)). They are all colorless, odorless gases. Their outer energy level is also full, so they are the least reactive elements. In nature, they seldom combine with other substances. For a short video about the noble gases and their properties, go to this URL: <http://www.youtube.com/watch?v=QLr...> (1:17).

Group 18: Noble Gases

Helium (Group 18)

2 He 4.0026 HELIUM
10 Ne 20.183 NEON
18 Ar 39.948 ARGON
36 Kr 83.8 KRYPTON
54 Xe 131.29 XENON
86 Rn 222.018 RADON

2 He 4.0026 HELIUM

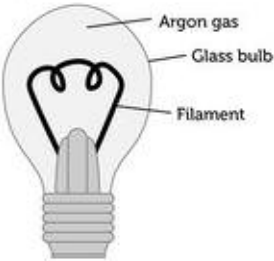


Helium (He) is a very light noble gas. That's why helium balloons rise up high in the air.

Argon (Group 18)

2 He 4.0026 HELIUM
10 Ne 20.183 NEON
18 Ar 39.948 ARGON
36 Kr 83.8 KRYPTON
54 Xe 131.29 XENON
86 Rn 222.018 RADON

18 Ar 39.948 ARGON



The noble gas argon (Ar) is used to fill light bulbs. It doesn't react with the metal filaments in the bulbs, so the bulbs last longer.

Noble gases include helium and argon.

Lesson Summary

Group 1 of the periodic table consists of hydrogen and the alkali metals. Hydrogen is a very reactive nonmetal. The alkali metals are the most reactive metals.

Group 2 consists of the alkaline Earth metals. They are very reactive but less so than the alkali metals.

Groups 3-12 contain transition metals. They are less reactive than metals in groups 1 and 2.

Groups 13-16 each contain at least one metalloid. They also contain metals and/or nonmetals. Elements in these groups vary in reactivity and other properties.

Group 17 contains halogens. They are highly reactive nonmetals.

Group 18 consists of noble gases. They are unreactive and rarely combine with other elements.

Lesson Review Questions

Recall

What are alkali metals? What is one example?

Identify an alkaline Earth metal. How reactive is it?

Which element is the only transition metal that is a liquid at room temperature?

In which groups of the periodic table would you find metalloids?

State why halogens are highly reactive.

Describe noble gases.

Apply Concepts

Assume you have a sample of an unknown element. At room temperature, it is a soft solid. You cut a small piece from the sample with a knife and drop the piece into a container of water. It bursts into flames. Which group of the

periodic table does the unknown element belong in?

Think Critically

Both hydrogen (H) and helium (He) are gaseous nonmetals. Why are they placed on opposite sides of the periodic table?

Points to Consider

Reactive elements combine easily with other elements. This explains why they usually exist in nature in compounds rather than in pure form.

How do you think elements join together to form compounds?

Do you think this might vary from one group of elements to another?

For **Table above**,

Lithium: User:Chemicalinterest/Wikimedia Commons. http://commons.wikimedia.org/wiki/File:Lithium_burning.JPG. Public Domain.

Boron: Christopher Auyeung. CC BY-NC 3.0. CK-12 Foundation.

Neon: Andy Wright. <http://www.flickr.com/photos/rightee/4356950/>. CC BY 2.0.

CHAPTER

4

Chapter 4 - Chemical Formulas, Equations and Reactions

Chapter Outline

- 4.1 [CHAPTER 4 GUIDED QUESTIONS](#)
 - 4.2 [ENDOTHERMIC OR EXOTHERMIC LAB](#)
 - 4.3 [CHEMICAL PHYSICAL FOLDABLE.DOCX](#)
 - 4.4 [CHEMICAL EQUATIONS](#)
 - 4.5 [BALANCED OR NOT PRACTICE](#)
 - 4.6 [SLIME LAB.DOCX](#)
 - 4.7 [CAESIN LAB - CHEMICAL REACTION.DOCX](#)
-

4.1 Chapter 4 Guided Questions

Chapter 4: Guided Questions

TABLE 4.1:

How are chemical formulas used to determine the number of atoms of each element found in compounds?

What is the purpose of a subscript in a chemical formula?

Analyze and describe the purpose of coefficients in a chemical formula?

4.2 Endothermic or Exothermic Lab

Name:Period:Page:

Endothermic or Exothermic?

Purpose: To study the production of heat energy during a chemical reaction.

Materials:

TABLE 4.2:

steel wool	3% hydrogen peroxide	Coffee filter	Pencil
sodium chloride	small ziplock bags	beaker	Lab paper

Procedure and Questions:

1. Teacher will pass out a beaker of 3% hydrogen peroxide to each group. **Observe and record the properties of the 3% hydrogen peroxide.**
2. Teacher will pass out small ziplock bag with a few strand of steel wool. **Observe and record the properties of the steel wool.**
3. Teacher will pass out a small cup with sodium chloride. **Observe and record the properties of the sodium chloride.**
4. Students will combine the 3% hydrogen peroxide and steel wool in the small Ziplock bag, and close bag. **Observe and record the properties.**
5. Students will now add the sodium chloride to the small Ziploc bag, and close bag.
6. Knead the “sandwich” through the bag, gently so the ingredients are not lost but come into contact well. Students will need to do this for about two minutes.
7. **Observe and record the properties.**
8. Did the temperature change? How could you tell?
9. If the temperature changed, how (did it go up or down)?
10. Was the reaction endothermic or exothermic?
11. Dispose of bag and contents in the garbage can. Be sure the bag is still closed.

4.3 Chemical Physical Foldable.docx

TABLE 4.3:

Milk turning sour	A glass breaking	Eggs Cooking
Chopping Onions	Sulfur Powder and Iron Filling are mixed together	Hydrogen Peroxide Bubbles in a cut
Dry Ice is Sublimed at room Temperature	Dissolving sugar in water	Newspaper burning
A nail rusting	Whipping egg whites	Hammering wood together to build a playhouse
Melting butter for popcorn	Rubbing alcohol evaporates on your hand	Bleaching hair from brown to blond
Mowing the lawn	Fireworks exploding	Aluminum foil is cut in half
Squeezing oranges to make orange juice	Magnetizing a compass needle	Ice cream melting
Water boils	Vinegar reacts when mixed with baking soda	Food scraps are turned into compost in a compost pile
Food begins to spoil	Bread becomes toast	Sun tanning
You take an antacid to settle your stomach	Bread rising	Zinc is immersed in acid and produces a gas

TABLE 4.4:

Milk turning sour	A glass breaking	Eggs Cooking
Chopping Onions	Sulfur Powder and Iron Filling are mixed together	Hydrogen Peroxide Bubbles in a cut
Dry Ice is Sublimed at room Temperature	Dissolving sugar in water	Newspaper burning
A nail rusting	Whipping egg whites	Hammering wood together to build a playhouse
Melting butter for popcorn	Rubbing alcohol evaporates on your hand	Bleaching hair from brown to blond
Mowing the lawn	Fireworks exploding	Aluminum foil is cut in half
Squeezing oranges to make orange juice	Magnetizing a compass needle	Ice cream melting
Water boils	Vinegar reacts when mixed with baking soda	Food scraps are turned into compost in a compost pile
Food begins to spoil	Bread becomes toast	Sun tanning
You take an antacid to settle your stomach	Bread rising	Zinc is immersed in acid and produces a gas

4.4 Chemical equations

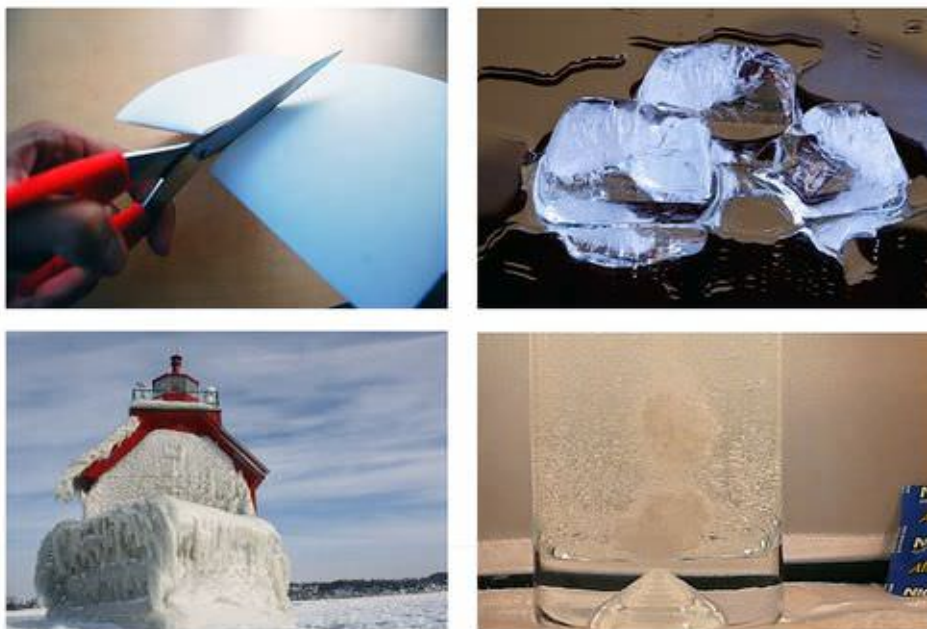


These stunning rock arches in Utah were carved by wind-blown sand. Repeated scouring by the sand wore away the rock, bit by tiny bit, like sandpaper on wood. The bits of rock worn away by the sand still contain the same **minerals** as they did when they were part of the large rock. They have not changed chemically in any way. Only the size and shape of the rock have changed, from a single large rock to millions of tiny bits of rock. Changes in size and shape are physical changes in matter.

What Is a Physical Change?

A **physical change** is a change in one or more **physical properties of matter** without any change in chemical properties. In other words, matter doesn't change into a different substance in a physical change. Examples of physical change include changes in the size or shape of matter. **Changes of state**—for example, from solid to liquid or from liquid to gas—are also physical changes. Some of the processes that cause physical changes include cutting, bending, dissolving, **freezing**, **boiling**, and **melting**. Four examples of physical change are pictured in the **Figure below**. You can learn more about physical changes and why they occur by watching the video at this URL:

<http://www.youtube.com/watch?v=RQTcSNVrNUk> (13:35)



Q: In the **Figure above**, what physical changes are occurring?

A: The paper is being cut into smaller pieces, which is changing its size and shape. The ice cubes are turning into a puddle of liquid **water** because they are **melting**. This is a **change of state**. The tablet is disappearing in the glass of water because it is dissolving into particles that are too small to see. The lighthouse is becoming coated with ice as ocean spray freezes on its surface. This is another change of state.

Reversing Physical Changes

When matter undergoes physical change, it doesn't become a different substance. Therefore, physical changes are often easy to reverse. For example, when liquid **water** freezes to form ice, it can be changed back to liquid water by heating and **melting** the ice.

Q: Salt dissolving in **water** is a physical change. How could this change be reversed?

A: The salt water could be boiled until the water evaporates, leaving behind the salt. Water vapor from the **boiling** water could be captured and cooled. The water vapor would condense and change back to liquid water.

Summary

A physical change in matter is a change in one or more of matter's physical properties. In a physical change, matter may change its size, shape, or state, but its chemical properties do not change.

Because the **chemical properties of matter** remain the same in a physical change, a physical change is often easy to reverse.

Explore More

Watch the video about physical changes at the following URL. Then answer the questions below.

<http://www.youtube.com/watch?v=WIOlnXbRpuk> (3:03)

Describe an example of **temperature** causing a change in the size of matter.

How is **temperature** related to changes in the state of matter?

Review

Define physical change.

What are some examples of physical change?

The wood in the **Figure below** is being cut with a chainsaw. Is this a physical change? Why or why not?

http://www.ck12.org/physical-science/Physical-Change-in-Physical-Science/asmtpractice/Physical-Change-in-Physical-Science-Practice/?referrer=recommended_modalities



Communities often use fireworks to celebrate important occasions. Fireworks certainly create awesome sights and sounds! Do you know what causes the brilliant lights and loud booms of a fireworks display? The answer is chemical changes.

What Is a Chemical Change?

A **chemical change** occurs whenever matter changes into an entirely different substance with different chemical properties. A chemical change is also called a chemical reaction. Many complex chemical changes occur to produce the explosions of fireworks. An example of a simpler chemical change is the burning of methane. Methane is the main component of natural gas, which is burned in many home furnaces. During burning, methane combines with oxygen in the air to produce entirely different chemical **substances**, including the **gases** carbon dioxide and **water** vapor. You can watch some very colorful chemical changes occurring in the video at this URL:

<http://www.youtube.com/watch?v=BqeWpywDuiY> (2:54)

Identifying Chemical Changes

Most chemical changes are not as dramatic as exploding fireworks, so how can you tell whether a chemical change has occurred? There are usually clues. You just need to know what to look for. A chemical change has probably occurred if bubbles are released, there is a change of **color**, or an odor is produced. Other clues include the release of **heat**, light, or loud sounds. Examples of chemical changes that produce these clues are shown in the **Figure below**.

Release of Bubbles

Bubbles are released when a chemical change produces a gas. The bubbles in this test tube were released when vinegar was added to baking soda. When the two substances combine, they change to water and the gas carbon dioxide.

Change of Color

These rusty pipes were once silver-colored. What happened to them? Iron in the pipes combined with oxygen in the air to produce a new substance—iron oxide—which is reddish brown. Iron oxide is commonly called rust.

Production of an Odor

You can tell that the food in this can has a stinky odor! When food spoils, it undergoes chemical changes that release unpleasant odors.

Release of Heat and Light

Burning is a chemical change that releases both heat and light. When a substance such as candle wax burns, it combines with oxygen and changes to other substances, including carbon dioxide and water vapor.

Production of Loud Sounds

Gunshots are very loud sounds. They occur because explosive chemical changes take place inside the gun when the shooter pulls the trigger. The changes also propel a bullet out of the end of the gun.

Q: In addition to iron rusting, what is another example of matter changing **color**? Do you think this color change is a sign that a new chemical substance has been produced?

A: Another example of matter changing **color** is a penny changing from reddish brown to greenish brown as it becomes tarnished. The color change indicates that a new chemical substance has been produced. Copper on the surface of the penny has combined with oxygen in the air to produce a different substance called copper oxide.

Q: Besides food spoiling, what is another change that produces an odor? Is this a chemical change?

A: When wood burns, it produces a smoky odor. Burning is a chemical change.

Q: Which signs of chemical change do fireworks produce?

A: Fireworks produce **heat**, light, and loud sounds. These are all signs of chemical change. You can learn how fireworks produce these signs of chemical change at this URL: <http://www.scifun.org/chemweek/fireworks/fireworks.htm>.

Can Chemical Changes Be Reversed?

Because chemical changes produce new **substances**, they often cannot be undone. For example, you can't change ashes from burning logs back into wood. Some chemical changes can be reversed, but only by other chemical changes. For example, to undo tarnish on copper pennies, you can place them in vinegar. The acid in the vinegar combines with the copper oxide of the tarnish. This changes the copper oxide back to copper and oxygen, making the pennies reddish brown again. You can try this at home to see how well it works.

Summary

A chemical change occurs whenever matter changes into an entirely different substance with different chemical properties. Burning is an example of a chemical change.

Signs of chemical change include the release of bubbles, a change of color, production of an odor, release of **heat** and light, and production of loud sounds.

Because chemical changes result in different **substances**, they often cannot be undone. Some chemical changes can be reversed, but only by other chemical changes.

Explore More

Chemical changes always result in new substances forming. Physical changes do not. Do the interactive lab at the following URL to see if you can identify the chemical changes.

<http://vital.cs.ohiou.edu/steamwebsite/downloads/ChangeLab.swf>

Review

What happens in any chemical change?

List three signs that a chemical change has occurred.

Give an example of a chemical change. Explain why you think it is a chemical change.

Why can chemical changes often not be reversed?

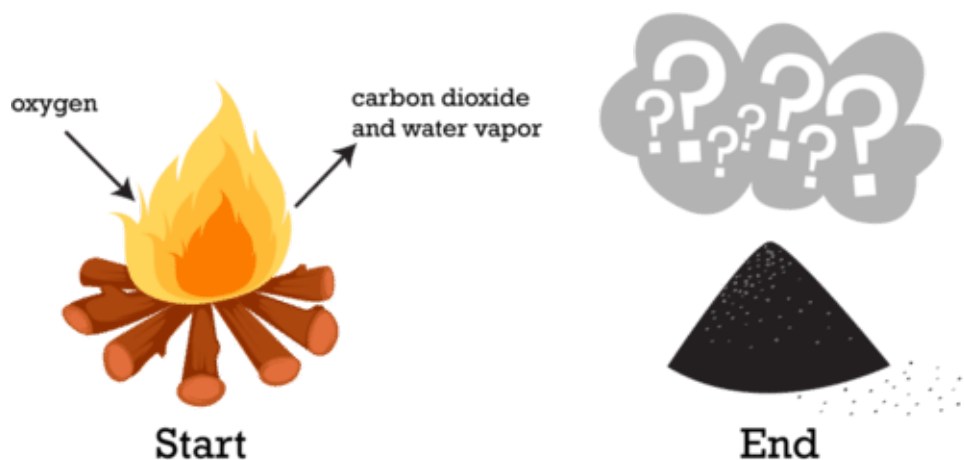
http://www.ck12.org/physical-science/Chemical-Change-in-Physical-Science/asmtpractice/Chemical-Change-in-Physical-Science-Practice/?referrer=practice_badge



If you build a campfire like this one, you start with a big pile of logs. As the fire burns, the pile of logs slowly shrinks. By the end of the evening, all that's left is a small pile of ashes. What happened to the matter that you started with? Was it destroyed by the fire?

Where's the Matter?

It may seem as though burning destroys matter, but the same amount, or mass, of matter still exists after a campfire as before. Look at the sketch in **Figure below**. It shows that when wood burns, it combines with oxygen and changes not only to ashes but also to carbon dioxide and **water** vapor. The **gases** float off into the air, leaving behind just the ashes. Suppose you had measured the mass of the wood before it burned and the mass of the ashes after it burned. Also suppose you had been able to measure the oxygen used by the fire and the gases produced by the fire. What would you find? The total mass of matter after the fire would be the same as the total mass of matter before the fire.



Burning is a chemical process.

Q: What can you infer from this example?

A: You can infer that burning does not destroy matter. It just changes matter into different **substances**.

Law of Conservation of Mass

This burning campfire example illustrates a very important law in science: the **law of conservation of mass**. This law states that matter cannot be created or destroyed. Even when matter goes through a physical or **chemical change**, the total mass of matter always remains the same.

Q: How could you show that the mass of matter remains the same when matter changes state?

A: You could find the mass of a quantity of liquid **water**. Then you could freeze the water and find the mass of the ice. The mass before and after **freezing** would be the same, showing that mass is conserved when matter changes state.

Summary

Burning and other changes in matter do not destroy matter. The mass of matter is always the same before and after the changes occur.

The law of conservation of mass states that matter cannot be created or destroyed.

Explore More

At the following URL, apply the law of conservation of mass to a scene from a Harry Potter film. Then answer the questions below.

<http://www.youtube.com/watch?v=3TsTOnNmkf8> (2:05)

What is the mass of the professor in kilograms? What is the mass of the cat in kilograms? (*Hint:* 1 pound = 0.45 kilograms)

The scene must be magic because it defies the law of conservation of mass. Explain why.

Review

What is the law of conservation of mass?

Describe an example of the law of conservation of mass.



Did you ever wonder what happens to a candle when it burns? A candle burning is a **chemical change** in matter. In a chemical change, one type of matter changes into a different type of matter, with different chemical properties.

Chemical changes occur because of **chemical reactions**. You can see more examples of chemical changes at this URL: <http://www.youtube.com/watch?v=66kuhJkQCVM>.

From Reactants to Products

All **chemical reactions**—including a candle burning—involve reactants and products.

Reactants are **substances** that start a chemical reaction.

Products are **substances** that are produced in the reaction.

When a candle burns, the reactants are fuel (the candlewick and wax) and oxygen (in the air). The products are carbon dioxide gas and **water** vapor.

Relating Reactants and Products

The relationship between reactants and products in a chemical reaction can be represented by a chemical equation that has this general form:

Reactants \rightarrow Products

The arrow (\rightarrow) shows the direction in which the reaction occurs. In many reactions, the reaction also occurs in the opposite direction. This is represented with another arrow pointing in the opposite direction (\leftarrow).

Q: Write a general chemical equation for the reaction that occurs when a fuel such as candle wax burns.

A: The burning of fuel is a combustion reaction. The general equation for this type of reaction is:



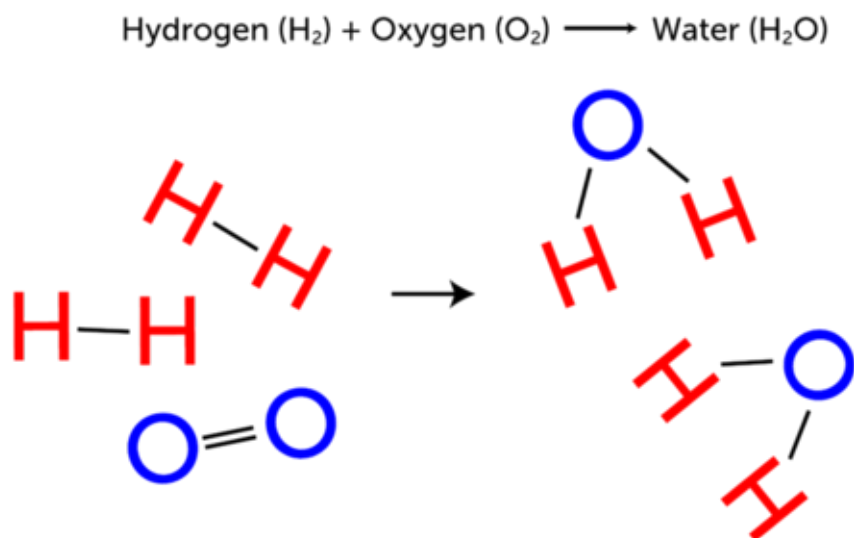
Q: How do the reactants in a chemical reaction turn into the products?

A: Bonds break in the reactants, and new bonds form in the products.

Breaking and Making Chemical Bonds

The reactants and products in a chemical reaction contain the same **atoms**, but they are rearranged during the reaction. As a result, the atoms end up in different combinations in the products. This makes the products new **substances** that are chemically different from the reactants.

Consider the example of **water** forming from hydrogen and oxygen. Both hydrogen and oxygen **gases** exist as diatomic (“two-atom”) molecules. These molecules are the reactants in the reaction. The **Figure below** shows that bonds must break to separate the **atoms** in the hydrogen and oxygen molecules. Then new bonds must form between hydrogen and oxygen atoms to form **water** molecules. The water molecules are the products of the reaction.



Q: Watch the animation of a similar chemical reaction at the following URL. Can you identify the reactants and the product in the reaction? http://www.youtube.com/watch?v=SErRUqJ_x30

A: The reactants are hydrogen (H₂) and fluorine (F₂), and the product is hydrogen fluoride (HF).

Summary

All chemical reactions involve both reactants and products. Reactants are substances that start a chemical reaction, and products are substances that are produced in the reaction.

A chemical reaction can be represented by the general **chemical formula**:

R

e

a

c

t

a

n

t

s

→

P

r

o

d

u

c

t

s

Bonds break and reform during chemical reactions. Reactants and products contain the same **atoms**, but they are rearranged during the reaction, so reactants and products are different substances.

Explore More

Do the activities at the following URL for practice with reactants and products.

<http://phet.colorado.edu/en/simulation/reactants-products-and-leftovers>

Review

Identify the reactants and products in the following chemical reaction:



How do reactants change into products during a chemical reaction?



Look at this rusty bike. It has been left outside in damp weather too many times, so the iron in the metal parts has rusted. Iron rusts when it combines with oxygen in the air. Iron rusting is an example of a chemical reaction. In a chemical reaction, **substances** change into entirely different substances. For example, the iron in the bike and the oxygen in the air have changed into rust.

Q: How could you represent this reaction, besides just describing it in words?

A: Scientists use a standard method to represent a chemical reaction, called a chemical equation.

What Is a Chemical Equation?

A **chemical equation** is a shorthand way to sum up what occurs in a chemical reaction. The general form of a chemical equation is:

Reactants \rightarrow Products

The reactants in a chemical equation are the **substances** that begin the reaction, and the products are the substances that are produced in the reaction. The reactants are always written on the left side of the equation and the products on

the right. The arrow pointing from left to right shows that the reactants change into the products during the reaction. This happens when chemical bonds break in the reactants and new bonds form in the products. As a result, the products are different chemical substances than the reactants that started the reaction. For a good overview of chemical equations and how to write them, watch the video at this URL: <http://www.youtube.com/watch?v=0zC6v5gU0k4>.

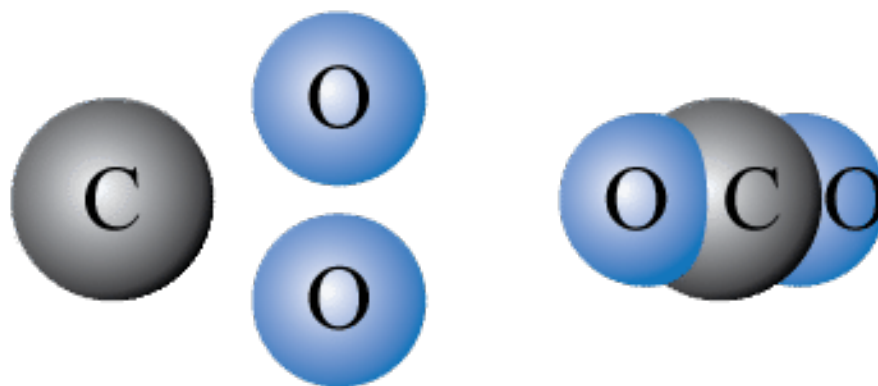
Q: What is the general equation for the reaction in which iron rusts?

A: Iron combines with oxygen to produce rust, which is the compound named iron oxide. This reaction could be represented by the general chemical equation below. Note that when there is more than one reactant, they are separated by plus signs (+). If more than one product were produced, plus signs would be used between them as well.

Iron + Oxygen → Iron Oxide

Using **Chemical Symbols and Formulas**

When scientists write chemical equations, they use chemical symbols and chemical formulas instead of names to represent **reactants and products**. Look at the chemical reaction illustrated in the **Figure below**. In this reaction, carbon reacts with oxygen to produce carbon dioxide. Carbon is represented by the chemical symbol C. The chemical symbol for oxygen is O, but pure oxygen exists as diatomic (“two-atom”) molecules, represented by the **chemical formula** O₂. A molecule of the compound carbon dioxide consists of one atom of carbon and two **atoms** of oxygen, so carbon dioxide is represented by the **chemical formula** CO₂.



Q: What is the chemical equation for this reaction?

A: The chemical equation is:



Q: How have the **atoms** of the reactants been rearranged in the products of the reaction? What bonds have been broken, and what new bonds have formed?

A: Bonds between the oxygen **atoms** in the oxygen molecule have been broken, and new bonds have formed between the carbon atom and the two oxygen atoms.

Is It Balanced?

All chemical equations, like equations in math, must balance. This means that there must be the same number of each type of atom on both sides of the arrow. That’s because matter is always conserved in a chemical reaction. This is the law of **conservation of mass**.

Look at the equation above for the reaction between carbon and oxygen in the formation of carbon dioxide. Count the number of atoms of each type. Are the numbers the same on both sides of the arrow? The answer is yes, so the equation is balanced.

Coefficients

Let's return to the chemical reaction in which iron (Fe) combines with oxygen (O₂) to form rust, or iron oxide (Fe₂O₃). The equation for this reaction is:



This equation illustrates the use of coefficients to balance chemical equations. A coefficient is a number placed in front of a chemical symbol or formula that shows how many atoms or molecules of the substance are involved in the reaction. From the equation for rusting, you can see that four atoms of iron combine with three molecules of oxygen to form two molecules of iron oxide.

Q: Is the equation for the rusting reaction balanced? How can you tell?

A: Yes, the equation is balanced. You can tell because there is the same number of each type of atom on both sides of the arrow. First count the iron atoms. There are four iron atoms in the reactants. There are also four iron atoms in the products (two in each of the two iron oxide molecules). Now count the oxygen atoms. There are six on each side of the arrow, confirming that the equation is balanced in terms of oxygen as well as iron.

Summary

Scientists use chemical equations to summarize what happens in **chemical reactions**. Reactants are placed on the left side of the equation and products are placed on the right. An arrow is used to indicate the direction in which the reaction occurs. Plus signs (+) are placed between multiple reactants or products.

In chemical equations, **reactants and products** are represented by **chemical symbols and formulas**. Numbers called coefficients are placed in front of the symbols and formulas to show how much of each substance is involved in the reaction.

Chemical equations must be balanced. A balanced equation has the same number of each type of atom on both sides of the equation.

Explore More

Watch the video on chemical equations at the URL below. Interpret the two "Your Turn" equations, and then watch the following explanations to see if your answers are correct. Continue on with the video and then write the two "Your Turn" equations. Again, watch the following explanations to see if your answers are correct.

http://www.youtube.com/watch?v=lSoRj_iBwYc

Review

What is a chemical equation? Identify the parts of a chemical equation.

Write a chemical equation for the chemical reaction in which calcium carbonate (CaCO₃) produces calcium oxide (CaO) and carbon dioxide (CO₂).

Describe in words the chemical reaction represented by the following chemical equation: $2\text{NO}_2 \rightarrow 2\text{O}_2 + \text{N}_2$

When is a chemical equation balanced?



The little boy on this seesaw weighs more than the little girl on the other side. That's why his side of the seesaw is on the ground and her side is up in the air. For a seesaw to balance, the two riders must be the same weight. A chemical equation that represents a chemical reaction is a little bit like a seesaw. For a chemical equation to balance, there must be the same number of each type of atom on both sides of the equation.

Writing Chemical Equations

A chemical equation represents the changes that occur during a chemical reaction. A chemical equation has the general form:

Reactants \rightarrow Products

An example of a simple chemical reaction is the reaction in which hydrogen (H_2) and oxygen (O_2) combine to produce **water** (H_2O). In this reaction, the reactants are hydrogen and oxygen and the product is **water**. To write the chemical equation for this reaction, you would start by writing the reactants on the left and the product on the right, with an arrow between them to show the direction in which the reaction occurs:

Equation 1:



Q: Look closely at equation 1. There's something wrong with it. Do you see what it is?

A: All **chemical equations** must be balanced. This means that there must be the same number of each type of atom on both sides of the arrow. That's because mass is always conserved in **chemical reactions**. Count the number of hydrogen and oxygen **atoms** on each side of the arrow. There are two hydrogen atoms in both **reactants and products**. There are two oxygen atoms in the reactants but only one in the product. Therefore, equation 1 is not balanced.

Using Coefficients

Coefficients are used to balance chemical equations. A coefficient is a number placed in front of a chemical symbol or formula. It shows how many **atoms** or molecules of the substance are involved in the reaction. For example, two molecules of hydrogen would be written as $2 H_2$, and two molecules of **water** would be written $2 H_2O$. A coefficient of 1 usually isn't written. Coefficients can be used to balance equation 1 (above) as follows:

Equation 2:



Equation 2 shows that two molecules of hydrogen react with one molecule of oxygen to produce two molecules of

water. The two molecules of hydrogen each contain two hydrogen **atoms** and so do the two molecules of water. Therefore, there are now four hydrogen atoms in both **reactants and products**.

Q: Is equation 2 balanced?

A: Count the oxygen atoms to find out. There are two oxygen atoms in the one molecule of oxygen in the reactants. There are also two oxygen atoms in the products, one in each of the two water molecules. Therefore, equation 2 is balanced.

Steps in Balancing a Chemical Equation

Balancing a chemical equation involves a certain amount of trial and error. In general, however, you should follow these steps:

Count each type of atom in **reactants and products**. Does the same number of each atom appear on both sides of the arrow? If not, the equation is not balanced, and you need to go to step 2.

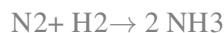
Place coefficients, as needed, in front of the symbols or formulas to increase the number of atoms or molecules of the **substances**. Use the smallest coefficients possible. Warning! Never change the subscripts in chemical formulas. Changing subscripts changes the substances involved in the reaction. Change only the coefficients.

Repeat steps 1 and 2 until the equation is balanced.

Q: Balance this chemical equation for the reaction in which nitrogen (N₂) and hydrogen (H₂) combine to form ammonia (NH₃):



A: First count the nitrogen atoms on both sides of the arrow. There are two nitrogen atoms in the reactants so there must be two in the products as well. Place the coefficient 2 in front of NH₃ to balance nitrogen:



Now count the hydrogen atoms on both sides of the arrow. There are six hydrogen atoms in the products so there must also be six in the reactants. Place the coefficient 3 in front of H₂ to balance hydrogen:



If you're still not sure how to balance chemical equations, watch the excellent video at this URL: <http://www.youtube.com/watch?>

Summary

A chemical equation represents the changes that occur during a chemical reaction. It has the general form: Reactants → Products. All chemical equations must be balanced. This means that there must be the same number of each type of atom on both sides of the arrow.

Coefficients are used to balance chemical equations. A coefficient is a number placed in front of a chemical symbol or formula. It shows how many atoms or molecules of the substance are involved in the reaction.

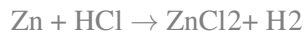
To balance a chemical equation, place coefficients as needed in front of the symbols or formulas so the same number of each type of atom occurs in both reactants and products.

Explore More

Practice balancing chemical equations by completing the worksheet at this URL: <http://chemistry.about.com/library/formulabalanc>

Review

Which of the following chemical equations is balanced?



Balance this chemical equation: $\text{CH}_4 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$

Sam was given the following equation to balance: $\text{H}_2\text{O} \rightarrow \text{H}_2 + \text{O}_2$. She balanced it as follows: $2 \text{H}_2\text{O} \rightarrow \text{H}_2 + \text{O}_2$. What did she do wrong? What is the correct way to balance the equation?

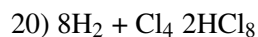
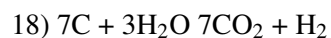
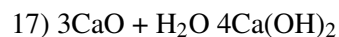
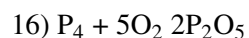
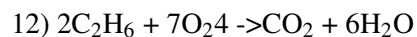
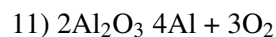
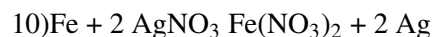
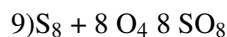
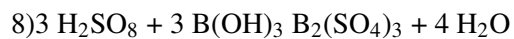
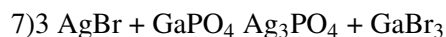
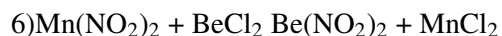
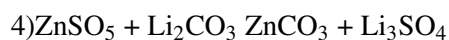
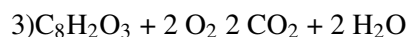
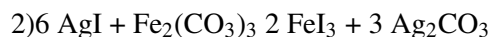
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http://www.ck12.org/physical-science/Balancing-Chemical-Equations-in-Physical-Science/lecture/Balancing-Chemical-Equations/?referrer=recommended_modalities

4.5 Balanced or Not Practice

Name: _____ Period: _____ Date: _____

Unit 4: Balancing Equations: Balanced or Not???



4.6 Slime Lab.docx

Elmer's glue (most kinds of white craft glue will work)

2 disposable cups

Food coloring (you pick the color)

Water

Borax Powder (available at most large grocery stores near the laundry detergent)

A plastic spoon (for stirring)

A tablespoon (for measuring)

What to do

Fill one small cup with water and add a spoonful of the Borax powder and stir it up. Then set it aside.

Fill the other small cup with about 1 inch (2.5 cm) of the glue.

Add three tablespoons (20 ml) of water to the glue and stir.

Add a few drops of the food coloring and stir it up until mixed.

Now the fun part. . . Add one tablespoons of the Borax solution you made earlier and stir well. Watch the slime form!

After the slime forms let it sit for about 30 seconds and then pull it off the spoon and play with it!

Tip: Keep your slime in a tightly closed plastic bag when you are not playing with it, and keep it away from carpet and your little sister's hair.

How does it work?

Now for the SCIENCE part. . . This POLYMER is unique because it has qualities of both a solid and a liquid. It can take the shape of its containers like a liquid does, yet you can hold it in your hand and pick it up like a solid. As you might know, solid molecules are tight together, liquid molecules spread out and break apart (drops) POLYMER molecules CHAIN themselves together (they can stretch and bend like chains) and that makes them special. Jell-O, rubber bands, plastic soda bottles, sneaker soles, even gum are all forms of polymers. The polymer you made should be kept in a sealed plastic bag when you aren't playing with it. Also, be sure to keep it away from young kids or pets who might think it's food. Have fun!

MAKE IT AN EXPERIMENT

The project above is a DEMONSTRATION. To make it a true experiment, you can try to answer these questions:

How can you make the polymer stretch the farthest?

Does the amount of Borax added change the slime?

What method of storage will make the polymer last the longest?

What brand of glue makes the stretchiest polymer?

Does the amount of water added to the glue affect the gooeyness of the slime?

4.7 Caesin Lab - Chemical Reaction.docx

Name: _____ Period: _____ Date: _____ pg: _____

Making Plastics

Making Casein Plastic

You will need:

TABLE 4.5:

bowl	White Vinegar	2 -250 mL Beaker	Plastic Spoon
Thermometer	Eye dropper	Hot Plate	250mL Skim Milk

Method:

1. Warm milk slowly to 50°C. While warming the milk students will **observe and record the properties of the milk and vinegar**.
2. Pass out 250mL of milk to each group.
3. Students will add an eye dropper full of vinegar to the beaker, slowly.
4. Students will stir the liquid with a plastic spoon.
5. Make sure the mixture is not too hot, then slowly pour the milk out onto your hand (over the bowl), "catching" the plastic in your fingers.
6. Students will **observe and record the properties of the casein.**

The plastic you have made consists mainly of a protein called **casein**. Casein is used to make medicines, glues and cosmetics.

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TEKS

TEKS - 8.5

CHAPTER **5**

Chapter 5 - Motion and Force

Chapter Outline

- 5.1 CHAPTER 5 GUIDED QUESTIONS
 - 5.2 COMBINING FORCES.DOCX
 - 5.3 CALCULATING WORK.DOCX
 - 5.4 CALCULATING ACCELERATION FROM FORCE AND MASS.DOCX
 - 5.5 DENSITY VIRTUAL LAB.DOCX
-

5.1 Chapter 5 Guided Questions

Chapter 5: Guided Questions

TABLE 5.1:

How is it possible for a car to accelerate without speeding up?

How can graphs represent a change in acceleration?

Explain the difference between a distance-time graph and speed-time graph?

Describe what happens to an object when forces are balanced? Unbalanced?

What affect does unbalanced forces have on an object? Give an example.

Describe the steps needed to calculate net force.

Explain the concept of Net Force.

5.2 Combining Forces.docx

Combining Forces

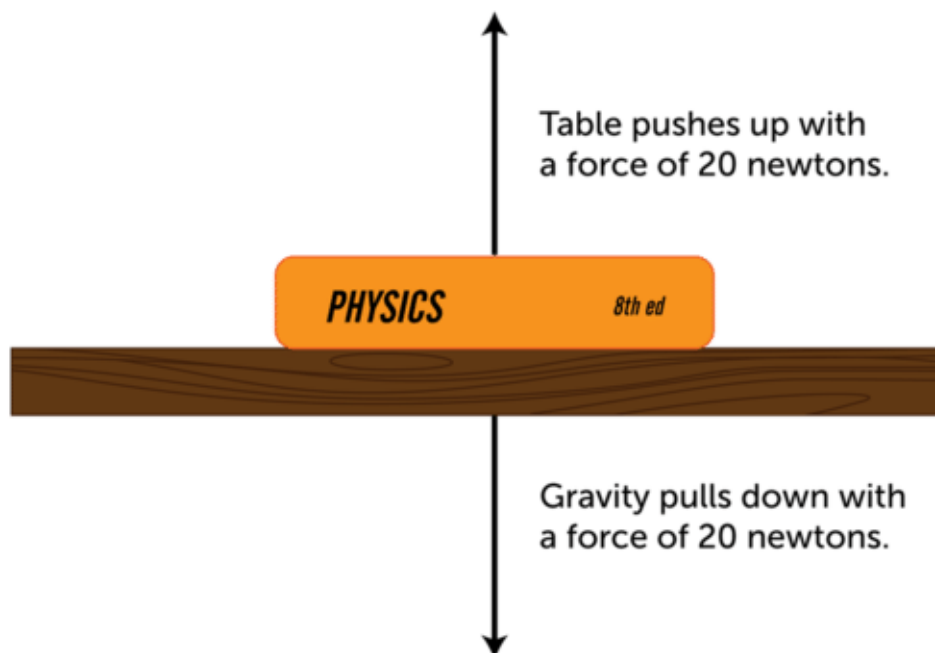


It's boys against girls in this friendly tug of war. The two teams are pulling the rope in opposite directions. Which team do you think will win? It depends on which side pulls on the rope with the greatest force. As this example shows, more than one force may act on an object at the same time. Would it surprise you to learn that at least two different forces are acting on you as you read this article? Can you guess what they are?

Pulling Down and Pushing Up

One force acting on you—and all the other objects on Earth—is gravity. Look at the physics book in the Figure below. Gravity pulls the book downward with a force of 20 Newtons. Why doesn't the book fall to the ground? The table pushes upward on the book with the same amount of force. The combined force, or net force, acting on the book is 0 Newtons. That's because upward and downward forces are balanced, so they cancel out. You can learn more about net force at this URL:

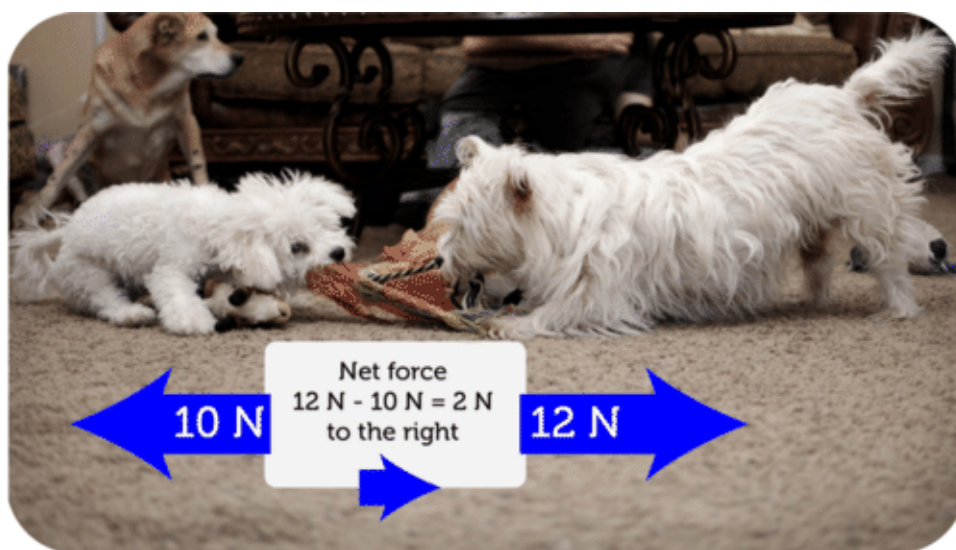
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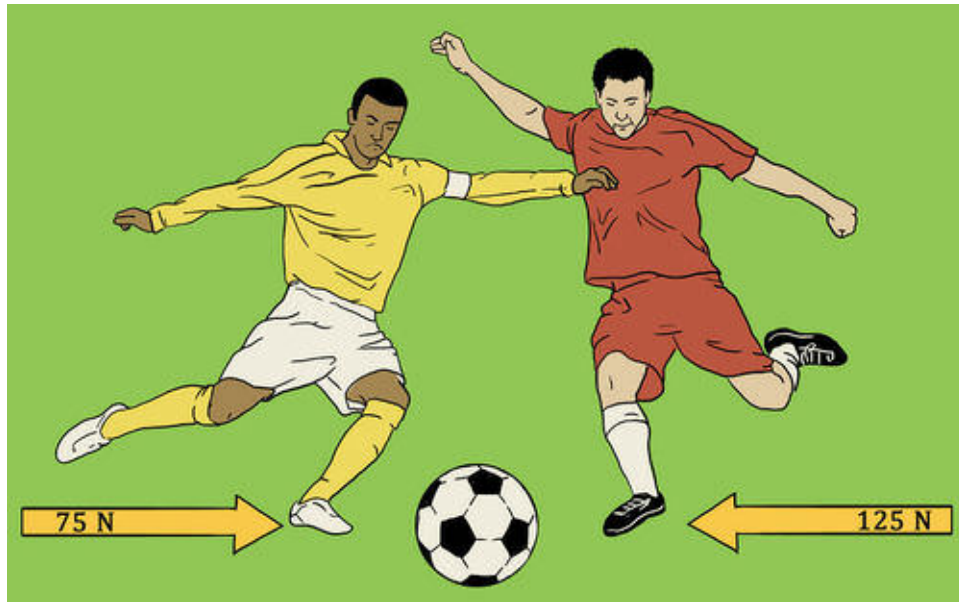
Forces Acting in Opposite Directions

In general, whenever forces act on an object in opposite directions—like the book on the table—the net force is equal to the difference between the two forces. In other words, one force is subtracted from the other to calculate the net force. If the opposing forces are equal, or balanced, the net force is zero, as it is for the book. That's why the book doesn't fall to the ground but instead remains resting on the table. However, if the opposing forces are unbalanced, the net force is greater than zero, although it will be less than either of the individual forces. In this case, the object will move in the same direction as the net force.

Look at the dogs playing tug-of-war in the Figure below. The dogs are pulling the rope in opposite directions, but one dog is pulling with more force than the other. The net force acting on the rope is 2 Newtons to the right, so the rope will move to the right.



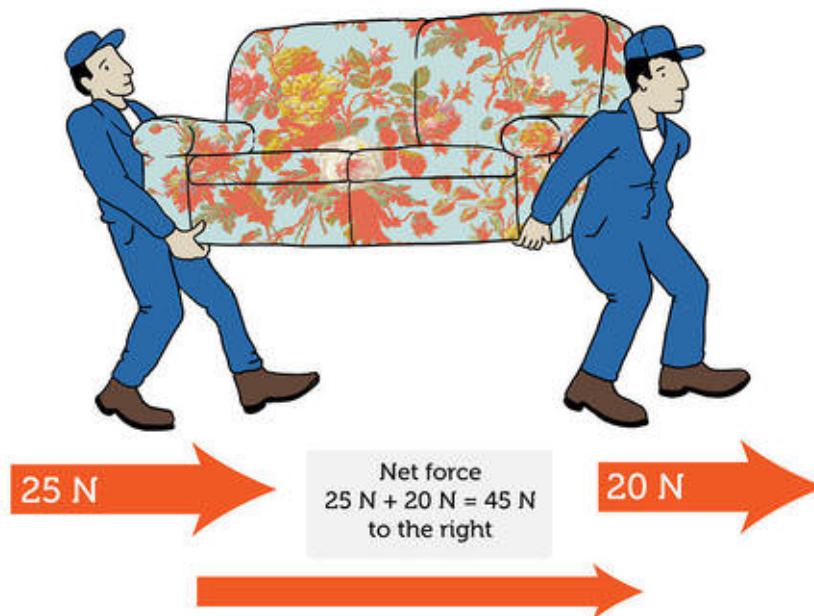
Q: The boys in the Figure below are about to kick the soccer ball in opposite directions. What will be the net force on the ball? In which direction will the ball move?



A: The net force on the ball will be 50 N to the left ($125\text{ N} - 75\text{ N} = 50\text{ N}$), so the ball will move to the left.

Forces Acting in the Same Direction

If two forces act on an object in the same direction, the net force is equal to the sum of the two forces. This always results in a stronger force than either of the individual forces alone. In the Figure below, after the man on the left picks up the couch, he will push the couch to the right with a force of 25 Newtons, and the man on the right will pull the couch to the right with a force of 20 Newtons. The net force on the couch is 45 Newtons to the right, so that's the way the couch will move.



Summary

The net force acting on an object is the combination of all of the individual forces acting on it.

If two forces act on an object in opposite directions, the net force is the difference between the two forces. In this case, the net force is always greater than or equal to zero but less than either of the individual forces.

If two forces act on an object in the same direction, the net force is the sum of the two forces. In this case, the net force is always greater than either of the individual forces.

Explore More

Practice calculating net force and determining the direction of motion by completing the worksheet at the following URL. You can check your answers on the last page of the worksheet.

http://www.beaconlearningcenter.com/documents/2424_01.pdf

Review

What is the net force acting on an object?

If an object has two forces acting on it, how can the net force equal 0?

Under what conditions does the net force acting on an object equal the sum of the individual forces?

What is the net force on the book in the Figure below? If the book moves, in which direction will it move?



Authors:

Jean Brainard, Ph.D.

5.3 Calculating Work.docx



Calculating Work



Clarissa is cutting the grass in her grandmother's yard using an old-fashioned push mower. The mower has no motor, so Clarissa is doing all the work. How much work does Clarissa do pushing the mower around the yard? The amount of work depends on how much force she uses and how far she pushes the mower.

Work, Force, and [Distance](#)

Work is the use of force to move an object. It is directly related to both the force applied to the object and the distance the object moves. Work can be calculated with this equation:

Work = Force x Distance.

How Much Work?

The equation for work can be used to calculate work if force and distance are known. To use the equation, force is expressed in Newtons (N), and distance is expressed in meters (m). For example, assume that Clarissa uses 100

Newtons of force to push the mower and that she pushes it for a total of 200 meters as she cuts the grass in her grandmother's yard. Then, the amount of work Clarissa does is:

$$\text{Work} = 100 \text{ N} \times 200 \text{ m} = 20,000 \text{ N} \cdot \text{m}$$

Notice that the unit for work in the answer is the Newton • meter ($\text{N} \cdot \text{m}$). This is the SI unit for work, also called the joule (J). One joule equals the amount of work that is done when 1 N of force moves an object over a distance of 1 m.

Q: After Clarissa mows her grandmother's lawn, she volunteers to mow a neighbor's lawn as well. If she pushes the mower with the same force as before and moves it over a total of 234 meters, how much work does she do mowing the neighbor's lawn?

A: The work Clarissa does can be calculated as:

$$\text{Work} = 100 \text{ N} \times 234 \text{ m} = 23,400 \text{ N} \cdot \text{m}, \text{ or } 23,400 \text{ J}$$

Calculating Force or Distance When Work Is Known

The work equation given above can be rearranged to find force or distance if the other variables are known:

$$\text{Force} = \frac{\text{Work}}{\text{Distance}}$$

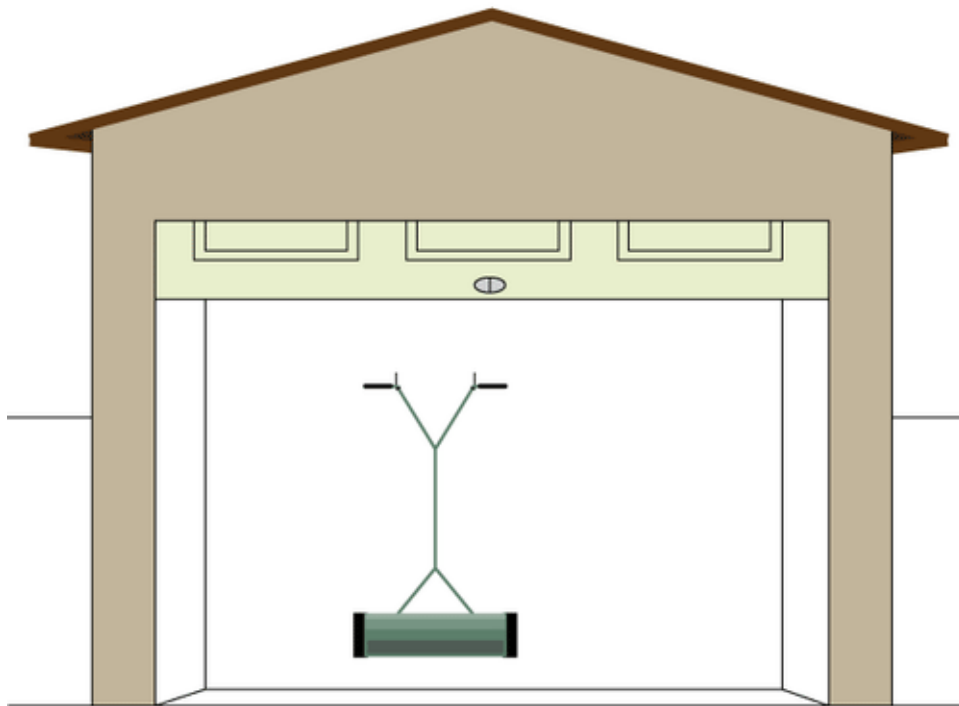
$$\text{Distance} = \frac{\text{Work}}{\text{Force}}$$

After Clarissa finishes mowing both lawns, she pushes the lawn mower down the sidewalk to her own house. If she pushes the mower over a distance of 30 meters and does 2700 joules of work, how much force does she use? Substitute the known values into the equation for force:

$$\text{Force} = \frac{2700 \text{ J}}{30 \text{ m}} = 90 \text{ N}$$

Q: When Clarissa gets back to her house, she hangs the 200-Newton lawn mower on some hooks in the garage (see the Figure below). To lift the mower, she does 400 joules of work. How far does she lift the mower to hang it?

A: Substitute the known values into the equation for distance:



Summary

Work can be calculated with the equation: $\text{Work} = \text{Force} \times \text{Distance}$.

The SI unit for work is the joule (J), or Newton • meter (N • m). One joule equals the amount of work that is done when 1 N of force moves an object over a distance of 1 m.

The equation for work can be rearranged to find force or distance if the other variables are known.

Explore More

At the following URL, review how to calculate work from force and distance. Then solve the practice problems (except for problem 8) at the bottom of the Web page.

<http://www2.franciscan.edu/academic/mathsci/mathscienceintegration/MathScienceIntegation-1011.htm>

Review

Write the equation for calculating work when force and distance are known.

What is the SI unit for work? What does it represent?

Clarissa helps her mom put the 200-Newton lawn mower in the back of her mom's truck. They lift the mower up from the ground to the truck bed, which is 1.1 meters above the ground. How much work do Clarissa and her mom do?

Clarissa climbs into the back of the truck to tie the lawn mower in place. If she does 528 joules of work raising herself to the truck bed, how much does she weigh?

Authors:

[Jean Brainard, Ph.D.](#)

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June 14, 2016

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5.4 Calculating Acceleration from Force and Mass.docx



Calculating Acceleration from Force and Mass

The acceleration of an object equals the net force acting on it divided by its mass.



Xander goes airborne on his scooter as he exits a half-pipe at Newton's Skate Park. How did he gain enough **speed** in the half-pipe to fly into the air when he got to the top? His increase in speed was due partly to the force of gravity.

Acceleration, Force, and Mass

A change in an object's motion—such as Xander speeding up on his scooter—is called acceleration. Acceleration occurs whenever an object is acted upon by an unbalanced force. The greater the net force acting on the object, the greater its acceleration will be, but the mass of the object also affects its acceleration. The smaller its mass is, the greater its acceleration for a given amount of force. Newton's second law of motion summarizes these relationships. According to this law, the acceleration of an object equals the net force acting on it divided by its mass. This can be represented by the equation:

Acceleration=NetforceMass or $a=F/m$

Calculating Acceleration

This equation for acceleration can be used to calculate the acceleration of an object that is acted on by a net force. For example, Xander and his scooter have a total mass of 50 kilograms. Assume that the net force acting on Xander and the scooter is 25 Newtons. What is his acceleration? Substitute the relevant values into the equation for acceleration:

$$a = \frac{F}{m} = \frac{25 \text{ N}}{50 \text{ kg}} = 0.5 \text{ N/kg}$$

The Newton is the SI unit for force. It is defined as the force needed to cause a 1-kilogram mass to accelerate at 1 m/s². Therefore, force can also be expressed in the unit kg • m/s². This way of expressing force can be substituted for Newtons in Xander's acceleration so the answer is expressed in the SI unit for acceleration, which is m/s²:

$$a = 0.5 \text{ N/kg} = 0.5 \text{ kg} \cdot \text{m/s}^2 / \text{kg} = 0.5 \text{ m/s}^2$$

Q: Why are there no kilograms in the final answer to this problem?

A: The kilogram units in the numerator and denominator of the fraction cancel out. As a result, the answer is expressed in the correct SI units for acceleration.

Calculating Force

It's often easier to measure the mass and acceleration of an object than the net force acting on it. Mass can be measured with a balance, and average acceleration can be calculated from [velocity](#) and time. However, net force may be a combination of many unseen forces, such as gravity, [friction](#) with surfaces, and air resistance. Therefore, it may be more useful to know how to calculate the net force acting on an object from its mass and acceleration. The equation for acceleration above can be rewritten to solve for net force as:

Net Force = Mass × Acceleration, or

$$F = m \times a$$

Look at Xander in the Figure below. He's riding his scooter down a ramp. Assume that his acceleration is 0.8 m/s². How much force does it take for him to accelerate at this rate? Substitute the relevant values into the equation for force to find the answer:

$$F = m \times a = 50 \text{ kg} \times 0.8 \text{ m/s}^2 = 40 \text{ kg} \cdot \text{m/s}^2, \text{ or } 40 \text{ N}$$



Q: If Xander and his scooter actually had a mass of 40 kg instead of 50 kg, how much force would it take for him to accelerate at 0.8 m/s²?

A: It would take only 32 N of force (40 kg × 0.8 m/s²).

At the URL below, you can review how to calculate net force from mass and acceleration and try some practice problems. If you want to try more challenging problems, click on the relevant links at the bottom of the Web page.

<http://www2.franciscan.edu/academic/mathsci/mathscienceintegration/MathScienceIntegation-856.htm>

Summary

According to Newton's second law of motion, the acceleration of an object equals the net force acting on it divided by its mass, or $a = F/m$.

This equation for acceleration can be used to calculate the acceleration of an object when its mass and the net force acting on it are known.

The equation for acceleration can be rewritten as $F = m \times a$ to calculate the net force acting on an object when its mass and acceleration are known.

Explore More

At the following URL, solve the six problems on page 2.

<http://www2.fcsconline.org/staff/ferrisa/Kinesiology/Force%20WS.pdf>

Review

What is the equation for calculating the acceleration of an object when its mass and the net force acting on it are known?

Xander's friend Corey has a skateboard that he rides at Newton's Skate Park. That's Corey doing a jump in the Figure below. The combined mass of Corey and his skateboard is 60 kg. At the top of his jump, the net force acting on him is 30 Newtons. What is his acceleration at that moment?



What net force would have to act on Cory for him to have an acceleration of 1 m/s^2 ?

5.5 Density Virtual Lab.docx

http://highered.mheducation.com/sites/0078741858/student_view0/unit1/chapter3/virtual_labs.html#

CHAPTER **6** **Chapter 6 - Newton's Laws**

Chapter Outline

6.1 **CHAPTER 6 GUIDED QUESTIONS**

6.2 **NEWTON'S LAWS 1, 2 & 3**

6.1 Chapter 6 Guided Questions

Chapter 6: Guided Questions

TABLE 6.1:

How does Newton's law explain the effect of all forces acting on an object?

How does gravity and friction affect the motion of objects on earth?

What are some contact forces and some non-contact forces? How do you know?

When riding in a car, and car comes to a stop, why do you keep moving forward? Explain.

How is the acceleration of an object affected by the mass?

Which has greater inertia- a moving toy car or a large truck parked in a lot? Explain.

What relationship exists between force and acceleration?

6.2 Newton's Laws 1, 2 & 3



The sprinter in this photo is pushing off from the blocks at the start of a race. The blocks provide a counter force so she can take off in a hurry. With great effort, she will go from motionless to top speed in just a few seconds. She won't slow down until she crosses the finish line. By then, she will be going so fast that it will take her almost as much time to come to a full stop as it did to run the race.

No doubt you've experienced motions like these, even if you've never run a race. But do you know what explains these motions? For example, do you know why it's as hard to stop running as it is to start? These and other aspects of motion are explained by three laws of motion. The laws were developed by Sir Isaac Newton in the late 1600s. You'll learn about Newton's laws of motion in this chapter and how and why objects move as they do.

Flickr:tableatny. www.flickr.com/photos/53370644@N06/4976491750/. CC BY 2.0.

Lesson Objectives

State Newton's first law of motion.

Define inertia, and explain its relationship to mass.

Lesson Vocabulary

inertia

Newton's first law of motion

Introduction

The amusement park ride pictured in **Figure below** keeps changing direction as it zooms back and forth. Each time it abruptly switches direction, the riders are forced to the opposite side of the car. What force causes this to happen? In this lesson, you'll find out.



Amusement park rides like this one are exciting because of the strong forces the riders feel.

Force and Motion

Newton's first law of motion states that an object's motion will not change unless an unbalanced force acts on the object. If the object is at rest, it will stay at rest. If the object is in motion, it will stay in motion and its velocity will remain the same. In other words, neither the direction nor the speed of the object will change as long as the net force acting on it is zero. You can watch a video about Newton's first law at this URL: <http://videos.howstuffworks.com/discovery/29382-assignment-discovery-newtons-first-law-video.htm>.

Look at the pool balls in **Figure below**. When a pool player pushes the pool stick against the white ball, the white ball is set into motion. Once the white ball is rolling, it rolls all the way across the table and stops moving only after it crashes into the cluster of colored balls. Then, the force of the collision starts the colored balls moving. Some may roll until they bounce off the raised sides of the table. Some may fall down into the holes at the edges of the table. None of these motions will occur, however, unless that initial push of the pool stick is applied. As long as the net force on the balls is zero, they will remain at rest.



Force from the moving pool stick starts the white ball rolling. Force from the moving white ball sets the other balls into motion.



Pool balls remain at rest until an unbalanced force is applied to them. After they are in motion, they stay in motion until another force opposes their motion.

Inertia

Newton's first law of motion is also called the law of inertia. **Inertia** is the tendency of an object to resist a change in its motion. If an object is already at rest, inertia will keep it at rest. If the object is already moving, inertia will keep it moving.

Think about what happens when you are riding in a car that stops suddenly. Your body moves forward on the seat. Why? The brakes stop the car but not your body, so your body keeps moving forward because of inertia. That's why it's important to always wear a seat belt. Inertia also explains the amusement park ride in **Figure above**. The car keeps changing direction, but the riders keep moving in the same direction as before. They slide to the opposite side of the car as a result. You can see an animation of inertia at this URL: <http://www.physicsclassroom.com/mmedia/newtlaws/cci.cf>

Inertia and Mass

The inertia of an object depends on its mass. Objects with greater mass also have greater inertia. Think how hard it would be to push a big box full of books, like the one in **Figure below**. Then think how easy it would be to push the box if it was empty. The full box is harder to move because it has greater mass and therefore greater inertia.



The tendency of an object to resist a change in its motion depends on its mass. Which box has greater inertia?

Overcoming Inertia

To change the motion of an object, inertia must be overcome by an unbalanced force acting on the object. Until the soccer player kicks the ball in **Figure below**, the ball remains motionless on the ground. However, when the ball is kicked, the force on it is suddenly unbalanced. The ball starts moving across the field because its inertia has been overcome.



Force must be applied to overcome the inertia of a soccer ball at rest.

Once objects start moving, inertia keeps them moving without any additional force being applied. In fact, they won't stop moving unless another unbalanced force opposes their motion. What if the rolling soccer ball is not kicked by another player or stopped by a fence or other object? Will it just keep rolling forever? It would if another unbalanced force did not oppose its motion. Friction — in this case rolling friction with the ground — will oppose the motion of the rolling soccer ball. As a result, the ball will eventually come to rest. Friction opposes the motion of all moving objects, so, like the soccer ball, all moving objects eventually come to a stop even if no other forces oppose their motion.

Lesson Summary

Newton's first law of motion states that an object's motion will not change unless an unbalanced force acts on the object. If the object is at rest, it will stay at rest. If the object is in motion, it will stay in motion.

Inertia is the tendency of an object to resist a change in its motion. The inertia of an object depends on its mass. Objects with greater mass have greater inertia. To overcome inertia, an unbalanced force must be applied to an object.

Lesson Review Questions

Recall

State Newton's first law of motion.

Define inertia.

How does an object's mass affect its inertia?

Apply Concepts

Assume you are riding a skateboard and you run into a curb. Your skateboard suddenly stops its forward motion. Apply the concept of inertia to this scenario, and explain what happens next.

Think Critically

Why is Newton's first law of motion also called the law of inertia?

Points to Consider

In this lesson, you read that the mass of an object determines its inertia. You also learned that an unbalanced force must be applied to an object to overcome its inertia, whether it is moving or at rest. An unbalanced force causes an object to accelerate.

Predict how the mass of an object affects its acceleration when an unbalanced force is applied to it.

How do you think the acceleration of an object is related to the strength of the unbalanced force acting on it?

Lesson Objectives

State Newton's second law of motion.

Identify the relationship between acceleration and weight.

Lesson Vocabulary

Newton's second law of motion

Introduction

A car's gas pedal, like the one in **Figure below**, is sometimes called the accelerator. That's because it controls the acceleration of the car. Pressing down on the gas pedal gives the car more gas and causes the car to speed up. Letting up on the gas pedal gives the car less gas and causes the car to slow down. Whenever an object speeds up, slows down, or changes direction, it accelerates. Acceleration is a measure of the change in velocity of a moving object. Acceleration occurs whenever an object is acted upon by an unbalanced force.



The car pedal on the right controls the amount of gas the engine gets. How does this affect the car's acceleration?

Acceleration, Force, and Mass

Newton determined that two factors affect the acceleration of an object: the net force acting on the object and the object's mass. The relationships between these two factors and motion make up **Newton's second law of motion**. This law states that the acceleration of an object equals the net force acting on the object divided by the object's mass. This can be represented by the equation:

A
c
c
e
l
e
r
a
t
i
o
n
a

=
N
e
t

f
o
r
c
e
M
a
s
s

,

o
r

=
F
m

You can watch a video about how Newton's second law of motion applies to football at this URL: <http://science360.gov/obj/video/e38d-430b-bfb1-c505e628a2d4>.

Direct and Inverse Relationships

Newton's second law shows that there is a direct relationship between force and acceleration. The greater the force that is applied to an object of a given mass, the more the object will accelerate. For example, doubling the force on the object doubles its acceleration. The relationship between mass and acceleration, on the other hand, is an inverse relationship. The greater the mass of an object, the less it will accelerate when a given force is applied. For example, doubling the mass of an object results in only half as much acceleration for the same amount of force.

Consider the example of a batter, like the boy in **Figure below**. The harder he hits the ball, the greater will be its acceleration. It will travel faster and farther if he hits it with more force. What if the batter hits a baseball and a softball with the same amount of force? The softball will accelerate less than the baseball because the softball has greater mass. As a result, it won't travel as fast or as far as the baseball.



Hitting a baseball with greater force gives it greater acceleration. Hitting a softball with the same amount of force results in less acceleration. Can you explain why?

Calculating Acceleration

The equation for acceleration given above can be used to calculate the acceleration of an object that is acted on by an unbalanced force. For example, assume you are pushing a large wooden trunk, like the one shown in **Figure below**. The trunk has a mass of 10 kilograms, and you are pushing it with a force of 20 newtons. To calculate the acceleration of the trunk, substitute these values in the equation for acceleration:

$$a = \frac{F}{m} = \frac{20}{10}$$

0

N

1

0

k

g

=

2

N

k

g

Recall that one newton (1 N) is the force needed to cause a 1-kilogram mass to accelerate at 1 m/s². Therefore, force can also be expressed in the unit kg·m/s². This way of expressing force can be substituted for newtons in the solution to the problem:

a

=

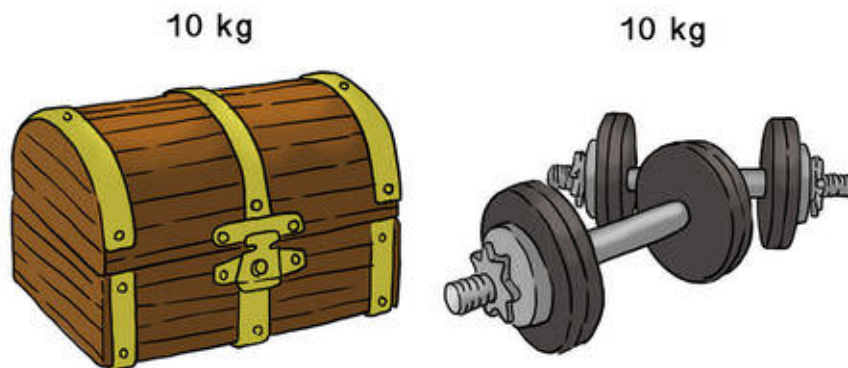
2

N

k

g $=$ 2 k g \cdot m $/$ s 2 k g $=$ 2 m $/$ s

Why are there no kilograms in the final answer to this problem? The kilogram units in the numerator and denominator of the fraction cancel out. As a result, the answer is expressed in the correct units for acceleration: m/s².



This empty trunk has a mass of 10 kilograms. The weights also have a mass of 10 kilograms. If the weights are placed in the trunk, what will be its mass? How will this affect its acceleration?

You Try It!

Problem: Assume that you add the weights to the trunk in **Figure above**. If you push the trunk and weights with a force of 20 N, what will be the trunk's acceleration?

Need more practice? You can find additional problems at this URL: <http://www.auburnschools.org/ajhs/lmcrowe/Week%2014/W>

Acceleration and Weight

Newton's second law of motion explains the weight of objects. Weight is a measure of the force of gravity pulling on an object of a given mass. It's the force (F) in the acceleration equation that was introduced above:

$$a = \frac{F}{m}$$

This equation can also be written as:

$$F = ma$$

×

a

The acceleration due to gravity of an object equals 9.8 m/s², so if you know the mass of an object, you can calculate its weight as:

F

=

m

×

9

.

8**m**

/

s**2**

As this equation shows, weight is directly related to mass. As an object's mass increases, so does its weight. For example, if mass doubles, weight doubles as well. You can learn more about weight and acceleration at this URL: http://www.nasa.gov/mov/192448main_018_force_equals_mass_time.mov.

Problem Solving

Problem: Daisy has a mass of 35 kilograms. How much does she weigh?

Solution: Use the formula:

F

=

m

×

9

.

8

m

/

s

2

F

=

3

5

k

g

×

9

.

8

m $/$ s 2 $=$ 3 4 3 \cdot 0 k g \cdot m $/$ s 2 $=$

3

4

3

.

0

N

You Try It!

Problem: Daisy's dad has a mass is 70 kg, which is twice Daisy's mass. Predict how much Daisy's dad weighs. Then calculate his weight to see if your prediction is correct.

Helpful Hints

The equation for calculating weight (

F

=

m

×

a

) works only when the correct units of measurement are used.

Mass must be in kilograms (kg).

Acceleration must be in m/s².

Weight (F) is expressed in kg·m/s² or in newtons (N).

Lesson Summary

Newton's second law of motion states that the acceleration of an object equals the net force acting on the object divided by the object's mass.

Weight is a measure of the force of gravity pulling on an object of a given mass. It equals the mass of the object (in kilograms) times the acceleration due to gravity (9.8 m/s²).

Lesson Review Questions

Recall

State Newton's second law of motion.

Describe how the net force acting on an object is related to its acceleration.

If the mass of an object increases, how is its acceleration affected, assuming the net force acting on the object remains the same?

What is weight?

Apply Concepts

Tori applies a force of 20 newtons to move a bookcase with a mass of 40 kg. What is the acceleration of the bookcase?

Ollie has a mass of 45 kilograms. What is his weight in newtons?

Think Critically

If you know your weight in newtons, how could you calculate your mass in kilograms? What formula would you use?

Points to Consider

Assume that a 5-kilogram skateboard and a 50-kilogram go-cart start rolling down a hill. Both are moving at the same speed. You and a friend want to stop before they plunge into a pond at the bottom of the hill.

Which will be harder to stop: the skateboard or the go-cart?

Can you explain why?

Lesson Objectives

State Newton's third law of motion.

Describe momentum and the conservation of momentum.

Lesson Vocabulary

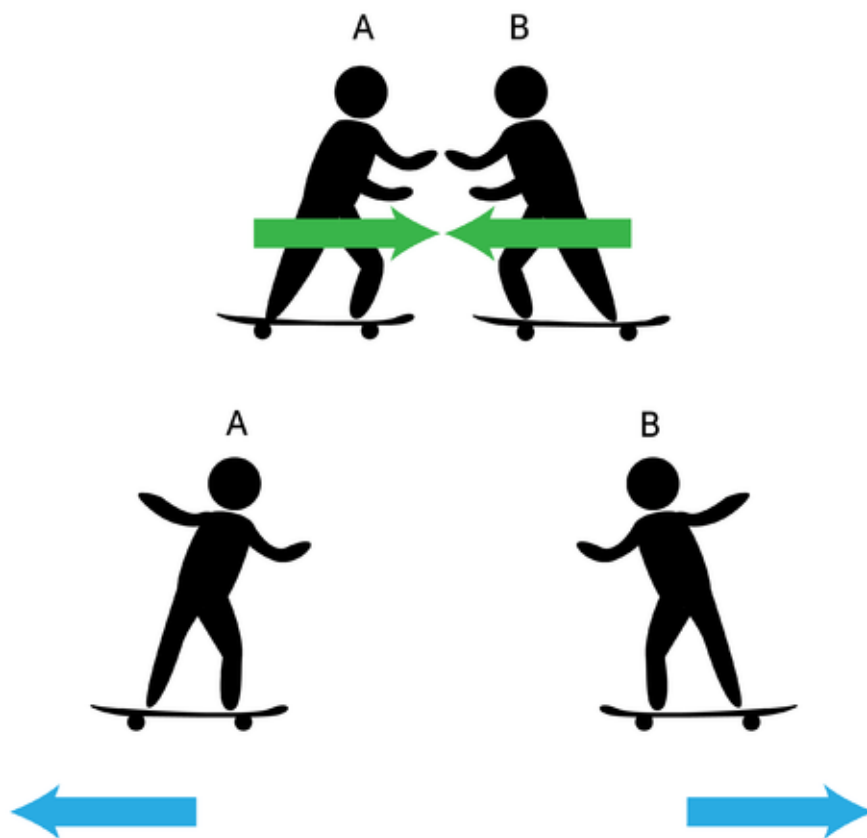
law of conservation of momentum

momentum

Newton's third law of motion

Introduction

Look at the skateboarders in **Figure below**. When they push against each other, it causes them to move apart. The harder they push together, the farther apart they move. This is an example of Newton's third law of motion.



A and B move apart by first pushing together.

Action and Reaction

Newton's third law of motion states that every action has an equal and opposite reaction. This means that forces always act in pairs. First an action occurs, such as the skateboarders pushing together. Then a reaction occurs that is equal in strength to the action but in the opposite direction. In the case of the skateboarders, they move apart, and the distance they move depends on how hard they first pushed together. You can see other examples of actions and reactions in **Figure below**. You can watch a video about actions and reactions at this URL: http://www.nasa.gov/mov/192449main_019_law_of_action.mov.



When the kangaroo pushes against the ground with its powerful hind legs, it can jump at least 10 meters (about 33 feet).

When the kayaker pushes against the water with her oar, the kayak moves forward.

When the break dancer supports his body with one hand on the floor, the floor pushes back with equal force.

When the rocket's engines thrust downward against the air, the rocket soars upward.

Each example shown here includes an action and reaction.

You might think that actions and reactions would cancel each other out like balanced forces do. Balanced forces, which are also equal and opposite, cancel each other out because they act on the same object. Action and reaction forces, in contrast, act on different objects, so they don't cancel each other out and, in fact, often result in motion. For example, in **Figure above**, the kangaroo's action acts on the ground, but the ground's reaction acts on the kangaroo. As a result, the kangaroo jumps away from the ground. One of the action-reaction examples in the **Figure above** does not result in motion. Do you know which one it is?

Momentum

What if a friend asked you to play catch with a bowling ball, like the one pictured in **Figure below**? Hopefully, you would refuse to play! A bowling ball would be too heavy to catch without risk of injury — assuming you could even throw it. That's because a bowling ball has a lot of mass. This gives it a great deal of momentum. **Momentum** is a property of a moving object that makes the object hard to stop. It equals the object's mass times its velocity. It can be represented by the equation:

$$M = m \times V$$

O
c
i
t
y

This equation shows that momentum is directly related to both mass and velocity. An object has greater momentum if it has greater mass, greater velocity, or both. For example, a bowling ball has greater momentum than a softball when both are moving at the same velocity because the bowling ball has greater mass. However, a softball moving at a very high velocity — say, 100 miles an hour — would have greater momentum than a slow-rolling bowling ball. If an object isn't moving at all, it has no momentum. That's because its velocity is zero, and zero times anything is zero.

Bowling Ball

Mass = 7.25 kg



Softball

Mass = 0.18 kg



A bowling ball and a softball differ in mass. How does this affect their momentum?

Calculating Momentum

Momentum can be calculated by multiplying an object's mass in kilograms (kg) by its velocity in meters per second (m/s). For example, assume that a golf ball has a mass of 0.05 kg. If the ball is traveling at a velocity of 50 m/s, its momentum is:

M
o
m

e
n
t
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Note that the SI unit for momentum is $\text{kg}\cdot\text{m}/\text{s}$.

Problem Solving

Problem: What is the momentum of a 40-kg child who is running straight ahead with a velocity of 2 m/s?

Solution: The child has momentum of: $40 \text{ kg} \times 2 \text{ m/s} = 80 \text{ kg}\cdot\text{m}/\text{s}$.

You Try It!

Problem: Which football player has greater momentum?

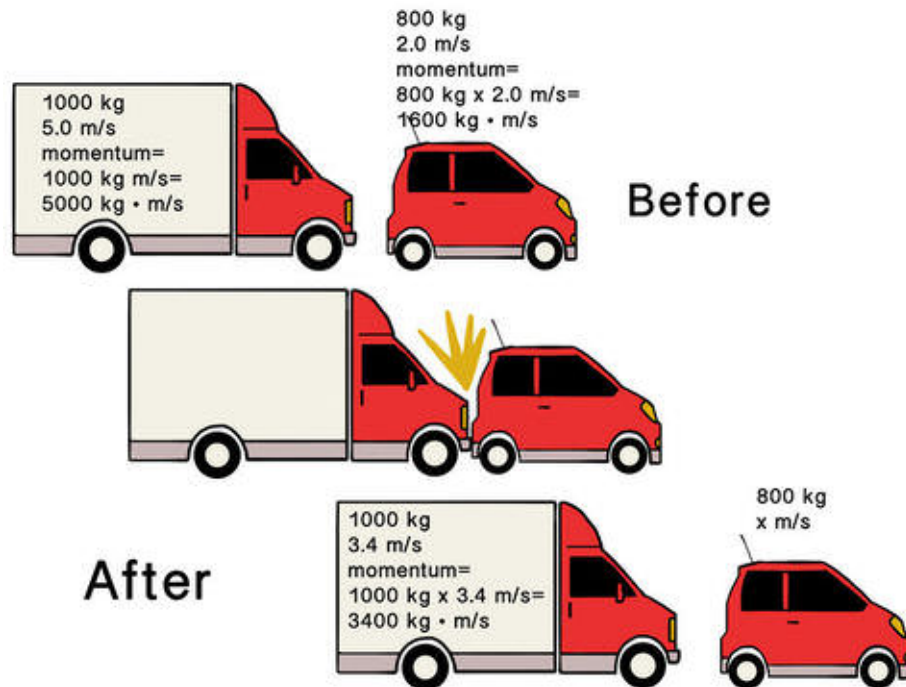
Player A: mass = 60 kg; velocity = 2.5 m/s

Player B: mass = 65 kg; velocity = 2.0 m/s

Conservation of Momentum

When an action and reaction occur, momentum is transferred from one object to the other. However, the combined momentum of the objects remains the same. In other words, momentum is conserved. This is the **law of conservation of momentum**.

Consider the example of a truck colliding with a car, which is illustrated in **Figure below**. Both vehicles are moving in the same direction before and after the collision, but the truck is moving faster than the car before the collision occurs. During the collision, the truck transfers some of its momentum to the car. After the collision, the truck is moving slower and the car is moving faster than before the collision occurred. Nonetheless, their combined momentum is the same both before and after the collision. You can see an animation showing how momentum is conserved in a head-on collision at this URL: <http://www.physicsclassroom.com/mmedia/momentum/cthoi.cfm>.



How can you tell momentum has been conserved in this collision?

Lesson Summary

Newton's third law of motion states that every action has an equal and opposite reaction.

Momentum is a property of a moving object that makes it hard to stop. It equals the object's mass times its velocity. When an action and reaction occur, momentum may be transferred from one object to another, but their combined momentum remains the same. This is the law of conservation of momentum.

Lesson Review Questions

Recall

State Newton's third law of motion.

Define momentum.

If you double the velocity of a moving object, how is its momentum affected?

Apply Concepts

A large rock has a mass of 50 kg and is rolling downhill at 3 m/s. What is its momentum?

Create a diagram to illustrate the transfer and conservation of momentum when a moving object collides with a stationary object.

Think Critically

The reaction to an action is an equal and opposite force. Why doesn't this yield a net force of zero?

Momentum is a property of an object, but it is different than a physical or chemical property, such as boiling point or flammability. How is momentum different?

Points to Consider

In this chapter, you learned about forces and motions of solid objects, such as balls and cars. In the next chapter,

"Fluid Forces," you will learn about forces in fluids, which include liquids and gases.

How do fluids differ from solids?

What might be examples of forces in fluids? For example, what force allows some objects to float in water?

6

CHAPTER 7

Chapter 7 - Forces that Change the Earth

Chapter Outline

- 7.1 CHAPTER 7 GUIDED QUESTIONS
 - 7.2 THEORY OF PLATE TECTONICS
 - 7.3 CONTINENTAL DRIFT
 - 7.4 EARTH'S TECTONIC PLATES
 - 7.5 TECTONIC PLATE MOTIONS
 - 7.6 TRANSFORM PLATE BOUNDARIES
 - 7.7 EARTHQUAKES AT TRANSFORM PLATE BOUNDARIES
 - 7.8 DIVERGENT PLATE BOUNDARIES
 - 7.9 DIVERGENT PLATE BOUNDARIES IN THE OCEANS
 - 7.10 CONTINENT-CONTINENT CONVERGENT PLATE BOUNDARIES
 - 7.11 EARTHQUAKES AT CONVERGENT PLATE BOUNDARIES
 - 7.12 VOLCANOES AT PLATE BOUNDARIES
 - 7.13 OCEAN-CONTINENT CONVERGENT PLATE BOUNDARIES
 - 7.14 OCEAN-OCEAN CONVERGENT PLATE BOUNDARIES
 - 7.15 TOPOGRAPHIC MAPS
 - 7.16 REFERENCES
-

7.1 Chapter 7 Guided Questions

Chapter 7: Guided Questions

- Explain what Pangaea was.
-
- Describe seafloor spreading.
-
- How do mountains form along the mid- ocean ridge?
-
- Explain what causes continents to move over Earth's surface?
-
- Explain a convergent boundary and the crustal features that form.
-
- Explain a divergent boundary and the crustal features that form.
-
- Explain a transform boundary and the crustal features that form.
-
- How and why are topographic maps utilized and by whom?
-
- Why do the V-shaped contours indicate that a stream points uphill?
-
- What is the difference between elevation and relief?

7.2 Theory of Plate Tectonics

- Explain the theory of plate tectonics theory.
- Describe how plate tectonics leads to existence of supercontinents such as Pangaea.



What would Wegener think?

Like any great theory, plate tectonics makes a tremendous amount of sense. The whole story fits together so perfectly. Wegener had so much evidence that the continents had once been joined. Seafloor spreading is a perfect mechanism for moving those continents. It's really too bad that Alfred Wegener is not here to learn about the theory of plate tectonics. It seems certain that he would be ecstatic!

Plate Tectonics Theory

The theory of plate tectonics is what brings together continental drift and seafloor spreading. Plates are made of lithosphere topped with oceanic and/or continental crust. The plates are moved around on Earth's surface by seafloor spreading. Convection in the mantle drives seafloor spreading. Oceanic crust is created at mid-ocean ridges. The crust moves outward from the ridge over time. The crust may eventually sink into the mantle and be destroyed. If a continent sits on a plate with a mid-ocean ridge, the continent will be pushed along.

Plate Boundaries

Two plates meet at a **plate boundary**. There are three types of plate boundaries since there are three ways that plates can meet. Plates can move away from each other. They can move toward each other. Finally, they can slide past each other. The three types of plate boundaries are divergent, convergent, and transform. They are described in the following three concepts.

Most geological activity takes place at plate boundaries. This activity includes volcanoes, earthquakes, and mountain building. The activity occurs as plates interact. Giant slabs of lithosphere moving around can create a lot of activity! The features seen at a plate boundary are determined by the direction of plate motion and by the type of crust found at the boundary.

What the Theory Explains

The theory of plate tectonics explains most of the features of Earth's surface. It explains why earthquakes, volcanoes and mountain ranges are where they are. It explains where to find some mineral resources. Plate tectonics is the key that unlocks many of the mysteries of our amazing planet. Plate tectonics theory explains why:

- Earth's geography has changed over time and continues to change today.
- some places are prone to earthquakes while others are not.
- certain regions may have deadly, mild, or no volcanic eruptions.
- mountain ranges are located where they are.
- many ore deposits are located where they are.
- living and fossil species of plants and animals are found where they are.
- some continental margins have a lot of geological activity, and some have none.

Plate tectonic motions affect Earth's rock cycle, climate, and the evolution of life.

Summary

- The theory of plate tectonics brings together continental drift and seafloor spreading.
- At a plate boundary, two plates can be moving apart, together or past each other.
- Plate tectonics theory explains many things in geology, such as where volcanoes, earthquakes, mountain ranges, ore deposits, and other features are located.

Explore More

Use the resource below to answer the questions that follow.

- **Plate Tectonics** at http://www.youtube.com/watch?v=nfziy_860GU (3:27)



MEDIA

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/58936>

1. Where is the Cascade Range found?

2. What does the Cascade Range include?
3. What formed the Cascade mountains?
4. What is a plate boundary?
5. List the three ways plates interact.
6. What is subduction?
7. What is the Ring of Fire?
8. What do colliding plates form?

Review

1. What is a plate boundary?
2. What three interactions can plates have? These are the three major types of plate boundaries.
3. In general, what does the theory of plate tectonics explain?

7.3 Continental Drift

Key Concepts

- Idea of continental drift
- Evidence for continental drift

Lesson Objectives

- Be able to explain the continental drift hypothesis.
- Describe the evidence Wegener used to support his continental drift idea.
- Describe how the north magnetic pole appeared to move and how that is evidence for continental drift.

Lesson Vocabulary

- **continental drift:** early 20th century hypothesis that the continents move over Earth's surface
- **magnetic field:** area surrounding a magnet over which it exerts magnetic force

Teaching Strategies

Introducing the Lesson

Show students a map of the world. Ask them if the continents have always been where they are now. Students may think that the continents are unmoving. They may be surprised when you tell them that the continents used to be in very different positions millions of years ago. Have them look at the map of Pangaea in the FlexBook® student edition lesson, and explain that this is how Earth looked about 250 million years ago. Tell them they will see evidence for it when they read this lesson.

Demonstration

Demonstrate continental drift to the class with the animation at the URL below. The animation shows the movement of the continents over the past 250 million years, starting at the time of the dinosaurs, when all of today's continents formed the supercontinent Pangaea. Students can watch as Pangaea breaks apart and the continents move to their present positions. Point out how quickly India travels toward Asia near the end of the animation at about 60 million years ago. Explain that when the two landmasses collided, the collision formed the Himalaya Mountains.

http://www.tectonics.caltech.edu/outreach/animations/anim_pangaea/Resources/anim_pangaea.mov

Building Science Skills

You may want to use the lesson plan at the following URL when you teach students about Wegener's hypothesis and the evidence that supports it. Students will follow steps similar to those taken by Wegener to examine fossil evidence

for continental drift. They will map the locations of fossils and discuss how well the fossil evidence supports the hypothesis.

<http://www.discoveryeducation.com/teachers/free-lesson-plans/continental-drift.cfm>

Differentiated Instruction

Provide kinesthetic learners with cutouts of the continents (see URL below). Have them try to fit the continents together to form the supercontinent Pangaea. Tell them to look at the map of Pangaea in the FlexBook® student edition lesson if they need help. In simple terms, relate the puzzle to the hypothesis of continental drift. Ask students how the shapes of the continents help support the hypothesis.

<http://www.williamsclass.com/SixthScienceWork/PangeaProject.htm>

Enrichment

Assign interested students the self-paced lesson “Continental Drift: What’s the Big Idea?” at the URL below. The online lesson, which reviews and extends FlexBook® content, includes a video and reading passage, as well as several quizzes. As a final assignment, students are asked to choose one of two topics and write an essay that includes supporting details and vocabulary from the lesson. Ask students to read their essay to the class.

<http://www.teachersdomain.org/resource/midlit10.sci.splwegener/>

Science Inquiry

You can use the “Great Continental Drift Mystery” at the following URL when you teach the lesson. It allows students to explore and interpret a diversity of evidence for continental drift. Students will study and draw maps and add clues to maps as they try to solve the mystery.

<http://www.yale.edu/ynhti/curriculum/units/1991/6/91.06.05.x.html>

Common Misconceptions

Students may have many misconceptions about continental drift. For example, they may think that continents drift because they float on the oceans. This and other misconceptions about continental drift are discussed at the URL below. The Web site also provides links to multi-media materials you can use to counter the misconceptions.

<http://sci-misconceptions.wikispaces.com/>

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Earth Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook® student edition.

Lesson Quiz

Check students' mastery of the lesson with Lesson 6.2 Quiz in *CK-12 Earth Science for Middle School Quizzes and Tests*.

Points to Consider

Why is continental drift referred to as a hypothesis and not a theory?

Why is Wegener's continental drift idea accepted today?

Explain how each of these phenomena can be used as evidence for continental drift:

- the fit of the continents

 - the distribution of fossils

 - the distribution of similar rock types

 - rocks from ancient climate zones

7.4 Earth's Tectonic Plates

- Describe tectonic plates and how they move.



“With such wisdom has nature ordered things in the economy of this world, that the destruction of one continent is not brought about without the renovation of the earth in the production of another.” —James Hutton, *Theory of the Earth, with Proofs and Illustrations, Vol. 1*, 1795.

Hutton’s quote predates plate tectonics theory by about one-and-a-half centuries, but it seems as if he was talking about divergent and convergent plate boundaries. The next step in understanding the development of plate tectonics theory is to learn what it is that moves around on Earth’s surface. It’s not really a continent; it’s a plate. What is a plate?

What is a Plate?

What portion of Earth makes up the “plates” in plate tectonics? Again, the answer came about in part due to war. In this case, the Cold War.

During the 1950s and early 1960s, scientists set up seismograph networks to see if enemy nations were testing atomic bombs. These seismographs also recorded all of the earthquakes around the planet. The seismic records were used to locate an earthquake’s **epicenter**, the point on Earth’s surface directly above the place where the earthquake occurs.

Why is this relevant? It turns out that earthquake epicenters outline the plates. This is because earthquakes occur everywhere plates come into contact with each other.

Preliminary Determination of Epicenters 358,214 Events, 1963 - 1998

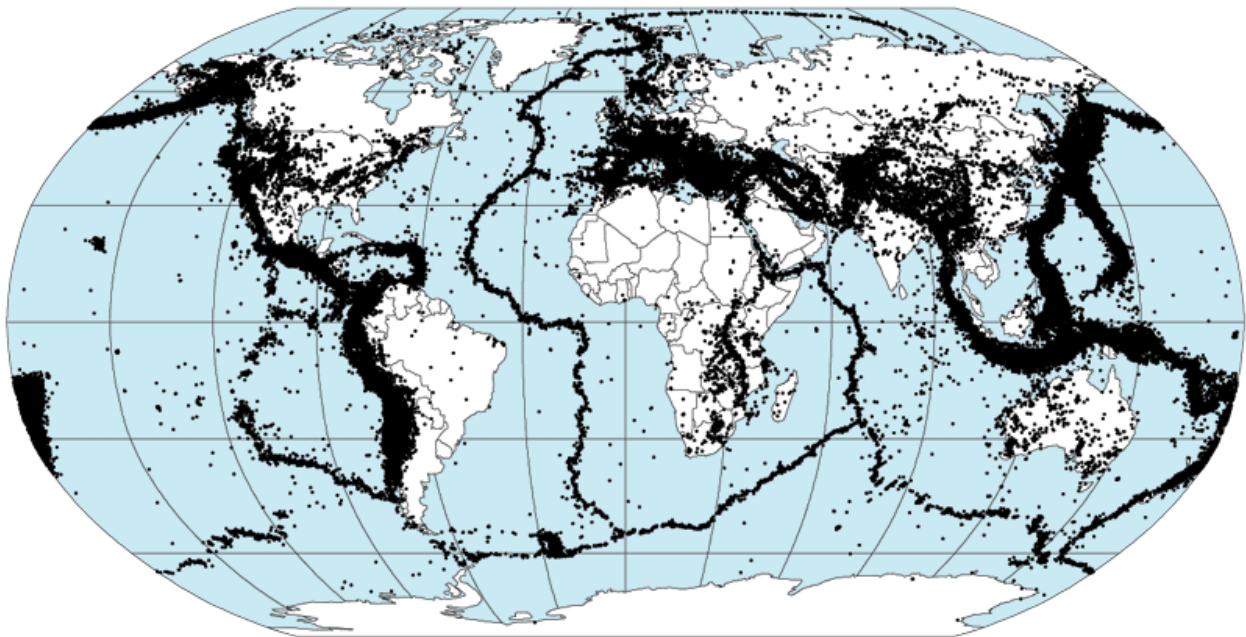


FIGURE 7.1

Earthquakes outline the plates.

The lithosphere is divided into a dozen major and several minor plates (**Figure 7.1**). A single plate can be made of all oceanic lithosphere or all continental lithosphere, but nearly all plates are made of a combination of both.

The movement of the plates over Earth’s surface is termed **plate tectonics**. Plates move at a rate of a few centimeters a year, about the same rate fingernails grow.

How Plates Move

If seafloor spreading drives the plates, what drives seafloor spreading?

This goes back to Arthur Holmes’ idea of mantle convection. Picture two convection cells side by side in the mantle,

similar to the illustration in **Figure 7.2**.

1. Hot mantle from the two adjacent cells rises at the ridge axis, creating new ocean crust.
2. The top limb of the convection cell moves horizontally away from the ridge crest, as does the new seafloor.
3. The outer limbs of the convection cells plunge down into the deeper mantle, dragging oceanic crust as well. This takes place at the deep sea trenches.
4. The material sinks to the core and moves horizontally.
5. The material heats up and reaches the zone where it rises again.

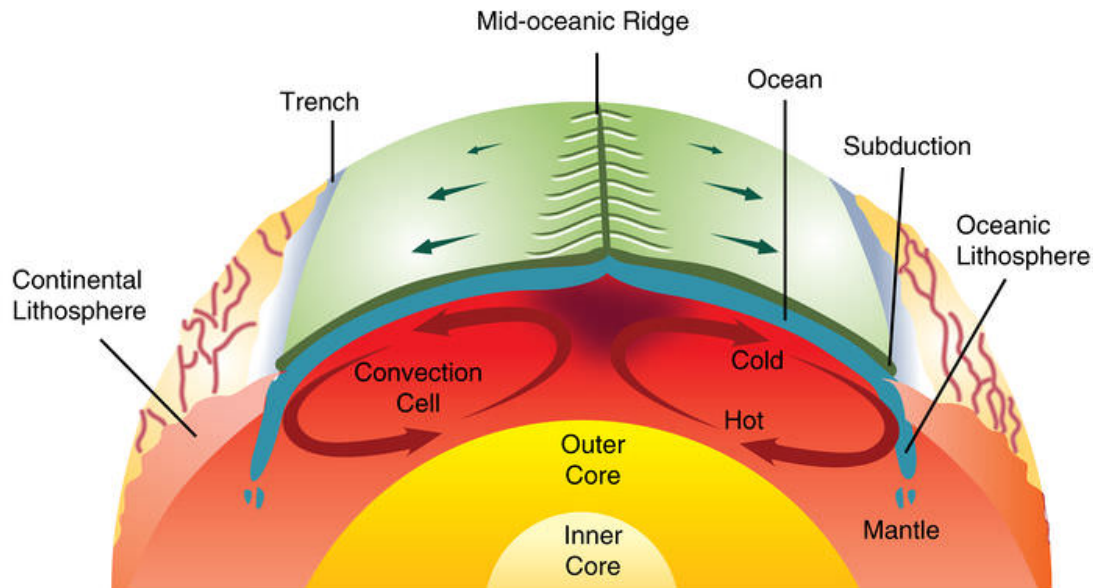


FIGURE 7.2

Mantle convection drives plate tectonics. Hot material rises at mid-ocean ridges and sinks at deep sea trenches, which keeps the plates moving along the Earth's surface.

Mantle convection is shown in these animations:

- http://www.youtube.com/watch?v=p0dWF_3PYh4
- http://earthguide.ucsd.edu/eoc/teachers/t_tectonics/p_convection2.html

Plate Boundaries

Plate boundaries are the edges where two plates meet. How can two plates move relative to each other? Most geologic activities, including volcanoes, earthquakes, and mountain building, take place at plate boundaries. The features found at these plate boundaries are the mid-ocean ridges, trenches, and large transform faults (**Figure 7.3**).

- **Divergent plate boundaries:** the two plates move away from each other.
- **Convergent plate boundaries:** the two plates move towards each other.

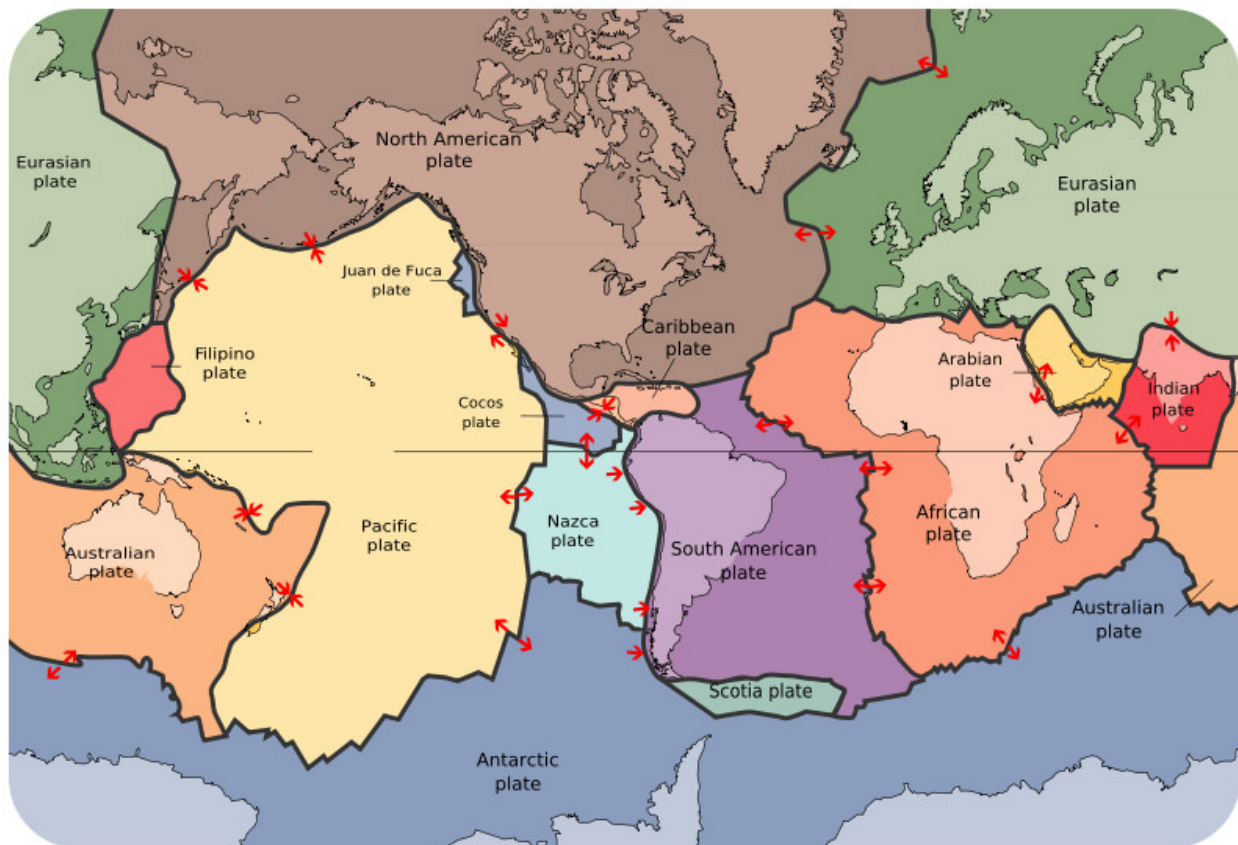


FIGURE 7.3

The lithospheric plates and their names. The arrows show whether the plates are moving apart, moving together, or sliding past each other.

- **Transform plate boundaries:** the two plates slip past each other.

The type of plate boundary and the type of crust found on each side of the boundary determines what sort of geologic activity will be found there. We can visit each of these types of plate boundaries on land or at sea.

Summary

- The plate in plate tectonics is a large chunk of lithosphere that can carry continental crust, oceanic crust, or some of each.
- Plates can be identified by the locations of earthquake epicenters. At the boundaries of plates are mid-ocean ridges, trenches, and large faults.
- Plates move by seafloor spreading, which is driven by mantle convection.
- Plates meet at plate boundaries. The three types are divergent, convergent, and transform.

Making Connections



MEDIA

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/55145>

Explore More

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=1-HwPR_4mP4

1. How many types of plate boundaries are there? What are they?
2. Why didn't Wegener know about divergent plate boundaries?
3. What is happening at the Mid Atlantic Ridge?
4. What happens at a convergent plate boundary? What types of plates can meet up at convergent boundaries?
5. What happens at a transform boundary?
6. What three catastrophic effects can happen where plates move past each other?

Review

1. How does the topography of the seafloor give evidence for seafloor spreading?
2. How does seafloor spreading fit into the idea that continents move about on Earth's surface?
3. How do convection cells drive the plates around Earth's surface?
4. What are the three types of plate boundaries?

7.5 Tectonic Plate Motions

- Describe how plates move.
- Explain a convection cell.
- Describe seafloor spreading.



What is tectonics?

Dividing the lithosphere into plates is one thing. Having the plates move around on the planet is another! A conveyor belt is a good analogy for how a plate moves. How the plates move and where they move is the "tectonics" part of plate tectonics.

Plate Motions

Scientists have determined the direction that each plate is moving (**Figure 7.4**). Plates move around the Earth's surface at a rate of a few centimeters a year. This is about the same rate that fingernails grow.

How Plates Move

Convection within the Earth's mantle causes the plates to move. Mantle material is heated above the core. The hot mantle rises up toward the surface (**Figure 7.5**). As the mantle rises, it cools. At the surface, the material moves horizontally away from a mid-ocean ridge crest. The material continues to cool. It sinks back down into the mantle at a deep sea trench. The material sinks back down to the core. It moves horizontally again, completing a **convection cell**.

Seafloor spreading takes place as plates move apart from each other at a mid-ocean ridge. Mantle convection drives seafloor spreading.

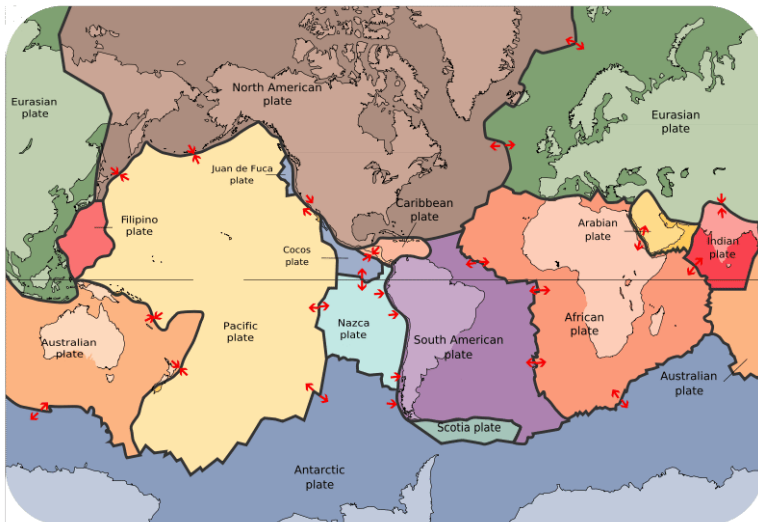


FIGURE 7.4

Earth's plates are shown in different colors. Arrows show the direction the plate is moving.

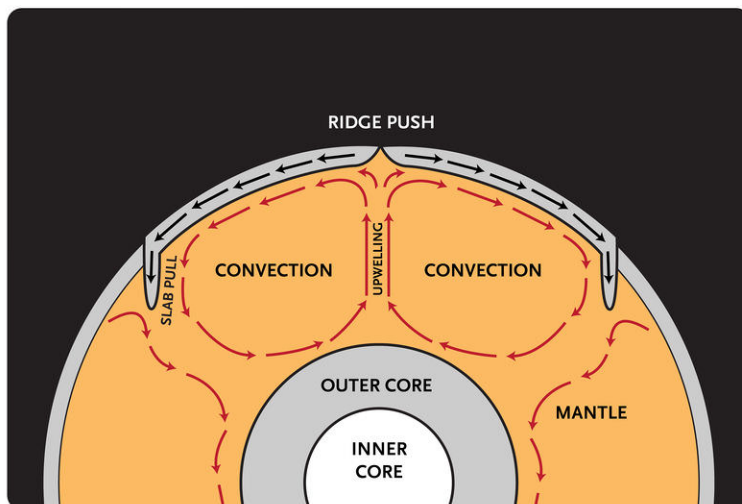


FIGURE 7.5

Plates move for two reasons. Upwelling mantle at the mid-ocean ridge pushes plates outward. Cold lithosphere sinking into the mantle at a subduction zone pulls the rest of the plate down with it.

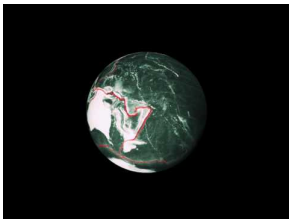
Summary

- Plates move by seafloor spreading
- Seafloor spreading is driven by mantle convection.
- Plates move as if on a conveyor belt.

Explore More

Use the resource below to answer the questions that follow.

- **Tectonic Plate Movement** at <http://www.youtube.com/watch?v=prfgw8uKXA8> (3:18)



MEDIA

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/58934>

1. What would the Earth look like without the biosphere and atmosphere?
2. What are plates?
3. How fast are the plates moving?
4. What happens at the ridges?
5. What are subduction zones?
6. What heats Earth's interior?

Review

1. Describe how convection takes place in the mantle.
2. How does mantle convection cause seafloor spreading?
3. How does seafloor spreading move plates?

7.6 Transform Plate Boundaries

- Describe the activity and features of transform plate boundaries on land and in the ocean.



What could cause such an enormous scar on the land?

A transform plate boundary! As we continue up the West Coast, we move from a divergent plate boundary to a transform plate boundary. As in Iceland, where we could walk across a short bridge connecting two continental plates, we could walk from the Pacific Plate to the North American plate across this transform plate boundary. In this image, the San Andreas Fault across central California is the gash that indicates the plate boundary.

Transform Plate Boundaries

With transform plate boundaries, the two slabs of lithosphere are sliding past each other in opposite directions. The boundary between the two plates is a **transform fault**.

Transform Faults On Land

Transform faults on continents separate two massive plates of lithosphere. As they slide past each other, they may have massive earthquakes.

The San Andreas Fault in California is perhaps the world's most famous transform fault. Land on the west side is moving northward relative to land on the east side. This means that Los Angeles is moving northward relative to Palm Springs. The San Andreas Fault is famous because it is the site of many earthquakes, large and small. (**Figure 7.6**).

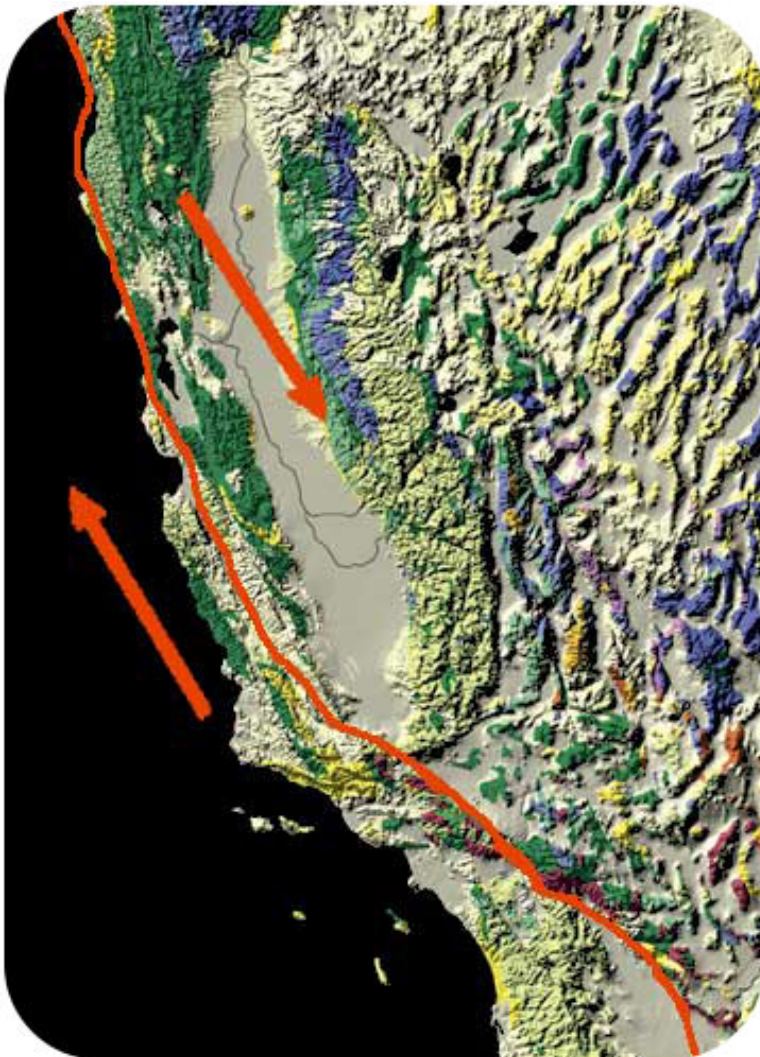


FIGURE 7.6

At the San Andreas Fault in California, the Pacific Plate is sliding northeast relative to the North American plate, which is moving southwest. At the northern end of the picture, the transform boundary turns into a subduction zone.

Transform plate boundaries are also found in the oceans. They divide mid-ocean ridges into segments. In the diagram of western North America, the mid-ocean ridge up at the top, labeled the Juan de Fuca Ridge, is broken apart by a transform fault in the oceans. A careful look will show that different plates are found on each side of the

ridge: the Juan de Fuca plate on the east side and the Pacific Plate on the west side.

Summary

- A transform plate boundary divides two plates that are moving in opposite direction from each other.
- On land, transform faults are the site of massive earthquakes because they are where large slabs of lithosphere slide past each other.
- Transform faults in the oceans break mid-ocean ridges into segments.

Making Connections



MEDIA

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/59085>

Explore More

Use the resource below to answer the questions that follow.

- **Transform Plate Boundaries** at

<http://www.learner.org/interactives/dynamicearth/slip3.html>

1. Describe the motion of transform plate boundaries.
2. What is a fault?
3. What do transform plate boundaries produce?
4. Explain a strike-slip fault.
5. What is the best studied fault?
6. What two plates make this boundary?
7. Which direction are each of these plates moving?

Review

1. What is the direction of plate motion at a transform plate boundary?
2. Why are transform faults on continents prone to massive earthquakes?
3. How do transform faults in the oceans compare with those on land?

7.7 Earthquakes at Transform Plate Boundaries

- Describe earthquakes that take place at transform plate boundaries.



Would you like to live in San Francisco?

Lots of people live in California for the weather. Transplants from snowy climates think they've found paradise in the state's warm sunshine. What if you got your dream job in San Francisco? Would you take it? Are you afraid enough of the region's potential for large earthquakes that you wouldn't? Look at the map of faults in the Bay Area (**Figure 7.7**) before you decide.

Transform Plate Boundaries

Deadly earthquakes occur at transform plate boundaries. Transform faults have shallow focus earthquakes. Why do you think this is so?

California

As you learned in the chapter Plate Tectonics, the boundary between the Pacific and North American plates runs through much of California as the San Andreas Fault zone. As you can see in the (Figure 7.7), there is more than just one fault running through the area. There is really a fault zone. The San Andreas Fault runs from south to north up the peninsula, through San Francisco, gets through part of Marin north of the bay, and then goes out to sea. The other faults are part of the fault zone, and they too can be deadly.

The faults along the San Andreas Fault zone produce around 10,000 earthquakes a year. Most are tiny, but occasionally one is massive. In the San Francisco Bay Area, the Hayward Fault was the site of a magnitude 7.0 earthquake in 1868. The 1906 quake on the San Andreas Fault had a magnitude estimated at about 7.9 (Figure 7.7). About 3,000 people died and 28,000 buildings were lost, mostly in the fire that followed the earthquake.

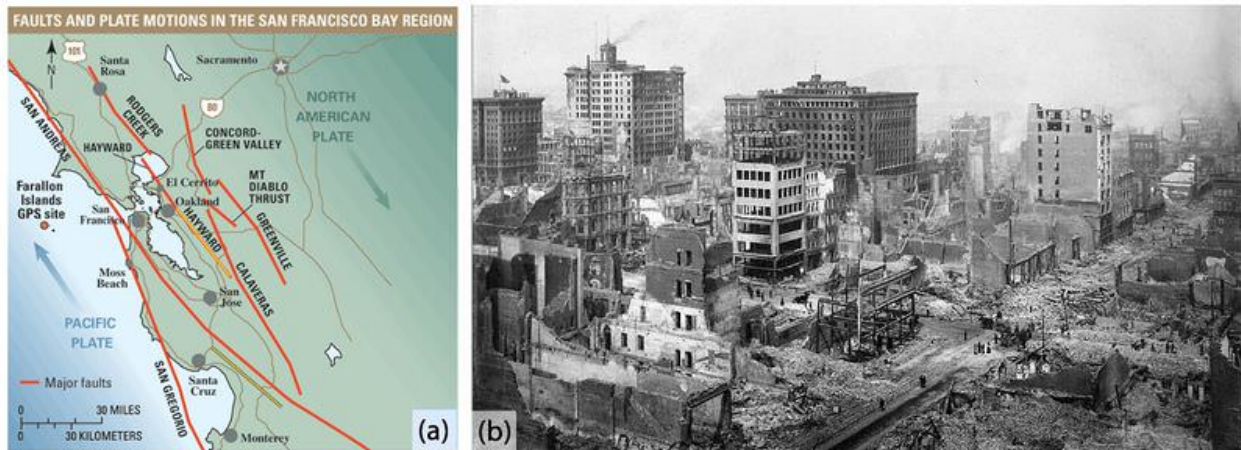


FIGURE 7.7

(a) The San Andreas Fault zone in the San Francisco Bay Area. (b) The 1906 San Francisco earthquake is still the most costly natural disaster in California history.

Recent California earthquakes occurred in:

- 1989: Loma Prieta earthquake near Santa Cruz, California. Magnitude 7.1 quake, 63 deaths, 3,756 injuries, 12,000+ people homeless, property damage about \$6 billion.
- 1994: Northridge earthquake on a blind thrust fault near Los Angeles. Magnitude 6.7, 72 deaths, 12,000 injuries, damage estimated at \$12.5 billion.

In this video, the boundaries between three different tectonic plates and the earthquakes that result from their interactions are explored: <http://www.youtube.com/watch?v=upEh-1DpLMg> (1:59).



MEDIA

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/1420>

New Zealand

New Zealand also has a transform fault with strike-slip motion, causing about 20,000 earthquakes a year! Only a small percentage of those are large enough to be felt. A 6.3 quake in Christchurch in February 2011 killed about 180 people.

Summary

- Transform fault earthquakes have shallow focus because the plates meet near the surface.
- The San Andreas Fault is actually a fault zone made up of a number of other active faults.
- New Zealand also has a transform plate boundary.

Explore More

Use these resources to answer the questions that follow.

<https://www.youtube.com/watch?v=DDtqbwGwQGE>

1. Where does the San Andreas Fault go offshore in the north? Where does it begin in the south?
2. Where is the most dangerous part of the San Andreas?
3. What is the Carizzo Plain expression of the San Andreas Fault like? Why is it so visible there?
4. He says the largest oceanic plate in the world is stitched to the continental plate. Which plates is he referring to and what type of lithosphere meets on each side of the fault?
5. What does Wallace Creek do at the fault?
6. Why was Daly City a dangerous place to build houses?
7. In the Bay Area what does the fault do that's dangerous for the future?
8. How are scientists mapping the San Andreas in the northern region?
9. Did developers know where the San Andreas Fault went when they built the community of San Bruno?

Review

1. Why are earthquakes at convergent plate boundaries sometimes deep, while those at transform plate boundaries are always shallow?
2. Are the earthquakes that take place along the other faults in the San Andreas Fault Zone always smaller than the earthquakes that take place on the San Andreas Fault itself?
3. Do you expect that the quiet along the San Andreas Fault near San Francisco since 1906 means that earthquake activity is calming down along that plate boundary? What does it mean and why?

7.8 Divergent Plate Boundaries

- Describe the activity and features of divergent plate boundaries on land.



What can we see in Western North America?

When we got off the Atlantis in Iceland a new batch of scientists got on for a different scientific investigation. We're now going to fly to western North America to see a different set of plate tectonic features. Western North America has all three of the different types of plate boundaries and the features that are seen at them.

Tectonic Features of Western North America

We're on a new trip now. We will start in Mexico, in the region surrounding the Gulf of California, where a divergent plate boundary is rifting Baja California and mainland Mexico apart. Then we will move up into California, where plates on both sides of a transform boundary are sliding past each other. Finally we'll end up off of the Pacific Northwest, where a divergent plate boundary is very near a subduction zone just offshore.

In the **Figure 7.8** a red bar where seafloor spreading is taking place. A long black line is a transform fault and a black line with hatch marks is a trench where subduction is taking place. Notice how one type of plate boundary transitions into another.

Plate Divergence on Land

A divergent plate boundary on land rips apart continents (**Figure 7.9**).

In **continental rifting**, magma rises beneath the continent, causing it to become thinner, break, and ultimately split apart. New ocean crust erupts in the void, ultimately creating an ocean between continents. On either side of the ocean are now two different lithospheric plates. This is how continents split apart.

These features are well displayed in the East African Rift, where rifting has begun, and in the Red Sea, where water is filling up the basin created by seafloor spreading. The Atlantic Ocean is the final stage, where rifting is now separating two plates of oceanic crust.


FIGURE 7.8

This map shows the three major plate boundaries in or near California.

Baja California

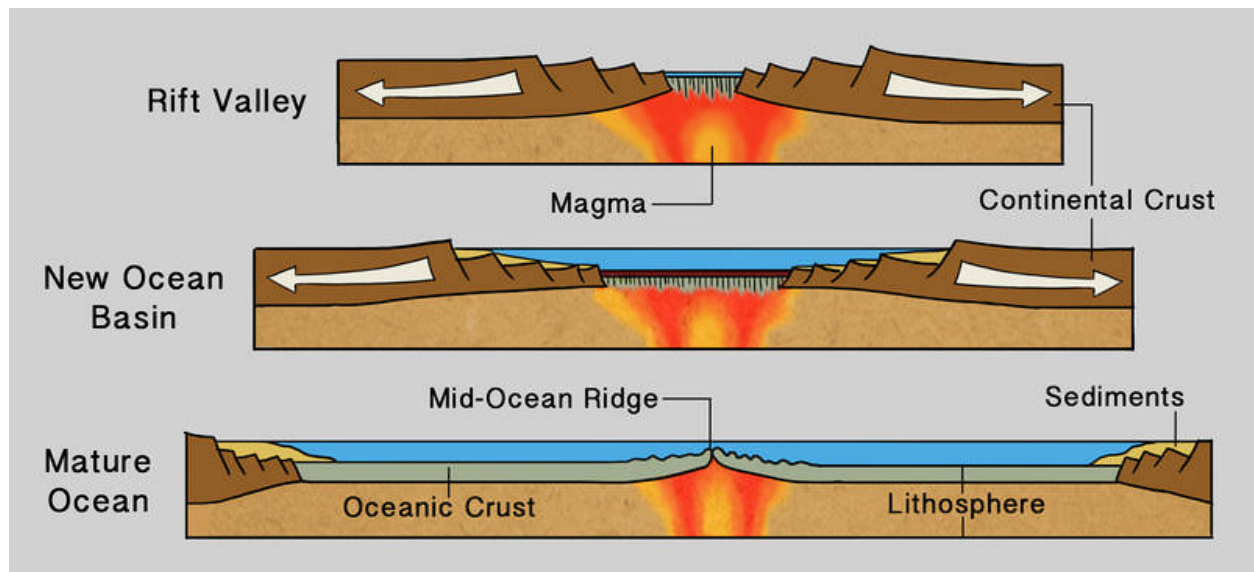
Baja California is a state in Mexico just south of California. In the **Figure 7.10**, Baja California is the long, skinny land mass on the left. You can see that the Pacific Ocean is growing in between Baja California and mainland Mexico. This body of water is called the Gulf of California or, more romantically, the Sea of Cortez. Baja is on the Pacific Plate and the rest of Mexico is on the North American Plate. Extension is causing the two plates to move apart and will eventually break Baja and the westernmost part of California off of North America. The Gulf of California will expand into a larger sea.

Rifting has caused volcanic activity on the Baja California peninsula as seen in the **Figure 7.11**.

Can you relate what is happening at this plate boundary to what happened when Pangaea broke apart?

Summary

- Where continental rifting takes place, continents are split apart and an ocean may grow or be created between the two new plates.
- Baja California is rifting apart from mainland Mexico.
- Continental rifting can create major ocean basins, like the Atlantic.

**FIGURE 7.9**

When plate divergence occurs on land, the continental crust rifts, or splits. This effectively creates a new ocean basin as the pieces of the continent move apart.

Making Connections



MEDIA

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/55492>

Explore More

Use this resource to answer the questions that follow.

<http://www.cotf.edu/ete/modules/msese/earthsysfr/plates3.html>

1. What are divergent boundaries?
2. Which layer is pulled apart?
3. What occurs along the faults on land?
4. What results when the magma reaches the surface?
5. List examples of rift valleys on land.

Review

1. How is a divergent plate boundary on land different from one in the ocean?



FIGURE 7.10

Baja California is rifting apart from mainland Mexico, as seen in this satellite image.

2. What is happening to the Baja California peninsula?
3. How did continental rifting play into the breakup of Pangaea?

**FIGURE 7.11**

Volcanism in Baja California is evidence of rifting.

7.9 Divergent Plate Boundaries in the Oceans

- Describe the activity and features of divergent plate boundaries in the ocean and on land.



How could you walk between two plates?

On a bridge! Let's get off the Atlantis in Iceland. It's good to feel solid ground beneath our feet again! While in Iceland we'll take a walk on Leif the Lucky Bridge. Why did we sail across the ocean for this? Iceland is one place where a mid-ocean ridge is found above sea level.

Plate Divergence in the Ocean

Iceland provides us with a fabulous view of a mid-ocean ridge above sea level (**Figure 7.12**) As you can see, where plates diverge at a mid-ocean ridge is a rift valley that marks the boundary between the two plates. Basalt lava erupts into that rift valley and forms new seafloor. Seafloor on one side of the rift is part of one plate and seafloor on the other side is part of another plate.

Leif the Lucky Bridge straddles the divergent plate boundary. Look back at the photo at the top. You may think that the rock on the left side of the valley looks pretty much like the rock on the right side. That's true –it's all basalt and it even all has the same magnetic polarity. The rocks on both sides are extremely young. What's different is that the rock one side of the bridge is the youngest rock of the North American Plate while the rock on the other side is the youngest rock on the Eurasian plate.

This is a block diagram of a divergent plate boundary. Remember that most of these are on the seafloor and only in Iceland do we get such a good view of a divergent plate boundary in the ocean.

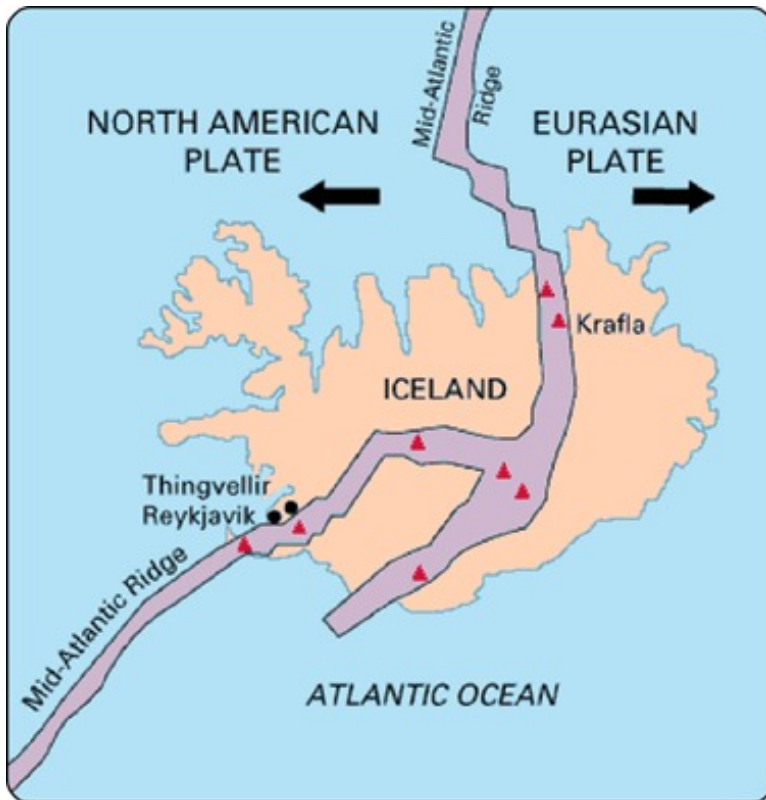


FIGURE 7.12

Iceland is the one location where the ridge is located on land: the Mid-Atlantic Ridge separates the North American and Eurasian plates

Convection Cells at Divergent Plate Boundaries

Remember that the mid-ocean ridge is where hot mantle material upwells in a convection cell. The upwelling mantle melts due to pressure release to form lava. Lava flows at the surface cool rapidly to become basalt, but deeper in the crust, magma cools more slowly to form gabbro. The entire ridge system is made up of igneous rock that is either extrusive or intrusive. The seafloor is also igneous rock with some sediment that has fallen onto it.

Earthquakes are common at mid-ocean ridges since the movement of magma and oceanic crust results in crustal shaking.

USGS animation of divergent plate boundary at mid-ocean ridge: http://earthquake.usgs.gov/learn/animations/animation.php?flash_title=Divergent+Boundary&flash_file=divergent&flash_width=500&flash_height=200 .

Divergent plate boundary animation: http://www.iris.edu/hq/files/programs/education_and_outreach/aotm/11/AOTM_09_01_Divergent_480.mov .

Summary

- Oceanic plates diverge at mid-ocean ridges. New seafloor is created in the rift valley between the two plates.
- Lava cools to form basalt at the top of the seafloor. Deeper in the crust the magma cools more slowly to form gabbro.
- Iceland is a location where we can see a mid-ocean ridge above sea level.

Making Connections

**MEDIA**

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/81167>

Explore More

Use this resource to answer the questions that follow.

<https://www.khanacademy.org/science/cosmology-and-astronomy/earth-history-topic/plate-tectonics/v/plate-tectonics—geological-features-of-divergent-plate-boundaries>

1. What happens at divergent plate boundaries?
2. What happens in the early stages of a divergent plate boundary?
3. The speaker makes a mistake at around 1:20 in the video. What is it?
4. Be aware that when the speaker is talking about hotspots he referring to places that are hot, not a hotspot like Hawaii. What happens to the material that is hot?
5. How does the hot material break through the lithosphere?
6. What forms first as the crust pulls apart? What is a famous example of this?
7. What is the Red Sea?
8. When the rift valley is submerged what is it called?
9. How does an ocean like the Atlantic form?

Review

1. What is the direction of plate motion at a divergent plate boundary?
2. Describe the relationship between the convection cell and volcanism at the mid-ocean ridge.
3. Why is the Leif the Lucky bridge so interesting?

7.10 Continent-Continent Convergent Plate Boundaries

- Describe continent-continent convergent plate boundaries.
- Explain how mountains are formed.



What do you see at a continent-continent convergent plate boundary?

Big mountains! The best place to see two continental plates converging is in the Himalaya Mountains. These mountains are the highest above sea level on Earth. They are very popular with mountain climbers.

Continent-Continent Convergence

Another type of **convergent plate boundary** is when two continental plates collide. Continental lithosphere is low in density and very thick. Continental lithosphere cannot subduct. So when two continental plates collide, they just smash together. This is just like what happens if you put your hands on two sides of a sheet of paper and bring your hands together. The material has nowhere to go but up (**Figure 7.13**)! Earthquakes and metamorphic rocks result from the tremendous forces of the collision. But the crust is too thick for magma to get through. As a result, there are no volcanoes at continent-continent collision zones.

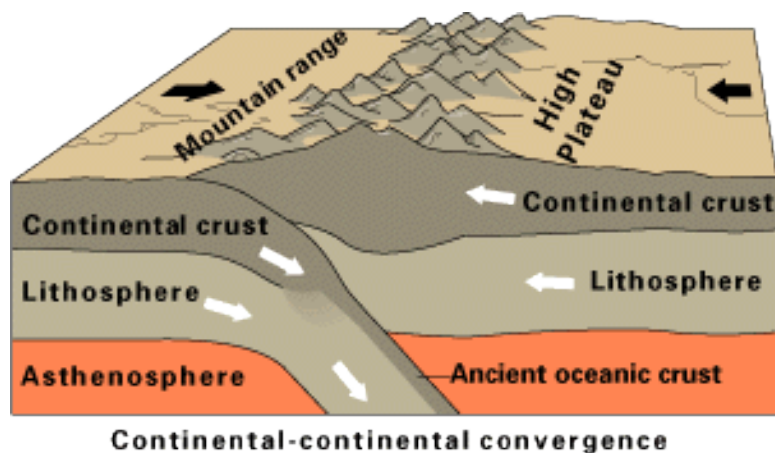


FIGURE 7.13

When two plates of continental crust collide, the material pushes upward. This forms a high mountain range. The remnants of subducted oceanic crust remain beneath the continental convergence zone.

Mountain Building

Continent-continent convergence creates some of the world's largest mountains ranges. The Himalayas (**Figure 7.14**) are the world's tallest mountains. They are forming as two continents collide. The Appalachian Mountains are the remnants of a larger mountain range. This range formed from continent-continent collisions in the time of Pangaea.



FIGURE 7.14

The Karakoram Range is part of the Himalaya Mountains. K2, pictured here, is over 20,000 feet high. The number of mountains this tall in the Himalayas is impressive.

Summary

- Continental crust is too buoyant to subduct.
- When two continental plates converge, they smash together and create mountains.
- The amazing Himalaya Mountains are the result of this type of convergent plate boundary.
- The Appalachian Mountains resulted from ancient convergence when Pangaea came together.

Explore More

Use the resources below to answer the questions that follow.

- **Continent-Continent Convergent Boundaries** at

https://www.youtube.com/watch?v=_fGz0eWp59Y

1. What two types of plates come together at continent-continent convergent plate boundaries?
2. Which plate sinks into the mantle? What is the result of this?
3. What are two examples of this type of plate boundary?
4. At what type of plate boundary are the highest peaks on Earth located?
5. Where is the continental crust thickest on Earth?

Review

1. Compare and contrast these two types of convergent plate boundaries: (1) continent-continent, and (2) ocean-continent.
2. What causes mountain ranges to rise at convergent plate boundaries?
3. How did the Appalachian Mountains form?

7.11 Earthquakes at Convergent Plate Boundaries

- Describe earthquakes that take place at convergent plate boundaries.



How do earthquakes create refugees?

People who've lost their homes in a large earthquake in Pakistan live in a refugee camp, which appears as tents in the photo. Despite suffering the loss of their homes, material possessions, and sometimes loved ones, refugees are often most damaged by the fear that another earthquake could strike. With many people, each aftershock brings renewed terror.

Convergent Plate Boundaries

Earthquakes at convergent plate boundaries mark the motions of subducting lithosphere as it plunges through the mantle (**Figure 7.15**). Eventually the plate heats up enough to deform plastically and earthquakes stop.

Convergent plate boundaries produce earthquakes all around the Pacific Ocean basin.

Ocean-Ocean: Japan

Earthquakes in Japan are caused by ocean-ocean convergence. The Philippine Plate and the Pacific Plate subduct beneath oceanic crust on the North American or Eurasian plates. This complex plate tectonics situation creates a chain of volcanoes, the Japanese islands, and as many as 1,500 earthquakes annually.

In March 2011 an enormous 9.0 earthquake struck off of Sendai in northeastern Japan. This quake, called the 2011 Tōhoku earthquake, was the most powerful ever to strike Japan and one of the top five known in the world. Damage from the earthquake was nearly overshadowed by the tsunami it generated, which wiped out coastal cities and towns (**Figure 7.16**). Several months after the earthquake, about 22,000 people were dead or missing, and 190,000

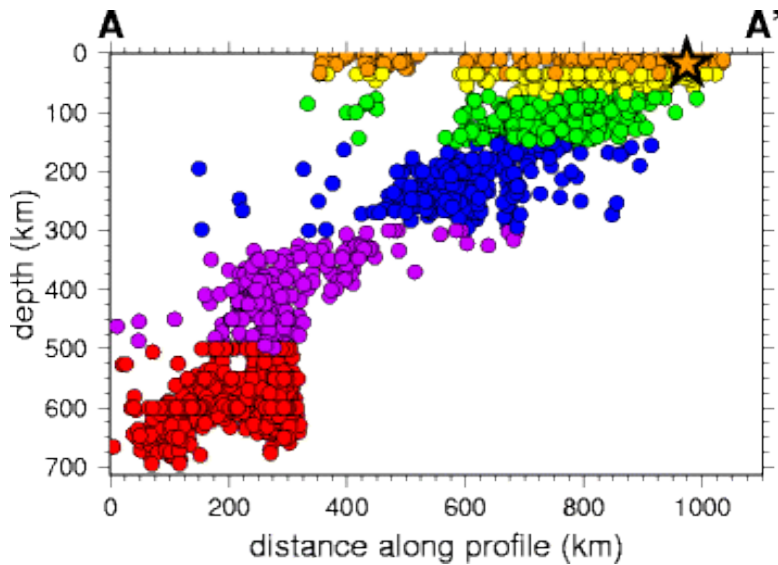


FIGURE 7.15

This cross section of earthquake epicenters with depth outlines the subducting plate with shallow, intermediate, and deep earthquakes.

buildings had been damaged or destroyed. Aftershocks, some as large as major earthquakes, have continued to rock the region.

A map of aftershocks is seen here: <http://earthquake.usgs.gov/earthquakes/seqs/events/usc0001xgp/> .

Here is an interactive feature article about the earthquake: <http://www.nytimes.com/interactive/2011/03/11/world/asia/maps-of-earthquake-and-tsunami-damage-in-japan.html> .



FIGURE 7.16

Destruction in Ofunato, Japan, from the 2011 Tōhoku Earthquake.

Ocean-Continent: Cascades

The Pacific Northwest of the United States is at risk from a potentially massive earthquake that could strike any time. The subduction of three small plates beneath North America produces active volcanoes, the Cascades. As with an active subduction zone, there are also earthquakes. Surprisingly, large earthquakes only hit every 300 to 600 years. The last was in 1700, with an estimated magnitude of around 9. A quake of that magnitude today could produce an

incredible amount of destruction and untold fatalities.

An image of earthquakes beneath the Pacific Northwest and the depth to the epicenter is shown here: <http://pubs.usgs.gov/ds/91/> .

Elastic rebound at a subduction zone generates an earthquake in this animation: http://www.iris.edu/hq/files/programs/education_and_outreach/aotm/5/AOTF5_Subduction_ElasticRebound480.mov .

Continent-Continent: Asia

Massive earthquakes are the hallmark of the thrust faulting and folding when two continental plates converge (**Figure 7.17**). The 2001 Gujarat earthquake in India was responsible for about 20,000 deaths, and many more people became injured or homeless.



FIGURE 7.17

Damage from the 2005 Kashmir earthquake.

In Understanding Earthquakes: From Research to Resilience, scientists try to understand the mechanisms that cause earthquakes and tsunamis and the ways that society can deal with them (**3d**): <http://www.youtube.com/watch?v=W5Qz-aZ2nUM> (8:06).



MEDIA

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/1417>

Summary

- Earthquakes occur all along the subducting plate as it plunges into the mantle.
- All three types of convergent plate boundaries produce massive earthquakes.
- Subduction zones around the Pacific Rim are responsible for many of the world's earthquakes.

Explore More

Use the resource below to answer the questions that follow.

- **Convergent Plate Boundaries** at

<http://crack.seismo.unr.edu/ftp/pub/louie/class/100/plate-tectonics.html>

1. Earthquake epicenters delineate something important. What is that?
2. Why do earthquakes happen at divergent plate boundaries?
3. What occurs in and near subduction zones?
4. Why are earthquakes found at subduction zones?
5. Why are convergent plate boundary earthquakes at depths between surface to 700 km?
6. Why do you think the earthquakes stop at about 700 km?

Review

1. Why does a subducting plate produce so many earthquakes and what type of quakes does it produce?
2. What caused the most destruction from the 2011 Japan earthquake and why?
3. Why do you think the Pacific Northwest has such infrequent but exceptionally massive earthquakes? There are several possible reasons.

7.12 Volcanoes at Plate Boundaries

- Describe volcanic activity at convergent and divergent plate boundaries.
- Explain why volcanic activity occurs at these plate boundaries.



What good are plate boundaries?

Plate boundaries create natural resources, such as gold. But plate boundaries also create beautiful scenery like mountains. Volcanoes at convergent plate boundaries can be beautiful to look at. They can also be beautiful to visit or even climb!

Convergent Plate Boundaries

Converging plates can be oceanic, continental, or one of each. If at least one is oceanic, it will subduct. A subducting plate creates volcanoes. Many of the world's volcanoes are the result of subduction at a convergent plate boundary. A map of the world's active volcanoes is pictured below ([Figure 7.18](#)).

Melting

Mantle melting can come about three ways: (1) when the temperature rises, (2) if the pressure lowers (which lowers the melting point), and (3) if water is added, which lowers the melting point. Two of these (1 and 3) might explain why there are volcanoes at convergent plate boundaries: the temperature of the subducting plate increases as it sinks into the hot mantle (1). Sediments lying on top of the subducting plate contain water. As the sediments subduct, the water rises into the overlying mantle material. This lowers the melting temperature of the mantle (3). When the mantle above the subducting plate melts, volcanoes form above it. This leads to volcanoes in an island arc or continental arc.

Active Volcanoes, Plate Tectonics, and the "Ring of Fire"

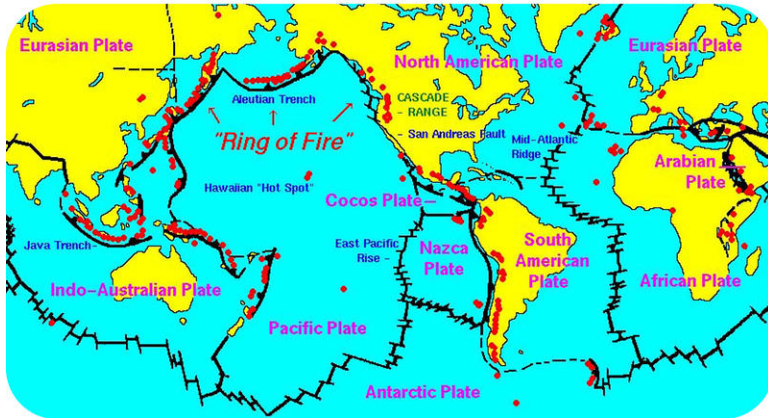


FIGURE 7.18

World map of active volcanoes.

Pacific Rim

Convergent plate boundaries are found around much of the Pacific Ocean basin. Trenches mark subduction zones. Volcanoes are found in an arc above those subduction zones.

The Cascades (**Figure 7.19**) are a chain of volcanoes at a convergent boundary. In this region, an oceanic plate is subducting beneath a continental plate.

The Cascades have been active for 27 million years. The mountains we see today are no more than 2 million years old. The volcanoes receive a lot of winter snow, and many are covered by glaciers (**Figure 7.20**).

The Cascades are shown on this interactive map with photos and descriptions of each of the volcanoes: http://www.iiris.edu/hq/files/programs/education_and_outreach/aotm/interactive/6.Volcanoes4Rollover.swf .

Divergent plate boundaries

At divergent plate boundaries hot mantle rock rises into the space where the plates are moving apart. As the hot mantle rock rises, it goes from higher to lower pressure. This is because there is no longer the weight of all the rock above it. Lower pressure lowers the melting temperature of the rock (2 in the previous section). This is why there is volcanism at divergent plate boundaries. Lava erupts through long cracks in the ground, or **fissures**.

Mid-Ocean Ridges

Volcanoes erupt at mid-ocean ridges, such as the Mid-Atlantic ridge. Seafloor spreading creates new seafloor in the rift valleys. This type of volcanism makes all of the ocean floor! Where a hotspot is located along the ridge, such as at Iceland, volcanoes grow high enough to create islands (**Figure 7.21**).

Continental Rifting

Eruptions are found at divergent plate boundaries as continents break apart, known as **continental rifting**. The Mount Gahinga volcanoes (**Figure 7.22**) are in the East African Rift between the African and Arabian plates. Baja California is breaking apart from mainland Mexico, also by continental rifting.



FIGURE 7.19

The Cascade Range is formed by volcanoes created from subduction of oceanic crust beneath the North American continent.



FIGURE 7.20

Mt. Rainier, Washington.

**FIGURE 7.21**

A volcanic eruption on Iceland, where the Mid-Atlantic Ridge breaches the ocean surface.

**FIGURE 7.22**

Mount Gahinga, a mountain in Uganda, located in the East African Rift valley.

Summary

- Subduction at convergent plate boundaries leads to melting and volcanoes.
- Convergent plate boundaries line the Pacific Ocean basin so that volcanic arcs line the region.
- Melting at divergent plate boundaries is due to release of pressure.
- At mid-ocean ridges seafloor is pulled apart and new seafloor is created. Rifting in a continent can create a new ocean eventually.

Explore More

Use the resource below to answer the questions that follow.

- **Plate Tectonics** at <http://www.youtube.com/watch?v=ryrXAGY1dmE> (1:14)



MEDIA

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/1407>

1. Where does the melted mantle rock rise?
2. What does spreading cause?
3. What happens where there is plate convergence?
4. How is carbon dioxide released from the rock?
5. How is carbon dioxide returned to the atmosphere?

Review

1. What are the two sources of melting at convergent plate boundaries?
2. Why are there so many volcanoes around the Pacific Ocean basin?
3. What causes melting at divergent plate boundaries?

7.13 Ocean-Continent Convergent Plate Boundaries

- Describe the activity and features of convergent plate boundaries where an oceanic plate meets a continental plate.



What do you see at an ocean-continent convergent boundary?

We continue our field trip up the West Coast. Just offshore from Washington, Oregon, and Northern California is a subduction zone, where the Juan de Fuca Plate is sinking into the mantle. The Juan de Fuca Plate is being created at a spreading center, the Juan de Fuca Ridge. Let's see the results of subduction of the Juan de Fuca Plate.

Convergent Plate Boundaries

When two plates converge, what happens depends on the types of lithosphere that meet. The three possibilities are oceanic crust to oceanic crust, oceanic crust to continental crust, or continental crust to continental crust. If at least one of the slabs of lithosphere is oceanic, that oceanic plate will plunge into the trench and back into the mantle. The meeting of two enormous slabs of lithosphere and subduction of one results in magma generation and earthquakes. If both plates meet with continental crust, there will be mountain building. Each of the three possibilities is discussed in a different concept.

In this concept we look at subduction of an oceanic plate beneath a continental plate in the Pacific Northwest.

Ocean-Continent Convergence

When oceanic crust converges with continental crust, the denser oceanic plate plunges beneath the continental plate. This process, called **subduction**, occurs at the oceanic trenches. The entire region is known as a **subduction zone**. Subduction zones have a lot of intense earthquakes and volcanic eruptions. The subducting plate causes melting in the mantle above the plate. The magma rises and erupts, creating volcanoes. These coastal volcanic mountains are found in a line above the subducting plate (**Figure 7.23**). The volcanoes are known as a **continental arc**.

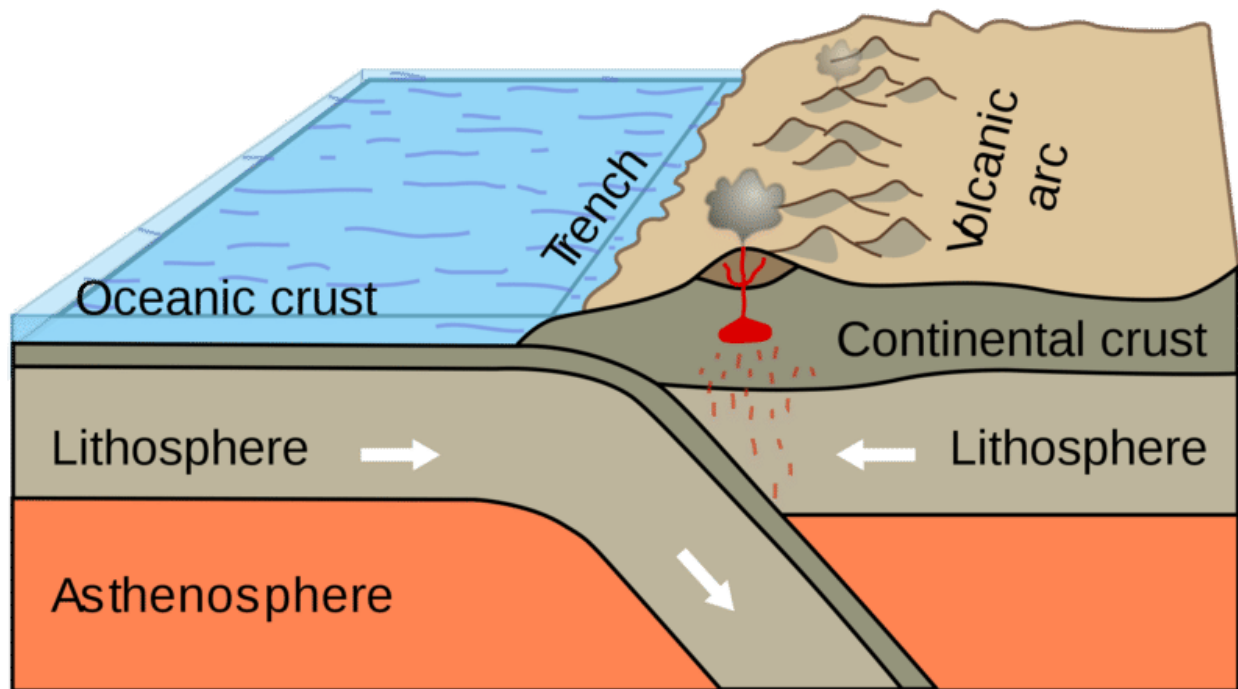


FIGURE 7.23

Subduction of an oceanic plate beneath a continental plate causes earthquakes and forms a line of volcanoes known as a continental arc.

The movement of crust and magma causes earthquakes. A map of earthquake epicenters at subduction zones is found here: http://earthguide.ucsd.edu/eoc/teachers/t_tectonics/p_earthquakesubduction.html .

This animation shows the relationship between subduction of the lithosphere and creation of a volcanic arc: <http://e>

arthguide.ucsd.edu/eoc/teachers/t_tectonics/p_subduction.html .

Remember that the mid-ocean ridge is where hot mantle material upwells in a convection cell. The upwelling mantle melts due to pressure release to form lava. Lava flows at the surface cool rapidly to become basalt, but deeper in the crust, magma cools more slowly to form gabbro. The entire ridge system is made up of igneous rock that is either extrusive or intrusive. The seafloor is also igneous rock with some sediment that has fallen onto it.

Cascades Volcanoes

The volcanoes of northeastern California —Lassen Peak, Mount Shasta, and Medicine Lake volcano —along with the rest of the Cascade Mountains of the Pacific Northwest, are the result of subduction of the Juan de Fuca plate beneath the North American plate (**Figure 7.24**). The Juan de Fuca plate is created by seafloor spreading just offshore at the Juan de Fuca ridge.

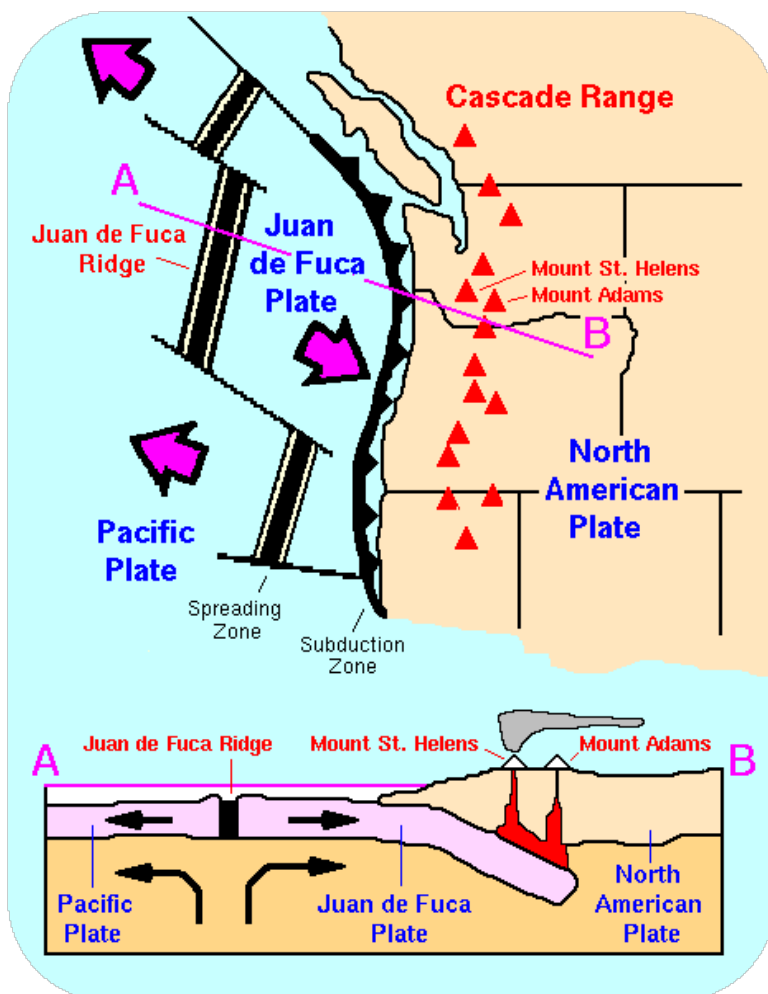


FIGURE 7.24

The Cascade Mountains of the Pacific Northwest are a continental arc.

Intrusions at a Convergent Boundary

If the magma at a continental arc is felsic, it may be too viscous (thick) to rise through the crust. The magma will cool slowly to form granite or granodiorite. These large bodies of intrusive igneous rocks are called **batholiths**,

which may someday be uplifted to form a mountain range. California has an ancient set of batholiths that make up the Sierra Nevada mountains (**Figure 7.25**).



FIGURE 7.25

The Sierra Nevada batholith cooled beneath a volcanic arc roughly 200 million years ago. The rock is well exposed here at Mount Whitney. Similar batholiths are likely forming beneath the Andes and Cascades today.

An animation of an ocean continent plate boundary is seen here: http://www.iris.edu/hq/files/programs/education_and_outreach/aotm/11/AOTM_09_01_Convergent_480.mov .

Summary

- When two plates come towards each other they create a convergent plate boundary.
- The plates can meet where both have oceanic crust or both have continental crust, or they can meet where one has oceanic and one has continental.
- Dense oceanic crust will subduct beneath continental crust or a less dense slab of oceanic crust.
- The oceanic plate subducts into a trench, resulting in earthquakes. Melting of mantle material creates volcanoes at the subduction zone.
- If the magma is too viscous to rise to the surface it will become stuck in the crust to create intrusive igneous rocks.

Making Connections

**MEDIA**

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/59086>

Explore More

Use these resources to answer the questions that follow.

<https://www.khanacademy.org/science/cosmology-and-astronomy/earth-history-topic/plate-tectonics/v/plate-tectonics--geological-features-of-convergent-plate-boundaries>

1. At what type of plate boundary do plates run into each other?
2. When one of the plates is oceanic, what happens?
3. What two things cause the mountain ranges that are the volcanic arc?
4. What is happening at a deep trench?
5. What happens when two continental plates run together?
6. What made Mt. Everest so high?

Review

1. What is the direction of plate motion at a convergent plate boundary?
2. Describe the relationship between the convection cell and subduction at a trench.
3. Subduction is sometimes called crustal recycling. Why do you think this is the case?
4. What happens if magma is too viscous to rise through the crust to erupt at the surface?

7.14 Ocean-Ocean Convergent Plate Boundaries

- Learn the activity and features of convergent plate boundaries where one oceanic plate subducts beneath another oceanic plate.



What do you see in this satellite photo?

We continue our trip up western North America to find a convergent plate boundary where oceanic crust subducts beneath oceanic crust. North of the contiguous U.S. lies Canada, and north of Canada lies Alaska. A line of volcanoes, known as the Aleutian Islands, is the result of ocean-ocean convergence. In this satellite image is an erupting volcano, topped by snow or ice, and surrounded by seawater - a member of the Aleutian chain. Let's take a look at this boundary and the volcanic arc.

Convergent Plate Boundaries

When two plates converge, what happens depends on the types of lithosphere that meet. We explored what happens when oceanic crust meets continental crust. Another type of convergent plate boundary is found where two oceanic plates meet. In this case the older, denser slab of oceanic crust will plunge beneath the less dense one.

Ocean-Ocean

The features of a subduction zone where an oceanic plate subducts beneath another oceanic plate are the same as a continent-ocean subduction zone. An ocean trench marks the location where the plate is pushed down into the mantle. In this case, the line of volcanoes that grows on the upper oceanic plate is an **island arc**. Do you think earthquakes are common in these regions (**Figure 7.26**)?

In the north Pacific, the Pacific Plate is subducting beneath the North American Plate just as it was off of the coast of the Pacific Northwest. The difference is that here the North American plate is covered with oceanic crust. Remember

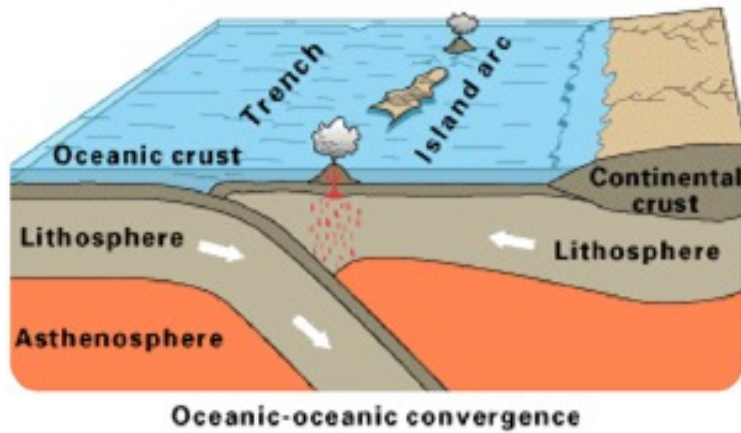


FIGURE 7.26

Subduction of an ocean plate beneath other oceanic crust results in a volcanic island arc, an ocean trench, and many earthquakes

that most plates are made of different types of crust. This subduction creates the Aleutian Islands, many of which are currently active (see **Figure 7.27**). Airplanes sometimes must avoid flying over these volcanoes for fear of being caught in an eruption.

Summary

- If the two plates that meet at a convergent plate boundary both are of oceanic crust, the older, denser plate will subduct beneath the less dense plate.
- The features of an ocean-ocean subduction zone are the same as those of an ocean-continent subduction zone, except that the volcanic arc will be a set of islands known as an island arc.
- The older plate subducts into a trench, resulting in earthquakes. Melting of mantle material creates volcanoes at the subduction zone.

Explore More

Use the resources below to answer the questions that follow.

- **Subduction Zones** at

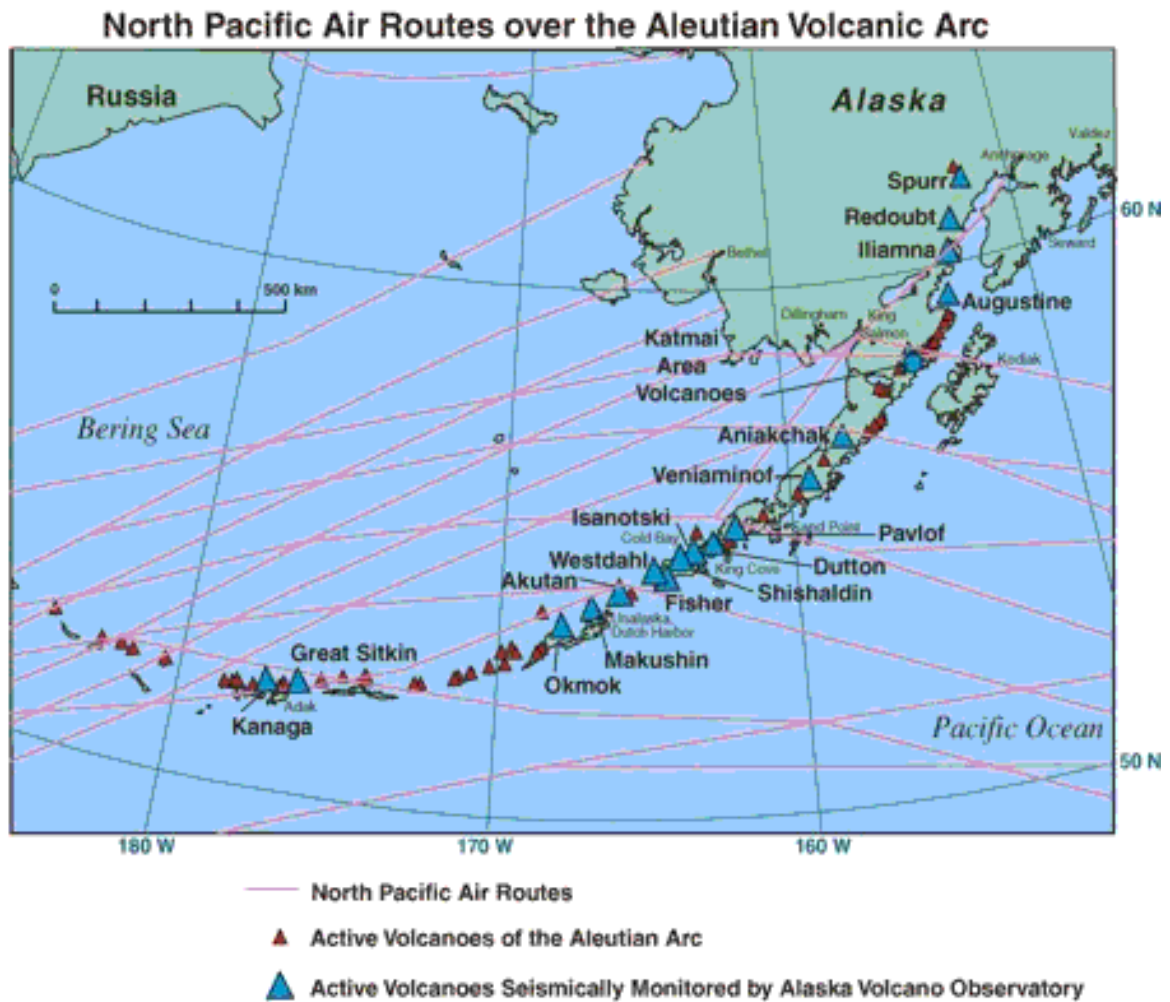
<http://www.nature.nps.gov/geology/usgsnps/pltec/converge.html>

1. Describe a subduction zone.
2. What forms this subduction zone?
3. Where and why does melting occur?
4. What is formed on the continental plate?
5. Where can an example of this plate boundary be found?

- **Volcanic Arcs** at

http://earthguide.ucsd.edu/eoc/teachers/t_tectonics/p_subduction.html

6. Why do arc volcanoes appear in a line?
7. Why are there volcanoes near subduction zones?



These North Pacific air routes carry more than 20,000 people and millions of dollars in cargo every day.

FIGURE 7.27

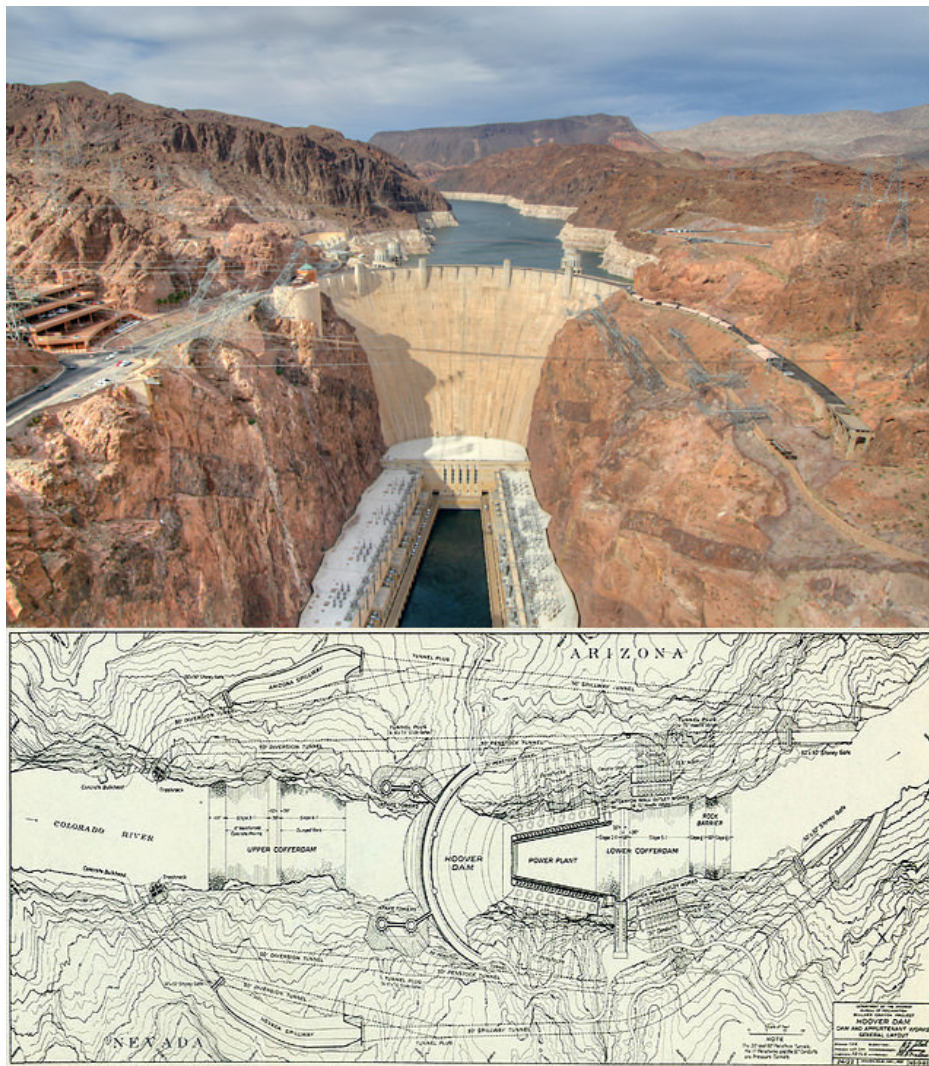
The arc of the island arc that is the Aleutian Islands is easily seen in this map of North Pacific air routes over the region.

Review

1. Compare and contrast the features of an ocean-ocean convergent plate boundary with the features of an ocean-continent convergent plate boundary.
2. How do the Aleutian volcanoes differ from the Cascades volcanoes?
3. How do island arcs get their name?

7.15 Topographic Maps

- Define topographic map and contour line.
- List the rules of topographic maps.
- Understand contour maps.
- Explain a geologic map.



Can a map help you understand a place even if you've never been there?

Hills, streams, valleys, and snowfields all show up on some types of maps. With practice, people can look at a topographic map and see what the landscape is really like. Of course, it's not the same as being there! But a topographic map can give you a good feel for an area before you go. It can also help you to identify features once you are there. What does this map tell you about the region? Can you identify features that appear in the photo on the map?

Topographic Maps

The topography of a region can be shown on a map. **Topographic maps** represent geographical features, such as hills and valleys. Topographic maps use contour lines to show geographical features. A **contour line** is a line of equal elevation. If you walk along a contour line, you will not go uphill or downhill. Topographic maps are also called contour maps. The rules of topographic maps are:

- Each line connects all points of a specific elevation.
- Contour lines never cross. After all, a single point can only have one elevation.
- Every fifth contour line is bolded and labeled.
- Adjacent contour lines are separated by a constant difference in elevation (such as 20 feet or 100 feet). The difference in elevation is the **contour interval**. The contour interval is indicated in the map legend.
- Scales indicate horizontal distance and are also found on the map legend.

Interpreting Contour Maps

How does a topographic map tell you about the terrain? Let's consider the following principles:

1. **The spacing of contour lines shows the slope of the land.** Contour lines that are close together indicate a steep slope. This is because the elevation changes quickly in a small area. Contour lines that seem to touch indicate a very steep slope, like a cliff. When contour lines are spaced far apart, the slope is gentle. So contour lines help us see the three-dimensional shape of the land.

Look at the topographic map of Stowe, Vermont (**Figure 7.28**). There is a steep hill rising just to the right of the city of Stowe. You can tell this because the contour lines there are closely spaced. The contour lines also show that the hill has a sharp rise of about 200 feet. Then the slope becomes less steep toward the right.

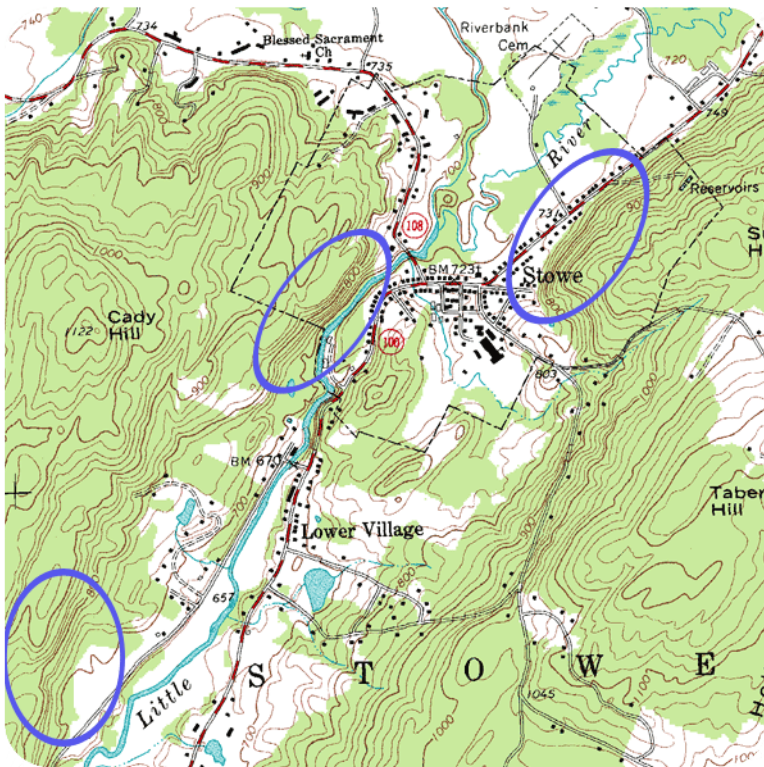


FIGURE 7.28

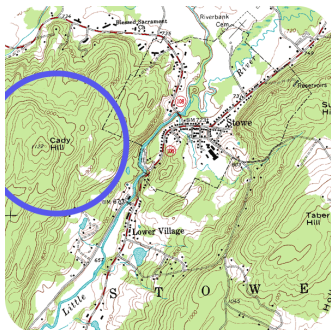
Portion of a USGS topographic map of Stowe, VT.

2. **Concentric circles indicate a hill.** Pictured below is another side of the topographic map of Stowe, Vermont (**Figure 7.29**). When contour lines form closed loops, there is a hill. The smallest loops are the higher elevations on the hill. The larger loops encircling the smaller loops are downhill. If you look at the map, you can see Cady Hill in the lower left and another, smaller hill in the upper right.

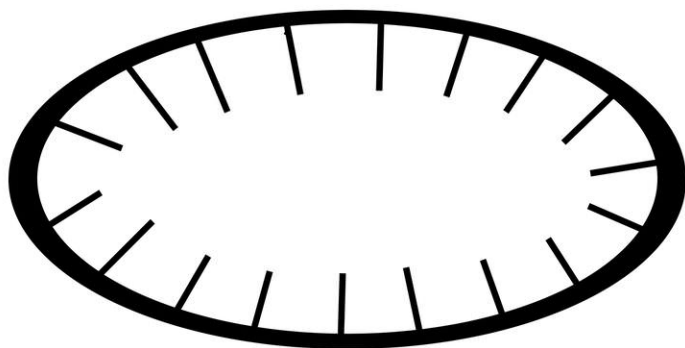
3. **Hatched concentric circles indicate a depression.** The hatch marks are short, perpendicular lines inside the circle. The innermost hatched circle represents the deepest part of the depression (**Figure 7.30**). The outer hatched circles represent higher elevations.

4. **V-shaped portions of contour lines indicate stream valleys.** The “V” shape of the contour lines point uphill. There is a V shape because the stream channel passes through the point of the V. The open end of the V represents the downstream portion. A blue line indicates that there is water running through the valley. If there is not a blue line, the V pattern indicates which way water flows. Below, you can see examples of V-shaped markings (**Figure 7.31**). Try to find the direction a stream flows.

5. **Like other maps, topographic maps have a scale so that you can find the horizontal distance.** You can use the horizontal scale to calculate the slope of the land (vertical height/horizontal distance). Common scales used in

**FIGURE 7.29**

Portion of a USGS topographic map of Stowe, VT. Cady Hill (elevation 1122 feet) is shown by concentric circles in the lower left portion of the map. Another hill (elevation ~ 960 feet) is on the upper right portion of the map.

**FIGURE 7.30**

On a contour map, a circle with inward hatches indicates a depression.

**FIGURE 7.31**

Illustrations of three-dimensional ground configurations (top) and corresponding topographic map (bottom). Note that the V-shaped markings on the topographic maps correspond to drainage channels. Also, the closely-spaced contour lines denote the rapid rising cliff face on the left side.

United States Geological Service (USGS) maps include the following:

- 1:24,000 scale - 1 inch = 2000 feet
- 1:100,000 scale - 1 inch = 1.6 miles
- 1:250,000 scale - 1 inch = 4 miles

Including contour lines, contour intervals, circles, and V-shapes allows a topographic map to show three-dimensional information on a flat piece of paper. A topographic map gives us a good idea of the shape of the land.

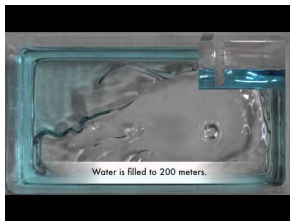
Summary

- Topographic maps reveal the shape of a landscape. Elevations indicate height above sea level.
- Contour lines are lines of equal elevation. Contour intervals are the difference in elevation between two contour lines.

Explore More

Use the resource below to answer the questions that follow.

- **Understanding Topographic Maps** at <http://www.youtube.com/watch?v=EqyfJMgFL-U> (2:49)



MEDIA

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/1636>

1. What is sea level?
2. How far apart are topographic lines?
3. What do the contour lines represent?
4. How do you know that there's a crater at the top of the volcano rather than a peak?
5. What is the purpose of a topographic map?

Review

1. What is a contour line? What is a contour interval?
2. What will a hill look like on a topographic map? How will a basin look different from a hill?
3. How do contour lines indicate a steep slope? How do they indicate a stream?
4. Why might a geologic map be useful to geologists?

7.16 References

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3. Courtesy of the US Geological Survey. [The lithospheric plates and their names](#) . Public Domain
4. Courtesy of the US Geological Survey. [Map of Earth's tectonic plates](#) . Public Domain
5. Christopher Auyeung. [Convection cells move plates](#) . CC BY-NC 3.0
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7. (a) Courtesy of US Geological Survey; (b) Photographed by HD Chadwick and courtesy of National Archives and Records Administration. [Map of faults in the San Francisco Bay Area](#) . Public Domain
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31. Laura Guerin, based on image by the U.S. Geological Survey. [A 3D ground model and its topographic map](#) .
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CHAPTER 8

Chapter 8 - Climate Interactions

Chapter Outline

- 8.1 CHAPTER 8 GUIDED QUESTIONS
 - 8.2 HOW OCEAN CURRENTS MODERATE CLIMATE
 - 8.3 CLIMATE INTERACTIONS OCEAN CURRENTS STUDENT NOTES
 - 8.4 CLIMATE INTERACTIONS FRONTS STUDENT NOTES
 - 8.5 WINDS
 - 8.6 HUMIDTY AND AIR MASSES STUDENT NOTES
 - 8.7 HOW TO READ A WEATHER MAP WS
 - 8.8 ANEMOMETER LAB
 - 8.9 CLIMATE INTERACTION WEATHER SYMBOLS
 - 8.10 REFERENCES
-

8.1 Chapter 8 Guided Questions

Chapter 8: Guided Questions

TABLE 8.1:

How do convection currents form and what are their effects on the Earth?

What are the causes and effects of air currents?

Compare/Contrast the four types of air masses.

What distinguishes all the different types of air masses?

How do fronts form?

Why do you think the weather changes along fronts?

What effects do land and sea breezes have on local weather?

Identify and explain the direction in which land and sea breezes originate and blow.

Describe the information contained in a weather map.

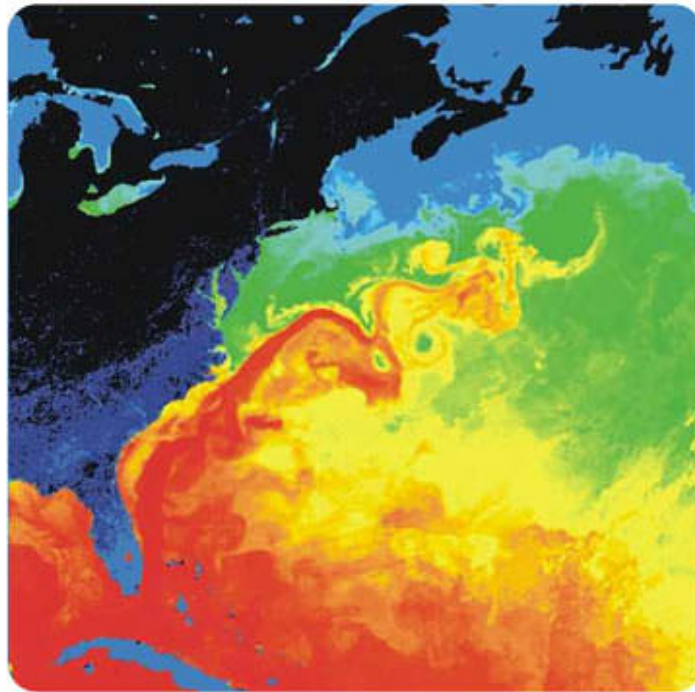
What information does a satellite map provide?

What are the prominent characteristics of a hurricane?

8.2 How Ocean Currents Moderate Climate

- Explain how ocean currents like the Gulf Stream influence Earth's climate.

Gulf Stream: Ocean and Land Temperatures



Why is northwestern Europe relatively warm?

The Gulf Stream waters do a lot for Europe. The equatorial warmth this current brings to the North Atlantic moderates temperatures in northern Europe. In a satellite image of water temperature in the western Atlantic it is easy to pick out the Gulf Stream, which brings warmer waters from the Equator up the coast of eastern North America.

Effect on Global Climate

Surface currents play an enormous role in Earth's climate. Even though the Equator and poles have very different climates, these regions would have more extremely different climates if ocean currents did not transfer heat from the equatorial regions to the higher latitudes.

The Gulf Stream is a river of warm water in the Atlantic Ocean, about 160 kilometers wide and about a kilometer deep. Water that enters the Gulf Stream is heated as it travels along the Equator. The warm water then flows up the east coast of North America and across the Atlantic Ocean to Europe (see opening image). The energy the Gulf Stream transfers is enormous: more than 100 times the world's energy demand.

The Gulf Stream's warm waters raise temperatures in the North Sea, which raises the air temperatures over land between 3 to 6°C (5 to 11°F). London, U.K., for example, is at about six degrees further south than Quebec, Canada.

However, London's average January temperature is 3.8°C (38°F), while Quebec's is only -12°C (10°F). Because air traveling over the warm water in the Gulf Stream picks up a lot of water, London gets a lot of rain. In contrast, Quebec is much drier and receives its precipitation as snow.

**FIGURE 8.1**

London, England in winter.

**FIGURE 8.2**

Quebec City, Quebec in winter.

Summary

- Water in the Gulf Stream travels along the Equator and is heated as it goes.
- The Gulf Stream brings warm water north along the Atlantic coast of the United States and then across the northern Atlantic to the British Isles.
- A tremendous amount of energy is transferred from the equatorial regions to the polar regions by ocean currents.

Explore More

Use this resource to answer the questions that follow.

<https://www.youtube.com/watch?v=J7kIGdhW9jQ>

1. What drives ocean and atmospheric circulation? What does the ocean store more of than the atmosphere?
2. What are surface ocean currents driven by? What are deeper ocean currents driven by?
3. What is the importance of upwelling nutrients in the ocean?
4. What causes El Nino and La Nina? What happens during these events?
5. How does heat exchange between ocean surface and atmosphere influence climate?
6. How do hurricanes form in the oceans? Where does the heat come from to power them?
7. What kind of life would be on Earth if there were no oceans?

Review

1. Explain why England is relatively mild and rainy in winter but central Canada, at the same latitude and during the same season, is dry and frigid.
2. Where else do you think ocean currents might moderate global climate?
3. What would Earth be like if ocean water did not move?

8.3 Climate Interactions Ocean Currents Student notes

_____ currents flow _____ from the equator. _____ currents flow _____ the equator.

What are the Four Factors that Influence Surface Currents?

1. _____ 2. _____

3. _____ 4. _____

Sun:

- Energy from the _____ heats the _____. - _____ water is _____ dense than cold water.

- Warm water _____, and cold water sinks. - As warm water rises, cold water moves it to _____ it.

Wind:

- Just as wind moves from _____ pressure to _____ pressure areas, so does the _____.

- Winds blow across the _____ of the water, causing _____.

- The water _____ because the surface currents flow _____ than the winds.

Gravity:

- As water piles up and flows from _____ pressure to _____ pressure, _____ will pull down on the water.

- This forms _____ columns or mounds of water. - The _____ causes the water to curve.

The Coriolis Effect:

- Causes water to move to the _____ in the _____ Hemisphere

- Causes water to move to the _____ in the _____ Hemisphere

Surface Current:

- Make up _____ of oceans' water- Up to maximum depth of _____

- Surface _____ currents are caused by the surface _____ patterns.

Gyres:

- Vertical _____ or mounds of water at the surface and flow around them

- Produce enormous _____ currents

- Five major locations:

North Pacific - _____ - South Pacific - _____

Indian Ocean - _____ - South Atlantic - _____

North Atlantic - _____

Gulf Stream:

- A _____ surface current - Begins at the tip of _____

- Flows up the _____ coastline of the U.S. - Crosses the _____ Ocean

- Causes _____ climate in NW Europe

Upwelling:

- Surface waters blow to the _____ of the wind.

- As less _____, surface water moves off shore, cold, deep, denser waters come to the _____ to replace them.

Deep Water Currents:

- Make up about _____ of oceans' water- Differences in _____ cause them to move.

- Differences in density are related to _____ and _____.

- At high latitudes, they sink _____ into the ocean _____.

- Temperatures are so cold, they cause the _____ to _____.

El Nino

- Abnormally _____ surface ocean temperatures off the coast of _____ America

- Causes _____ weather patterns across the globe

- Starts because the easterly trade winds _____ and allow the warm waters in the Western Pacific to move _____ toward South America

- This changes where the _____ occurs.

- Causing _____ where it usually doesn't occur and _____ where it usually rains

La Nina

- Abnormally _____ surface ocean temperatures off the coast of _____ America

- Causes _____ weather patterns across the globe

Ocean's Effect on Climate

- Ocean currents move more _____ than winds.

- Oceans hold more _____ than the atmosphere and land.

- Cold currents will cause nearby coastlines to be _____.

- Warm currents will cause nearby coastlines to be _____.

Name: _____ Period: ___ Date: _____ Page: _____

El Nino, La Nina, and Normal Temperatures

Normal

El Nino

La Nina

8.4 Climate Interactions Fronts Student Notes

What are Warm Fronts and Cold Fronts caused by?

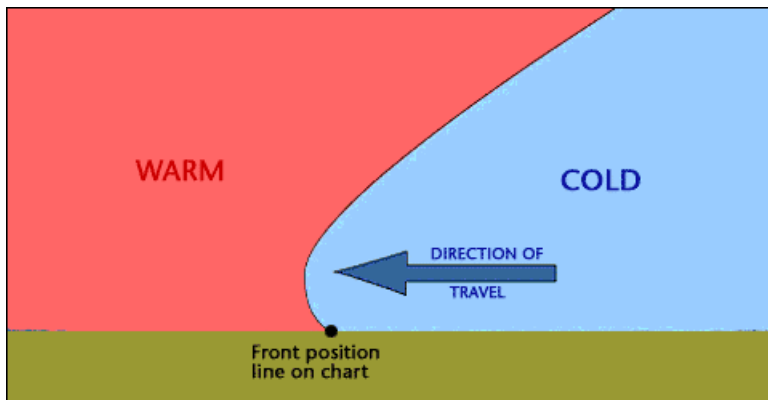
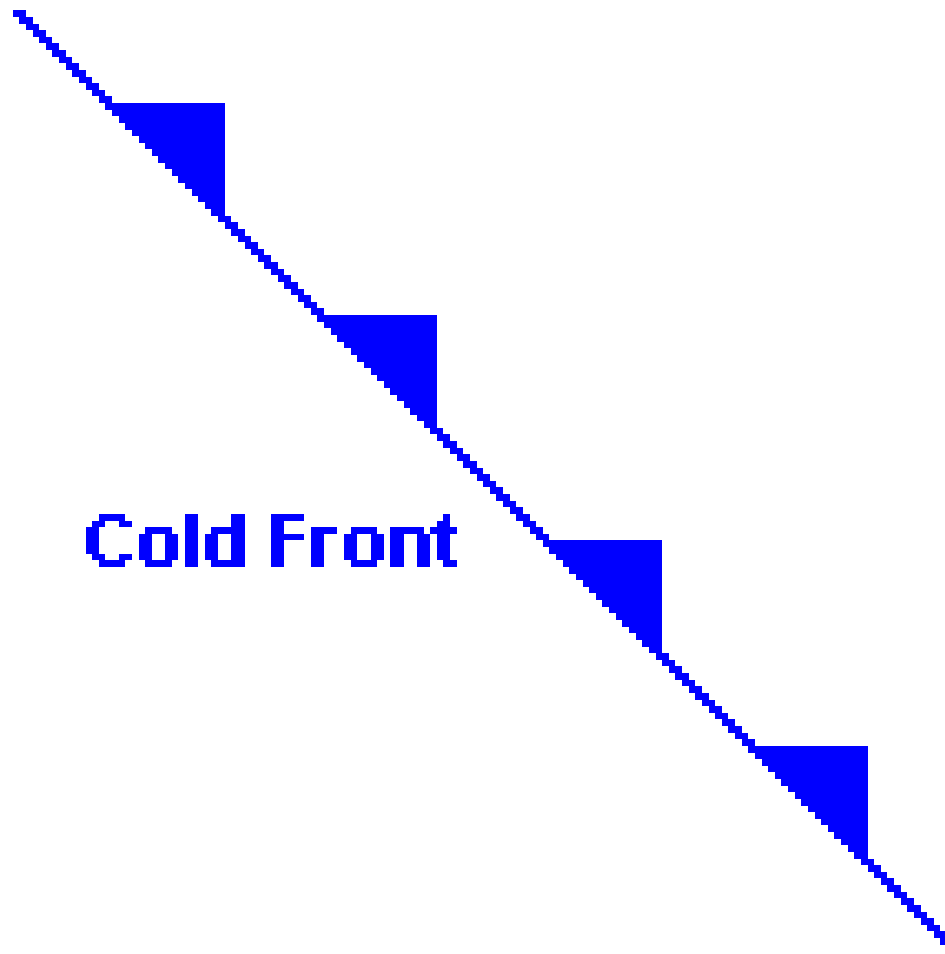


FIGURE 8.3

Cold Fronts:

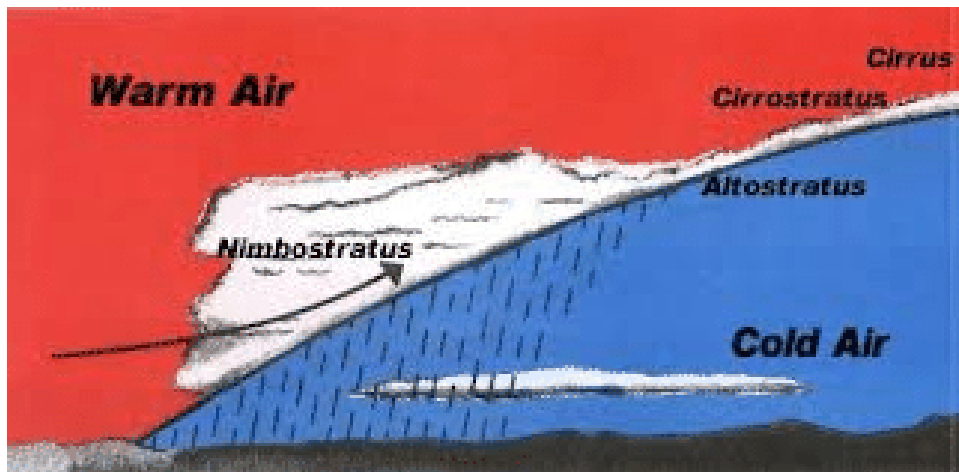
Form where _____ moves towards _____.

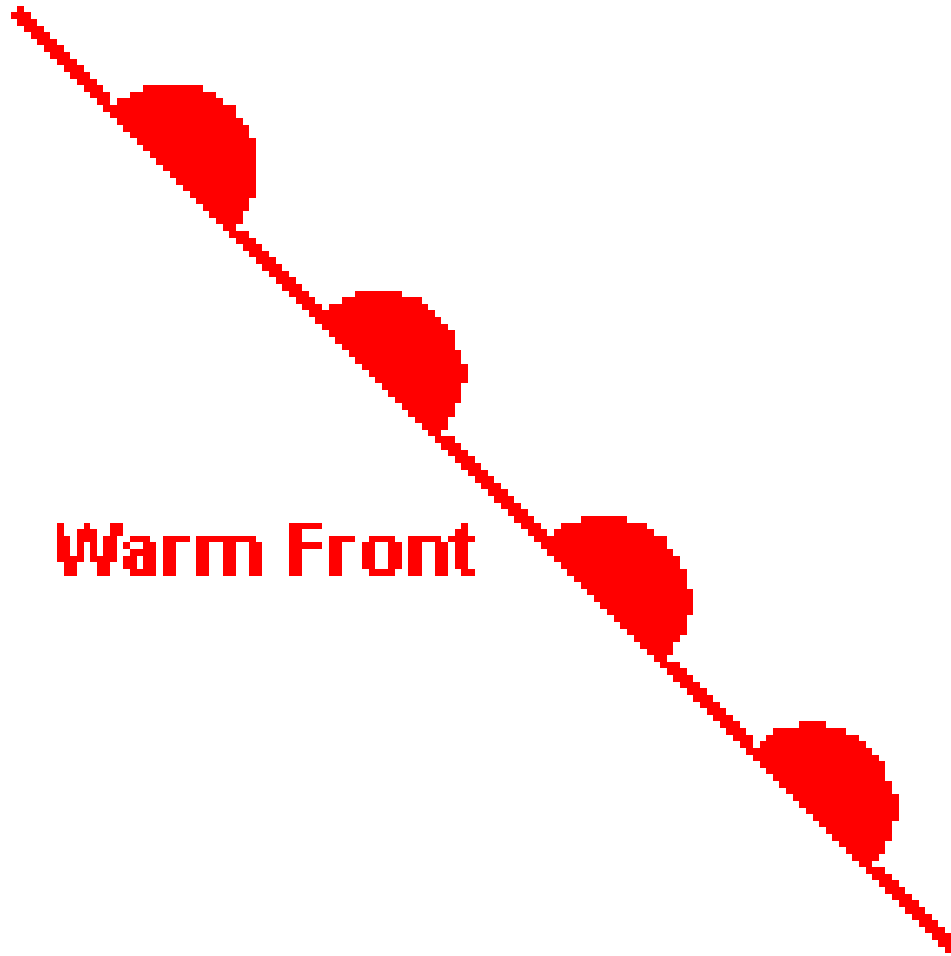
Creates _____.



Warm Front:

Form where _____ moves towards _____.

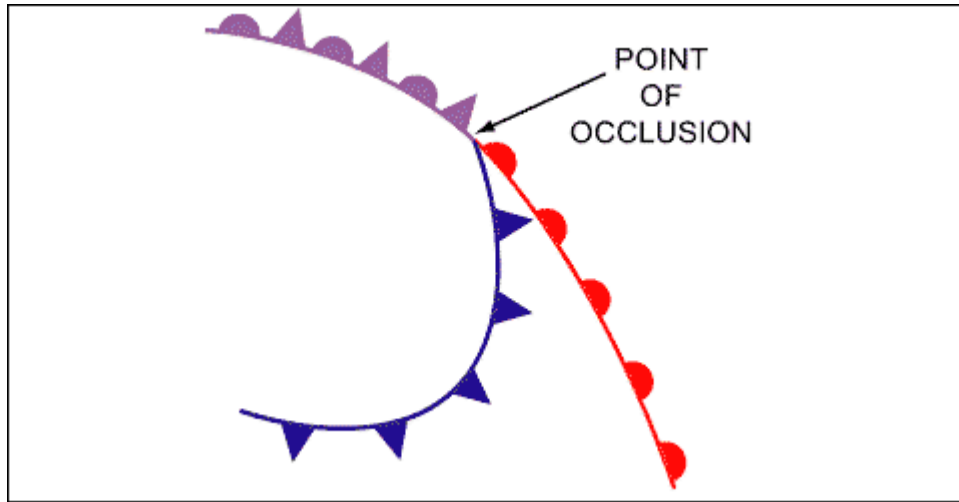




Occluded Front:

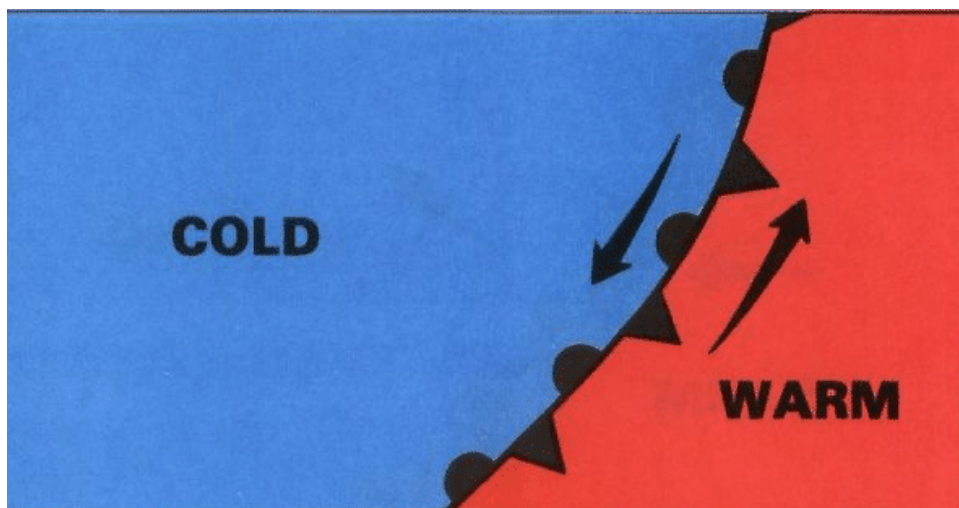
When a _____ over takes a _____ and forces it up (Mix)



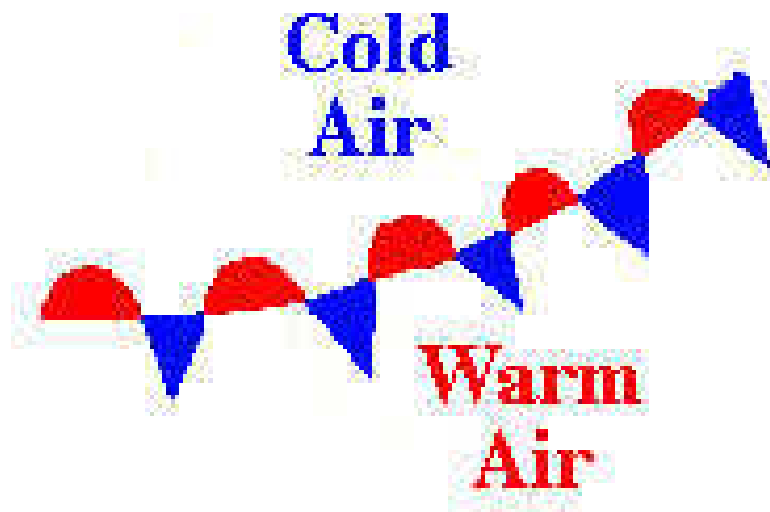


Stationary Front:

When a _____ and _____ can not over take each other (TIE)



Stationary Front



8.5 Winds

- Describe the types of local winds and how they are created.
- Explain how local winds influence a region's environment.

Local Winds

Local winds are winds that blow over a limited area. Local winds blow between small low and high pressure systems. They are influenced by local geography. Nearness to an ocean, lake, or mountain range can affect local winds. Some examples are found below. Local winds can affect the weather and climate of a region.

Land and Sea Breezes

Ocean water is slower to warm up and cool down than land. So the sea surface is cooler than the land in the daytime. It is also cooler than the land in the summer. The opposite is also true. The water stays warmer than the land during the night and the winter. These differences in heating cause local winds known as land and sea breezes (**Figure 8.4**).

- A **sea breeze** blows from sea to land during the day or in summer. That's when air over the land is warmer than air over the water. The warm air rises. Cool air from over the water flows in to take its place.
- A **land breeze** blows from land to sea during the night or in winter. That's when air over the water is warmer than air over the land. The warm air rises. Cool air from the land flows out to take its place.

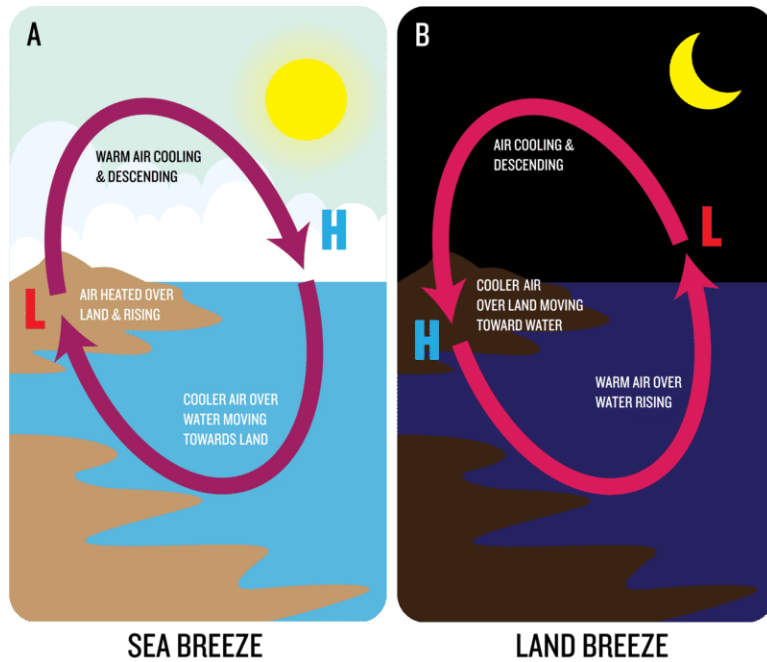


FIGURE 8.4

Land and sea breezes blow because of daily differences in heating.

Monsoons

Monsoons are like land and sea breezes, but on a larger scale. They occur because of seasonal changes in the temperature of land and water. In the winter, they blow from land to water. In the summer, they blow from water to land. In regions that experience monsoons, the seawater offshore is extremely warm. The hot air absorbs a lot of the moisture and carries it over the land. Summer monsoons bring heavy rains on land. Monsoons occur in several places around the globe. The most important monsoon in the world is in southern Asia (**Figure 8.5**). These monsoons are important because they carry water to the many people who live there.

Mountain and Valley Breezes

The air on a mountain slope warms more than the air over the nearby valley. The warm air rises and brings cool air up from below. This is a **valley breeze**. At night the mountain slope cools more than the air over the valley. The air flows downhill creating a **mountain breeze**.

Katabatic Winds

Katabatic winds move the same way as mountain and valley breezes. However, they are much stronger. Katabatic winds form over a high plateau that is surrounded by mountains. In winter, the plateau grows cold. Air sinks through the gaps in the mountains. Over Antarctica and Greenland, these winds are frigid.

Chinook Winds

Chinook winds (**Figure 8.6**) occur when air is forced over a mountain range. Warm air rises over the Sierra Nevada in California, for example, because it is pushed eastward by the westerly winds. The air cools as it rises and precipitates. The air is now dry. It sinks down the far side of the mountains and may create strong winds. These

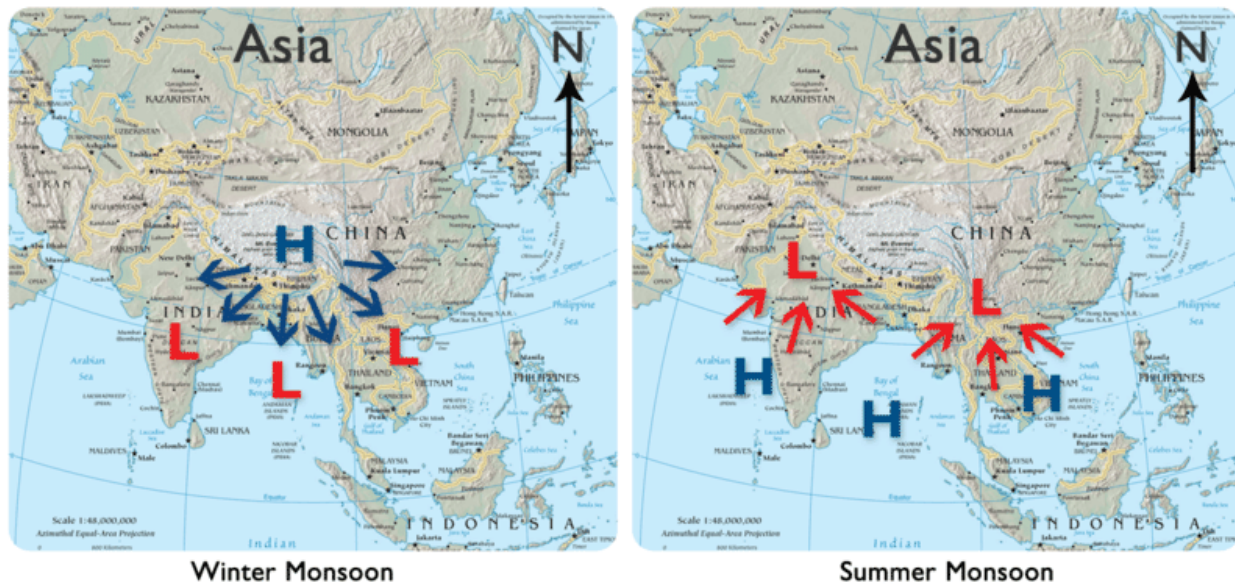


FIGURE 8.5

Monsoons blow over southern Asia.

Chinook winds are relatively warm. If there is snow, the winds may melt it quickly. The dry sinking air creates a **rainshadow effect**. Rainshadow effect is responsible for many of the world's deserts.

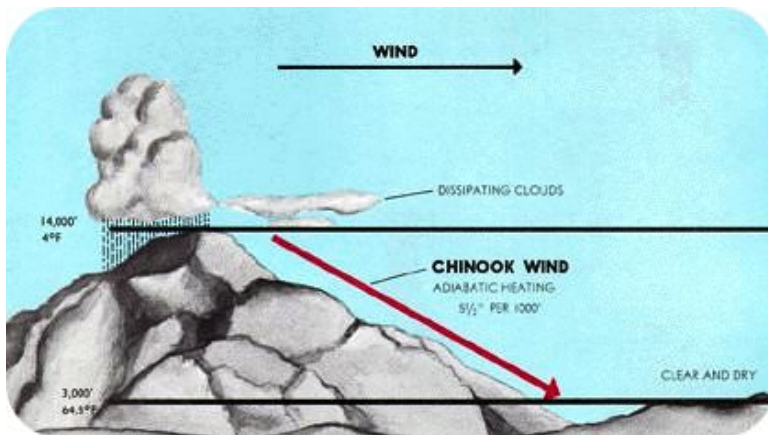


FIGURE 8.6

As air rises over a mountain it cools and loses moisture. The air warms by compression on the leeward side. The resulting warm and dry winds are Chinook winds. The leeward side of the mountain experiences rainshadow effect.

Santa Ana Winds

Santa Ana winds (Figure 8.7) are responsible for many large fires in Southern California (Figure 8.8). The Santa Ana winds arrive at the end of California's long summer drought season. Air east of the Sierra Nevada Mountains cools in late fall. This creates a high pressure zone. The air is then forced downhill through the deserts of the Southwest. It blows westward toward the ocean. The air is blocked by the San Gabriel and San Bernardino

Mountains. So it is funneled rapidly through the mountain passes. If a fire starts, it spreads quickly. The result is large-scale devastation.

**FIGURE 8.7**

The winds are especially fast through Santa Ana Canyon, for which they are named. Santa Ana winds blow dust and smoke westward over the Pacific from Southern California.

**FIGURE 8.8**

In October 2007, Santa Ana winds fueled many fires that together burned 426,000 acres of wild land and more than 1,500 homes in Southern California.

Desert Winds

High summer temperatures on the desert create high winds and monsoon storms. Strong winds in the desert can pick up dust and blow it around. A dust storm known as a **haboob** (Figure 8.9) forms in the downdrafts on the front of a thunderstorm.

Summary

- Local winds blow between high pressure and low pressure areas.



FIGURE 8.9

A haboob in the Phoenix metropolitan area, Arizona.

- Winds blow up and down slope, on and off land and sea, through deserts or over mountain passes.
- Some local winds are well known in an area: haboobs in the desert, Santa Ana winds in Southern California, Chinook winds in Colorado.

Explore More

Use the resources below to answer the questions that follow.

- **Chinook Winds: The Snow Eaters** at <http://www.youtube.com/watch?v=VEJmQglWnQY> (1:16)



MEDIA

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/10254>

1. What are Chinook winds?
2. Where do Chinook winds occur?
3. Explain how Chinook winds work.

- **Santa Ana Winds** at <http://www.youtube.com/watch?v=Dq1f1VAKXSw> (1:15)



MEDIA

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/1596>

4. What are the Santa Ana winds?
5. Where do the Santa Ana winds occur?
6. What causes the Santa Ana winds?
7. Explain how the Santa Ana winds affect the weather.
8. What is one extremely bad result of the Santa Ana winds?

Review

1. What causes local winds to blow?
2. Describe valley breezes and mountain breezes. How are they an example of how local winds form?
3. How do Chinook winds lead to rainshadow effect?

8.6 Humidity and Air Masses Student Notes

Name: _____ Pd. _____ Date: _____ Page: _____

Climate Interactions: Humidity and Air Masses

Humidity:

- The _____ measure of the amount of _____ in the air
- Measured with a _____
- Water vapor affects the _____ of the _____.
- _____ air is _____ than _____ air.

Air Masses:

What is an Air Mass?

A _____ of air that has the same _____ and _____ throughout.

How do Air Masses Form?

- If a large body of air sits over an area of land or water for a long period of time, it will take on the _____ of the _____ or _____ beneath it.
- _____ - _____

Location, Location, Location. . .

- Air masses over the _____ will have _____ temperatures.
- Air masses over _____ regions will have _____ temperatures.
- Air masses over water (_____) will have _____ (moisture content).
- Air masses over land (_____) will have _____ humidity (_____ content).

Where do air masses form?

- Air masses tend to _____ in areas with _____.
- Remember, they sit over an _____ for a _____ period of time _____ moving.

Labeling Air Masses

- Air masses that form over water are called _____.
- Air masses that form over land are called _____.

Classification of Air Masses

TABLE 8.2:

Abbreviation	Name	Characteristics
--------------	------	-----------------

TABLE 8.2: (continued)

	maritime tropical	
	continental tropical	
	maritime polar	
	continental polar	
	continental arctic	

How do air masses move?

- _____
- _____ air _____, and _____ air moves in to _____ -
 ___ it.
- A _____ pattern is formed.
- Causes air and water currents to form _____

Density:

_____ air _____ and _____ Air _____

8.7 How to read a weather map WS

Name: _____ Period: _____ Date: _____

Reading Weather Maps

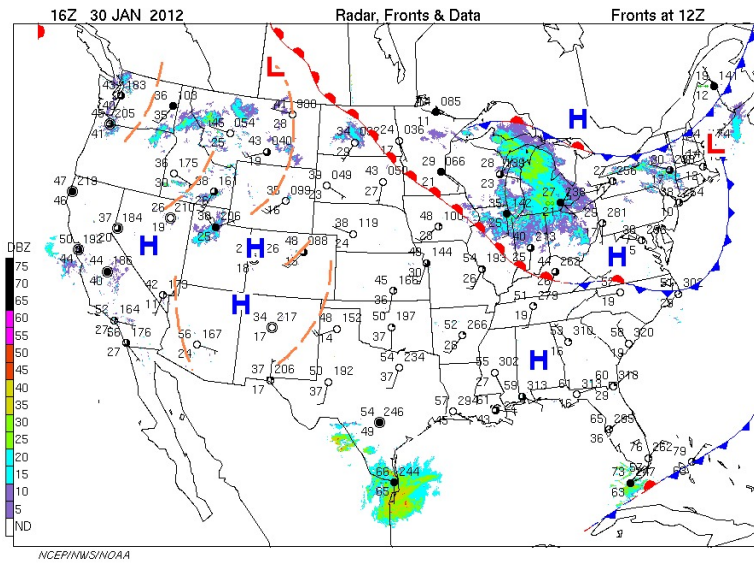


FIGURE 8.10

The symbols on the weather map blow show the locations for Fronts, High- and Low- Pressures areas, and different kinds of precipitation across the United States. The key below the map tells that the symbols mean.

Label as we go through PowerPoint

FIGURE 8.11

What do you need to add in front of this number?

Directions: Answer the question below based on the information in the weather map.

TABLE 8.3:

	Temperature	Dew Point	Wind Directions	Wind Speed	Amount of sky cover	Barometric Pressure
1. Dallas, TX						
2. San Francisco, CA						
3. Seattle, WA						
4. Minneapolis, MN						
5. Kansas City, MO						
6. Nashville, TN						
7. Detroit, MI						
8. Atlanta, GA						

9. What do you notice about the states that has a **HIGH PRESSURE** over them?

10. What is happening in the state that has a **WARM FRONT** passing through them?

11. What is happening in the northeastern part of the United States?

12. From looking at the surface current map, what weather is associated with a **HIGH PRESSURE**?

13. How is weather in Iowa, South Dakota, and Missouri; different than Indiana, Ohio, and Michigan? And Why?

Glue on Page _____ Put Glue Here

8.8 Anemometer Lab

Anemometer Lab

Materials Needed:

Empty Plastic Bottle Sand Funnel

Paper Cups (5) Marker Push Pin

Unsharpened #2 wooden Pencil Sharpened #2 wooden pencil

Plastic Straws (2) Stapler Tape

Multi-speed Fan Stop Watch

Procedures:

- Using your funnel, fill your plastic bottle $\frac{3}{4}$ full of sand.
- Using a marker color one of the paper cups so that it is easily distinguished from the others.
- Using your sharpened #2 pencil, carefully poke a hole through the side of 4 of the paper cups (include the colored cup from Step 2)
- With the 5th cup, again take your sharpened #2 pencil and poke a hole through the side. However, this time, poke the hole so that it comes out the other side of the cup.
- IMPORTANT - Make sure the holes are even on each side !!
- Again using the 5th cup. Poke holes perpendicular and $\frac{1}{4}$ inch above the previous holes made. As in step 4 the pencil will penetrate both sides of the cup. Again, make sure the holes are even on each side.
- Using the sharpened pencil poke a hole in the bottom, center of cup #5.
- Take 2 straws and pass them through the side holes made in cup #5.
- Turn Cup #5 so that the open end is facing upwards.
- With the remaining 4 cups attach them to the straws using a stapler. The cups should all be facing in the same direction. (The open end of one cup should be facing the bottom end of the next cup.)
- Insert the unsharpened pencil (eraser end first) through the bottom of cup #5 so that the eraser rests up against the criss-crossed straws. Insert the push pin into the straws so that it connects to the eraser.
- Insert the unsharpened end of the pencil into the bottle of sand deep enough so that the anemometer is sturdy, yet above the bottle so it is free to spin.
- Use tape to secure where needed: Where the pencil and cup # 5 meet or around the opening of the bottle to help keep the pencil vertical.
- Complete the attached Lab Report
-

To calculate the MPH of using your anemometer, use the following formula:

Count the number of revolutions (watch your marked cup) in a 15 second period.

Multiply this number by 2

Divide your answer by 10.

This is the approximate wind speed in MPH.

Complete the Table:

- Who or what profession would be interested in knowing the speed of the wind? Why is this important to them?
•
- This lab is an approximation of wind speed. What are some of the factors that limit our accuracy in calculating wind speed?
•
- How are winds generated ?
•

8.9 Climate Interaction Weather Symbols

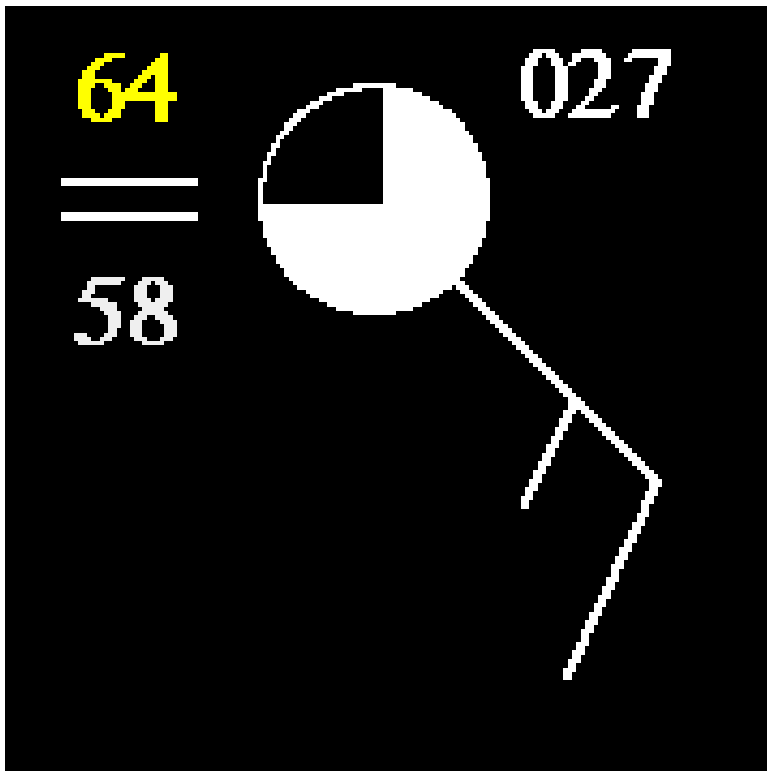


FIGURE 8.12

Temperature:

The value in the upper left corner is the temperature in degrees Fahrenheit. (Label the Temperature in the diagram above)

In this example, the reported temperature is _____ degrees.

Weather System:

The weather system is located under the temperature this indicates the type of weather occurring at the time the observation is taken. (Label the Weather System in the diagram above:)

In this case, _____ was reported.

If there were thunderstorms occurring when the observation was taken, then the symbol for thunderstorms would have appeared instead.

Cloud Cover:

The symbol in the middle of the circle indicates the amount of cloud cover observed at the time the observation is taken. (Label the Cloud Cover in the diagram above:)

In this case, _____ were reported.

Wind Direction:

Wind direction is found by using a _____.

Wind direction is always described as the direction _____ which the wind moved

Wind Speed:

Wind speed is measured using an a _____. Speed is measured in mph or knots (1.15 mph = 1 knot)

_____ are used to show wind speed on a station model

Wind Barb:

The symbol coming off of the circle is known as a _____.

The wind barb indicates wind _____ and wind _____.

Wind barbs point in the direction " _____ " which the wind is blowing.

8.1

,

-

Inter

-8 -

8.10 References

1. Mikey. [London during the winter](#) . CC BY 2.0
2. Flickr:abdallah. [Quebec during the winter](#) . CC BY 2.0
3. Christopher Auyueng. [Land and sea breezes blow in different directions if it is day or night](#) . CC BY-NC 3.0
4. Map courtesy of the Central Intelligence Agency's World Factbook; modified by CK-12 Foundation - Hana Zavadska. [Monsoons blow over southern Asia](#) . Public Domain
5. Courtesy of US Federal Aviation Administration. [Diagram of Chinook winds](#) . Public Domain
6. Courtesy of NASA. [Satellite image of Santa Ana winds](#) . Public Domain
7. Alex Miroshnichenko (Flickr:Miro-Foto). [Santa Ana winds fuel wildfires in Southern California](#) . CC BY 2.0
8. Greg Gorman. [Picture of a haboob in Phoenix, Arizona](#) . CC BY 2.0

CHAPTER

9

Chapter 9 - Earth's Cycles

Chapter Outline

- 9.1 CHAPTER 9 GUIDED QUESTIONS
 - 9.2 ROTATION OF EARTH
 - 9.3 REVOLUTIONS OF EARTH
 - 9.4 REVOLUTIONS OF EARTH
 - 9.5 LUNAR PHASES
 - 9.6 TIDES
 - 9.7 SHORT-TERM CLIMATE CHANGE
 - 9.8 REFERENCES
-

9.1 Chapter 9 Guided Questions

Chapter 9: Guided Questions

- What is the position of the Sun, Earth, and moon during a Neap Tide? Spring Tide?
-
- Compare and contrast a Neap tide to a Spring tide. Compare and contrast high tide to low tide.
- How does the moons revolution affect the tides?
- Describe how the moon's shape changes as the moon wanes? Waxes?
- Describe the causes of an eclipse.
- Compare the positions of the Earth, Moon and Sun during a solar and lunar eclipse.
- Explain why Earth has seasons. What causes day and night?
- Compare the revolution of the Earth to the Earth's rotation.
- What is the axis and how does it affect the Earth?
- Describe the solstices and when they occur.
- Describe the equinoxes and when do they occur.

9.2 Rotation of Earth

- Describe Earth's rotation on its axis.



What would you do if you were in Paris?

Take a view from the top of the Eiffel Tower? March up the stairs to eye the gargoyles at Notre Dame? Nibble on coffee and croissants in a sidewalk cafe? Visit Foucault's Pendulum in the Pantheon? Yes! When in Paris, don't forget to go to the Pantheon and visit this testament to Earth's rotation.

Foucault's Pendulum

In 1851, a French scientist named Léon Foucault took an iron sphere and hung it from a wire. He pulled the sphere to one side and then released it, as a pendulum. Although a pendulum set in motion should not change its motion, Foucault observed that his pendulum did seem to change direction relative to the circle below. Foucault concluded that Earth was moving underneath the pendulum. People at that time already knew that Earth rotated on its axis, but Foucault's experiment was nice confirmation.

**FIGURE 9.1**

Foucault's Pendulum is at the Pantheon in Paris, France.

Earth's Rotation

Imagine a line passing through the center of Earth that goes through both the North Pole and the South Pole. This imaginary line is called an **axis**. Earth spins around its axis, just as a top spins around its spindle. This spinning movement is called Earth's **rotation**.

An observer in space will see that Earth requires 23 hours, 59 minutes, and 4 seconds to make one complete rotation on its axis. But because Earth moves around the Sun at the same time that it is rotating, the planet must turn just a little bit more to reach the same place relative to the Sun. Hence the length of a day on Earth is actually 24 hours.

At the Equator, the Earth rotates at a speed of about 1,700 km per hour, but at the poles the movement speed is nearly nothing.

Day-Night Cycle

Earth rotates once on its axis about every 24 hours. To an observer looking down at the North Pole, the rotation appears counterclockwise. From nearly all points on Earth, the Sun appears to move across the sky from east to west each day. Of course, the Sun is not moving from east to west at all; Earth is rotating. The Moon and stars also seem to rise in the east and set in the west.

Earth's rotation means that there is a cycle of daylight and darkness approximately every 24 hours, the length of a day. Different places experience sunset and sunrise at different times and the amount of daylight and darkness also differs by location.

Shadows are areas where an object obstructs a light source so that darkness takes on the form of the object. On Earth, a shadow can be cast by the Sun, Moon, or (rarely) Mercury or Venus.

Summary

- Foucault's pendulum shows that Earth moves beneath a swinging pendulum.
- Earth rotates on its axis every 24 hours.
- Earth rotates so that the Sun, Moon, and stars appear to travel from east to west each day.

Explore More

Use these resources to answer the questions that follow.

<https://www.youtube.com/watch?v=9n04SEzuvXo>

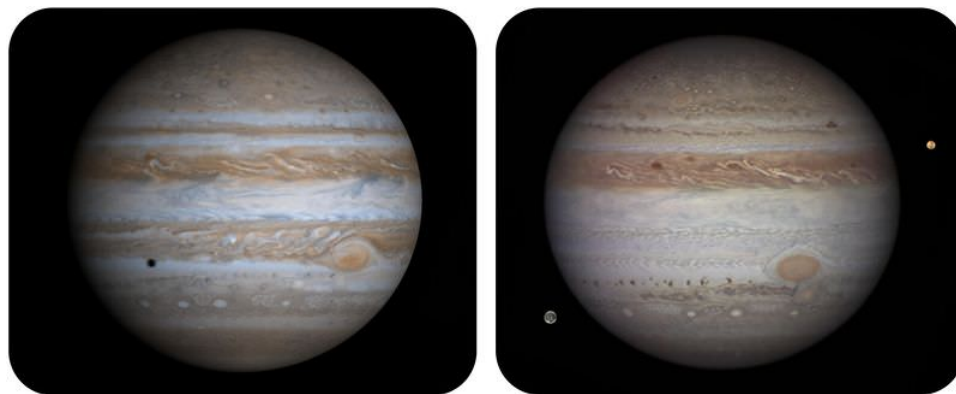
1. What is the tilt of Earth's axis of rotation?
2. How often does Earth rotate on its axis?
3. Under what circumstances is it summer in the Northern Hemisphere?
4. As Earth revolves around the Sun over 6 months, how much does the tilt of the axis of rotation change?
5. Under what circumstances is it summer in the Southern Hemisphere? At this time, what is the season in the Northern Hemisphere?
6. What is the wobble effect? How long is one cycle of this effect?
7. What will happen to the seasons in 13,000 years and why?

Review

1. How does Foucault's pendulum show that Earth rotates on its axis?
2. Why do the Sun, Moon, and stars appear to rise in the east and set in the west each day?
3. Why does a point on the Equator travel at a speed of 1,700 km per hour and a point at the poles not travel at all?

9.3 Revolutions of Earth

- Describe Earth's revolution around the Sun.



What kind of revolution are we talking about?

Copernicus caused a revolution. He said that Earth revolved around the Sun. With his telescope, Galileo found a lot of evidence for this. He could see moons orbiting Jupiter. If moons can orbit Jupiter, surely Earth can orbit the Sun. Yes? In the two images above, you can see Jupiter at two different times, showing moons in different places.

Earth's Revolution

Earth orbits a star. That star is our Sun. One **revolution** around the Sun takes 365.24 days. That is equal to one year. Earth stays in orbit around the Sun because of the Sun's gravity (**Figure 9.2**).

Earth's orbit is not a circle. It is a bit elliptical. So as we travel around the Sun, sometimes we are a little farther away from the Sun. Sometimes we are closer to the Sun.

Students sometimes think the slightly oval shape of our orbit causes Earth's seasons. That's not true! The seasons are due to the tilt of Earth's axis, as discussed in the previous concept.

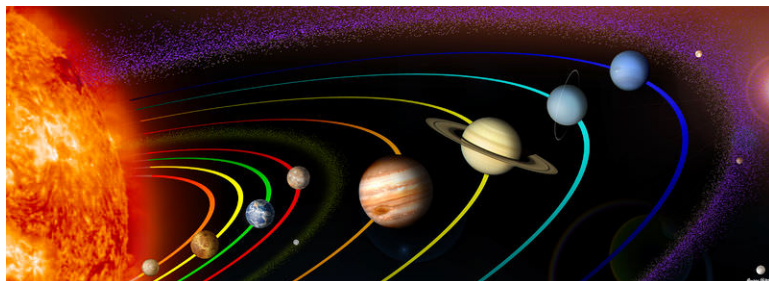


FIGURE 9.2

Earth and the other planets in the solar system make elliptical orbits around the Sun. The ellipses in this image are highly exaggerated.

The distance between the Earth and the Sun is about 93 million miles, or 150 million kilometers. Earth revolves around the Sun at an average speed of about 27 kilometers (17 miles) per second. Mercury and Venus are closer to the Sun, so they take shorter times to make one orbit. Mercury takes only about 88 Earth days to make one trip around the Sun. All of the other planets take longer amounts of time. The exact amount depends on the planet's

distance from the Sun. Saturn takes more than 29 Earth years to make one revolution around the Sun. How old would you be if you were on Jupiter?

Summary

- Earth's orbit around the Sun is somewhat elliptical.
- Earth's seasons are not caused by the shape of its orbit.
- Earth and the other planets of the solar system revolve around the Sun.

Explore More

Use the resource below to answer the questions that follow.

- **Earth's Orbits Around the Sun** at http://www.teachertube.com/viewVideo.php?video_id=6913 (2:50)

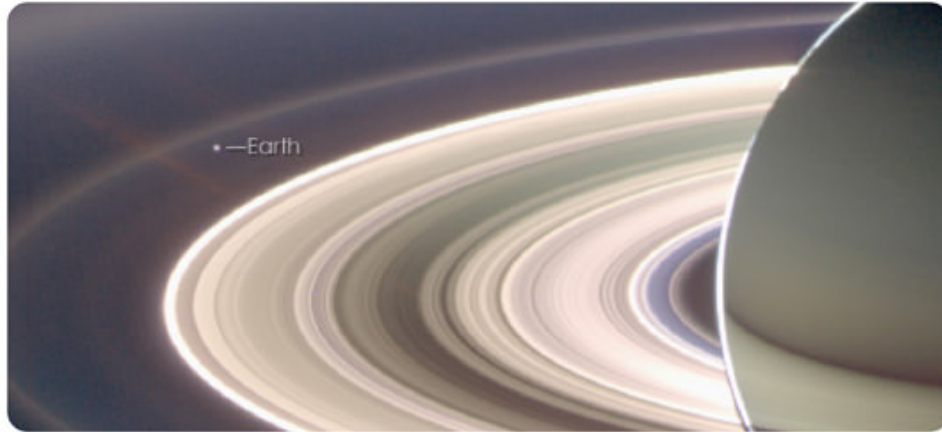
1. What is in the center of the solar system?
2. How long does an orbit around the Sun take?
3. Why does it look like Sun is moving around Earth?
4. What is the shape of Earth's orbit around the Sun?

Review

1. How long does it take for Earth to make one revolution around the Sun?
2. Is Earth farther from the Sun in the winter and closer in the summer? Explain.
3. Describe Earth's orbit around the Sun. Describe the orbits of the other planets.

9.4 Revolutions of Earth

- Define the geocentric and heliocentric models of Earth's revolution.
- Describe Earth's revolution around the Sun.



How else can we identify a planet?

Saturn and Earth are both planets. Saturn is round, like Earth, but Saturn has fantastic rings, which Earth does not. A planet needs to be round but it doesn't need rings. Both of these bodies orbit a star, another thing planets need to do. That star is our Sun.

Earth Orbits a Star

Certainly no one today doubts that Earth orbits a star, the Sun. Photos taken from space, observations made by astronauts, and the fact that there has been so much successful space exploration that depends on understanding the structure of the solar system all confirm it. But in the early 17th century saying that Earth orbited the Sun rather than the reverse could get you tried for heresy, as it did Galileo. Let's explore the evolution of the idea that Earth orbits the Sun.

The Geocentric Universe

To an observer, Earth appears to be the center of the universe. That is what the ancient Greeks believed. This view is called the **geocentric model**, or "Earth-centered" model, of the universe. In the geocentric model, the sky, or heavens, are a set of spheres layered on top of one another. Each object in the sky is attached to a sphere and moves around Earth as that sphere rotates. From Earth outward, these spheres contain the Moon, Mercury, Venus, the Sun, Mars, Jupiter, and Saturn. An outer sphere holds all the stars. Since the planets appear to move much faster than the stars, the Greeks placed them closer to Earth. The geocentric model explained why all the stars appear to rotate around Earth once per day. The model also explained why the planets move differently from the stars and from each other.

One problem with the geocentric model is that some planets seem to move backwards (in retrograde) instead of in their usual forward motion around Earth. A demonstration animation of retrograde motion of Mars as it appears to Earth can be found here: <http://projects.astro.illinois.edu/data/Retrograde/index.html> .

Around 150 A.D. the astronomer Ptolemy resolved this problem by using a system of circles to describe the motion of planets (**Figure 9.3**). In Ptolemy's system, a planet moves in a small circle, called an epicycle. This circle moves around Earth in a larger circle, called a deferent. Ptolemy's version of the geocentric model worked so well that it remained the accepted model of the universe for more than a thousand years.

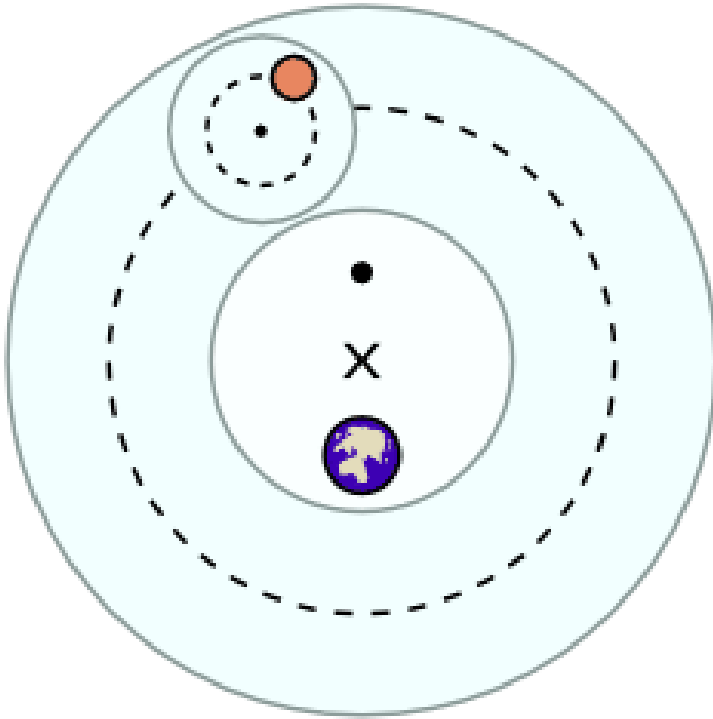


FIGURE 9.3

According to Ptolemy, a planet moves on a small circle (epicycle) that in turn moves on a larger circle (deferent) around Earth.

An animation of Ptolemy's system can be seen here: <http://www.youtube.com/watch?v=FHSWVLwbbNw>

The Heliocentric Universe

Ptolemy's geocentric model worked, but it was complicated and occasionally made errors in predicting the movement of planets. At the beginning of the 16th century A.D., Nicolaus Copernicus proposed that Earth and all the other planets orbit the Sun. With the Sun at the center, this model is called the **heliocentric model**, or "sun-centered" model.

Although Copernicus' model was simpler –it didn't need epicycles and deferents - it still did not perfectly describe the motion of the planets. Johannes Kepler solved the problem a short time later when he determined that the planets moved around the Sun in ellipses (ovals), not circles (**Figure 9.4**). Kepler's model matched observations perfectly.

Animation of Kepler's Laws of Planetary Motion: <http://projects.astro.illinois.edu/data/KeplersLaws/index.html>

The heliocentric model did not catch on right away. When Galileo Galilei first turned a telescope to the heavens in 1610, he made several striking discoveries. Galileo discovered that the planet Jupiter has **moons** orbiting around it. This provided the first evidence that objects could orbit something besides Earth.

An animation of three of Jupiter's moons orbiting the planet can be seen here: http://upload.wikimedia.org/wikipedia/commons/e/e7/Galilean_moon_Laplace_resonance_animation_de.gif .

Galileo also discovered that Venus has phases like the Moon (**Figure 9.5**), which provides direct evidence that Venus orbits the Sun.

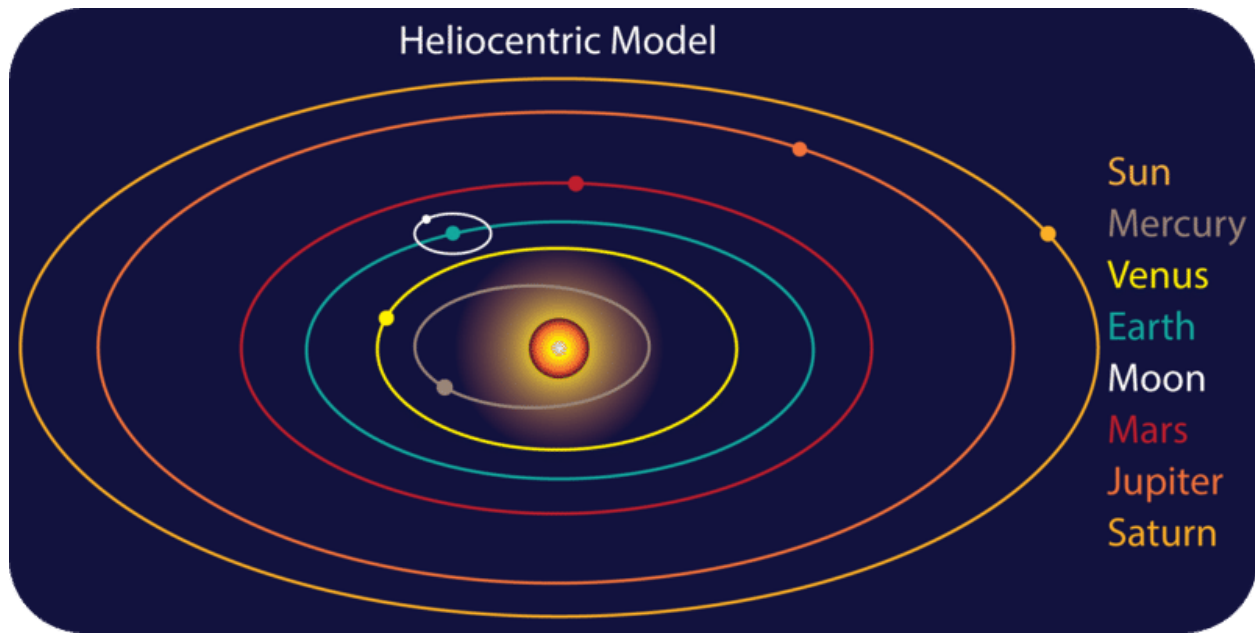


FIGURE 9.4

Kepler's model showed the planets moving around the Sun in ellipses.

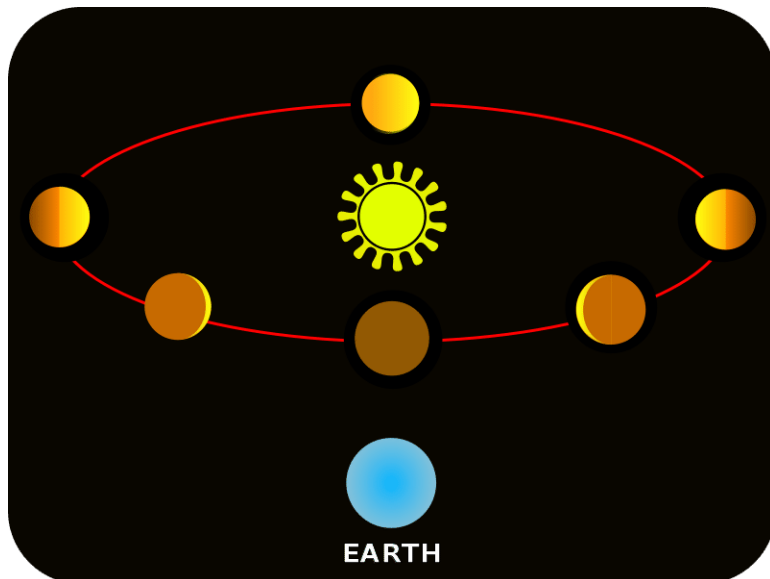


FIGURE 9.5

The phases of Venus.

Galileo's discoveries caused many more people to accept the heliocentric model of the universe, although Galileo himself was found guilty of heresy. The shift from an Earth-centered view to a Sun-centered view of the universe is referred to as the Copernican Revolution.

In their elliptical orbits, each planet is sometimes farther away from the Sun than at other times. This movement is called **revolution**. At the same time, Earth spins on its **axis**. Earth's axis is an imaginary line passing through the

planet's center that goes through both the North Pole and the South Pole. This spinning movement is called Earth's **rotation**.

Earth's Revolution

Copernicus, Galileo, and Kepler were all right: Earth and the other planets travel in an elliptical orbit around the Sun. The gravitational pull of the Sun keeps the planets in orbit. This ellipse is barely elliptical; it's very close to being a circle. The closest Earth gets to the Sun each year is at perihelion (147 million km) on about January 3rd, and the furthest is at aphelion (152 million km) on July 4th. The shape of Earth's orbit has nothing to do with Earth's seasons.

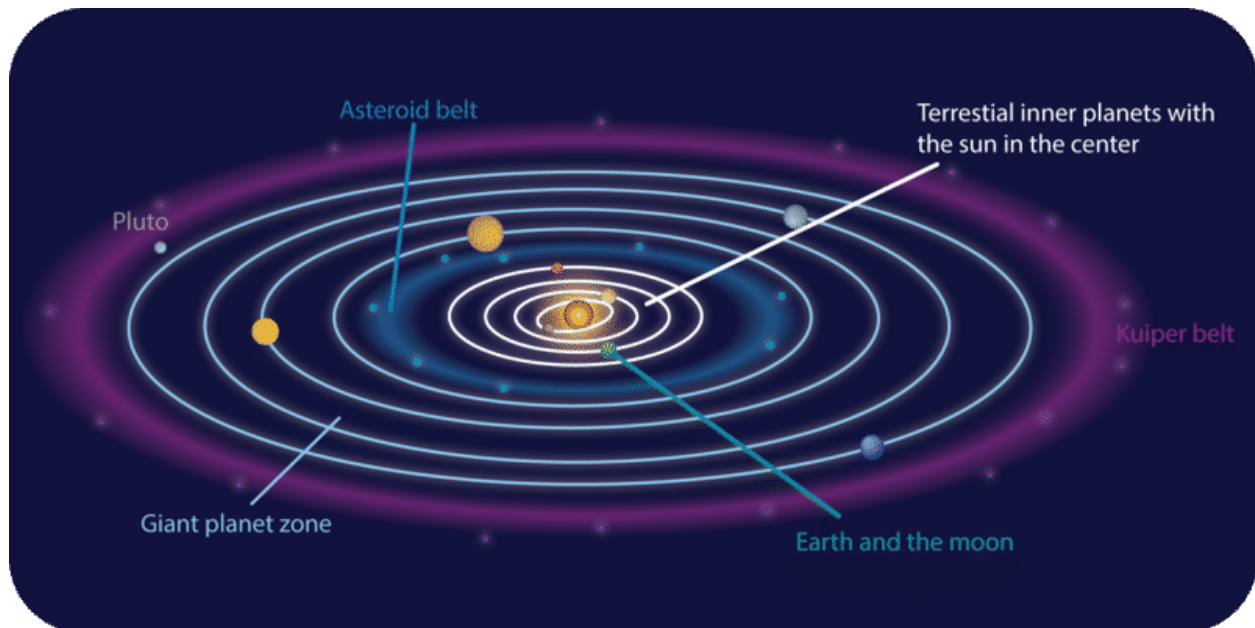


FIGURE 9.6

Earth and the other planets in the solar system make elliptical orbits around the Sun.

For Earth to make one complete revolution around the Sun takes 365.24 days. This amount of time is the definition of one year. Earth has one large moon, which orbits Earth once every 29.5 days, a period known as a month.

Summary

- In the geocentric model of the universe, Earth is at the center.
- In the heliocentric model of the universe, the Sun is at the center. The heliocentric model is the modern view of the solar system, but not the entire universe.
- Earth and the other planets of the solar system revolve around the Sun.

Explore More

Use this resource to answer the questions that follow.

<http://www.universetoday.com/36487/difference-between-geocentric-and-heliocentric/>

1. What does geocentric mean? What is the geocentric model?
2. What does heliocentric mean?
3. When did the heliocentric theory gain popularity and what prompted it?
4. Why was did geocentric theory remain popular for so long?
5. Why did the heliocentric theory eventually take precedence?

Review

1. How does the heliocentric model differ from the geocentric model?
2. Why do you think people had a hard time switching from one worldview to the other?
3. Describe Earth's orbit around the Sun.

9.5 Lunar Phases

- List the names of the phases of the moon.
- Describe what causes the phases of the Moon.



Can the Moon cast shadows?

Of course! A full moon is very bright. It is bright enough to cast shadows. If you are out away from city lights and the Moon is full you might cast your own Moon shadow.

The Phases of the Moon

The Moon does not produce any light of its own. It only reflects light from the Sun. The Moon has phases because it orbits around Earth. One orbit takes about 28 days. As the moon moves around Earth, different parts of it appear to be lit up by the Sun. The Moon sometimes appears fully lit and sometimes completely dark. Sometimes it is partially lit. The different appearances of the Moon are referred to as phases of the Moon (**Figure 9.7**).

A **full moon** occurs when the whole side facing Earth is lit. This happens when Earth is between the Moon and the Sun.

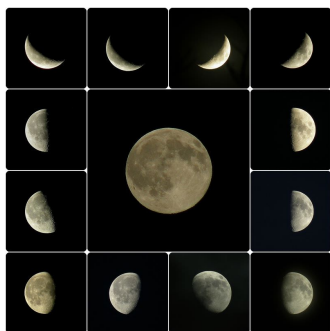


FIGURE 9.7

The moon's phases are a result of the moon's orbit around Earth.

About one week later, the Moon enters the quarter-moon phase. Only half of the Moon's lit surface is visible from Earth, so it appears as a half circle.

Another week later, the Moon moves between Earth and the Sun. The side of the Moon facing Earth is completely dark. This is called a **new moon**. Sometimes you can just barely make out the outline of the new moon in the sky. This is because some sunlight reflects off the Earth and hits the Moon.

One week after that, the Moon is in another quarter-moon phase. Finally, in one more week, the Moon is back to full.

Before and after the quarter-moon phases are the gibbous and crescent phases. During the **crescent** moon phase, the Moon is less than half lit. It is seen as only a sliver or crescent shape. During the **gibbous** moon phase, the Moon is more than half lit. It is not full. The Moon undergoes a complete cycle of phases about every 29.5 days.

Summary

- The appearance of the Moon from Earth has distinct phases.
- A full moon is completely lit; a new moon is completely dark.
- A gibbous moon is more than half lit; a crescent moon is less than half lit.

Explore More

Use the resource below to answer the questions that follow.

- **Phases of the Moon** at <http://www.youtube.com/watch?v=nXseTWTZlks> (3:15)



MEDIA

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/136806>

1. Why does the moon have phases?
2. What are the four main phases of the moon? How long does it take to change from one to another?
3. What is the name for a moon that is less than half full? More than half full?
4. What is the name for a moon that is getting larger? Getting smaller?
5. What causes a lunar eclipse? Why doesn't a lunar eclipse occur during each full moon?

Review

1. Describe how the Sun, Moon, and Earth are aligned during a full moon.
2. Describe how the Sun, Moon, and Earth are aligned during a new moon.
3. Draw and label pictures of the Moon in its phases.

9.6 Tides

- Define tides.
- Describe types of tides.
- Explain why tides occur.

Bay of Fundy Tides



Low Tide



High Tide

How could a tide be so extreme?

These two photos show high tide (left) and low tide (right) at Bay of Fundy on the Gulf of Maine. The Bay of Fundy has the greatest tidal ranges on Earth at 38.4 feet. Why is this tidal range so extreme? Why aren't all tidal ranges so great? Tidal range depends on many factors, including the slope of the continental margin.

The Tides

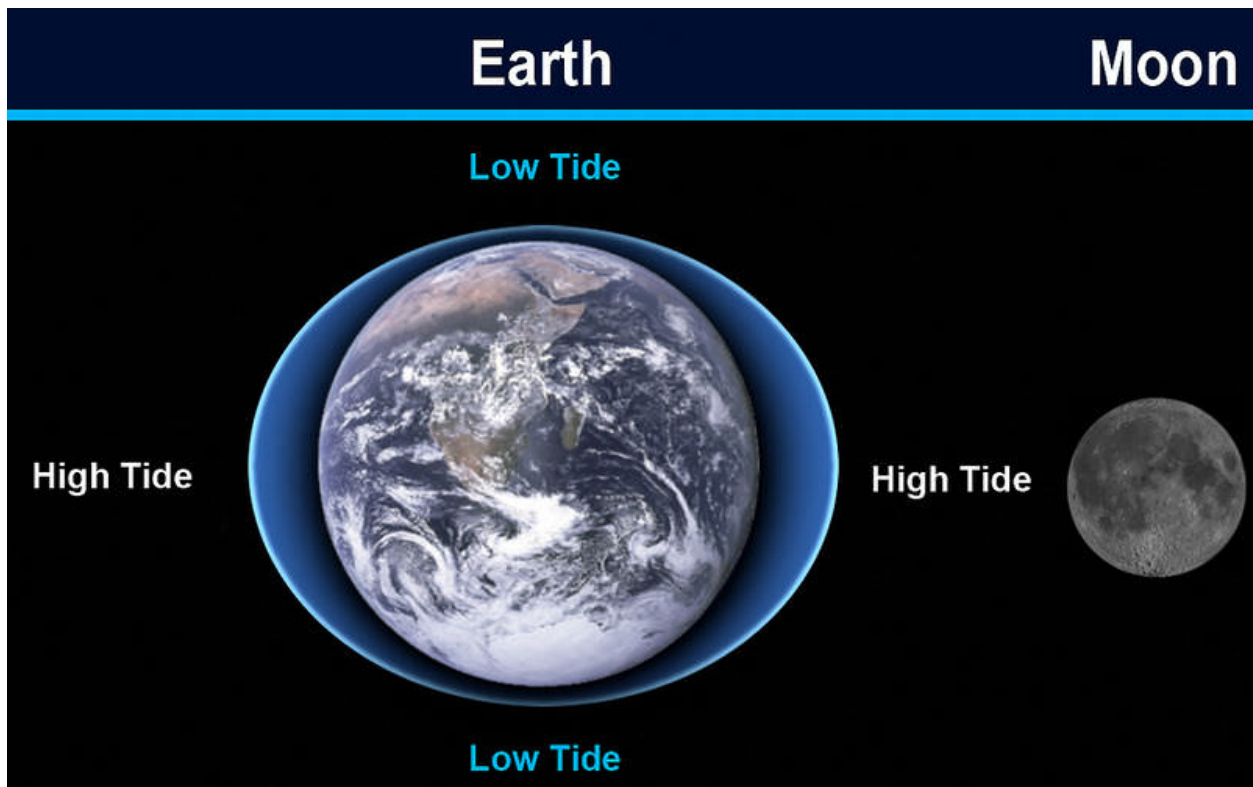
Tides are the daily rise and fall of sea level at any given place. The pull of the Moon's gravity on Earth is the primary cause of tides and the pull of the Sun's gravity on Earth is the secondary cause (**Figure 9.8**). The Moon has a greater effect because, although it is much smaller than the Sun, it is much closer. The Moon's pull is about twice that of the Sun's.

To understand the tides it is easiest to start with the effect of the Moon on Earth. As the Moon revolves around our planet, its gravity pulls Earth toward it. The lithosphere is unable to move much, but the water is pulled by the gravity and a bulge is created. This bulge is the high tide beneath the Moon. On the other side of the Earth, a high tide is produced where the Moon's pull is weakest. These two water bulges on opposite sides of the Earth aligned with the Moon are the **high tides**. The places directly in between the high tides are **low tides**. As the Earth rotates beneath the Moon, a single spot will experience two high tides and two low tides approximately every day.

High tides occur about every 12 hours and 25 minutes. The reason is that the Moon takes 24 hours and 50 minutes to rotate once around the Earth, so the Moon is over the same location every 24 hours and 50 minutes. Since high tides occur twice a day, one arrives each 12 hours and 25 minutes. What is the time between a high tide and the next low tide?

The gravity of the Sun also pulls Earth's water towards it and causes its own tides. Because the Sun is so far away, its pull is smaller than the Moon's.

Some coastal areas do not follow this pattern at all. These coastal areas may have one high and one low tide per day or a different amount of time between two high tides. These differences are often because of local conditions, such as the shape of the coastline that the tide is entering.


FIGURE 9.8

The gravitational attraction of the Moon to ocean water creates the high and low tides.

Tidal Range

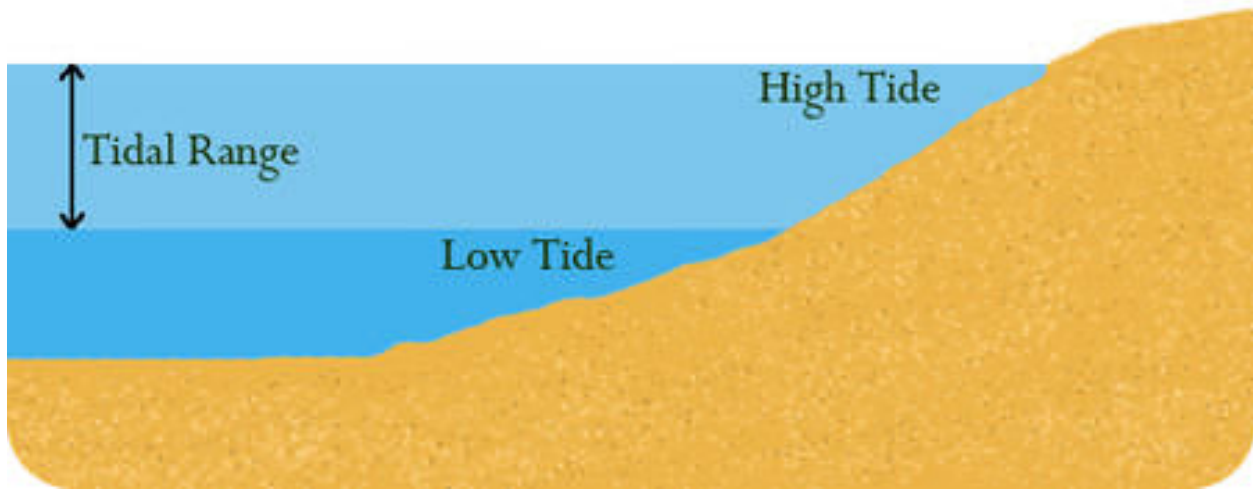
The **tidal range** is the difference between the ocean level at high tide and the ocean level at low tide (**Figure 9.9**). The tidal range in a location depends on a number of factors, including the slope of the seafloor. Water appears to move a greater distance on a gentle slope than on a steep slope.

Monthly Tidal Patterns

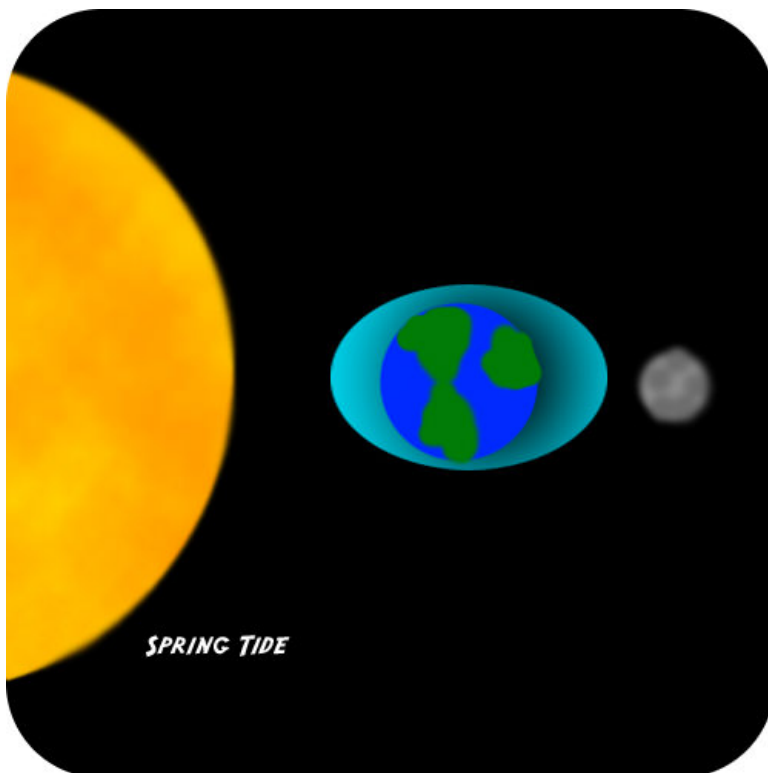
If you look at the diagram of high and low tides on a circular Earth above, you'll see that tides are waves. So when the Sun and Moon are aligned, what do you expect the tides to look like?

Waves are additive, so when the gravitational pull of both bodies is in the same direction, the high tides are higher and the low tides lower than at other times through the month (**Figure 9.10**). These more extreme tides, with a greater tidal range, are called **spring tides**. Spring tides don't just occur in the spring; they occur whenever the Moon is in a new-moon or full-moon phase, about every 14 days.

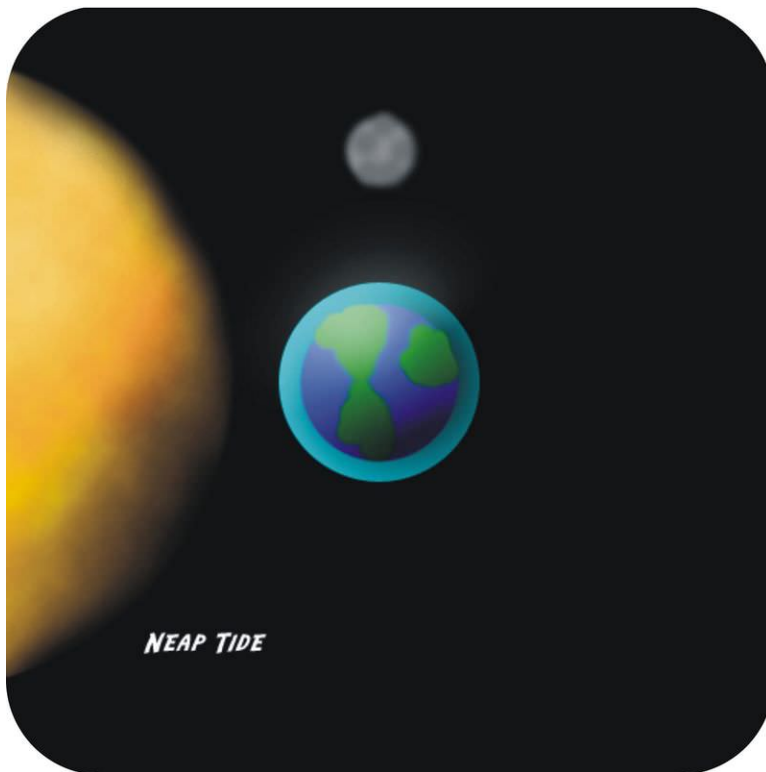
Neap tides are tides that have the smallest tidal range, and they occur when the Earth, the Moon, and the Sun form a 90° angle (**Figure 9.11**). They occur exactly halfway between the spring tides, when the Moon is at first or last quarter. How do the tides add up to create neap tides? The Moon's high tide occurs in the same place as the Sun's low tide and the Moon's low tide in the same place as the Sun's high tide. At neap tides, the tidal range is relatively small.

**FIGURE 9.9**

The tidal range is the difference between the ocean level at high tide and low tide.

**FIGURE 9.10**

A spring tide occurs when the gravitational pull of both Moon and the Sun is in the same direction, making high tides higher and low tides lower and creating a large tidal range.

**FIGURE 9.11**

A neap tide occurs when the high tide of the Sun adds to the low tide of the Moon and vice versa, so the tidal range is relatively small.

This animation shows the effect of the Moon and Sun on the tides: <http://www.onr.navy.mil/Focus/ocean/motion/tides1.htm> .

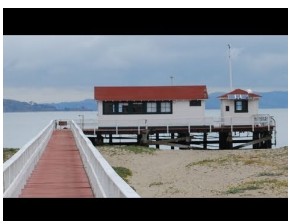
A detailed animation of lunar tides is shown here: <http://www.pbs.org/wgbh/nova/venice/tides.html> .

Here is a link to see these tides in motion: http://oceanservice.noaa.gov/education/kits/tides/media/tide06a_450.gif .

A simple animation of spring and neap tides is found here: http://oceanservice.noaa.gov/education/kits/tides/media/supp_tide06a.html .

Studying ocean tides' rhythmic movements helps scientists understand the ocean and the Sun/Moon/Earth system. This QUEST video explains how tides work, and visits the oldest continually operating tidal gauge in the Western Hemisphere.

Watch it at <http://www.kqed.org/quest/television/science-on-the-spot-watching-the-tides> .

**MEDIA**

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/116518>

Summary

- The primary cause of tides is the gravitational attraction of the Moon, which causes two high and two low tides a day.
- When the Sun's and Moon's tides match, there are spring tides; when they are opposed, there are neap tides.
- The difference between the daily high and the daily low is the tidal range.

Explore More

Use this resource to answer the questions that follow.

<https://www.youtube.com/watch?v=gftT3wHJGtg>

1. If the moon only goes around Earth once per day why are there two high tides per day?
2. If you are standing on the shore and it is high tide, what are the two possible locations for the moon relative to where you are?
3. What is the secondary reason for the tides? Why are these tides weaker than the moon's tides?
4. Why is it good that the moon is not closer to the Earth?

Review

1. Using the terminology of waves, describe how the gravitational attraction of the Moon and Sun make a high tide and a low tide.
2. Describe the causes of spring and neap tides.
3. What are the possible reasons that the Bay of Fundy has such a large tidal range?

9.7 Short-Term Climate Change

- Describe common short-term climate variations.



Why is El Niño important to a discussion on climate change?

In 1973 a severe El Niño shut off upwelling off of South America, resulting in the collapse of the anchovetta fishery. Without small fish to eat, larger marine organisms died off. Since then, severe El Niño events have become more frequent.

El Niño Southern Oscillation

Short-term changes in climate are common and they have many causes (**Figure 9.12**). The largest and most important of these is the oscillation between El Niño and La Niña conditions. This cycle is called the ENSO (El Niño Southern Oscillation). The ENSO drives changes in climate that are felt around the world about every two to seven years.

Normal Conditions

In a normal year, the trade winds blow across the Pacific Ocean near the Equator from east to west (toward Asia). A low pressure cell rises above the western equatorial Pacific. Warm water in the western Pacific Ocean raises sea levels by half a meter. Along the western coast of South America, the Peru Current carries cold water northward, and then westward along the Equator with the trade winds. Upwelling brings cold, nutrient-rich waters from the deep sea.

El Niño

In an **El Niño** year, when water temperature reaches around 28°C (82°F), the trade winds weaken or reverse direction and blow east (toward South America) (**Figure 9.13**). Warm water is dragged back across the Pacific Ocean and

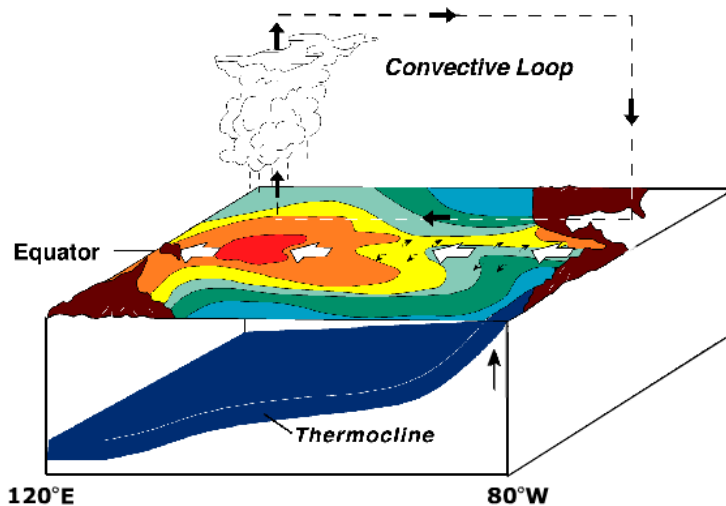


FIGURE 9.12

Under normal conditions, low pressure and warm water (shown in red) build up in the western Pacific Ocean. Notice that continents are shown in brown in the image. North and South America are on the right in this image.

piles up off the west coast of South America. With warm, low-density water at the surface, upwelling stops. Without upwelling, nutrients are scarce and plankton populations decline. Since plankton form the base of the food web, fish cannot find food, and fish numbers decrease as well. All the animals that eat fish, including birds and humans, are affected by the decline in fish.

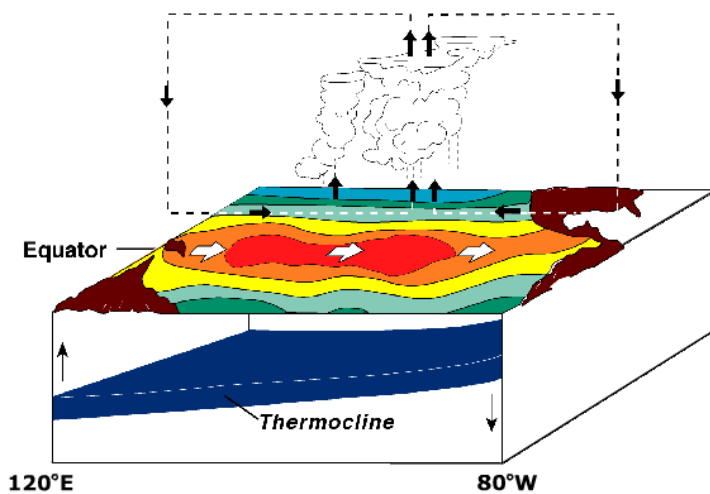


FIGURE 9.13

In El Niño conditions, the trade winds weaken or reverse directions. Warm water moves eastward across the Pacific Ocean and piles up against South America.

By altering atmospheric and oceanic circulation, El Niño events change global climate patterns.

- Some regions receive more than average rainfall, including the west coast of North and South America, the southern United States, and Western Europe.
- Drought occurs in other parts of South America, the western Pacific, southern and northern Africa, and southern Europe.

An El Niño cycle lasts one to two years. Often, normal circulation patterns resume. Sometimes circulation patterns bounce back quickly and extremely (Figure 9.14). This is a **La Niña**.

La Niña

In a La Niña year, as in a normal year, trade winds moves from east to west and warm water piles up in the western Pacific Ocean. Ocean temperatures along coastal South America are colder than normal (instead of warmer, as in El Niño). Cold water reaches farther into the western Pacific than normal.

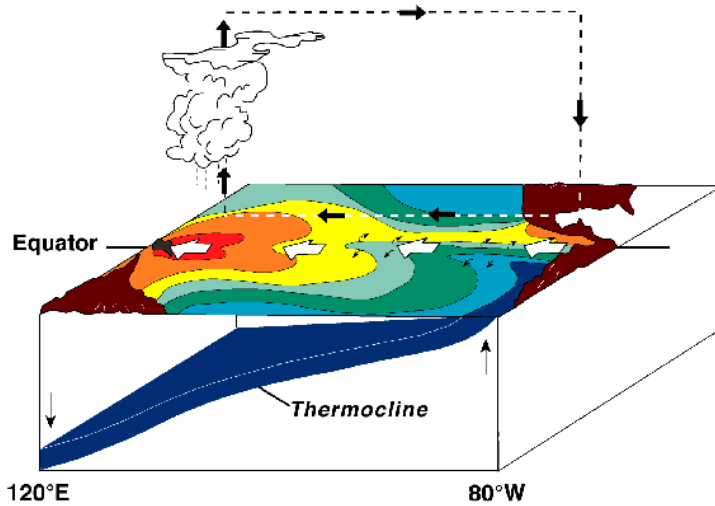


FIGURE 9.14

A La Niña year is like a normal year but the circulation patterns are more extreme.

An online guide to El Niño and La Niña events from the University of Illinois is found here: <http://ww2010.atmos.uiuc.edu/%28Gh%29/guides/mtr/el/ni/home.rxml> .

Other important oscillations are smaller and have a local, rather than global, effect. The North Atlantic Oscillation mostly alters climate in Europe. The Mediterranean also goes through cycles, varying between being dry at some times and warm and wet at others.

This ABC News video explores the relationship of El Niño to global warming. El Niño is named as the cause of strange weather across the United States in the winter of 2007 in this video: <http://www.youtube.com/watch?v=5uk9nwtAOio> (3:33).



MEDIA

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/1524>

Summary

- El Niño and La Niña are two examples of short-term climate changes lasting one to a few years.
- In an El Niño, the trade winds reverse direction, as do the equatorial surface currents, causing warm water to pool off of South America and stop upwelling.
- A La Niña is like normal conditions only more so.

Practice

Use this resource to answer the questions that follow.

<https://www.youtube.com/watch?v=ovDp1crqdOU>

1. What are El Niño and La Niña characterized by?
2. What is the temperature situation like in the equatorial Pacific during a La Niña?
3. What is the temperature situation like in the equatorial Pacific during a El Niño?
4. What happens when upwelling is shut off offshore of South America?
5. What happens to the United States during an El Niño?
6. What happens to the United States during an La Niña?

Review

1. Describe what happens with wind and current directions during an El Niño event.
2. Why does an El Niño cause a collapse of the food chain off of South America?
3. How does a La Niña event compare with an El Niño event?

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9.8 References

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14. Courtesy of US National Oceanic and Atmospheric Administration. [Diagram of La Nina years on the Pacific Ocean](#) . Public Domain

CHAPTER

10

Chapter 10 - Light Years and Theories

Chapter Outline

- 10.1 CHAPTER 10 GUIDED QUESTIONS
 - 10.2 UNIVERSE
 - 10.3 BIG BANG
 - 10.4 LIGHT YEARS (LY)
 - 10.5 REFERENCES
-

10.1 Chapter 10 Guided Questions

Chapter 10: Guided Questions

- How are light years used to measure distances in the universe?

Why is a light year a unit of distance rather than time?

- Why do we need to use light years as a way of measuring cosmic distances?

Explain a theory.

- What is the theory of the Big Bang?
- Why do scientists believe that the universe is expanding?

10.2 Universe

- Define Universe.
- Describe the evolution of human understanding of the Universe.



What's at the edge of the Universe?

This image is of the farthest away objects in the Universe. It was taken by the Hubble Space Telescope. The image looks back about 13 billion years. The galaxies in this image were all very young. It has just taken 13 billion years for their light to reach us.

The Universe

The study of the Universe is called **cosmology**. Cosmologists study the structure and changes in the present Universe. The **Universe** contains all of the star systems, galaxies, gas, and dust, plus all the matter and energy that exists now. Plus all that existed in the past, and all that will exist in the future. The Universe includes all of space and time.

Human Understanding of the Universe

What did the ancient Greeks recognize as the Universe? Their Universe had Earth at the center, the Sun, the Moon, five planets, and a sphere to which all the stars were attached. This idea held for many centuries. Galileo and his telescope helped people recognize that Earth is not the center of the Universe. They also found out that there are many more stars than were visible to the naked eye. All of those stars were in the Milky Way Galaxy.

In the early 20th century, an astronomer named Edwin Hubble (**Figure 10.1**) discovered something amazing. He showed that the Andromeda Nebula was over 2 million light years away. This was many times farther than the farthest distances that had ever been measured. Hubble realized that many of the objects that astronomers called nebulas were not actually clouds of gas. They were collections of millions or billions of stars. We now call these features galaxies.

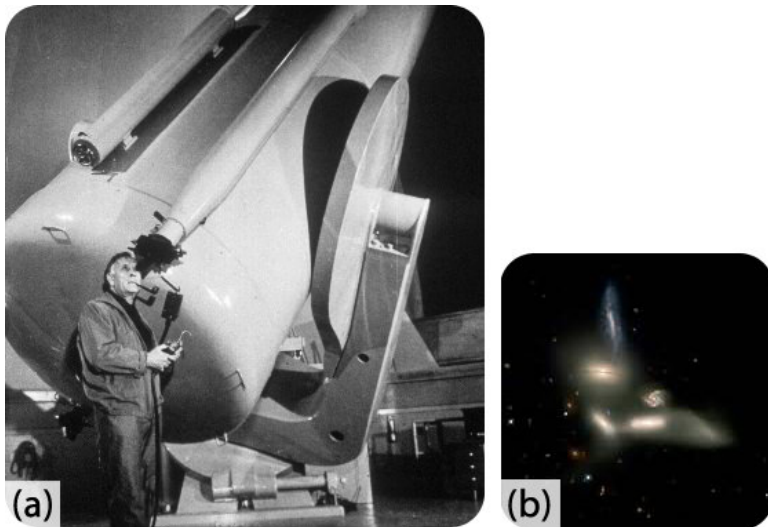


FIGURE 10.1

(a) Edwin Hubble used the 100-inch reflecting telescope at the Mount Wilson Observatory in California to show that some distant specks of light were galaxies. (b) Hubble's namesake space telescope spotted this six galaxy group. Edwin Hubble demonstrated the existence of galaxies.

Hubble showed that the Universe was much larger than our own galaxy. Today, we know that the Universe contains about a hundred billion galaxies. This is about the same number of galaxies as there are stars in the Milky Way Galaxy.

Summary

- The Universe contains about a hundred billion galaxies.
- The idea of a Universe has changed through human history.
- Edwin Hubble determined that there was much more to space than our own galaxy.

Explore More

Use the resources below to answer the questions that follow.

- **Cosmology** at http://www.windows2universe.org/the_universe/Cosmology.html

1. What is cosmology?
2. What is the Universe?
3. Why can't we observe everything in the Universe?

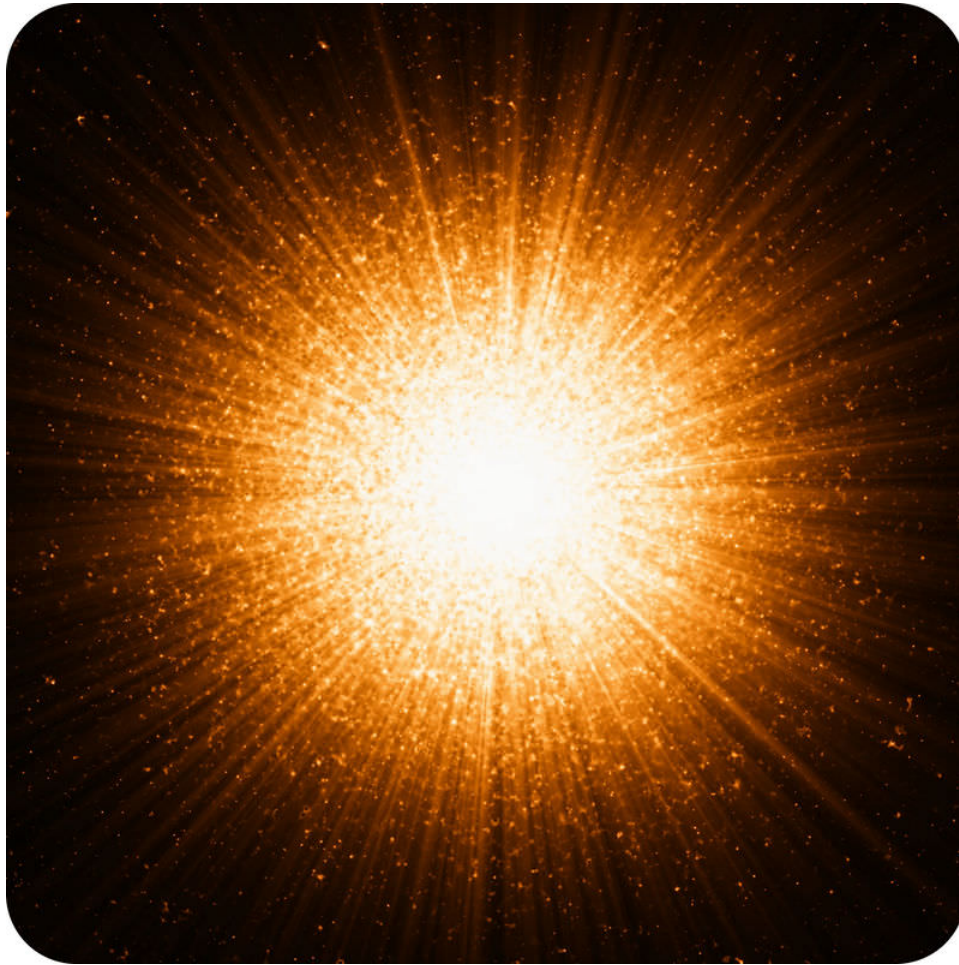
4. What are we actually looking at when we observe the cosmos? Why?
 - **The Future of Our Universe** at http://www.windows2universe.org/the_universe/Current.html
5. What is happening to our Universe?
6. What is the Universe filled with? What does that give us clues about?

Review

1. What do cosmologists study?
2. What was the importance of Edwin Hubble seeing that the Andromeda nebula was actually a galaxy?
3. What makes up the Universe?

10.3 Big Bang

- Explain and give evidence supporting the Big Bang theory.
- Describe what occurred after the Big Bang.



How did everything begin in the Big Bang?

The time when the Universe began is the explosion known as the Big Bang. Everything in the Universe was part of that explosion, although not in its current form.

The Big Bang Theory

There is a great deal of evidence that the Universe started with a big bang. The **Big Bang theory** is the most widely accepted cosmological explanation of how the Universe formed. Think about the expanding Universe, then reverse it. If we start at the present and go back into the past, the Universe gets smaller. What is the end result of a contracting Universe? A point.

According to the Big Bang theory, the Universe began about 13.7 billion years ago. Everything that is now in the Universe was squeezed into a point. It was all in a single, hot, chaotic mass. Then an enormous explosion—a big

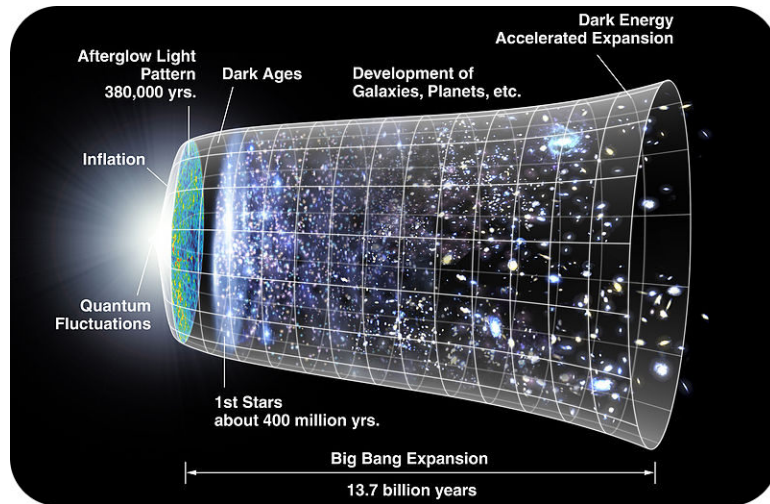


FIGURE 10.2

Timeline of the Big Bang and the expansion of the Universe.

bang—took place. The big bang caused the Universe to start expanding rapidly. All the matter and energy, even space itself, came out of this explosion (**Figure 10.2**).

What came before the Big Bang? There is no way for scientists to know, since there is no remaining evidence.

After the Big Bang

In the first few moments after the Big Bang, the Universe was unimaginably hot and dense. As the Universe expanded, it became less dense. It began to cool. After only a few seconds, protons, neutrons, and electrons could form. After a few minutes, hydrogen came together. There was so much energy that nuclear fusion began. This created helium.

Clumps of matter were held together by gravity. Eventually, these clumps formed stars. There are now countless trillions of stars, billions of galaxies, and other structures that form the visible Universe.

The galaxies at the edge of the Universe are a great distance away. But they are something else that is distant. Because it takes so long for light from so far away to reach us, they are also very far back in time (**Figure 10.3**).

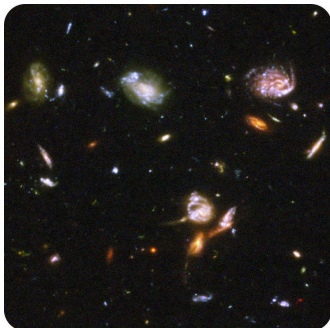


FIGURE 10.3

Images from very far away show what the Universe was like not too long after the Big Bang.

Background Radiation

The Big Bang hypothesis was not immediately accepted. But an important line of evidence for the Big Bang was discovered in 1964. In a static Universe, the space between objects should have no heat at all. The temperature should measure 0 K (Kelvin is an absolute temperature scale). But two researchers at Bell Laboratories used a microwave receiver to measure the background radiation in the Universe. They discovered that it is not 0 K, but 3 K (**Figure 10.4**). This tiny amount of heat is left over from the Big Bang. Nearly all astronomers and cosmologists now accept the Big Bang theory.

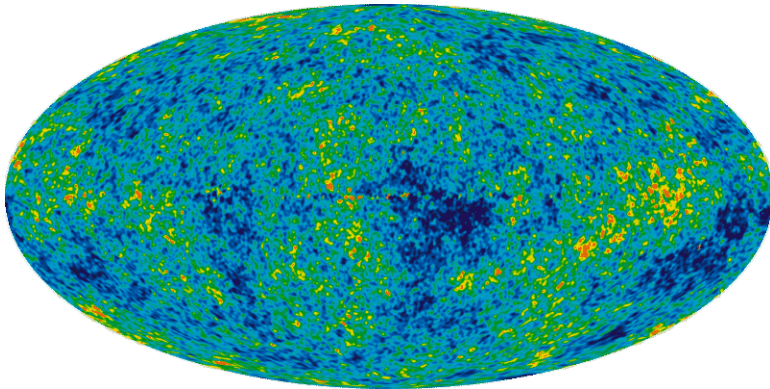


FIGURE 10.4

Background radiation in the Universe was good evidence for the Big Bang theory.

KQED: Nobel Laureate George Smoot and the Origin of the Universe

George Smoot, a scientist at Lawrence Berkeley National Lab, shared the 2006 Nobel Prize in Physics for his work on the origin of the Universe. Using background radiation, detected by the Cosmic Background Explorer Satellite (COBE), Smoot was able to make a picture of the Universe when it was 12 hours old. Learn more at: <http://science.kqed.org/quest/video/nobel-laureate-george-smoot-and-the-origin-of-the-universe/> .



MEDIA

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/5747>

Summary

- The Big Bang theory states that the Universe began as a point and expanded outward.
- No one can know what came before the Big Bang.
- The tiny bit of background radiation in the Universe is energy remaining from the Big Bang.

Explore More

Use the resource below to answer the questions that follow.

- **Stephen Hawking - The Big Bang** at <http://www.youtube.com/watch?v=gs-yWMuBNr4>



MEDIA

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/58952>

1. When did the Big Bang occur?
2. What did not exist before the Big Bang?
3. Describe the early Universe.
4. What was created at the Big Bang?
5. What happens when matter and antimatter collide?
6. Why is there a Universe at all?
7. When did the Universe become visible?

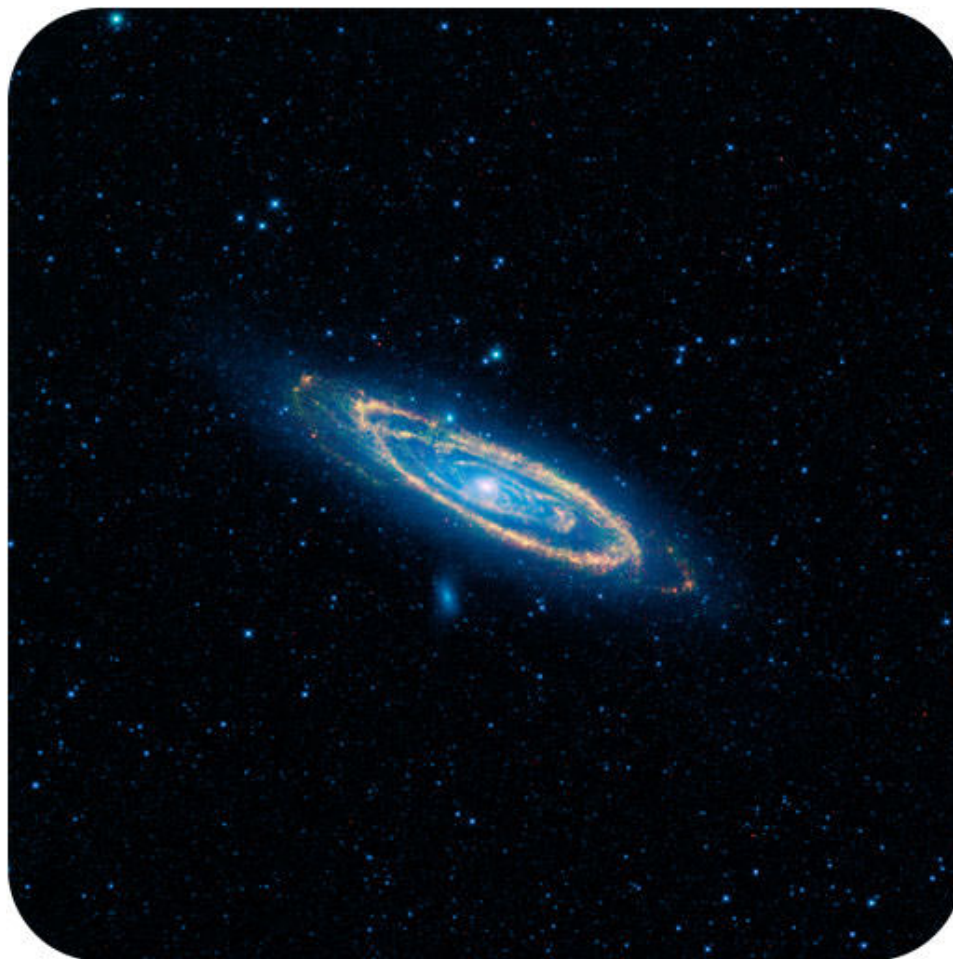
Review

1. If the Universe is now expanding, why must it once have been a point?
2. What evidence is there that the Universe began in a big bang?
3. What happened in the first minutes after the Big Bang?

10.4 Light Years (ly)

ly)

- Describe electromagnetic waves and the electromagnetic spectrum.
- Explain how astronomers use radiation to tell them about the Universe.



The Speed of Light

In space, light travels at about 300,000,000 meters per second (670,000,000 miles per hour). How fast is that? A beam of light could travel from New York to Los Angeles and back again nearly 40 times in just one second. Even at that amazing rate, objects in space are so far away that it takes a lot of time for their light to reach us. Even light from the nearest star, our sun, takes about eight minutes to reach Earth.

Light-Years

We need a really big unit to measure distances out in space because distances between stars are so great. A **light-year**, 9.5 trillion kilometers (5.9 trillion miles), is the distance that light travels in one year. That's a long way! Out in space, it's actually a pretty short distance.

Proxima Centauri is the closest star to us after the Sun. This near neighbor is 4.22 light-years away. That means the light from Proxima Centauri takes 4.22 years to reach us. Our galaxy, the Milky Way Galaxy, is about 100,000 light-years across. So it takes light 100,000 years to travel from one side of the galaxy to the other! It turns out that even 100,000 light-years is a short distance. The most distant galaxies we have detected are more than 13 billion light-years away. That's over a hundred-billion-trillion kilometers!

Looking Back in Time

When we look at stars and galaxies, we are seeing over great distances. More importantly, we are also seeing back in time. When we see a distant galaxy, we are actually seeing how the galaxy used to look. For example, the Whirlpool Galaxy is about 23 million light-years from Earth (**Figure 10.5**). When you see an image of the galaxy what are you seeing? You are seeing the galaxy as it was 23 million years ago!



FIGURE 10.5

The Whirlpool Galaxy as it looked 23 million years ago.

Since scientists can look back in time, they can better understand the Universe's history. Check out http://science.nasa.gov/headlines/y2002/08feb_gravlens.htm to see how this is true.

Summary

- Light travels very fast but still takes a long time to get across space. A light-year is the distance light can travel in one year..

Review

1. Why do astronomers use light-years as a measure of distance?
2. Why does light we see today tell us something about what happened earlier in the history of the Universe?

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10.5 References

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4. Courtesy of NASA/WMAP Science Team. [One piece of evidence that supports the Big Bang theory is background radiation](#) . Public Domain
5. Courtesy of NASA and The Hubble Heritage Team. [Image of the Whirlpool Galaxy](#) . Public Domain

CHAPTER **11** **Chapter 11 - Characteristics of the Universe**

Chapter Outline

- 11.1 CHAPTER 11 GUIDED QUESTIONS
 - 11.2 THE HERTZSPRUNG-RUSSELL DIAGRAM (H-R)
 - 11.3 LIFE CYCLES OF STARS
 - 11.4 GALAXIES
 - 11.5 ELECTROMAGNETIC SPECTRUM
 - 11.6 REFERENCES
-

11.1 Chapter 11 Guided Questions

Chapter 11: Guided Questions

TABLE 11.1:

Compare and Contrast the three types of galaxies.
Describe the formation of nebulae.
How could you describe a nebula in terms of composition?
How does a Hertzsprung-Russell diagram function?
What are some advantages and limitations of the Hertzsprung- Russell diagram as a model for classification?
How do stars, nebulae and galaxies differ?

- How could you describe a galaxy in terms of shape and composition?
- How would you describe the Sun in terms of location in our Solar System and size?
- How are wavelengths used when discussing stars?
- Why are electromagnetic waves best to use when studying space?
- How are waves on the electromagnetic spectrum classified?
- How can a spectroscope be used to give us information about the universe?
- What do different wavelengths of light tell us about components of our universe?

11.2 The Hertzsprung-Russell Diagram (H-R)

- Describe the stars present in each of the significant areas on the Hertzsprung-Russell Diagram.

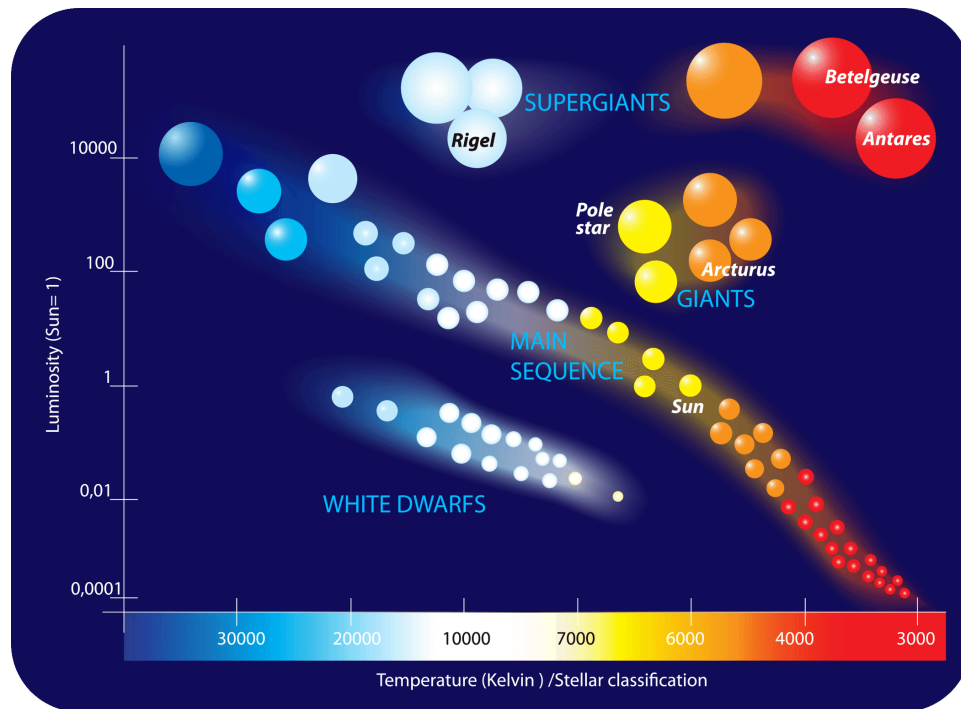


The star constellation “Orion, The Hunter”. Orion is one of the most beautiful of all constellations, and one of the easiest to find. It looks like a large (slightly twisted) rectangle high in winter’s south-southeastern sky. Two of the brightest stars in the evening sky lie at opposite corners of the rectangle: bright orange-red Betelgeuse at the northeastern corner (upper left in the photo) and even brighter Rigel at the southwest (lower right in the photo). Betelgeuse is at least 300 times the Sun’s diameter, and perhaps much more. It puts out about 100,000 times more energy than the Sun does. When Betelgeuse dies, it will create a fireball that will briefly outshine billions of normal stars. Betelgeuse is a red giant and Rigel is a blue giant.

Hertzsprung-Russell Diagram

The Hertzsprung-Russell diagram (often referred to as the H-R diagram) is a scatter graph that shows various classes of stars in the context of properties such as their **luminosity**, absolute magnitude, color, and effective temperature. Created around 1910 by Ejnar Hertzsprung and Henry Norris Russell, the diagram provided a great help in understanding stellar evolution.

There are several forms of the Hertzsprung-Russell diagram, and the nomenclature is not very well defined. The original diagram displayed the spectral type of stars on the horizontal axis and the absolute magnitude on the vertical axis. The form below shows Kelvin temperature along the horizontal axis going from high temperature on the left to low temperature on the right and luminosity on the vertical axis. We can think of the luminosity as brightness in multiples of the Sun. A luminosity of 100 on the axis would mean 100 times as bright as the Sun.



Most of the stars occupy a region in the diagram along a line called the Main Sequence. During that stage, stars are fusing hydrogen into helium in their cores. The position of the Sun in the main sequence is shown in the diagram.

You should note that the axial scales for this diagram are not linear. The vertical scale is logarithmic, each line is 100 times greater than the previous line. On the horizontal axis, as we move to the right, the temperature reduces by between 1,000 and 10,000 degrees K between each line.

If all other factors were the same, the highest temperature stars would also be the most luminous (the brightest). In the main sequence of stars, we see that as the temperature increases to the left, the luminosity also increases, demonstrating that the hottest stars in this grouping are also the brightest. There are stars, however, that are less bright than their temperature would predict. This group of stars is called white dwarfs. These stars are less bright than expected because of their very small size. These dwarf stars are only one one-thousandth the size of stars in the main sequence. There are also stars that are much brighter than their temperature would predict. This group of stars are called red giants. They are brighter than their temperature would predict because they are much larger than stars in the main sequence. These stars have expanded to several thousand times the size of stars in the main sequence. Stars that are reddish in color are cooler than other stars while stars that are bluish in color are hotter than other stars.

A white dwarf is a stellar remnant that is very dense. A white dwarf's mass is comparable to the Sun and its volume is comparable to that of Earth. The very low brightness of a white dwarf comes from the emission of stored heat energy.

White dwarfs are thought to be the final evolutionary state of any star whose mass is not great enough to become a neutron star. Approximately 97% of the stars in our galaxy will become neutron stars. After the hydrogen-fusing lifetime of a main-sequence star of low or medium mass ends, it will expand to a red giant which fuses helium to carbon and oxygen in its core. If a red giant has insufficient mass to generate the core temperatures required to fuse carbon, around 1 billion K, an inert mass of carbon and oxygen will build up at its center. After blowing off its outer layers to form a planetary nebula, the core will be left behind to form the remnant white dwarf. White dwarfs are composed of carbon and oxygen.

A white dwarf is very hot when it is formed, but since it has no source of energy (no further fusion reactions), it will gradually radiate away its energy and cool down. Over a very long time, a white dwarf will cool to temperatures at which it will no longer emit significant light, and it will become a cold *black dwarf*.

A red giant star is a star with a mass like the Sun that is in the last phase of its life, when Hydrogen fusion reactions

in the core decrease due to the lack of fuel. With the gravitational collapse of the core, the fusion reactions now occur in a shell surrounding the core. The outer layer of the star expands enormously up to 1000 times the size of the Sun. When the Sun becomes a red giant, its volume will include the orbit of Mercury and Venus and maybe even Earth. The increased size increases the luminosity even though the outer layer cools to only 3000 K or so. The cooler outer layer causes it to be a red star. After a few more million years, the star evolves into a white dwarf-planetary nebula system.

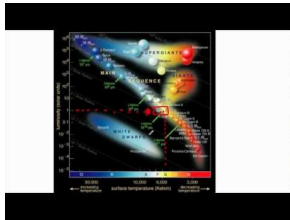
Summary

The Hertzsprung-Russell diagram (often referred to as the H-R diagram) is a scatter graph that shows various classes of stars in the context of properties such as their luminosity, absolute magnitude, color, and effective temperature.

Practice

Questions

http://www.youtube.com/watch?v=tt6d9_PQ7TE



MEDIA

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/65435>

Follow up questions:

1. The scales on the HR Diagram are _____.
2. The spectral class is related to _____.
3. What color are the stars on the left side of the HR diagram?

Review

Questions

1. Which of the following is a reasonable estimate for the surface temperature of the Sun as taken from the HR diagram?
 1. 10,000 K
 2. 8,000 K
 3. 6,000 K
 4. 4,000 K
 5. 2,000 K
2. Would the surface temperature of white dwarfs be higher or lower than that of red giants?
 1. higher

2. lower
 3. could be higher or lower
 3. What is the color of the stars with the highest surface temperature?
 1. blue
 2. yellow
 3. red
 4. What is the color of the stars with the lowest surface temperature?
 1. blue
 2. yellow
 3. red
 5. Most of the stars on the HR Diagram are classified as what type of stars?
 1. white dwarf
 2. main sequence
 3. red giant
 4. supergiant
 6. How is it possible for the Sun to be more luminous than a white dwarf if the Sun has a lower temperature than the white dwarf?
- **luminosity:** Luminosity is the rate at which a star or other object emits energy, usually in the form of electromagnetic radiation.

11.3 Life Cycles of Stars

- Describe the main stages in the life cycle of stars, including formation and main sequence.
- Describe the differences in the life cycles of different types of stars.
- Explain the relationship between a star's life cycle and its size.



What changes do stars undergo in their lifetimes?

Stars have a life cycle, just like people: they are born, grow, change over time, and eventually grow old and die. Most stars change in size, color, and class at least once in their lifetime. What astronomers know about the life cycles of stars is because of data gathered from visual, radio, and X-ray telescopes.

Star Formation

As discussed in the chapter The Solar System, stars are born in clouds of gas and dust called nebulae, like the one shown in **Figure 11.1**.

For more on star formation, check out http://www.spacetelescope.org/science/formation_of_stars.html and <http://hurrricanes.nasa.gov/universe/science/stars.html> .

The Main Sequence

For most of a star's life, nuclear fusion in the core produces helium from hydrogen. A star in this stage is a **main sequence star**. This term comes from the Hertzsprung-Russell diagram shown in the **Figure 11.2**. For stars on the main sequence, temperature is directly related to brightness. A star is on the main sequence as long as it is able to balance the inward force of gravity with the outward force of nuclear fusion in its core. The more massive a star, the more it must burn hydrogen fuel to prevent gravitational collapse. Because they burn more fuel, more massive stars have higher temperatures. Massive stars also run out of hydrogen sooner than smaller stars do.

Our Sun has been a main sequence star for about 5 billion years and will continue on the main sequence for about 5 billion more years (**Figure 11.3**). Very large stars may be on the main sequence for only 10 million years. Very small stars may last tens to hundreds of billions of years.

The fate of the Sun and inner planets is explored in this video: http://www.space.com/common/media/video/player.php?videoRef=mm32_SunDeath .

Red Giants and White Dwarfs

As a star begins to use up its hydrogen, it fuses helium atoms together into heavier atoms such as carbon. A blue giant star has exhausted its hydrogen fuel and is in a transitional phase. When the light elements are mostly used

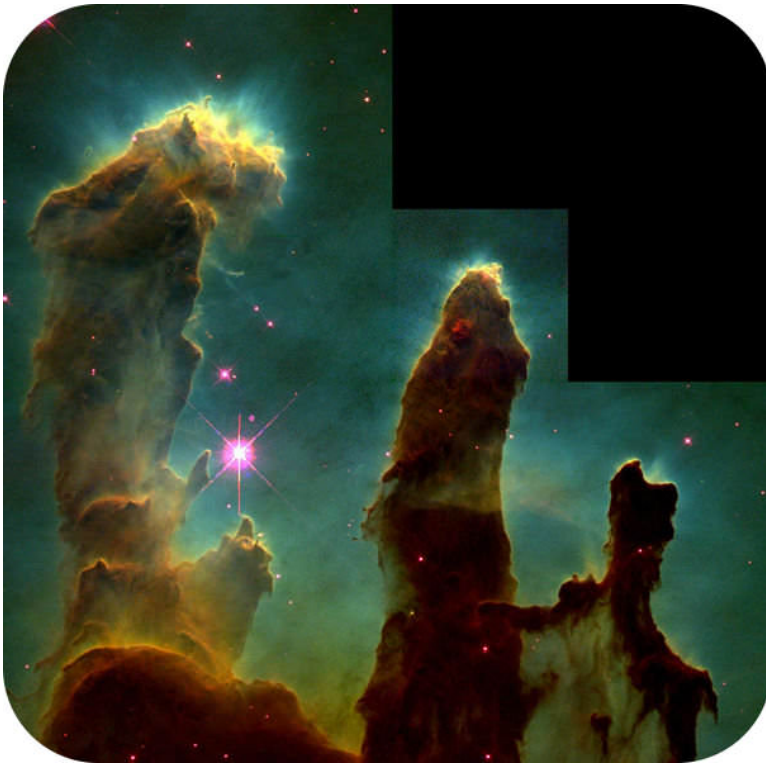


FIGURE 11.1

The Pillars of Creation within the Eagle Nebula are where gas and dust come together as a stellar nursery.

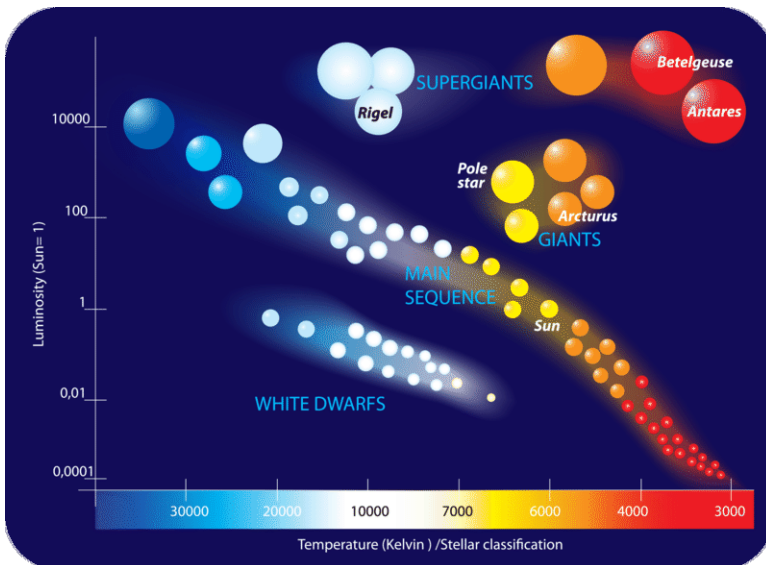


FIGURE 11.2

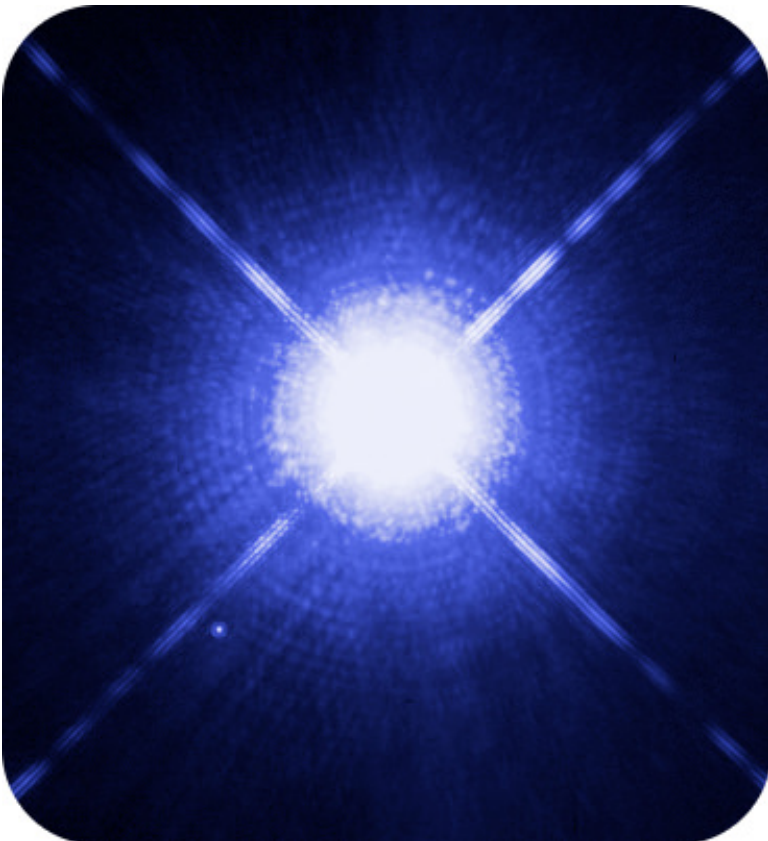
Hertzsprung-Russell diagram.

up, the star can no longer resist gravity and starts to collapse inward. The outer layers of the star grow outward and cool. The larger, cooler star turns red in color and so is called a **red giant**.

Eventually, a red giant burns up all of the helium in its core. What happens next depends on how massive the star is. A typical star, such as the Sun, stops fusion completely. Gravitational collapse shrinks the star's core to a white, glowing object about the size of Earth, called a **white dwarf** (Figure 11.4). A white dwarf will ultimately fade out.

**FIGURE 11.3**

Our Sun is a medium-sized star in about the middle of its main sequence life.

**FIGURE 11.4**

Sirius, the brightest star in the sky, is actually a binary star system. Sirius A is on the main sequence. Sirius B, the tiny dot on the lower left, is a white dwarf.

Supergiants and Supernovas

A star that runs out of helium will end its life much more dramatically. When very massive stars leave the main sequence, they become red supergiants (**Figure 11.5**).



FIGURE 11.5

The red star Betelgeuse in Orion is a red supergiant.

Unlike a red giant, when all the helium in a red supergiant is gone, fusion continues. Lighter atoms fuse into heavier atoms up to iron atoms. Creating elements heavier than iron through fusion uses more energy than it produces, so stars do not ordinarily form any heavier elements. When there are no more elements for the star to fuse, the core succumbs to gravity and collapses, creating a violent explosion called a **supernova** (**Figure 11.6**). A supernova explosion contains so much energy that atoms can fuse together to produce heavier elements such as gold, silver, and uranium. A supernova can shine as brightly as an entire galaxy for a short time. All elements with an atomic number greater than that of lithium were formed by nuclear fusion in stars.

An animation of the Crab Supernova is seen here: <http://www.youtube.com/watch?v=0J8srN24pSQ> .

Neutron Stars

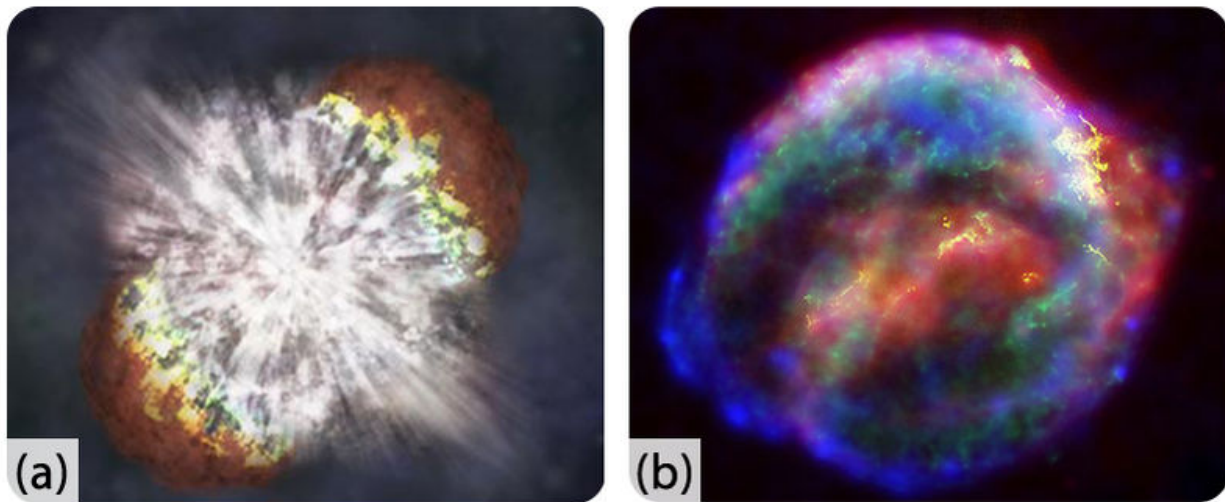
After a supernova explosion, the leftover material in the core is extremely dense. If the core is less than about four times the mass of the Sun, the star becomes a **neutron star** (**Figure 11.7**). A neutron star is more massive than the Sun, but only a few kilometers in diameter. A neutron star is made almost entirely of neutrons, relatively large particles that have no electrical charge.

Black Hole

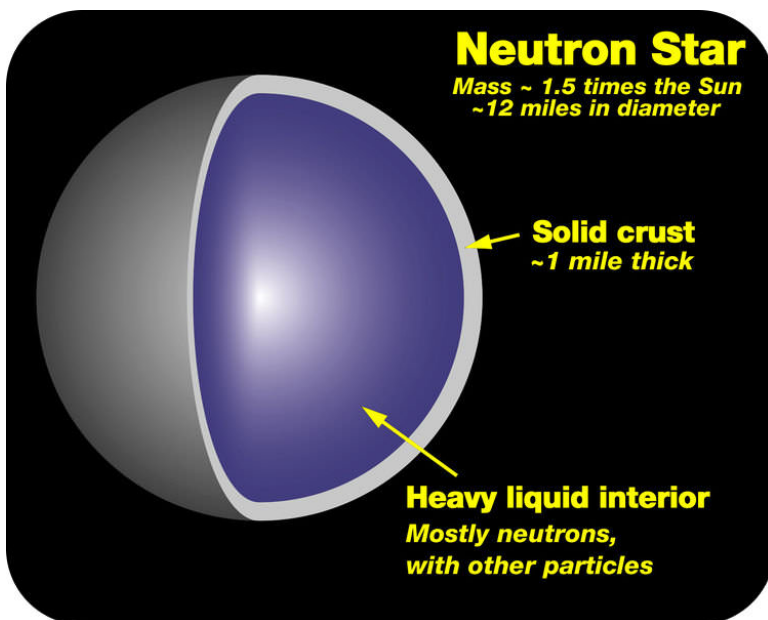
If the core remaining after a supernova is more than about five times the mass of the Sun, the core collapses into a **black hole**. Black holes are so dense that not even light can escape their gravity. With no light, a black hole cannot be observed directly. But a black hole can be identified by the effect that it has on objects around it, and by radiation that leaks out around its edges.

How to make a black hole: http://www.space.com/common/media/video/player.php?videoRef=black_holes#playerTop .

A video about black holes is seen on Space.com: http://www.space.com/common/media/video/player.php?videoRef=black_holes .

**FIGURE 11.6**

(a) NASA's Chandra X-ray observatory captured the brightest stellar explosion so far, 100 times more energetic than a typical supernova. (b) This false-color image of the supernova remnant SN 1604 was observed as a supernova in the Milky Way galaxy. At its peak it was brighter than all other stars and planets, except Venus, in the night sky.

**FIGURE 11.7**

After a supernova, the remaining core may end up as a neutron star.

A *Star's Life Cycle* video from Discovery Channel describes how stars are born, age and die (2f): <http://www.youtube.com/watch?v=H8Jz6FU5D1A> (3:11).

**MEDIA**

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/1489>

A video of neutron stars is available at: http://www.youtube.com/watch?v=VMnLVkV_ovc (4:24).

**MEDIA**

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/1490>

Summary

- Stars spend most of their lives on the main sequence, fusing hydrogen into helium for energy.
- As stars burn up their hydrogen and fuse helium into larger atoms they begin to collapse and become red giants. When the helium is gone they become white dwarfs.
- When a massive star has no more elements left to fuse it explodes as a supernova, from which the chemical elements heavier than lithium form.
- An extremely massive core will collapse after a supernova explosion to become a black hole, which is black because no light can escape it.

Making Connections

**MEDIA**

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/60979>

Practice

Use this resource to answer the questions that follow.

http://www.odec.ca/projects/2002/wongj/public_html/animations.html

1. What is the birthplace of stars? What happens there?
2. Describe the main sequence star.
3. What causes a red giant to form?
4. Why does a red giant core collapse?
5. What does a red giant become?
6. What happens to a white dwarf?
7. What is the structure of high mass stars?

8. What happens as this star ages?
9. What do neon and magnesium fuse into?
10. How is an iron core produced?
11. What do high mass stars become?

Review

1. Why do some stars become red giants and others become supernovae?
2. Why are supernovae crucial to the evolution of the universe?
3. How does a star become a black hole? What are the characteristics of a black hole?

11.4 Galaxies

- Define galaxy, and describe types of galaxies.



What's happening with those galaxies?

Find a clear night sky and get out a good pair of binoculars or a telescope. You can see this feature (although not quite as well). The Whirlpool galaxy has an enhanced spiral structure due to its interactions with its companion galaxy NGC 5195.

Galaxies

Galaxies are the biggest groups of stars and can contain anywhere from a few million stars to many billions of stars. Every star that is visible in the night sky is part of the Milky Way Galaxy. To the naked eye, the closest major galaxy — the Andromeda Galaxy, shown in **Figure 11.8** — looks like only a dim, fuzzy spot. But that fuzzy spot contains one trillion — 1,000,000,000,000 — stars!

Galaxies are divided into three types according to shape: spiral galaxies, elliptical galaxies, and irregular galaxies.

Spiral Galaxies

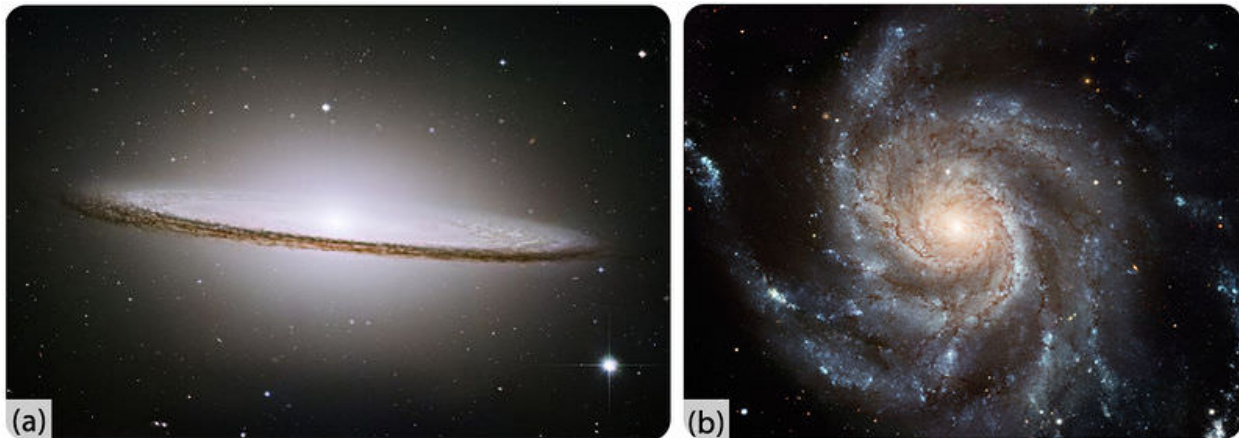
Spiral galaxies spin, so they appear as a rotating disk of stars and dust, with a bulge in the middle, like the Sombrero Galaxy shown in **Figure 11.9**. Several arms spiral outward in the Pinwheel Galaxy (seen in **Figure 11.9**) and are appropriately called **spiral arms**. Spiral galaxies have lots of gas and dust and lots of young stars.

Elliptical Galaxies

Figure 11.10 shows a typical egg-shaped **elliptical galaxy**. The smallest elliptical galaxies are as small as some

**FIGURE 11.8**

The Andromeda Galaxy is a large spiral galaxy similar to the Milky Way.

**FIGURE 11.9**

(a) The Sombrero Galaxy is a spiral galaxy that we see from the side so the disk and central bulge are visible. (b) The Pinwheel Galaxy is a spiral galaxy that we see face-on so we can see the spiral arms. Because they contain lots of young stars, spiral arms tend to be blue.

globular clusters. Giant elliptical galaxies, on the other hand, can contain over a trillion stars. Elliptical galaxies are reddish to yellowish in color because they contain mostly old stars.

Most elliptical galaxies contain very little gas and dust because the gas and dust have already formed into stars. However, some elliptical galaxies, such as the one shown in **Figure 11.11**, contain lots of dust. Why might some elliptical galaxies contain dust?

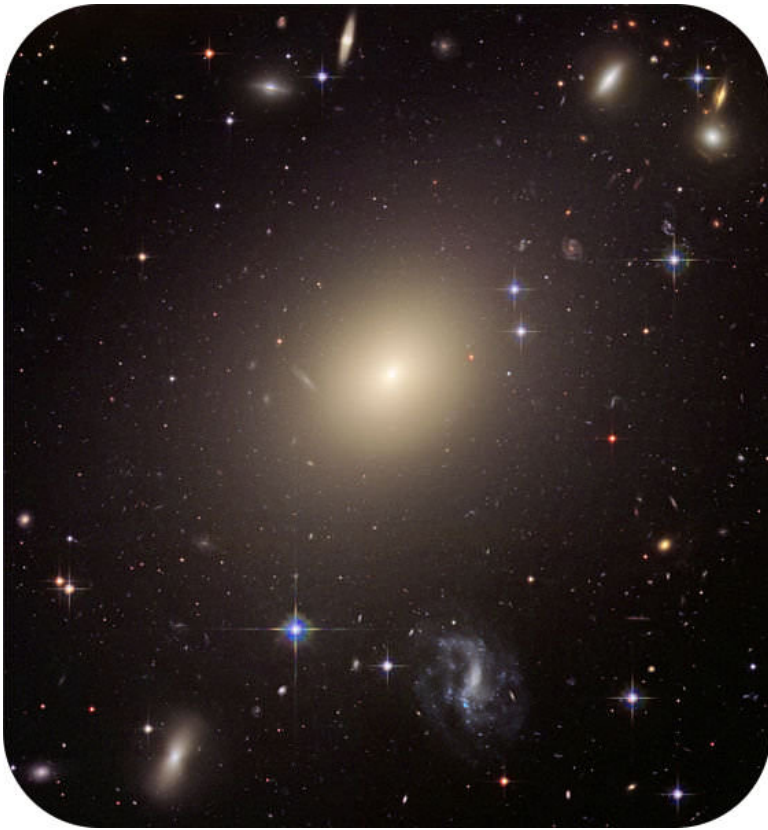


FIGURE 11.10

The large, reddish-yellow object in the middle of this figure is a typical elliptical galaxy. What other types of galaxies can you find in the figure?

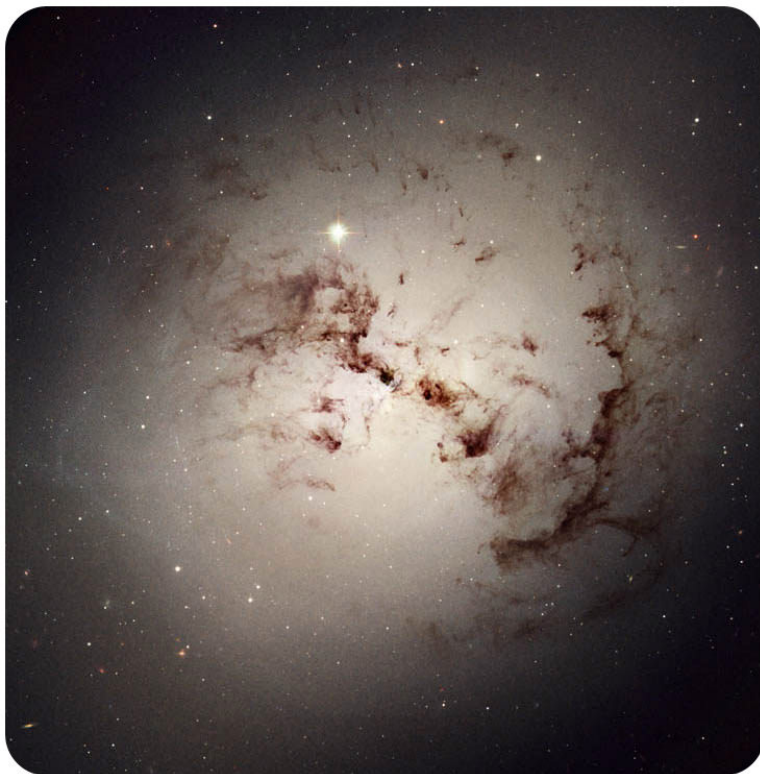


FIGURE 11.11

Astronomers believe that these dusty elliptical galaxies form when two galaxies of similar size collide.

Irregular Galaxies

Is the galaxy in **Figure 11.12** a spiral galaxy or an elliptical galaxy? It is neither one! Galaxies that are not clearly elliptical galaxies or spiral galaxies are **irregular galaxies**. How might an irregular galaxy form? Most irregular galaxies were once spiral or elliptical galaxies that were then deformed either by gravitational attraction to a larger galaxy or by a collision with another galaxy.



FIGURE 11.12

This galaxy, called NGC 1427A, has neither a spiral nor an elliptical shape.

Dwarf Galaxies

Dwarf galaxies are small galaxies containing only a few million to a few billion stars. Dwarf galaxies are the most common type in the universe. However, because they are relatively small and dim, we don't see as many dwarf galaxies from Earth. Most dwarf galaxies are irregular in shape. However, there are also dwarf elliptical galaxies and dwarf spiral galaxies.

Look back at the picture of the elliptical galaxy. In the figure, you can see two dwarf elliptical galaxies that are companions to the Andromeda Galaxy. One is a bright sphere to the left of center, and the other is a long ellipse below and to the right of center. Dwarf galaxies are often found near larger galaxies. They sometimes collide with and merge into their larger neighbors.

Images from the Hubble Space Telescope are seen in this video: http://www.space.com/common/media/video/player.php?videoRef=black_holes#playerTop .

Summary

- A galaxy is composed of millions to billions of stars.
- Galaxies can be spiral, elliptical or irregular. Dwarf galaxies are smaller, but are more common than other galaxies.
- Galaxies that have lots of dust and gas are locations where stars are forming.

Explore More

Use this resource to answer the questions that follow.

- <http://ircamera.as.arizona.edu/NatSci102/NatSci102/lectures/galaxytypes.htm>

1. List the different basic types of galaxies.
2. What determines the type of galaxy?
3. What is the bulge?
4. What is the disk?
5. Describe spiral galaxies.
6. Describe elliptical galaxies.
7. Describe irregular galaxies.

Review

1. What makes a galaxy different from other galaxies or types of astronomical objects?
2. What makes irregular galaxies take an irregular shape?
3. How do dwarf galaxies interact with other galaxies?

11.5 Electromagnetic Spectrum

- Describe electromagnetic radiation and its properties.
- Give an overview of the electromagnetic spectrum.



It's a warm sunny Saturday, and Michael and Lavar have a big day planned. They're going to ride across town to meet their friends and then go to the zoo. The boys may not realize it, but they will be bombarded by electromagnetic radiation as they ride their bikes and walk around the zoo grounds. The only kinds of radiation they can detect are visible light, which allows them to see, and infrared light, which they feel as warmth on their skin.

Q: Besides visible light and infrared light, what other kinds of electromagnetic radiation will the boys be exposed to in sunlight?

A: Sunlight consists of all the different kinds of electromagnetic radiation, from harmless radio waves to deadly gamma rays. Fortunately, Earth's atmosphere prevents most of the harmful radiation from reaching Earth's surface. You can read about the different kinds of electromagnetic radiation in this article.

Electromagnetic Radiation

Electromagnetic radiation is energy that travels in waves across space as well as through matter. Most of the electromagnetic radiation on Earth comes from the sun. Like other waves, electromagnetic waves are characterized by certain wavelengths and wave frequencies. Wavelength is the distance between two corresponding points on adjacent waves. Wave frequency is the number of waves that pass a fixed point in a given amount of time. Electromagnetic waves with shorter wavelengths have higher frequencies and more energy.

A Spectrum of Electromagnetic Waves

Visible light and infrared light are just a small part of the full range of electromagnetic radiation, which is called the **electromagnetic spectrum**. You can see the waves of the electromagnetic spectrum in the **Figure 11.13**. At the top

of the diagram, the wavelengths of the waves are given. Also included are objects that are about the same size as the corresponding wavelengths. The frequencies and energy levels of the waves are shown at the bottom of the diagram. Some sources of the waves are also given. For a video introduction to the electromagnetic spectrum, go to this URL: <http://www.youtube.com/watch?v=cfXzwh3KadE> .

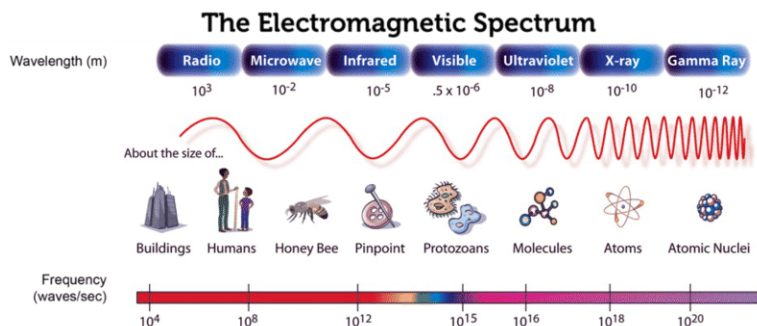


FIGURE 11.13

- On the left side of the electromagnetic spectrum diagram are radio waves and microwaves. Radio waves have the longest wavelengths and lowest frequencies of all electromagnetic waves. They also have the least amount of energy.
- On the right side of the diagram are X rays and gamma rays. They have the shortest wavelengths and highest frequencies of all electromagnetic waves. They also have the most energy.
- Between these two extremes are waves that are commonly called light. Light includes infrared light, visible light, and ultraviolet light. The wavelengths, frequencies, and energy levels of light fall in between those of radio waves on the left and X rays and gamma rays on the right.

Q: Which type of light has the longest wavelengths?

A: Infrared light has the longest wavelengths.

Q: What sources of infrared light are shown in the diagram?

A: The sources in the diagram are people and light bulbs, but all living things and most other objects give off infrared light.

Summary

- Electromagnetic radiation travels in waves through space or matter. Electromagnetic waves with shorter wavelengths have higher frequencies and more energy.
- The full range of electromagnetic radiation is called the electromagnetic spectrum. From longest to shortest wavelengths, it includes radio waves, microwaves, infrared light, visible light, ultraviolet light, X rays, and gamma rays.

Explore More

At the first URL below, read about electromagnetic waves with different frequencies. Then use the information to complete the table at the second URL. <http://www.darvill.clara.net/emag/index.htm> and <http://www.darvill.clara.net/emag/gcseemag.pdf>

Review

1. Describe the relationship between the wavelength and frequency of electromagnetic waves.
2. What is the electromagnetic spectrum?
3. Which electromagnetic waves have the longest wavelengths?
4. Identify a source of microwaves.
5. Which type of light has the highest frequencies?
6. Explain why gamma rays are the most dangerous of all electromagnetic waves.

8

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11.6 References

1. User:TheStarmon/Wikimedia Commons. http://commons.wikimedia.org/wiki/File:Orion_tjt.jpg .
2. Image copyright Designua, 2014. <http://www.shutterstock.com> .
3. Courtesy of NASA, Jeff Hester, and Paul Scowen (Arizona State University). [The Pillars of Creation in the Eagle Nebula are the site of active star formation](#) . Public Domain
4. Image copyright Designua, 2014. [The Hertzsprung-Russell diagram plots luminosity against star color with the hottest stars on the left side](#) . Used under license from Shutterstock.com
5. Masahiko Ohkubo. [The sun is a medium sized star in the middle of its life](#) . CC BY 2.0
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7. Courtesy of Akira Fujii and the Hubble European Space Agency. [The red star Betelgeuse in Orion is a red supergiant](#) . Public Domain
8. (a) Courtesy of NASA/CXC/M.Weiss; (b) Courtesy of NASA/ESA/JHU/R.Sankrit W.Blair. [A supernova is an intensely powerful explosion that heavy stars undergo](#) . Public Domain
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14. Courtesy of NASA, ESA, and the Hubble Heritage Team (STScI/AURA). [This galaxy is an irregular galaxy that is neither spiral nor elliptical](#) . Public Domain
15. Courtesy of NASA. [The electromagnetic spectrum spans a wide range of wavelengths and frequencies](#) . public domain

CHAPTER

12

Chapter 12 - Interdependence Among Living Systems

Chapter Outline

- 12.1 CHAPTER 12 GUIDED QUESTIONS
 - 12.2 AUTOTROPHS AND HETEROTROPHS
 - 12.3 FOOD CHAINS AND FOOD WEBS
 - 12.4 COMPETITION IN COMMUNITIES
 - 12.5 IMPORTANCE OF THE OCEANS
 - 12.6 SOIL AND WATER RESOURCES
 - 12.7 REFERENCES
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12.1 Chapter 12 Guided Questions

Chapter 12: Guided Questions

How does population size affect the organisms in it?

What is the relationship between population, community, and ecosystem?

How does an ecosystem relate to a biosphere?

What will happen to a population if a food becomes less plentiful? What is a limiting factor?

What factors affect the size of a population?

What is the difference between biotic and abiotic?

12.2 Autotrophs and Heterotrophs

- Define photosynthesis.
- State the chemical reaction of photosynthesis.
- Describe how autotrophs and heterotrophs obtain energy.
- Explain the relationship between producers and consumers.
- Distinguish photosynthesis from chemosynthesis.



Name one major difference between a plant and an animal.

There are many differences, but in terms of energy, it all starts with sunlight. Plants absorb the energy from the sun and turn it into *food*. You can sit in the sun for hours and hours. You will feel warm, but you're not going to absorb any energy. You have to eat to obtain your energy.

Autotrophs vs. Heterotrophs

Living organisms obtain chemical energy in one of two ways.

Autotrophs, shown in **Figure 12.1**, store chemical energy in carbohydrate food molecules they build themselves. **Food** is chemical energy stored in organic molecules. Food provides both the energy to do work and the carbon to build bodies. Because most autotrophs transform sunlight to make food, we call the process they use **photosynthesis**. Only three groups of organisms - plants, algae, and some bacteria - are capable of this life-giving energy transformation. Autotrophs make food for their own use, but they make enough to support other life as well. Almost all other organisms depend absolutely on these three groups for the food they produce. The **producers**, as autotrophs are also known, begin **food chains** which feed all life. Food chains will be discussed in the "Food Chains and Food Webs" concept.

Heterotrophs cannot make their own food, so they must eat or absorb it. For this reason, heterotrophs are also known as **consumers**. Consumers include all animals and fungi and many protists and bacteria. They may consume autotrophs or other heterotrophs or organic molecules from other organisms. Heterotrophs show great diversity and may appear far more fascinating than producers. But heterotrophs are limited by our utter dependence on those autotrophs that originally made our food. If plants, algae, and autotrophic bacteria vanished from earth, animals, fungi, and other heterotrophs would soon disappear as well. All life requires a constant input of energy. Only autotrophs can transform that ultimate, solar source into the chemical energy in food that powers life, as shown in **Figure 12.2**.

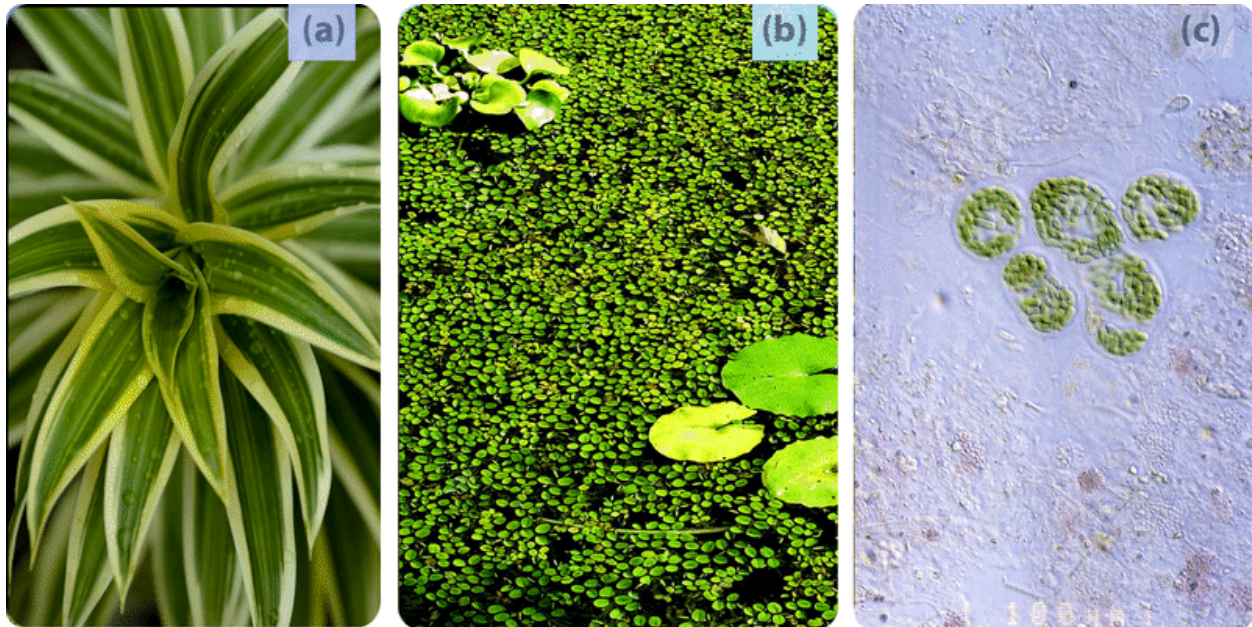


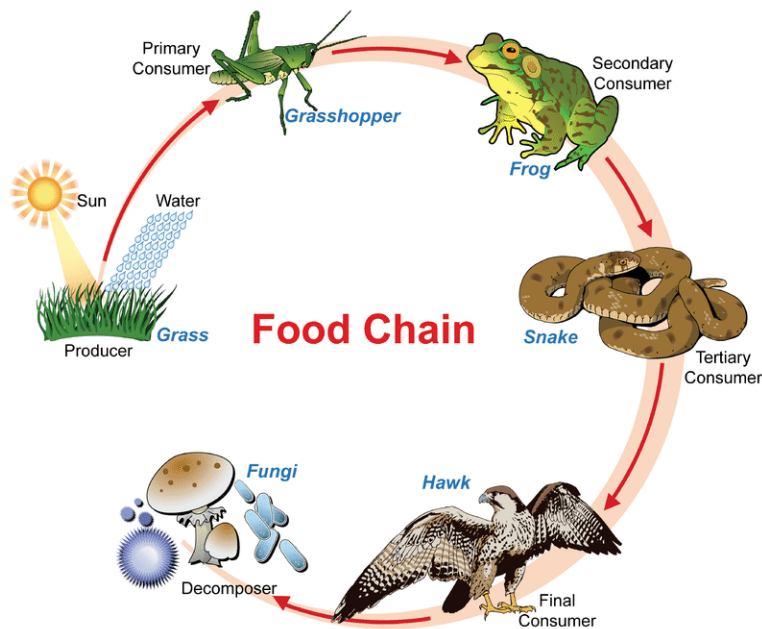
FIGURE 12.1

Photosynthetic autotrophs, which make food using the energy in sunlight, include (a) plants, (b) algae, and (c) certain bacteria.

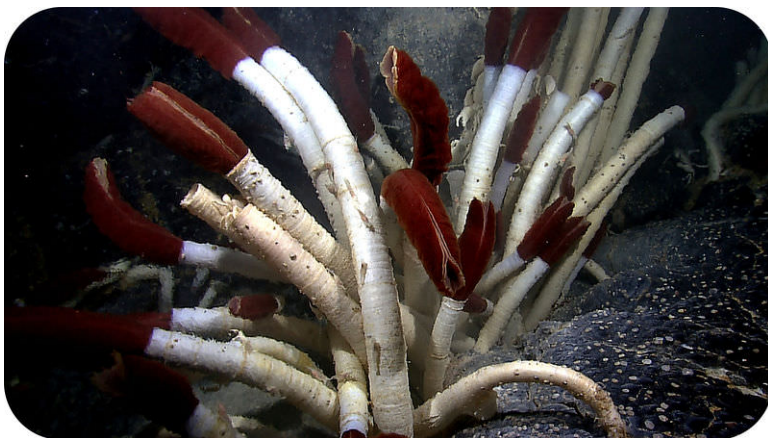
Photosynthesis provides over 99 percent of the energy for life on earth. A much smaller group of autotrophs - mostly bacteria in dark or low-oxygen environments - produce food using the chemical energy stored in inorganic molecules such as hydrogen sulfide, ammonia, or methane. While photosynthesis transforms light energy to chemical energy, this alternate method of making food transfers chemical energy from inorganic to organic molecules. It is therefore called **chemosynthesis**, and is characteristic of the tubeworms shown in **Figure 12.3**. Some of the most recently discovered chemosynthetic bacteria inhabit deep ocean hot water vents or “black smokers.” There, they use the energy in gases from the Earth’s interior to produce food for a variety of unique heterotrophs: giant tube worms, blind shrimp, giant white crabs, and armored snails. Some scientists think that chemosynthesis may support life below the surface of Mars, Jupiter’s moon, Europa, and other planets as well. Ecosystems based on chemosynthesis may seem rare and exotic, but they too illustrate the absolute dependence of heterotrophs on autotrophs for food.

Making and Using Food

The flow of energy through living organisms begins with photosynthesis. This process stores energy from sunlight in the chemical bonds of glucose. By breaking the chemical bonds in glucose, cells release the stored energy and make

**FIGURE 12.2**

A food chain shows how energy and matter flow from producers to consumers. Matter is recycled, but energy must keep flowing into the system. Where does this energy come from? Though this food chain "ends" with decomposers, do decomposers, in fact, digest matter from each level of the food chain? (see the "Flow of Energy" concept.)

**FIGURE 12.3**

Tubeworms deep in the Galapagos Rift get their energy from chemosynthetic bacteria living within their tissues. No digestive systems needed!

the ATP they need. The process in which glucose is broken down and ATP is made is called **cellular respiration**.

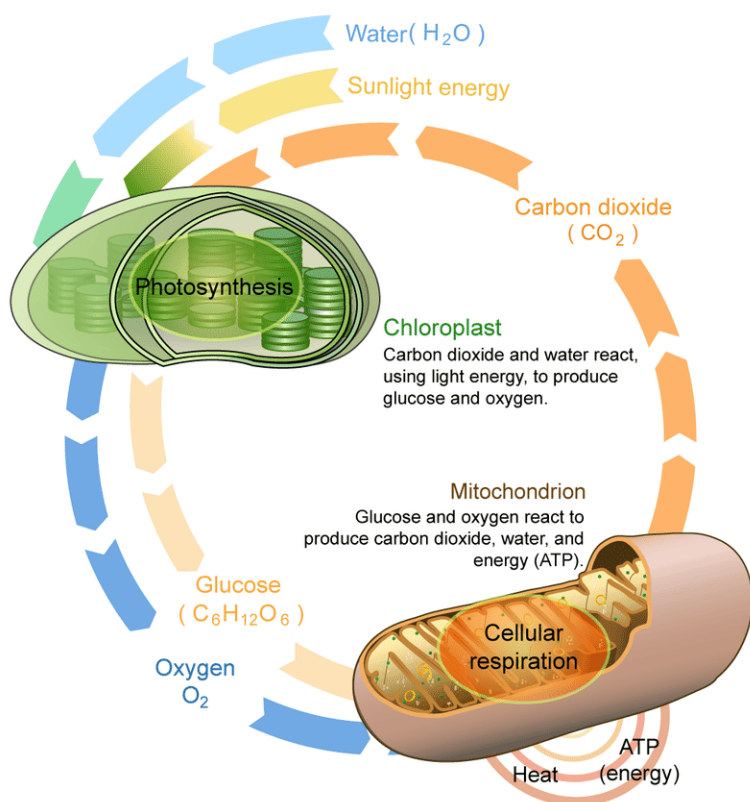
Photosynthesis and cellular respiration are like two sides of the same coin. This is apparent from **Figure 12.4**. The products of one process are the reactants of the other. Together, the two processes store and release energy in living organisms. The two processes also work together to recycle oxygen in Earth's atmosphere.

Photosynthesis

Photosynthesis is often considered to be the single most important life process on Earth. It changes light energy into chemical energy and also releases oxygen. Without photosynthesis, there would be no oxygen in the atmosphere. Photosynthesis involves many chemical reactions, but they can be summed up in a single chemical equation:



Photosynthetic autotrophs capture light energy from the sun and absorb carbon dioxide and water from their environ-

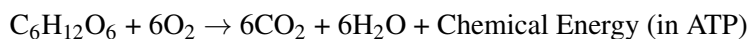
**FIGURE 12.4**

This diagram compares and contrasts photosynthesis and cellular respiration. It also shows how the two processes are related.

ment. Using the light energy, they combine the reactants to produce glucose and oxygen, which is a waste product. They store the glucose, usually as starch, and they release the oxygen into the atmosphere.

Cellular Respiration

Cellular respiration actually “burns” glucose for energy. However, it doesn’t produce light or intense heat as some other types of burning do. This is because it releases the energy in glucose slowly, in many small steps. It uses the energy that is released to form molecules of ATP. Cellular respiration involves many chemical reactions, which can be summed up with this chemical equation:



Cellular respiration occurs in the cells of all living things. It takes place in the cells of both autotrophs and heterotrophs. All of them burn glucose to form ATP.

Summary

- Autotrophs store chemical energy in carbohydrate food molecules they build themselves. Most autotrophs make their "food" through photosynthesis using the energy of the sun.
- Heterotrophs cannot make their own food, so they must eat or absorb it.
- Chemosynthesis is used to produce food using the chemical energy stored in inorganic molecules.

Explore More

Use this resource to answer the questions that follow.

- **Autotroph vs. Heterotroph** at http://www.diffen.com/difference/Autotroph_vs_Heterotroph .
1. Define autotroph and heterotroph.
 2. What position do autotrophs fill in a food chain?
 3. Give examples of autotrophs and heterotrophs.
 4. Describe energy production in photoautotrophs.
 5. What is a chemoheterotroph?

Review

1. Compare autotrophs to heterotrophs, and describe the relationship between these two groups of organisms.
2. Name and describe the two types of food making processes found among autotrophs. Which is quantitatively more important to life on earth?
3. Describe the flow of energy through a typical food chain (describing "what eats what"), including the original source of that energy and its ultimate form after use.

12.3 Food Chains and Food Webs

Food Chains and Food Webs



Who eats whom?

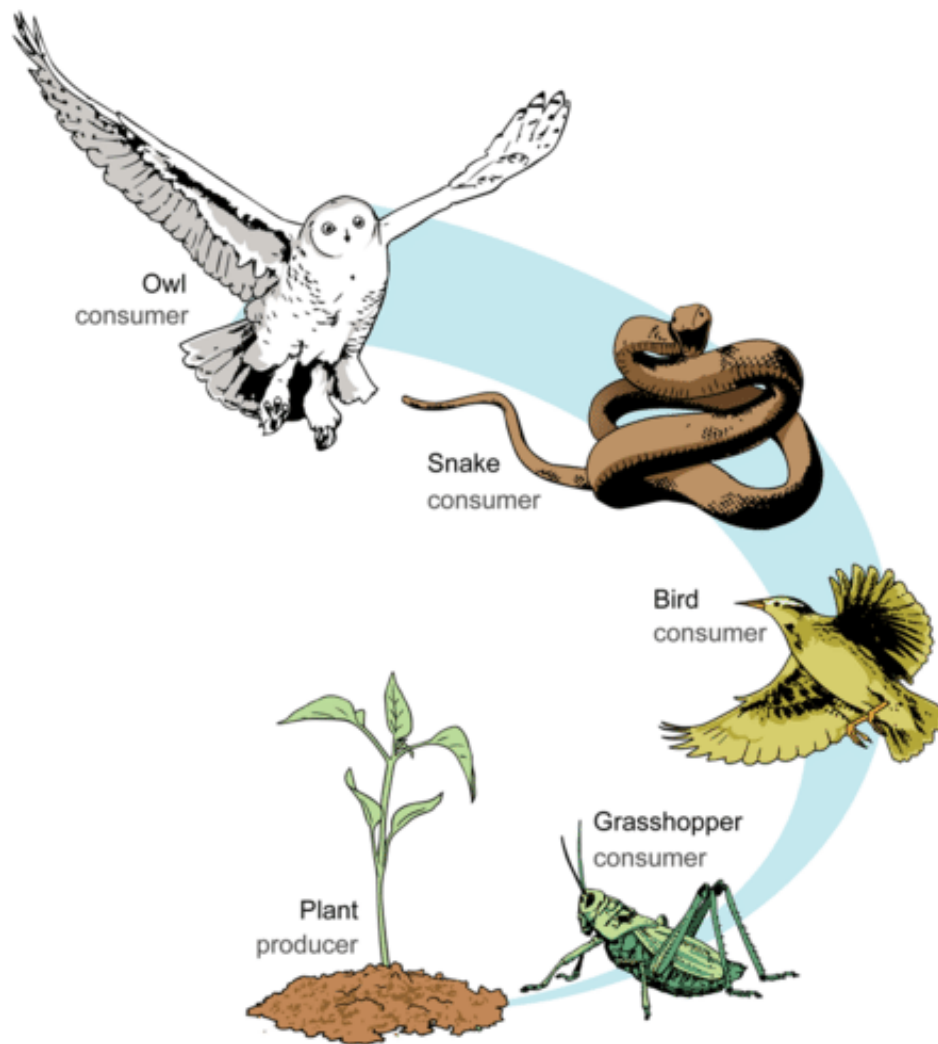
Describing the **flow of energy** within an ecosystem essentially answers this question. To survive, one must eat. Why? To get energy. Food chains and webs describe the transfer of energy within an ecosystem, from one organism to another. In other words, they show who eats whom.

Food Chains and Food Webs

Food chains and food webs are diagrams that represent feeding relationships. Essentially, they show who eats whom. In this way, they model how energy and matter move through **ecosystems**.

Food Chains

A **food chain** represents a single pathway by which energy and matter flow through an ecosystem. An example is shown in **Figure below**. Food chains are generally simpler than what really happens in nature. Most organisms consume—and are consumed by—more than one species.

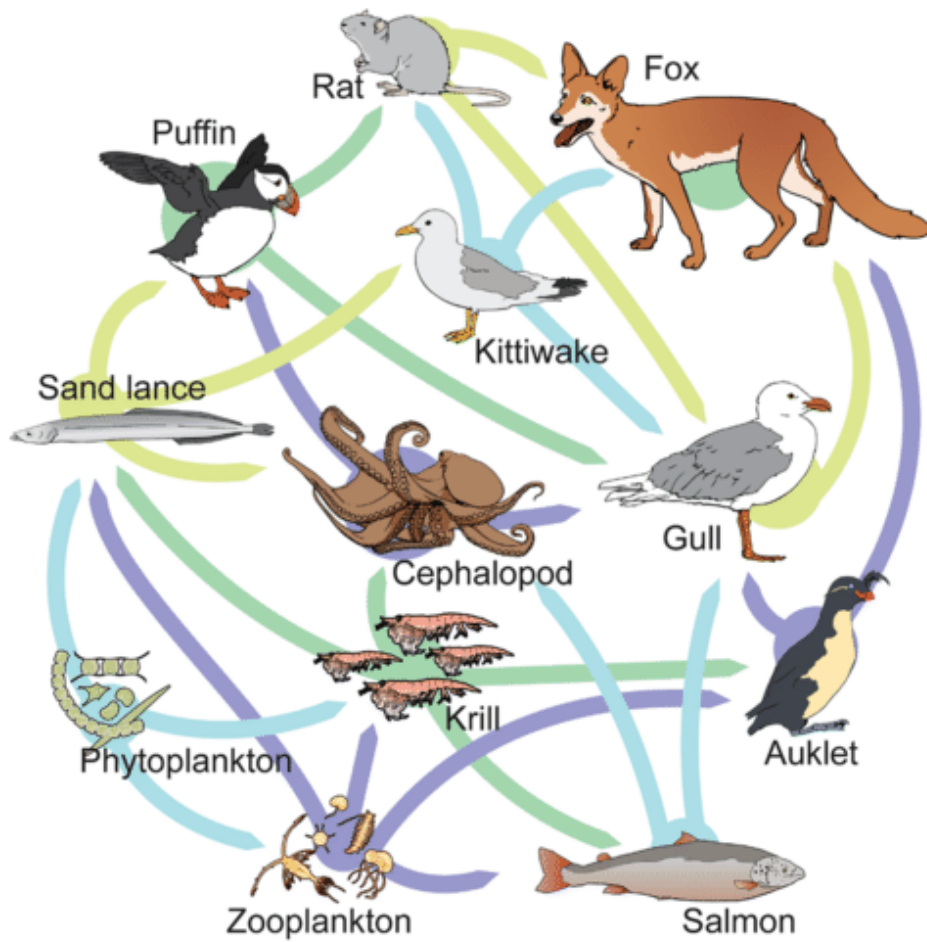


This food chain includes producers and consumers. How could you add decomposers to the food chain?

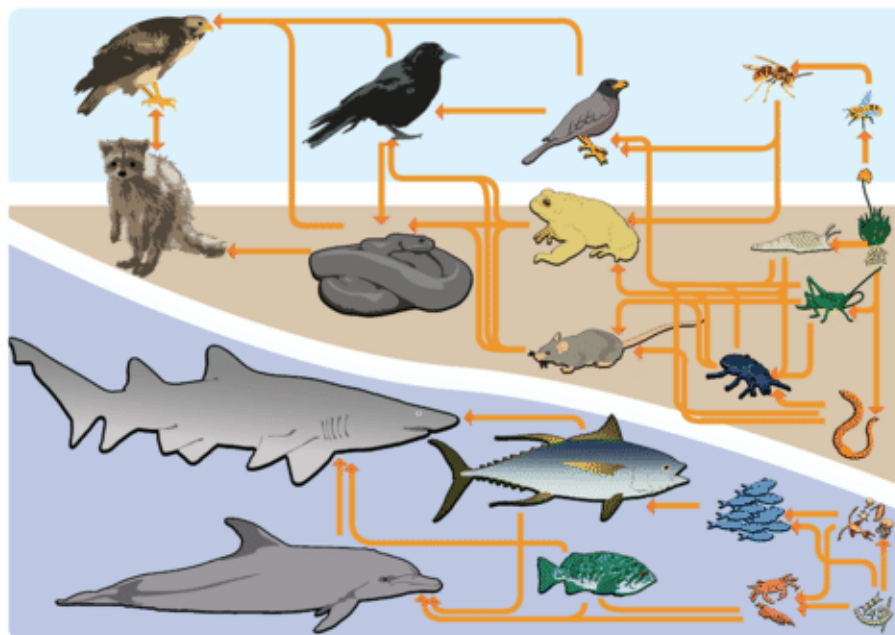
A musical summary of food chains can be heard at <http://www.youtube.com/watch?v=TE6wqG4nb3M> (2:46).

Food Webs

A **food web** represents multiple pathways through which energy and matter flow through an ecosystem. It includes many intersecting food chains. It demonstrates that most organisms eat, and are eaten, by more than one species. Examples are shown in **Figures below** and **below**.



Food Web. This food web consists of several different food chains. Which organisms are producers in all of the food chains included in the food web?



Examples of food webs.

Summary

Food chains and food webs are diagrams that represent feeding relationships.

Food chains and webs model how energy and matter move through **ecosystems**.

Explore More

Use this resource to answer the questions that follow.

Food Web at http://education.nationalgeographic.com/education/encyclopedia/food-web/?ar_a=1.

How does this resource define a food web?

How does this resource describe a food chain?

What is the role of **algae** in a food web?

How do bacteria that live in active volcanoes obtain their nutrition?

Give an example of a secondary and tertiary consumer.

Review

What is a food chain?

Describe the role of decomposers in food webs.

Why is a food web more realistic than a food chain?

Draw a terrestrial food chain that includes four feeding levels

12.4 Competition in Communities

- Describe competition, and outline how it can lead to extinction or specialization of species.



Does there have to be a winner?

When animals compete? Yes. Animals, or other organisms, will compete when both want the same thing. One must "lose" so the winner can have the resource. But competition doesn't necessarily involve physical altercations.

Competition

Competition is a relationship between organisms that strive for the same limited resources. The resources might be food, nesting sites, or territory. Two different types of competition are intraspecific and interspecific competition.

- **Intraspecific competition** occurs between members of the same species. For example, two male birds of the same species might compete for mates in the same territory. Intraspecific competition is a necessary factor in natural selection. It leads to adaptive changes in a species through time (see the *Population Genetics (Advanced)* concepts).
- **Interspecific competition** occurs between members of different species. For example, two predator species might compete for the same prey. Interspecific competition takes place in communities of interacting species. It is the type of competition referred to in the rest of this section.

This National Geographic video depicts bears and wolves competing for resources in Yellowstone National Park: http://video.nationalgeographic.com/video/animals/mammals-animals/bears-and-pandas/bear_grizzly_wolves/ .

Interspecific Competition and Extinction

When populations of different species in a community depend on the same resources, there may not be enough resources to go around. If one species has a disadvantage, such as more predators, it may get fewer of the necessary resources. As a result, members of that species are less likely to survive, and the species will have a higher death rate than the other species. Fewer offspring will be produced and the species may eventually die out in the area.

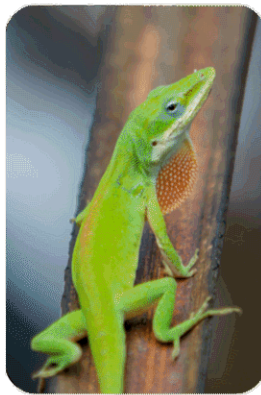
In nature, interspecific competition has often led to the extinction of species. Many other extinctions have occurred when humans introduced new species into areas where they had no predators. For example, rabbits were introduced into Australia in the mid-1800s for sport hunting. Rabbits had no predators in Australia and quickly spread throughout the continent. Many species of Australian mammals could not successfully compete with rabbits and went extinct.

Specialization in Anole Lizards

Many species of anole lizards prey on insects in tropical rainforests. Competition among them has led to the evolution of specializations. Some anoles prey on insects on the forest floor. Others prey on insects in trees. This allows the different species of anoles to live in the same area without competing.



Ground Anole



Tree Anole

FIGURE 12.5

Specialization lets different species of anole lizards live in the same area without competing.

Interspecific Competition and Specialization

Another possible outcome of interspecific competition is the evolution of traits that create distinct differences among the competing species. Through **natural selection**, competing species can become more specialized. This allows them to live together without competing for the same resources. An example is the anolis lizard. Many species of anolis live and prey on insects in tropical rainforests. Competition among the different species led to the evolution of specializations. Some anolis evolved specializations to prey on insects in leaf litter on the forest floor. Others evolved specializations to prey on insects on the branches of trees. This allowed the different species of anolis to co-exist without competing.

Vocabulary

- **competition:** The relationship between organisms that strive for the same limited resources.

- **interspecific competition:** Competition between members of different species.
- **intraspecific competition:** Competition between members of the same population for the same resource.
- **natural selection:** Evolutionary process by which certain beneficial traits becomes more common within a population, changing the characteristics (traits) of a species over time.

Summary

- Competition is a relationship between organisms that strive for the same limited resources. Interspecific competition often leads to extinction of one species. However, it may lead to greater specialization of the species, allowing them to co-exist without competing.

Practice

Use this resource to answer the questions that follow.

- <http://www.hippocampus.org/Biology> → Non-Majors Biology → Search: **Interactions Within Communities**
1. What are the three general types of interactions within a community?
 2. Define competition.
 3. What are some of the resources organisms compete for?
 4. What is the main outcome of competition? (*Hint:* affects the niche)
 5. Describe an example of interspecific competition.
 6. Why might intraspecific competition occur?

Review

1. What is competition?
2. Why do species compete?
3. What are two possible outcomes of interspecific competition? Explain your answer.

12.5 Importance of the Oceans

- Describe the important roles of oceans as related to climate, the water cycle, and biodiversity.



Just what is down there?

Mostly the oceans are cold, dark and have extremely high pressure. Except at the very top, they are completely inhospitable to humans. Even this humpback whale can only dive to about 700 feet, so there's a lot about the ocean it doesn't know. Earth would not be the same planet without its oceans.

Oceans Moderate Climate

The oceans, along with the atmosphere, keep temperatures fairly constant worldwide. While some places on Earth get as cold as -70°C and others as hot as 55°C , the range is only 125°C . On Mercury temperatures go from -180°C to 430°C , a range of 610°C .

The oceans, along with the atmosphere, distribute heat around the planet. The oceans absorb heat near the Equator and then move that solar energy to more polar regions. The oceans also moderate climate within a region. At the same latitude, the temperature range is smaller in lands nearer the oceans than away from the oceans. Summer temperatures are not as hot, and winter temperatures are not as cold, because water takes a long time to heat up or cool down.

Water Cycle

The oceans are an essential part of Earth's water cycle. Since they cover so much of the planet, most evaporation comes from oceans and most precipitation falls on oceans.

Biologically Rich

The oceans are home to an enormous amount of life. That is, they have tremendous biodiversity (**Figure 12.6**). Tiny ocean plants, called phytoplankton, create the base of a food web that supports all sorts of life forms. Marine life makes up the majority of all biomass on Earth. (**Biomass** is the total mass of living organisms in a given area.) These organisms supply us with food and even the oxygen created by marine plants.



FIGURE 12.6

Polar bears are well adapted to frigid Arctic waters.

Summary

- Oceans moderate Earth's temperature by not changing temperature rapidly and by distributing heat around the planet.
- Oceans are an enormous reservoir for water in the water cycle.
- Oceans have tremendous biodiversity and the majority of all biomass on Earth.

Making Connections



MEDIA

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/98794>

Explore More

Use this resource to answer the questions that follow.

http://cmore.soest.hawaii.edu/oceanacidification/documents/PML_TechnicalSheet_high_CO2_world.pdf Use pages 1 2.

1. How much of Earth's surface do the ocean's cover? How much of global primary productivity comes from the oceans?
2. How do the oceans regulate the Earth system?
3. What are the ocean's living and non-living resources?
4. What social and economic goods and services does the ocean provide?
5. What do ocean currents transport as they travel around the globe?
6. What does carbon dioxide do in the oceans?
7. If a lot of the carbon dioxide that has been released in the past 150 years has entered the deep ocean, when might it cause temperatures to rise and why?
8. How are marine organisms used for food and biotechnology?
9. What other resources are found in the ocean?
10. How does the ocean provide defense from storms?

Review

1. What organisms form the base of the ocean food web?
2. How do the oceans moderate Earth's temperature?
3. What role do oceans play in the water cycle?

12.6 Soil and Water Resources

- Describe the components of soil.
- Summarize the importance of soil.
- Describe threats to soil and water resources.
- Discuss consequences of excess runoff.



Could this land be used for agriculture?

Probably not. The quality of soil is very important in determining what can grow in a particular area. Good soil is not so easy to come by. Soil should be considered another resource that we, as a population, must strive to protect.

Soil and Water Resources

Theoretically, soil and water are renewable resources. However, they may be ruined by careless human actions.

Soil

Soil is a mixture of eroded rock, minerals, partly decomposed organic matter, and other materials. It is essential for plant growth, so it is the foundation of terrestrial ecosystems. Soil is important for other reasons as well. For example, it removes toxins from water and breaks down wastes.

Although renewable, soil takes a very long time to form—up to hundreds of millions of years. So, for human purposes, soil is a nonrenewable resource. It is also constantly depleted of nutrients through careless use, and eroded by wind and water. For example, misuse of soil caused a huge amount of it to simply blow away in the 1930s during the Dust Bowl (see **Figure 12.7**). Soil must be used wisely to preserve it for the future. Conservation practices include contour plowing and terracing. Both reduce soil erosion. Soil also must be protected from toxic wastes.

**FIGURE 12.7**

The Dust Bowl occurred between 1933 and 1939 in Oklahoma and other southwestern U.S. states. Plowing had exposed prairie soil. Drought turned the soil to dust. Intense dust storms blew away vast quantities of the soil. Much of the soil blew all the way to the Atlantic Ocean.

Water

Water is essential for all life on Earth. For human use, water must be fresh. Of all the water on Earth, only 1 percent is fresh, liquid water. Most of the rest is either salt water in the ocean or ice in glaciers and ice caps.

Although water is constantly recycled through the **water cycle**, it is in danger. Over-use and pollution of freshwater threaten the limited supply that people depend on. Already, more than 1 billion people worldwide do not have adequate freshwater. With the rapidly growing human population, the water shortage is likely to get worse.

KQED: Are We in Danger of Running Out of Water?

California's population is growing by 600,000 people a year, but much of the state receives as much annual rainfall as Morocco. With fish populations crashing, global warming, and the demands of the country's largest agricultural industry, the pressures on our water supply are increasing. Is the U.S.'s largest population in danger of running out of water? See <http://www.kqed.org/quest/television/state-of-thirst-californias-water-future> for additional information.



MEDIA

Click image to the left or use the URL below.

URL: <https://www.ck12.org/flx/render/embeddedobject/447>

Too Much of a Good Thing

Water pollution comes from many sources. One of the biggest sources is runoff. **Runoff** picks up chemicals such as fertilizer from agricultural fields, lawns, and golf courses. It carries the chemicals to bodies of water. The added nutrients from fertilizer often cause excessive growth of algae, creating **algal blooms** (see **Figure 12.8**). The algae use up oxygen in the water so that other aquatic organisms cannot survive. This has occurred over large areas of the ocean, creating **dead zones**, where low oxygen levels have killed all ocean life. A very large dead zone exists in the Gulf of Mexico. Measures that can help prevent these problems include cutting down on fertilizer use. Preserving wetlands also helps because wetlands filter runoff water.



FIGURE 12.8

Algal Bloom. Nutrients from fertilizer in runoff caused this algal bloom.

Summary

- Soil and water are renewable resources but may be ruined by careless human actions. Soil can be depleted of nutrients. It can also be eroded by wind or water.
- Over-use and pollution of freshwater threaten the limited supply that people depend on.

Explore More

Explore More I

Use this resources to answer the questions that follow.

- <http://www.hippocampus.org/Biology> → Non-Majors Biology → Search: **Human Impacts on Biogeochemical Cycles**
1. What happens when fertilizer ends up in waterways?
 2. Describe eutrophication.
 3. What has happened at the mouth of the Mississippi River?

Explore More II

- **Will There Be Enough Fresh Water?** at <http://www.concord.org/activities/will-there-be-enough-fresh-water> .

Review

1. What is soil?

2. Why is soil considered a nonrenewable resource?
3. How much water is drinkable?
4. Why would you expect a dead zone to start near the mouth of a river, where the river flows into a body of water?

12.7 References

1. (a) Corey Leopold; (b) Flickr:*higetiger (c) Courtesy of NASA. [Examples of photosynthetic autotrophs](#) . (a) CC BY 2.0; (b) CC BY 2.0; (c) Public Domain
2. Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation. [Energy flow in a food chain](#) . CC BY-NC 3.0
3. Courtesy of the NOAA Okeanos Explorer Program, Galapagos Rift Expedition 2011. [These tubeworms get their energy from chemosynthesis](#) . CC BY 2.0
4. Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation. [CK-12 Foundation](#) . CC BY-NC 3.0
5. Ground Anole: Flickr:pondhawk; Tree Anole: Jordan Walmsley. [Ground Anole: http://www.flickr.com/photos/38686613@N08/4750887836/](http://www.flickr.com/photos/38686613@N08/4750887836/); [Tree Anole: http://www.flickr.com/photos/champofsomething/8658719965/](http://www.flickr.com/photos/champofsomething/8658719965/) . CC BY 2.0
6. Erica Peterson. [Polar bear swimming in the Arctic Ocean](#) . CC BY 2.0
7. Left: National Oceanic and Atmospheric Administration; Right: U.S. Department of Agriculture. [Images of the Dust Bowl](#) . Public Domain
8. Dr. Jennifer L. Graham/U.S. Geological Survey. [Nutrients in fertilizer cause an algal bloom](#) . Public Domain

CONCEPT 13**Virtual Labs.docx**

Density Lab

http://highered.mheducation.com/sites/0078741858/student_view0/unit1/chapter3/virtual_labs.html#

Newton's Laws

<http://www.sciencechannel.com/games-and-interactives/newtons-laws-of-motion-interactive/>

Newtons Second Law

http://glencoe.mheducation.com/sites/0078617707/student_view0/chapter2/virtual_lab.html

Motion Graphs

<http://phet.colorado.edu/en/simulation/legacy/moving-man>

<https://www.youtube.com/watch?v=x2ve5yucNPQ>

Periodic Table

<https://www.learner.org/interactives/periodic/>

General

<http://www.myteacherpages.com/webpages/mri/virtual.cfm>