Exit Level

TAKS STUDY GUIDE

Texas Assessment of Knowledge and Skills

Science

A Student and Family Guide to Exit Level Science

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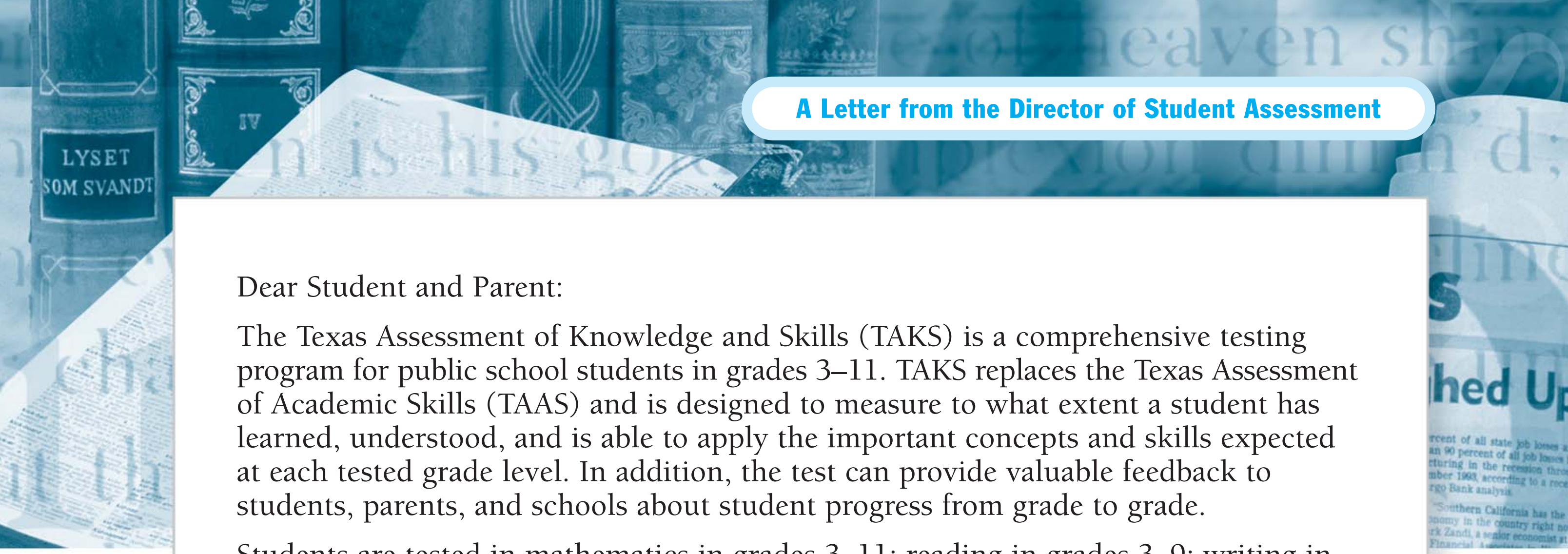

A Letter from the Director of Student Assessment

Dear Student and Parent:

The Texas Assessment of Knowledge and Skills (TAKS) is a comprehensive testing program for public school students in grades 3–11. TAKS replaces the Texas Assessment of Academic Skills (TAAS) and is designed to measure to what extent a student has learned, understood, and is able to apply the important concepts and skills expected at each tested grade level. In addition, the test can provide valuable feedback to students, parents, and schools about student progress from grade to grade.

Students are tested in mathematics in grades 3–11; reading in grades 3–9; writing in grades 4 and 7; English language arts in grades 10 and 11; science in grades 5, 8, 10, and 11; and social studies in grades 8, 10, and 11. Every TAKS test is directly linked to the Texas Essential Knowledge and Skills (TEKS) curriculum. The TEKS is the state-mandated curriculum for Texas public school students. Essential knowledge and skills taught at each grade build upon the material learned in previous grades. By developing the academic skills specified in the TEKS, students can build a strong foundation for future success.

The Texas Education Agency has developed this study guide to help students strengthen the TEKS-based skills that are taught in class and tested on TAKS. The guide is designed for students to use on their own or for students and families to work through together. Concepts are presented in a variety of ways that will help students review the information and skills they need to be successful on the TAKS. Every guide includes explanations, practice questions, detailed answer keys, and student activities. At the end of this study guide is an evaluation form for you to complete and mail back when you have finished the guide. Your comments will help us improve future versions of this guide.

There are a number of resources available for students and families who would like more information about the TAKS testing program. Information booklets are available for every TAKS subject and grade. Brochures are also available that explain the Student Success Initiative promotion requirements and the new graduation requirements for eleventh-grade students. To obtain copies of these resources or to learn more about the testing program, please contact your school or visit the Texas Education Agency website at www.tea.state.tx.us.

Texas is proud of the progress our students have made as they strive to reach their academic goals. We hope the study guides will help foster student learning, growth, and success in all of the TAKS subject areas.

Sincerely,

LChandler

Lisa Chandler
Director of Student Assessment
Texas Education Agency

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SCIENCE

How is the Science Study Guide organized?

Five objectives are tested on the exit level science TAKS test. This study guide is therefore organized into five main parts, one for each objective.

- Objective 1: The Nature of Science
- Objective 2: The Organization of Living Systems
- Objective 3: The Interdependence of Organisms and the Environment
- Objective 4: The Structures and Properties of Matter
- Objective 5: Motion, Forces, and Energy

For each objective there is a review and a set of practice questions. Start by reading the review for each objective. After you read the review, you can test your knowledge of the objective by trying the practice questions.

Will this study guide tell me everything I need to know about science?

No, but it's a great place to review what you've learned in school. This study guide explains some, but not all, of the science ideas that you need to know and understand. You can also increase your science knowledge by studying:

- Science books from your school or library
- Notes from your science classes
- Science tests, quizzes, and activity sheets
- Laboratory reports and notes from field investigations

What kinds of practice questions are in the Science Study Guide?

The science study guide contains questions similar to those found on the exit level science TAKS test. There are three types of questions in the science study guide.

- **Multiple-Choice Questions:** Most of the practice questions are multiple-choice items with four answer choices. Many of these questions follow a short passage, a chart, a diagram, or a combination of these. Read each passage carefully. If there is a chart or diagram, study it. Passages, charts, and diagrams usually contain details and other information that will help you answer the question. Then read the question carefully and consider what you are being asked. Read **each** answer choice before you choose the **best** answer.

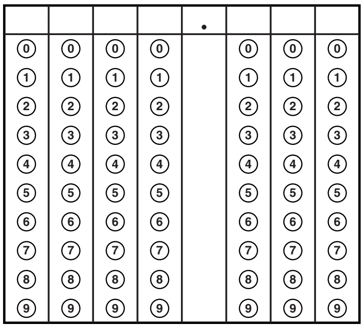
  It's always a good idea to reread the question after you have thought about each answer choice.

- **Griddable Questions:** Some questions use an eight-column answer grid like the ones used on the exit level mathematics TAKS test. Griddable questions ask you to measure something or use math to solve a science problem. You will see an example of a griddable question on page 99.
- **Cluster Questions:** Some multiple-choice questions are grouped together in clusters. Each cluster begins with a stimulus that may include a passage, a diagram, a chart, or a combination of these. The information in the stimulus will help you focus on the cluster questions.

The stimulus is followed by two to five multiple-choice questions. The cluster questions usually test several different science objectives, but they are all related to the stimulus. To answer the cluster questions, you will need to use information from the stimulus, as well as your own knowledge of science, so read and study the stimulus carefully before you answer the cluster questions. Then think about what you already know from your study of science. You will see examples of science clusters on pages 102–105.

How do I use an answer grid?

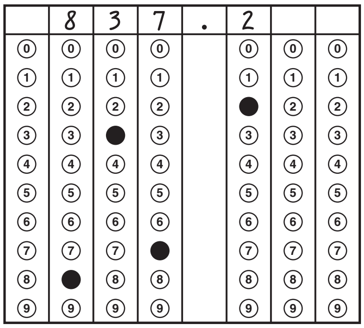
The answer grid contains four columns of numerals followed by a fixed decimal point and three additional columns of numerals. Your answer will always be limited to a number from 0 to 9,999.999.



This is the grid found on the actual test.

Let's say you are asked to calculate the power required to lift an object 1.5 meters. If your answer is 837.2 watts, you should write the digit 8 at the top of the hundreds column, a 3 in the tens column, a 7 in the ones column, and a 2 in the tenths column. Be careful to record the digits in the column with the correct place value with respect to the decimal point.

Then fill in the bubbles that correspond to your answer. Find the correct bubbles and darken the circles. Check to make sure that you bubbled in the same number that you wrote at the top of each column.



Extra zeros before or after the answer will not affect your score.

How will I know whether I answered the practice questions correctly?

The answers to the practice questions are in an answer key at the back of this book (page 111). For most questions, the answer key explains why each answer choice is correct or incorrect. After you answer the practice questions, you can check your answers to see how you did. If you chose the wrong answer to a question, carefully read the answer explanation to find out why your answer is incorrect. Then read the explanation for the correct answer.

If you still do not understand the correct answer, ask a friend, family member, or teacher for help. When you choose the correct answer, it is still a good idea to read the answer explanation. It may help you better understand why the answer is correct.

Is there anything else in the Science Study Guide?

Yes! A formula chart is provided on page 8 of this study guide. It is identical to the formula chart that will be provided to you when you take the exit level science TAKS test. You will need the formula chart to answer some of the practice questions. The good news is that you don’t have to memorize the formulas, constants, and conversions. However, you do need to know how to use them to solve science problems. Remember, knowing which formula to use is just as important as knowing how to use it. You’ll learn more about formulas, constants, and conversions in the review for Objectives 4 and 5. The formula chart also contains a 20-centimeter ruler.

A periodic table of the elements is provided on page 9. You will be provided with an identical periodic table when you take the exit level science TAKS test. You will need information from the periodic table to answer some of the practice questions. You’ll learn more about the periodic table in the review for Objective 4.

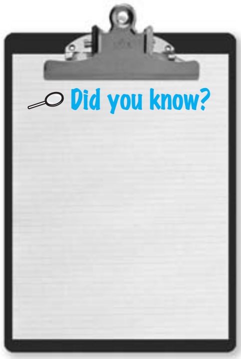
In addition to the materials on pages 8 and 9, a tear-out copy of the formula chart and periodic table is provided at the back of this study guide.

There is a science activity called “Climbing Mount Everest” that begins on page 106. You can do this activity at home. It will help you practice and strengthen some of the science skills that you’ll review in Objective 5 (Motion, Forces, and Energy). The review for Objective 5 begins on page 79. After you complete the activity, you can compare your results with the sample results on pages 120–121.

Many of the review pages contain clipboards. The clipboards contain tips, helpful information, important facts, and interesting details.

Remember! clipboards contain information that you have probably learned before. They are reminders to help refresh your memory.

Did you know? clipboards contain fun science facts that are probably not familiar to you.



How do I use this study guide?

Carefully read the review section. If you do not understand something, ask for help. Then answer the practice questions. Use the answer key at the back of this study guide to check your answers. It is a good idea to read all five reviews and answer all the practice questions even if you passed some of these objectives. Study at a pace that is comfortable for you. The Science Study Guide contains a lot of information. If you plan to read all the reviews and answer all the practice questions, you may want to allow yourself several weeks.

FORMULA CHART
for Grades 10–11 Science Assessment

Density $= \dfrac{\text{mass}}{\text{volume}}$	$D = \dfrac{m}{v}$
$\left(\begin{array}{c}\text{heat gained or}\\ \text{lost by water}\end{array}\right) = \left(\text{mass}\right)\left(\begin{array}{c}\text{change in}\\ \text{temperature}\end{array}\right)\left(\begin{array}{c}\text{specific}\\ \text{heat}\end{array}\right)$	$Q = (m)(\Delta T)(C_p)$
Speed $= \dfrac{\text{distance}}{\text{time}}$	$v = \dfrac{d}{t}$
Acceleration $= \dfrac{\text{final velocity} - \text{initial velocity}}{\text{change in time}}$	$a = \dfrac{v_f - v_i}{\Delta t}$
Momentum = mass × velocity	$p = mv$
Force = mass × acceleration	$F = ma$
Work = force × distance	$W = Fd$
Power $= \dfrac{\text{work}}{\text{time}}$	$P = \dfrac{W}{t}$
% efficiency $= \dfrac{\text{work output}}{\text{work input}} \times 100$	$\% = \dfrac{W_O}{W_I} \times 100$
Kinetic energy $= \dfrac{1}{2}(\text{mass} \times \text{velocity}^2)$	$KE = \dfrac{mv^2}{2}$
Gravitational potential energy = mass × acceleration due to gravity × height	$GPE = mgh$
Energy = mass × $(\text{speed of light})^2$	$E = mc^2$
Velocity of a wave = frequency × wavelength	$v = f\lambda$
Current $= \dfrac{\text{voltage}}{\text{resistance}}$	$I = \dfrac{V}{R}$
Electrical power = voltage × current	$P = VI$
Electrical energy = power × time	$E = Pt$

Constants/Conversions

g = acceleration due to gravity = $9.8\ \text{m/s}^2$

c = speed of light = 3×10^8 m/s

speed of sound = 343 m/s at 20°C

$1\ \text{cm}^3 = 1$ mL

1 wave/second = 1 hertz (Hz)

1 calorie (cal) = 4.18 joules

1000 calories (cal) = 1 Calorie (Cal) = 1 kilocalorie (kcal)

newton (N) = kgm/s^2

joule (J) = Nm

watt (W) = J/s = Nm/s

volt (V) ampere (A) ohm (Ω)

Periodic Table of the Elements

Atomic number — 14
Symbol — **Si**
Atomic mass — 28.086
Silicon — Name

	Group 1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIII	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 **H** 1.008 Hydrogen																	2 **He** 4.0026 Helium
2	3 **Li** 6.941 Lithium	4 **Be** 9.012 Beryllium											5 **B** 10.81 Boron	6 **C** 12.011 Carbon	7 **N** 14.007 Nitrogen	8 **O** 15.999 Oxygen	9 **F** 18.998 Fluorine	10 **Ne** 20.179 Neon
3	11 **Na** 22.990 Sodium	12 **Mg** 24.305 Magnesium											13 **Al** 26.982 Aluminum	14 **Si** 28.086 Silicon	15 **P** 30.974 Phosphorus	16 **S** 32.066 Sulfur	17 **Cl** 35.453 Chlorine	18 **Ar** 39.948 Argon
4	19 **K** 39.098 Potassium	20 **Ca** 40.08 Calcium	21 **Sc** 44.956 Scandium	22 **Ti** 47.88 Titanium	23 **V** 50.942 Vanadium	24 **Cr** 51.996 Chromium	25 **Mn** 54.938 Manganese	26 **Fe** 55.847 Iron	27 **Co** 58.933 Cobalt	28 **Ni** 58.69 Nickel	29 **Cu** 63.546 Copper	30 **Zn** 65.39 Zinc	31 **Ga** 69.72 Gallium	32 **Ge** 72.61 Germanium	33 **As** 74.922 Arsenic	34 **Se** 78.96 Selenium	35 **Br** 79.904 Bromine	36 **Kr** 83.80 Krypton
5	37 **Rb** 85.468 Rubidium	38 **Sr** 87.62 Strontium	39 **Y** 88.906 Yttrium	40 **Zr** 91.224 Zirconium	41 **Nb** 92.906 Niobium	42 **Mo** 95.94 Molybdenum	43 **Tc** (98) Technetium	44 **Ru** 101.07 Ruthenium	45 **Rh** 102.906 Rhodium	46 **Pd** 106.42 Palladium	47 **Ag** 107.868 Silver	48 **Cd** 112.41 Cadmium	49 **In** 114.82 Indium	50 **Sn** 118.71 Tin	51 **Sb** 121.763 Antimony	52 **Te** 127.60 Tellurium	53 **I** 126.904 Iodine	54 **Xe** 131.29 Xenon
6	55 **Cs** 132.905 Cesium	56 **Ba** 137.33 Barium	57 **La** 138.906 Lanthanum	72 **Hf** 178.49 Hafnium	73 **Ta** 180.948 Tantalum	74 **W** 183.84 Tungsten	75 **Re** 186.207 Rhenium	76 **Os** 190.23 Osmium	77 **Ir** 192.22 Iridium	78 **Pt** 195.08 Platinum	79 **Au** 196.967 Gold	80 **Hg** 200.59 Mercury	81 **Tl** 204.383 Thallium	82 **Pb** 207.2 Lead	83 **Bi** 208.980 Bismuth	84 **Po** (209) Polonium	85 **At** (210) Astatine	86 **Rn** (222) Radon
7	87 **Fr** (223) Francium	88 **Ra** 226.025 Radium	89 **Ac** 227.028 Actinium	104 **Rf** (261) Rutherfordium	105 **Db** (262) Dubnium	106 **Sg** (263) Seaborgium	107 **Bh** (262) Bohrium	108 **Hs** (265) Hassium	109 **Mt** (266) Meitnerium	110 (269)								

Mass numbers in parentheses are those of the most stable or most common isotope.

Lanthanide Series	58 **Ce** 140.12 Cerium	59 **Pr** 140.908 Praseodymium	60 **Nd** 144.24 Neodymium	61 **Pm** (145) Promethium	62 **Sm** 150.36 Samarium	63 **Eu** 151.97 Europium	64 **Gd** 157.25 Gadolinium	65 **Tb** 158.925 Terbium	66 **Dy** 162.50 Dysprosium	67 **Ho** 164.930 Holmium	68 **Er** 167.26 Erbium	69 **Tm** 168.934 Thulium	70 **Yb** 173.04 Ytterbium	71 **Lu** 174.967 Lutetium
Actinide Series	90 **Th** 232.038 Thorium	91 **Pa** 231.036 Protactinium	92 **U** 238.029 Uranium	93 **Np** 237.048 Neptunium	94 **Pu** (244) Plutonium	95 **Am** (243) Americium	96 **Cm** (247) Curium	97 **Bk** (247) Berkelium	98 **Cf** (251) Californium	99 **Es** (252) Einsteinium	100 **Fm** (257) Fermium	101 **Md** (258) Mendelevium	102 **No** (259) Nobelium	103 **Lr** (262) Lawrencium

Revised October 15, 2001

Objective 1

The student will demonstrate an understanding of the nature of science.

From your studies in science, you should be able to demonstrate an understanding of the nature of science.

What's the nature of science?

Science is one way that people make sense of the world. Science involves asking questions about the natural world and finding ways to answer them. That's what we mean by the nature of science.

Here are just a few of the many ways to answer scientific questions: observing the natural world, performing experiments, completing investigations, doing library research, or building models. As you can see, science is more than just a subject you study in school.

How do I do a science investigation?

Most science investigations begin with a question. A good question for a science experiment is one that you can answer based on facts. Let's come up with one.

Here's a question that we couldn't use for a science investigation: Which brand of toothpaste tastes best? The answer to the question depends on the opinion of the person answering it. Different people would pick different brands. We could gather only opinions about the answer to this question, not facts.

I know that sugar dissolves faster in hot tea than in iced tea. Sugar also dissolves faster if I stir the tea. Dissolving is a physical change. I wonder if we could increase the rate of a chemical change in the same way in which we can increase the rate of a physical change.

How about this for our question: How do factors such as temperature and surface area affect the speed of a chemical change? We can perform an experiment by timing a chemical reaction under various conditions. We can gather facts from our experiment to help us answer our question.

Did you know?

Carbon dioxide (CO_2) is the gas released as bubbles when an effervescent antacid tablet is dropped in water. The tablets contain a compound, such as sodium bicarbonate ($NaHCO_3$), that reacts with water to produce the gas.

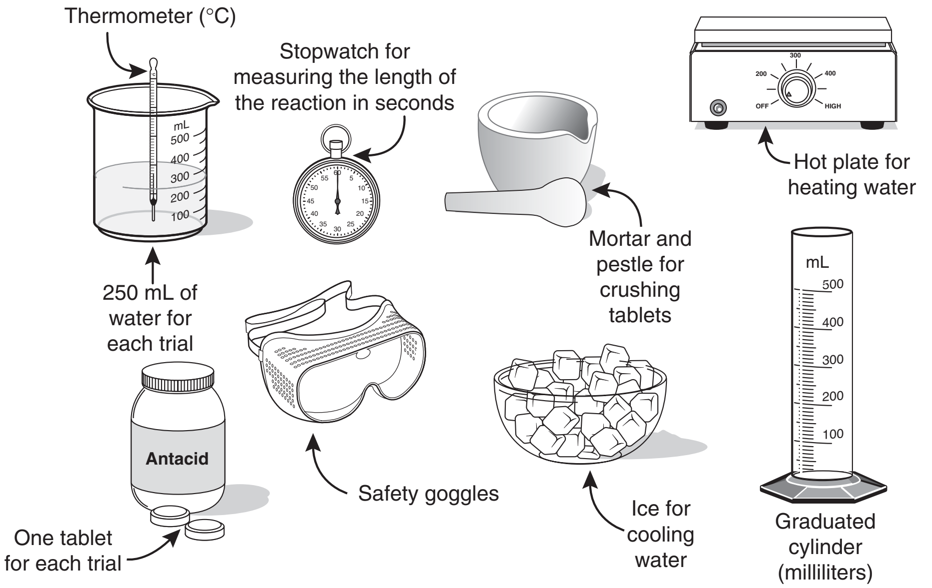
O.K., we have a question. How do we set up an experiment to answer it?

We start by making a plan. First of all, let's narrow things down a bit. We can't test every possible factor that could affect the rate of a chemical reaction. That's why we've picked two—temperature and surface area. We can't test every type of chemical reaction, either. Let's stick to just one. Let's use the chemical reaction of effervescent antacid tablets with water. (Effervescent tablets fizz when you put them into water.)

Now let's think about the materials we're going to need. We'll need effervescent antacid tablets, water, and a container. Let's use a beaker for our container so that we'll be able to see the reaction taking place. We'll also need a way to time the reaction. A watch or stopwatch that measures to the second will work.

We can change the temperature of the reaction by changing the temperature of the water, so we'll need a way to cool and heat the water. To measure the temperature, we'll need a thermometer.

Experimental Setup



We can increase the surface area of the tablets by crushing one into smaller pieces. We can crush a tablet by using a mortar and pestle to tap the tablet and break it into three or four pieces. Another way to increase the surface area of the tablets is by using a mortar and pestle to grind a tablet into fine powder.

O.K., we have our materials. Are we ready to start our experiment?

Not quite yet. First we need to decide how we are going to control our variables. A *variable* is anything in an experiment that we can change. We want to keep all the variables the same except for the ones we are trying to test. In our experiment, the variables that we are testing are water temperature and surface area of the tablet. We want to keep everything else in our experiment the same so that we can be fairly certain that any differences in the rate of the reaction are caused by differences in temperature and surface area.

To control our variables, we're going to use one tablet in each of our trials and place the tablet in the same amount of water (250 milliliters). We'll also use the same beaker each time, being careful to wash and rinse it after each trial.

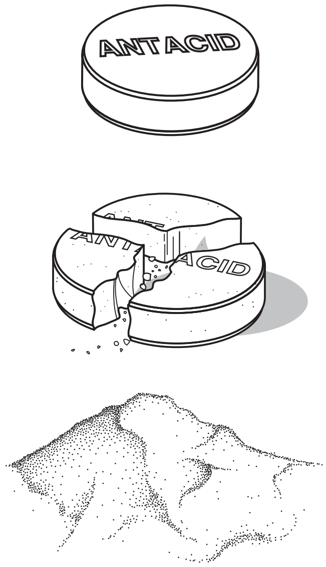
We also need to decide what water temperatures and surface area we're going to test.

How about hot, warm, and cold for temperature and small, medium, and large for surface area?

Good idea! But we need to be a little more specific. Let’s use water at 82°C for hot water (close to boiling), 26°C for warm water (about room temperature), and 2°C for cold water (close to freezing).

We’ll also need to define what we mean by small, medium, and large surface areas. For a small surface area, we use one whole tablet, and for a medium surface area, we can break a tablet into three pieces. For a large surface area, we can grind a tablet into powder.

We’ll do nine trials in all, one for each combination of temperature and surface area.



The more pieces, the more surface area is in contact with water.

		Water Temperature		
		Cold (2°C)	**Warm (26°C)**	**Hot (82°C)**
Surface Area	**Small (whole tablet)**	Trial 1	Trial 2	Trial 3
	Medium (3 pieces)	Trial 4	Trial 5	Trial 6
	Large (powder)	Trial 7	Trial 8	Trial 9

What are we going to use as a control?

A *control* is something to which we can compare our experimental results. In our experiment, we’re going to change the temperature of the water and the surface area of the tablets. We need to know approximately how fast the reaction will occur under conditions we’ll call “normal.”

Let’s pick warm water (26°C) and one whole tablet (small surface area) as our “normal” conditions. This will be our control. By looking at the table above, you can see that our normal conditions match Trial 2, so Trial 2 will be our control. We can compare all the other times we get during the experiment to Trial 2.

And what about a hypothesis? Don’t we need one of those?

Yes, we do! A *hypothesis* is an educated guess about what we think will happen in our experiment based on what we already know. A hypothesis is also a statement that we can test. Remember the question we’re trying to answer: How do factors such as temperature and surface area affect the speed of a chemical change? Let’s change our question to a statement, which will be our hypothesis.

What do we already know about the effects of temperature and surface area on the rate at which sugar dissolves in tea? We can use what we know about the rate of this physical change to come up with a hypothesis about the rate of a chemical change.

We know that sugar dissolves faster in hot tea than in cold tea and that it dissolves even faster if we stir the tea. I'm going to hypothesize that temperature and surface area will have similar effects on a chemical change. Will that work for our hypothesis?

Yes, that's perfect! We'll hypothesize that the rate of chemical change will increase as the temperature increases and as the surface area of the reactant increases. This is a statement that we will be able to test with our experiment.

Remember!

Rate always involves a change over a period of time.

What data do we need to collect? And how are we going to collect it?

We need a way to measure the rate of the reaction between water and the effervescent antacid tablet. One way we can measure the rate is to time the reaction from beginning to end. Reactions with faster rates will take less time.

We can start timing the reaction for each of our trials as soon as we drop the antacid tablet into the water, and we'll stop timing when the bubbling stops—in other words, when we can no longer see any visible reaction. When timing the reaction, the most reasonable unit to use is seconds.

To keep a record of our data, we'll make a data table. We'll have one column for each temperature and one row for each surface area. Remember, this is not the only way to organize our data.

I think we're ready now. Let's begin!

Finally! If you'll drop the antacid tablet into the water, I'll time the reaction. Then you can record the data in our table.

No problem! Here's our data organized in a data table.

Reaction Times

		Water Temperature		
		Cold (2°C)	Warm (26°C)	Hot (82°C)
Surface Area	Small (whole tablet)	144 s	51 s (control)	27 s
	Medium (3 pieces)	42 s	40 s	9 s
	Large (powder)	20 s	14 s	8 s

So now we have lots of data. What do we do with them?

We want to be able to use the data in the table to draw a conclusion about what happened in our experiment. But it can sometimes be difficult to do this when the data are in a table. Let's take our information and graph it. A graph really helps show trends. We can use a graph to compare the reaction times more easily.

Two types of graphs that are often used in science are bar graphs and line graphs. Bar graphs are used to display data in separate categories. Line graphs are often used to show how one variable in an experiment changes over time.

For our experiment, we could use a bar graph to show how the reaction time varied with surface area, or we could use a line graph to show how the reaction time varied with temperature. Both would be good ways to show the data in our table.

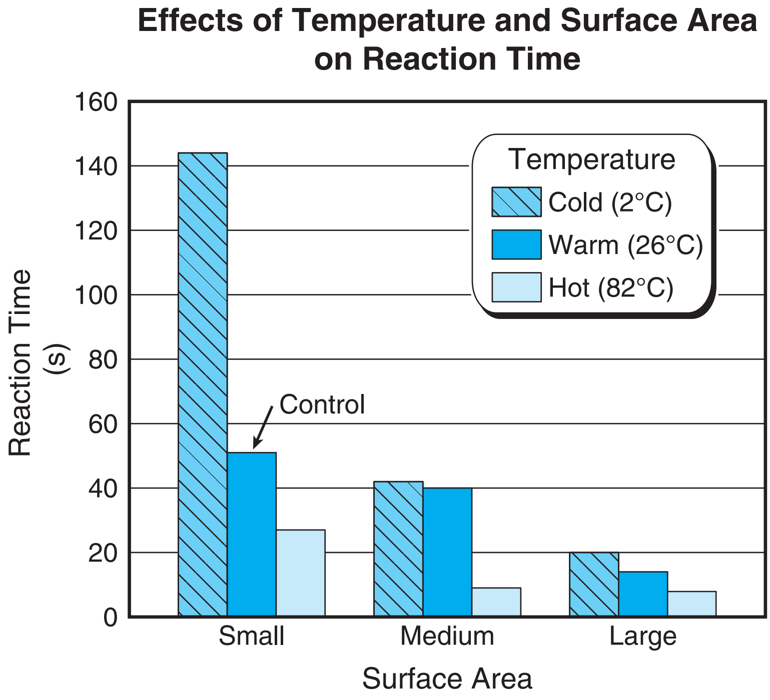
How do I set up a graph?

There are a few rules about what goes where on a graph. In general, the *independent* variable is plotted on the horizontal axis (x), and the *dependent* variable is plotted on the vertical axis (y). The independent (or manipulated) variable is the variable that we changed during the experiment. In our experiment, we had two independent variables: the water temperature and the surface area. For our graphs we'll need to pick one independent variable to plot along the horizontal axis.

The dependent (or responding) variable is the one that changes as a result of the independent variable. The dependent variable is the one that you measure or observe during the experiment. In our experiment the dependent variable was the reaction time.

How would the data look if we used a bar graph?

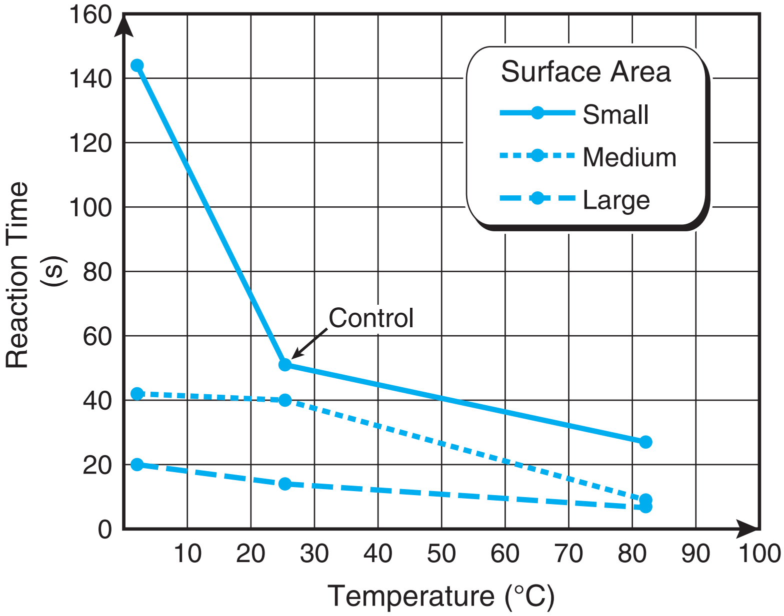
Here is an example of a bar graph showing the data from our experiment. In this graph the horizontal axis shows surface area. Each surface area category has three bars—one for each temperature. The graph's legend tells you which bars correspond to which temperature.



How would the data look if we used a line graph?

In this line graph, the horizontal axis shows temperature. The graph has three lines—one for each surface area. The graph's legend tells you which line corresponds to which surface area.

Effects of Temperature and Surface Area on Reaction Time



So, we've made graphs from our data. What are we supposed to do with them?

Now that the data are in a format that's easier to see, we can analyze the data and make a conclusion. If you look at the graphs, you should be able to see some patterns. For instance, we can see that the reaction time decreased as the water temperature increased. We can conclude that raising the temperature of the water made the reaction go faster.

We can also see that the reaction time decreased as the surface area of the tablets increased, so another way to increase the reaction rate is to increase the surface area of the reactants.

That means we proved our hypothesis. Right?

Not necessarily. Our data do support our hypothesis that the rate of the chemical change will increase as the temperature and surface area of the reactants increase. However, that doesn't mean we have proved our hypothesis.

For one thing, we performed only a single experiment, and we used only one trial for each set of conditions. If we repeated our experiment, we might get slightly different results. In addition, we tested only one type of chemical reaction. Although we can conclude that the conditions we explored will probably affect the speed of other chemical reactions, we can't assume this will work with all chemical reactions. It's possible that the data collected from experiments with other types of reactions will not support our hypothesis. But that's O.K.

A hypothesis is not considered right or wrong. A hypothesis is either supported by data or not supported by data. Even experiments in which the results don't support a hypothesis are important. The results of these experiments can help us come up with a new and improved hypothesis that we can test.

Is a hypothesis kind of like a theory?

A *theory* is a general explanation of a set of observations about the natural world. A theory helps explain how things happen in nature. Unlike a hypothesis, a theory is supported by lots of data collected from many different experiments and observations.

Theories can change over time as scientists gather more evidence. Nearly 2,000 years ago the scientist Ptolemy proposed a theory to explain the orbits of the planets. This theory stated that Earth was the center of the universe and that the sun, planets, and stars revolved around Earth. Ptolemy's theory was accepted as true until the mid-sixteenth century, when Nicolaus Copernicus proposed that Earth and the other planets in our solar system revolve around the sun. At first many people rejected Copernicus's ideas, but in time the theory of a sun-centered solar system was proved correct through careful observations and mathematical calculations.

Did you know?

Alchemists in the Middle Ages tried to change lead and other metals into gold. Although alchemists didn't succeed, they did discover methods for removing impurities from substances. Chemists still use these methods today.

I want to hear about an experiment that wasn't done right, one where the scientist made mistakes. Can you tell me about one?

Sure! Scientists make as many mistakes as other people do. Let me tell you about an experiment that I did. I'll describe it and let you try to figure out what was wrong with it.

I wanted to see whether temperature affected how long a light stick would glow. I hypothesized that as the temperature of the light stick was raised, the reactants inside the light stick would be used up faster, so light sticks exposed to high temperatures would glow for a shorter time than light sticks exposed to lower temperatures.

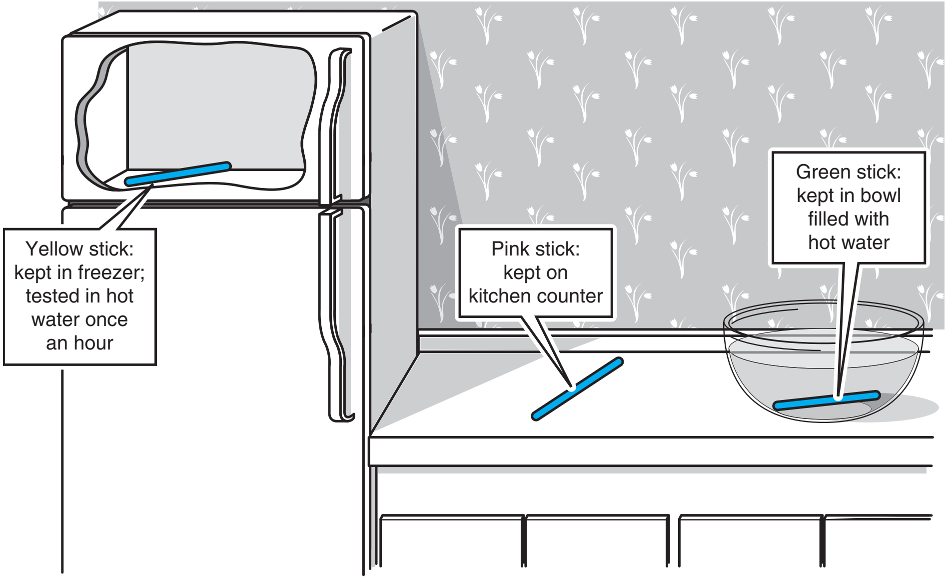
I bent three light sticks to start the chemical reaction that makes them glow. I put a yellow light stick in the freezer, a green light stick in a bowl of hot water, and a pink light stick on the kitchen counter.

What did you do next?

An hour later I checked on the three sticks. The yellow one in the freezer was no longer glowing, but the other two were. When I ran some hot water over the cold light stick, it started to glow again. Then I put it back in the freezer.

I checked on all three light sticks every hour for 12 hours. Each time, I took the yellow light stick out of the freezer and ran hot water over it to make sure it could still glow.

Experimental Setup



What kind of results did you get?

By the eighth hour, I noticed that the pink and green sticks were not glowing as brightly as they had earlier. And by the twelfth hour, only the yellow stick was still working.

I was surprised by my results. I thought that the green light stick in the bowl filled with hot water would stop working faster than the pink stick at room temperature. That wasn't what my experiment showed. Instead, the pink and green sticks stopped working at about the same time.

Can you figure out the main mistake I made in conducting this experiment?

Yes! You didn't control some of your variables. You used different types of light sticks in each of your trials.

You're right! Each light stick was a different color, which means that each stick contained different dyes. It's possible that some combinations of light-stick dyes could cause a faster rate of reaction than others. So, I had no way of knowing what was affecting the reaction rate—the temperature, the types of chemicals, or both.

I also didn't do a very good job of keeping the three sticks at a constant temperature. As the hot water in the bowl cooled off, for example, so did the green stick kept in the water. I also kept changing the temperature of the yellow stick in the freezer because I kept testing it in hot water.

Does that mean your experiment was a total failure? Did you learn anything at all from your data?

You can always learn something from any experiment, whether you get the results you expect or not. For example, I did learn that something caused the yellow light stick in the freezer to last longer than the green and pink sticks. I just can't be sure what that something is.

If I wanted to find out, I could repeat my experiment, but this time I would need to be more careful about controlling variables. I would have to start with three light sticks of exactly the same brand, size, and color. I would also have to think of a way to keep the light stick placed in hot water at a constant temperature. A third thing I would need to do is figure out how to check whether the light stick in the freezer can still glow without running hot water over it and changing its temperature. It would also be a good idea to keep the amount of light each stick is exposed to the same, just to make sure that the amount of light from external sources does not affect how long the light sticks glow.

Now I know how to set up an experiment, and I know science is important, but I'm not a scientist. Why do I need to know about science?

You might not end up in a career where you wear a white lab coat and peer through a microscope all day. But no matter what you do, you're still going to need science. You use science all the time in your daily life, but you may not always realize it. For example, when you work on your car, you use ideas and skills from physics. You use concepts from biology to take good care of your pets and concepts from earth science to understand weather reports. Even an activity as ordinary as cooking involves ideas and processes from chemistry.

As you study science, you learn how to use and analyze the information that you are exposed to every day. Here are some examples of what you can do with science knowledge and science skills: You can look at the nutrition labels on foods and make informed choices about your health. You can understand how and why your stereo system works. You can recognize which health and fitness programs are too good to be true. You can solve problems in different ways by using logic and trying a variety of options.

With an understanding of science, you can also understand and make educated choices on complex issues—such as global warming, cloning, and modern medicine—that may affect the future of the human race.

Now It's Your Turn

After you answer the practice questions, you can check your answers to see how you did. If you chose the wrong answer to a question, carefully read the answer explanation to find out why your answer is incorrect. Then read the explanation for the correct answer.

Question 1

The English physician Ronald Ross (1857–1932) dedicated his career to the investigation of malaria and how it is spread. Ross knew that a parasite called *Plasmodium* was always found in the blood of people infected with malaria. People had long thought that malaria was a result of breathing "bad air." Ross, however, thought that mosquitoes spread malaria from person to person. Which of these could best have helped Ross determine whether mosquitoes were involved in the spread of malaria?

A Observing wild mosquitoes for signs of malaria

B Injecting mosquitoes with *Plasmodium*

C Examining wild mosquitoes to see whether their tissues contain *Plasmodium*

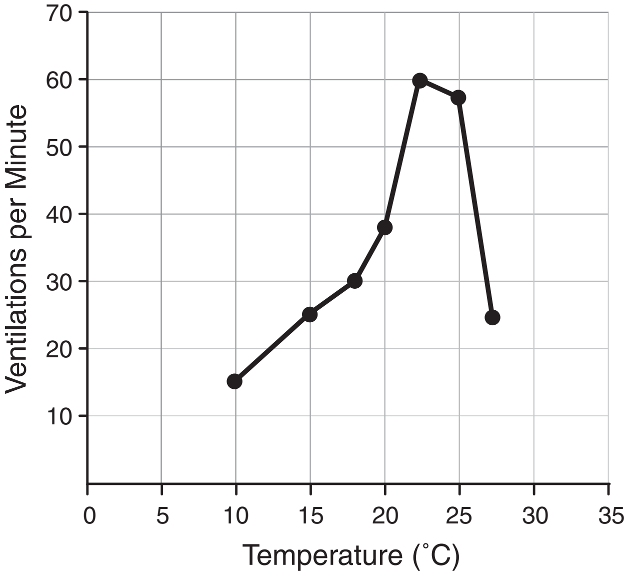
D Determining whether animals such as cows carry *Plasmodium* in their blood

Answer Key: page 111

Question 2

During a process called ventilation, a fish pumps water over its gills by opening and closing its mouth. Ventilation increases the contact between the fish's gills and the surrounding water so that the fish is able to obtain enough oxygen.

Effects of Temperature on the Ventilation Rate of Bluegill Sunfish



According to the graph, what would most likely happen to bluegill sunfish if the temperature of the water in which they live were to rise above 27°C for a period of two weeks?

A The rate of ventilation would remain constant, and the fish would suffer no ill effects.

B The rate of ventilation would slow, and the fish would die of thermal shock.

C The rate of ventilation would increase to counteract low oxygen levels.

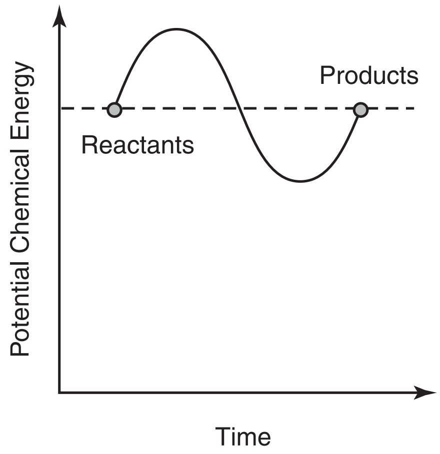
D The rate of ventilation would remain constant as the fish adapt to warmer water.

Answer Key: page 111

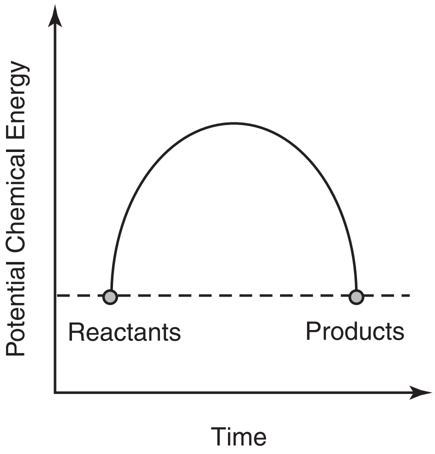
Question 3

Which graph illustrates the progress of a chemical reaction in which energy is released?

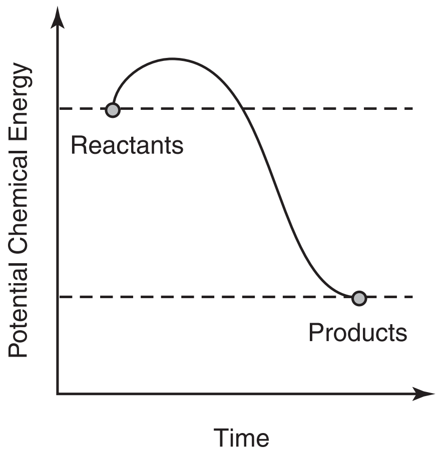
A



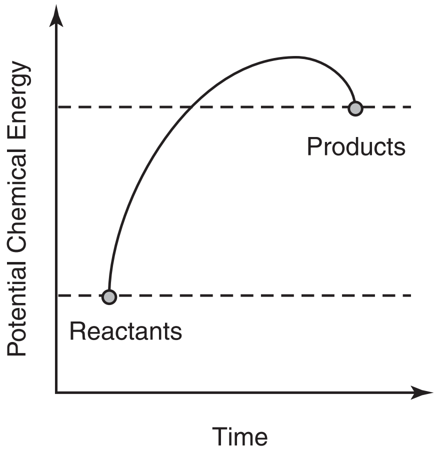
B



C



D

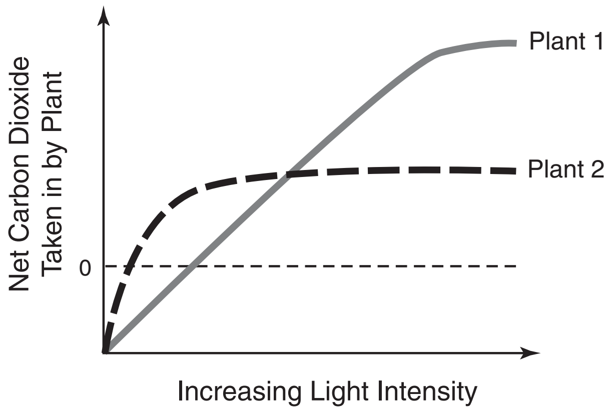


Answer Key: page 111

Question 4

A researcher measured the net amount of carbon dioxide taken in by two species of plants at various intensities of light. According to the graph, how is Plant 1 different from Plant 2?

Effect of Light Intensity on Plants 1 and 2



A Plant 1 requires more energy from respiration than Plant 2.

B Plant 1 is better suited to growing in a dry environment than Plant 2.

C Plant 2 will grow to maturity much faster than Plant 1.

D Plant 2 is better suited to growing in a shady environment than Plant 1.

Answer Key: page 111

Question 5

For a science project a student decided to determine the preferred food of birds called finches. He hung two feeders, one with sunflower seeds and one with millet, from a tree at a height of 12 feet. He hung two more feeders, one with sunflower seeds and one with millet, at a height of 4 feet on the same tree. He counted the number of finches at each feeder three times a day for five weeks. Based on his observations, the student concluded that finches' primary food source is sunflower seeds. However, his science teacher questioned the student's conclusion.

The teacher most likely questioned the student's conclusion because the student did not —

A mix the two types of food together

B place any of the feeders at ground level

C conduct his experiment in a laboratory setting

D observe finches feeding elsewhere in their habitat

Answer Key: page 112

Question 6

Cat Food Investigation

Group	Daily Diet	
	Cans of New Food (Brand 1)	Cans of Food Known Not to Cause Health Problems (Brand 2)
1	0.0	2.0
2	0.5	1.5
3	1.0	1.0
4	1.5	0.5

A pet food company conducted an investigation using a new type of cat food. Researchers measured several indicators of health in four groups of cats. Each group was fed a different diet. After six months the researchers found no difference in the health indicators among the groups and concluded that the new food has no ill effects on cats' health.

How could this investigation have been improved?

A Only one group of cats should have been used.

B Only one indicator of health should have been measured.

C A fifth group should have been added in which the cats were fed only Brand 1 food.

D Another set of groups should have been added in which cats ate the new food for only one month.

Answer Key: page 112

Question 7

One gram of protein has an energy value of about four Calories. An athlete wants to increase the percentage of Calories from protein in his diet. Which of these would have the greatest percentage of Calories from protein?

A An energy bar with 19 grams of protein and 210 Calories total

B An energy bar with 14 grams of protein and 200 Calories total

C An energy bar with 16 grams of protein and 230 Calories total

D An energy bar with 20 grams of protein and 280 Calories total

Answer Key: page 112

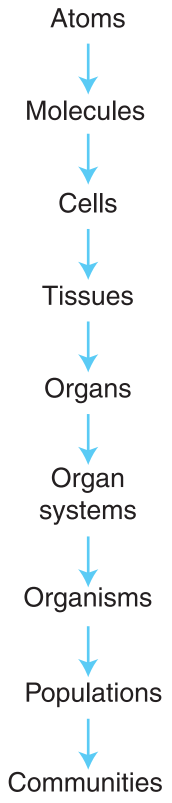
Objective 2

The student will demonstrate an understanding of the organization of living systems.

From your studies in biology, you should be able to demonstrate an understanding of the organization of living systems.

Could you repeat that? What am I supposed to understand?

Biology is all about life and organization. Living things are made up of *cells*, which are made up of *molecules*, such as DNA. In many organisms, cells are organized into *tissues*. Tissues are organized into *organs*, and organs are organized into *organ systems*. Even the organisms themselves are organized into larger groups called *populations* and *communities*.



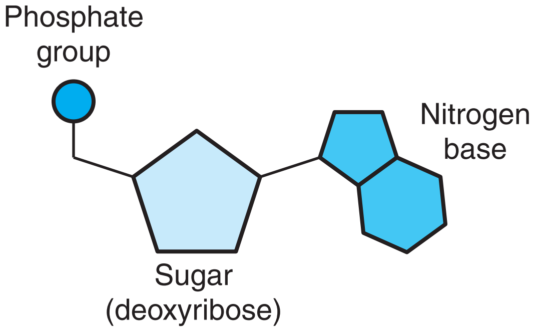
O.K., let's start at the beginning. What's DNA?

DNA, which stands for *deoxyribonucleic acid*, is a molecule found in the cells of all organisms. DNA contains the genetic information that controls what a cell can do and what types of molecules it can make.

What is DNA made of, and what does it look like?

DNA is a very organized molecule. It's made up of thousands (often millions) of units called *nucleotides*. Each nucleotide has three parts: a sugar called deoxyribose, a phosphate group, and a nitrogen base. The nucleotides are arranged in two strands, kind of like a ladder with the nitrogen bases making up the rungs. These strands twist around each other in a shape called a double helix.

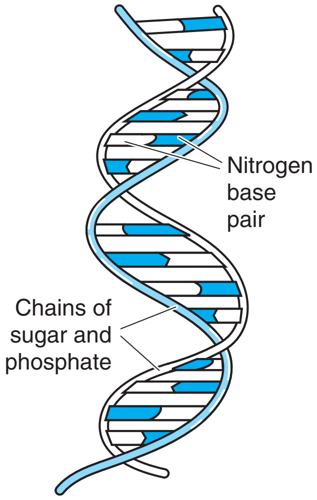
Nucleotide Structure



Did you know?

Helix is just a fancy word for "coil." A double helix is two coiled strands twisted around each other.

DNA Structure



So how does DNA carry genetic information?

The information that you're reading right now is made up of a sequence of letters. The meaning of the sequence depends on its order. For example, the words *ant* and *tan* contain the same letters, but they have different meanings because the letters are ordered differently.

DNA molecules can also be thought of as sequences of "letters." In DNA, however, the "letters" are different types of nitrogen bases. There are four different nitrogen bases in DNA: guanine (G), cytosine (C), adenine (A), and thymine (T). The genetic information of DNA is contained in the order of these bases.

What happens to DNA when a cell divides?

Each time a cell divides, it needs to copy its DNA. That way each new cell will have a complete set of the organism's genetic information. A cell can make a copy of its DNA because DNA molecules have two strands. Each strand contains all the information needed to make the other strand.

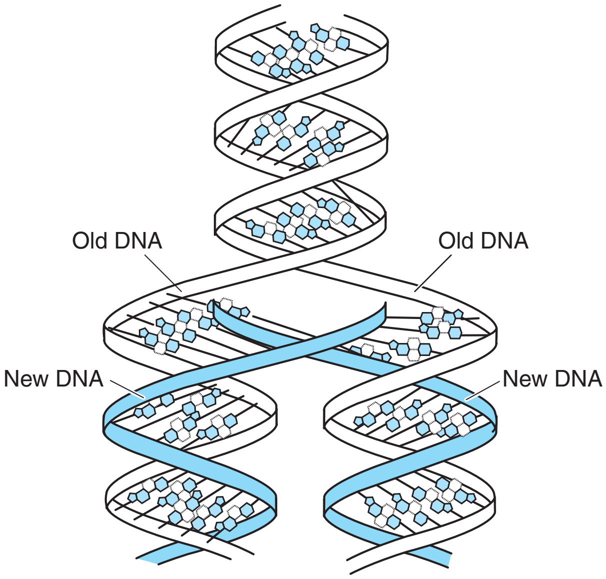
The nitrogen bases in DNA come in pairs, one on each strand. Whenever there's a guanine on one strand, there's a cytosine opposite it on the other strand. Whenever there's an adenine on one strand, there's a thymine on the opposite strand. The nitrogen-base sequence of a small section of DNA is shown below. Notice how the bases on the two strands pair up: G with C and A with T. These are called *complementary bases.*

Strand 1: T A C T T T A G T A A C

Strand 2: A T G A A A T C A T T G

Before a cell divides, the strands of its DNA separate. Each strand acts as a *template,* or pattern, for a new DNA molecule. This process is called *replication,* and it results in two identical copies of a DNA molecule.

DNA Replication



During replication, enzymes unwind the two strands of DNA. Pairing between complementary nitrogen bases forms new strands.

How does a cell use the information in the genetic code?

A cell makes a copy of the part of its DNA that tells it how to make a specific protein. This copy is called *messenger RNA* (or mRNA) because it's used to carry a message from the DNA to the rest of the cell. RNA stands for *ribonucleic acid.* Its structure is similar to DNA, except it has a different sugar (ribose instead of deoxyribose). In addition, RNA exists as a single strand instead of a double helix.

Making an mRNA molecule is a lot like making a new DNA molecule. A section of the DNA molecule unwinds, and complementary RNA nucleotides pair up with the DNA nucleotides. Like DNA, RNA has the nitrogen bases guanine, cytosine, and adenine, but instead of thymine, it has uracil (U). The process of copying the genetic information in DNA into mRNA is called *transcription.*

Transcription of a DNA Strand

DNA strand: T A C T T T A G T A A C

mRNA: A U G A A A U C A U U G

O.K., we've gone from DNA to mRNA. What happens next?

A molecule of mRNA contains information on how to build a specific protein. Proteins can be thought of as the machines of the cell. Each protein performs some specific task. For example, hemoglobin is a protein in red blood cells that helps carry oxygen from the lungs to body tissues.

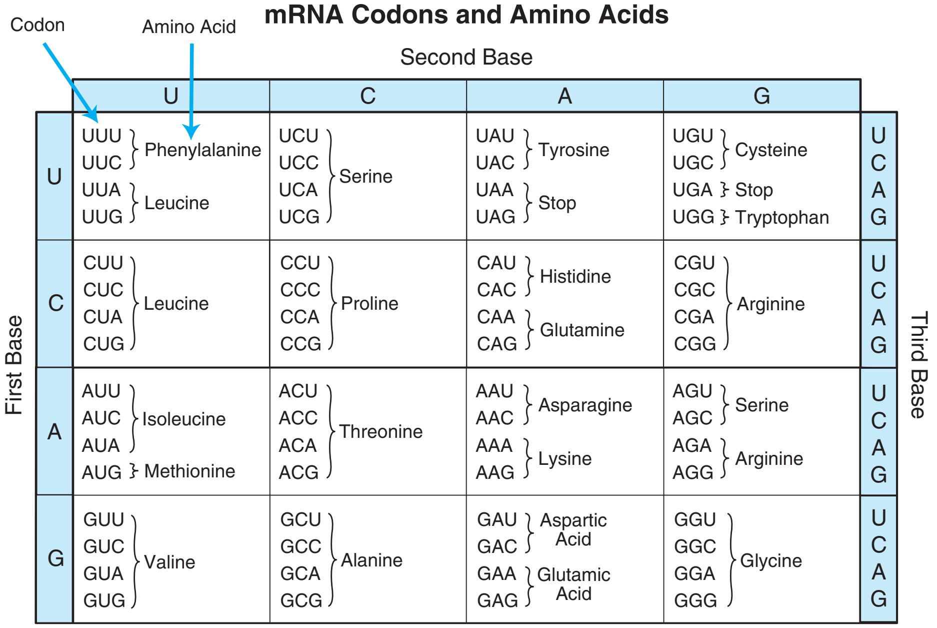
The information in mRNA is organized into three-letter blocks called *codons.* Codons are like the words of the RNA message. Each codon

Remember!

Proteins are made up of molecules called amino acids.

codes for a specific amino acid in the protein chain. For example, the codon AGU codes for the amino acid serine.

mRNA Codons and Amino Acids



Second Base

First Base	U		C		A		G		Third Base
U	UUU	Phenylalanine	UCU	Serine	UAU	Tyrosine	UGU	Cysteine	U
	UUC		UCC		UAC		UGC		C
	UUA	Leucine	UCA		UAA	Stop	UGA	Stop	A
	UUG		UCG		UAG		UGG	Tryptophan	G
C	CUU	Leucine	CCU	Proline	CAU	Histidine	CGU	Arginine	U
	CUC		CCC		CAC		CGC		C
	CUA		CCA		CAA	Glutamine	CGA		A
	CUG		CCG		CAG		CGG		G
A	AUU	Isoleucine	ACU	Threonine	AAU	Asparagine	AGU	Serine	U
	AUC		ACC		AAC		AGC		C
	AUA		ACA		AAA	Lysine	AGA	Arginine	A
	AUG	Methionine	ACG		AAG		AGG		G
G	GUU	Valine	GCU	Alanine	GAU	Aspartic Acid	GGU	Glycine	U
	GUC		GCC		GAC		GGC		C
	GUA		GCA		GAA	Glutamic Acid	GGA		A
	GUG		GCG		GAG		GGG		G

This chart shows the amino acids coded for by each of the 64 possible mRNA codons. To find which amino acid the codon CAA codes for, follow these steps. (1) Look on the left side of the chart to find the large row of codons that begin with C. (2) Move across this row until you get to the column of codons whose second base is A. (3) Move down this column until you get to the row of codons whose third base is A. The codon CAA codes for the amino acid glutamine.

The process in which a protein is produced from mRNA is called *translation*. In order for translation to begin, mRNA must first attach to a cell structure called a *ribosome*. If proteins are like the machines of the cell, then ribosomes are like the factories where the machines are made.

How do the amino acids match up with the mRNA codons?

That's the job of another type of RNA called *transfer RNA* (tRNA). Each type of tRNA matches a particular codon to a particular amino acid. As the mRNA moves through the ribosome, amino acids are joined together in the correct sequence to form a protein chain.

What happens if there's a mistake in the DNA?

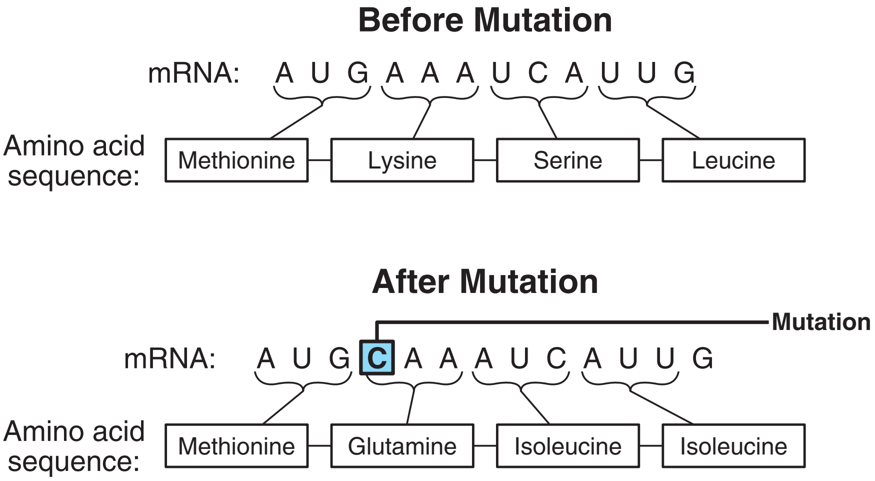
A mistake or change in the DNA sequence is called a *mutation*. As you can probably guess, a change in DNA can lead to a change in mRNA, which can lead to a change in a protein.

Mutations happen all the time, but they usually don't have any effect on an organism. Let me explain why that is. There are more mRNA codons than there are amino acids, so more than one codon may code for the same amino acid.

Suppose a DNA mutation led to a change in a single mRNA codon—from the codon AGA to the codon AGG. By looking at the chart on page 26, you can see that both of these codons code for the amino acid arginine. Even though the DNA and mRNA have changed, there is no change in the protein. However, it's also possible for a mutation to change a codon so that it *does* code for a different amino acid. When this happens, the protein might not work as well, or it might not work at all.

For example, sickle-cell anemia is caused by a mutation to a single base pair in the DNA that codes for hemoglobin. (Remember that hemoglobin is a protein that carries oxygen in red blood cells.) This mutation causes the mRNA to change from GAA to GUA. The amino acid valine would be added to the protein instead of glutamic acid. This change results in an abnormal form of hemoglobin that causes red blood cells to have a sickle, or crescent, shape. The sickle-shaped cells cannot flow well through narrow blood vessels, resulting in a variety of health problems.

Other types of mutations affect more than one codon. For instance, a mutation can cause one or more nucleotides to be added to or deleted from DNA. This type of mutation can lead to the production of a completely different protein. As a result, the mutation could be harmful, or even fatal, to the organism.



The addition of a nucleotide can affect the production of an entire protein. In this case, a mutation has caused an extra C to be added after the first mRNA codon.

Aren't there any good mutations?

Yes, there are! On rare occasions, a mutation can make an organism more likely to survive and reproduce. For example, a species of plant might produce a chemical with a scent that attracts pollinating flies. A mutation in one of the plants could make it produce a slightly different scent—one that is even more attractive to pollinators. This type of mutation would be beneficial to the plant.

However, even if a mutation benefits an organism, it may not be passed on to the organism's offspring. For organisms that reproduce sexually, mutations can be passed to the next generation only if they occur in the organism's sex cells (eggs or sperm).

Remember!

Organisms with traits that are favorable in a particular environment are more likely to survive and pass on their genes to the next generation. This process is called natural selection.

Did you know?

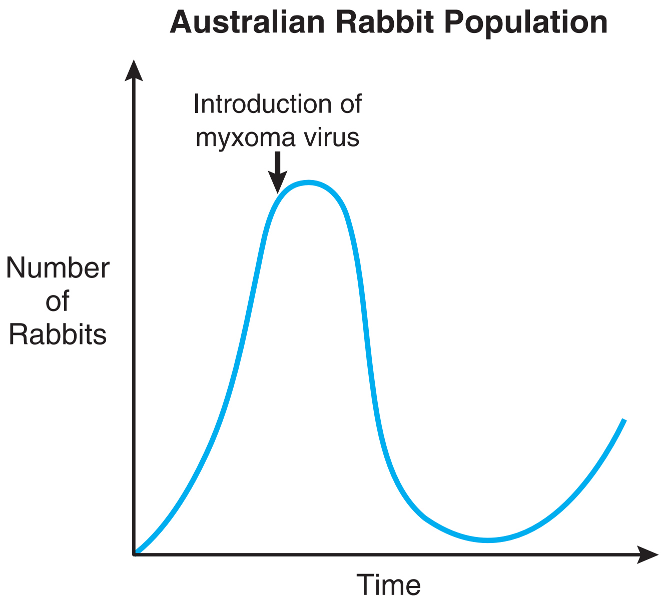
Because bacteria are single celled, any mutation can be passed on to the next generation. For this reason, as well as because of their extremely fast reproductive rate, bacteria often accumulate mutations and adapt to new living conditions faster than other organisms.

But what happens if a beneficial mutation is passed on to the offspring?

If the mutation makes the offspring more likely to survive and reproduce, they will be more likely to pass the mutation on to their own offspring. As the mutation is passed from generation to generation, larger and larger numbers of organisms will carry it. Eventually, the mutation could spread throughout a population or species. The evolution of a species refers to changes in its genetic makeup over time. As mutations accumulate within a species, the species evolves. We'll talk more about species and populations when we discuss Objective 3.

One example of evolution involves Australian rabbits. Rabbits are not native to Australia but were introduced there in the mid-1800s. The rabbit population grew rapidly, and they soon became serious pests. In 1950 scientists introduced the myxoma virus to Australia in an effort to control the rabbit population. (The myxoma virus is a natural parasite of South American rabbits.) At first the virus was very effective. In some places the rabbit population decreased by about 99%.

It wasn't long, however, before more rabbits began to survive infection by the virus, and the rabbit population began to increase once more. One reason for this was that resistance to the virus was increasing. Certain rabbits had mutations that made them more likely to survive the myxoma virus. As a result, they were more likely to pass on their genes to offspring. In the same way, their offspring were also more likely to survive and reproduce. With each generation more and more rabbits were born with genes that made them resistant to the myxoma virus. In other words, the rabbit population was evolving.



The graph approximates the effects of the myxoma virus on the Australian rabbit population over time. At first the virus was highly fatal to the rabbits, but over several generations resistance to the virus began to increase.

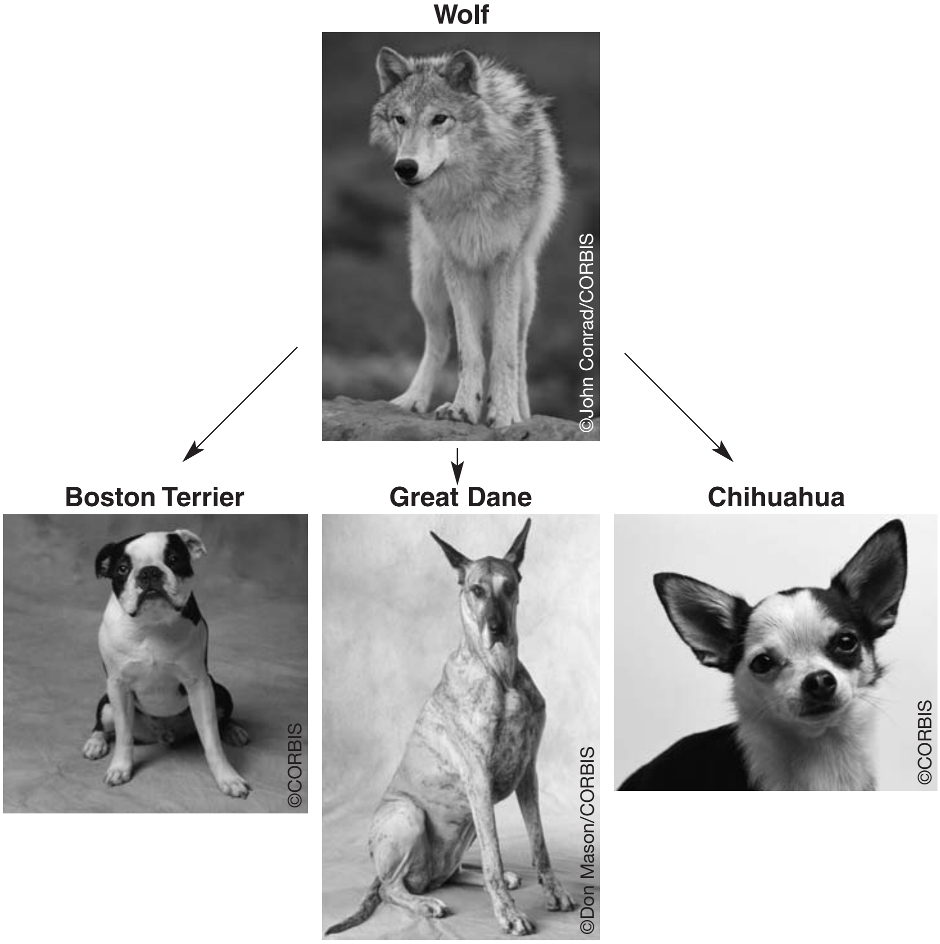
Was this an example of genetic engineering?

Not really. *Genetic engineering* includes any method that people use to change an organism's genes. Genetic engineering might seem new, but really we've been engineering plants and animals for thousands of years. For example, humans have produced hundreds of new types of plants and animals by using selective breeding. The first step of selective breeding is to identify traits that are desirable. Then only those organisms having these traits are allowed to breed. As a result, the genes for the desirable traits are passed on to the next generation. This process is repeated until an entire population is produced that possesses the desirable traits.

Modern genetic engineering also involves selecting desirable traits, but now scientists are actually able to move the genes that code for these traits from one organism to another. Scientists are even able to move genes from one species to another.

Remember!

As with any scientific endeavor, such as genetic engineering, scientists have many unanswered questions, and some effects of bioengineering have yet to be studied.



Humans bred all these types of dogs from wolves. Each type was bred for different purposes.

Why would scientists want to move genes around like that?

Let me give you an example. Scientists can take a human gene and insert it into the DNA of a bacterium. Because the bacterium has a human gene, it will produce a human protein. When the bacterium reproduces, its offspring will also be able to produce the human protein. Because bacteria reproduce so quickly, a large amount of the human protein can be produced and collected in a short amount of time.

One human gene that scientists have inserted into bacteria is the gene that codes for the protein insulin. Insulin is a hormone (or chemical messenger) that helps the body regulate the level of glucose in the blood. Type 1 diabetes is a disease in which the body does not produce enough insulin. It is estimated that there are between 850,000 and 1,700,000 people with type 1 diabetes in the United States alone. Scientists have been able to use genetically engineered bacteria to provide much of the insulin that type 1 diabetics need in order to survive.

Before human insulin could be produced from genetically engineered bacteria, people with type 1 diabetes had to rely on insulin obtained from pigs or other animals. One advantage of genetically engineered insulin is that, unlike pig insulin, it is identical to human insulin, and as a result patients are less likely to develop health problems from it. In addition, insulin obtained through genetic engineering is often less expensive, and shortages are less common.

How are bacterial cells different from human cells?

One of the main differences is that human cells have a nucleus but bacterial cells do not. Organisms whose cells lack nuclei are called *prokaryotes*. Prokaryotes include eubacteria and archaebacteria. Organisms whose cells have nuclei are called *eukaryotes*. Eukaryotes include protists, fungi, plants, and animals.

The *nucleus* in a eukaryotic cell acts as the command center of the cell and controls its activities. The cell's DNA is located in the nucleus, along with proteins for replication or transcription.

A nucleus is a type of organelle. An *organelle* is a structure within a cell that performs a specific function. Eukaryotic cells have a variety of organelles, but most of these are absent in prokaryotic cells.

What are some of the other organelles in eukaryotic cells?

The cells of plants and some protists have organelles called *chloroplasts*. Chloroplasts use the energy in sunlight to make a sugar called glucose. This process is called *photosynthesis* and can be summed up with the following chemical reaction.

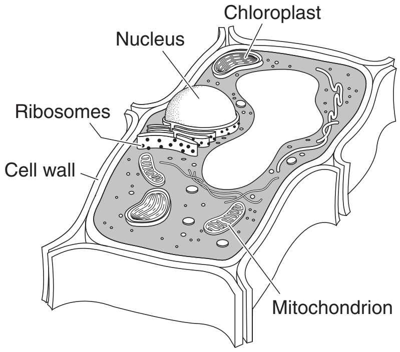
$$\underset{\text{Carbon dioxide}}{6CO_2} + \underset{\text{Water}}{6H_2O} \xrightarrow{\text{Light energy}} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6O_2}$$

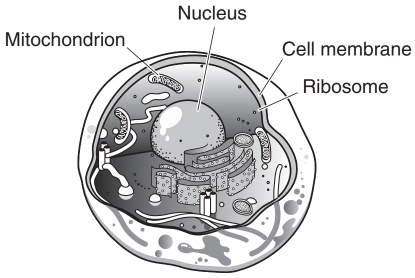
Plants use the glucose they produce from photosynthesis as an energy source. Animals also use glucose as an energy source. However, animal cells can't make glucose. So where do animals get glucose? They get it from eating plants or from eating animals that eat plants.

Another type of organelle—one found in all eukaryotes—is *mitochondria*. Mitochondria break down food molecules such as glucose to release energy, which can then be used for growth, health maintenance, and reproduction. The process by which cells break down glucose to produce energy is called *cellular respiration*. It can be summarized by the following reaction.

$$\underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6O_2} \rightarrow \underset{\text{Carbon dioxide}}{6CO_2} + \underset{\text{Water}}{6H_2O} + \underset{\text{Energy}}{\text{ATP}}$$

Ribosomes are organelles where proteins are made. (We talked about them earlier, remember?) Ribosomes are present in prokaryotes as well as eukaryotes.


Plant Cell


Animal Cell

How can I tell different types of cells apart?

If you understand the structure of a cell, you can understand its function. Knowing the types and number of organelles in a cell can sometimes give you a good idea of what the cell does. For example, leaf cells contain a large number of chloroplasts because the main function of leaves is photosynthesis.

Another example can be seen in muscle cells, which have a large number of mitochondria. Because muscles are involved in an animal's movement, muscle cells need to be able to produce a large amount of energy. This energy is made available by the cells' mitochondria.

How do cells keep themselves alive?

The conditions inside a cell have to be just right, or the cell will die. These conditions include many different factors, such as temperature, pH, and ion concentrations. Cells keep themselves alive by maintaining a stable internal state. This state is called *homeostasis*.

Cells have many ways of maintaining homeostasis. One method involves *transport proteins* in the cell membrane. Transport proteins act like guards that let only certain materials in or out. For example, ions are not able to cross the cell membrane on their own. They can cross only by means of a transport protein. As a result, the cell can control the concentration of ions in its cytoplasm. In animal cells, transport proteins maintain a high concentration of potassium ions in the

Did you know?

Human cells function best at about 37°C. That's why a fever is a sign that something is wrong—the body stops maintaining homeostasis in an effort to fight off disease.

cytoplasm and a low concentration of sodium ions. Maintaining the concentrations of these ions is important to the proper functioning of muscle and nerve cells.

What if the area around a cell doesn't have the materials the cell needs to maintain homeostasis?

In that case, the cell could die. In multicellular organisms, however, cells work together in organs and organ systems to help one another maintain homeostasis. For example, our circulatory system transports oxygen, nutrients, and other necessary materials to all the cells of the body.

Can you give me some examples of how the organ systems work together?

Of course! Let's focus on the circulatory, respiratory, and muscular systems in humans and see how they're related to some of the other systems.

	Circulatory	Respiratory	Muscular
Digestive	Blood carries digested nutrients to body cells.	The pharynx serves as a passageway for both air and food.	Muscles churn the stomach to aid in digestion.
Nervous	The brain stem controls heart rate.	The brain stem regulates breathing.	Signals travel down the spinal cord to the muscles.
Skeletal	Bone marrow produces blood cells.	The rib cage expands to help move air into the lungs.	The contraction and relaxation of skeletal muscles moves bones.
Endocrine	Blood carries hormones throughout the body.	Hormones can contribute to asthma attacks.	Hormones cause males to put on more muscle mass during puberty.
Reproductive	Nutrients diffuse through the placenta and are carried to the embryo through blood vessels in the umbilical cord.	Breathing rate increases to provide the extra oxygen needed during labor.	Muscle contractions in the uterus push the fetus out during labor.
Integumentary	Platelets in the blood help close small cuts in the skin.	Cells lining the nostrils produce mucus that keeps the nearby tissue from drying out.	Muscles raise the hair on the arms and legs to help retain heat.
Immune	White blood cells attack pathogens such as bacteria and viruses.	Mucus lining the respiratory passages helps trap pathogens.	Sneezing involves involuntary muscle contractions.
Excretory	Waste products are filtered from the blood in the kidneys.	The respiratory system removes the waste gas carbon dioxide from the body.	Muscle contractions are involved in emptying the urinary bladder.
Muscular	The heart is largely composed of muscle tissue.	Contraction of the diaphragm helps move air into the lungs.	
Respiratory	Oxygen moves from the lungs to the blood, and carbon dioxide moves from the blood to the lungs.		Breathing rate increases during exercise to help meet the increased oxygen demand by skeletal muscles.

Now It’s Your Turn

After you answer the practice questions, you can check your answers to see how you did. If you chose the wrong answer to a question, carefully read the answer explanation to find out why your answer is incorrect. Then read the explanation for the correct answer.

Question 8

The endoplasmic reticulum is an organelle found in animal cells. One of the main functions of the endoplasmic reticulum is to carry materials from one part of a cell to another. One way that the endoplasmic reticulum helps maintain the body’s homeostasis is by —

A transferring energy from carbohydrates to ATP
B using genetic information to manufacture muscle proteins
C transporting oxygen from the lungs to all parts of the body
D delivering hormones to the cell membrane, where they can be secreted

Answer Key: page 112

Question 9

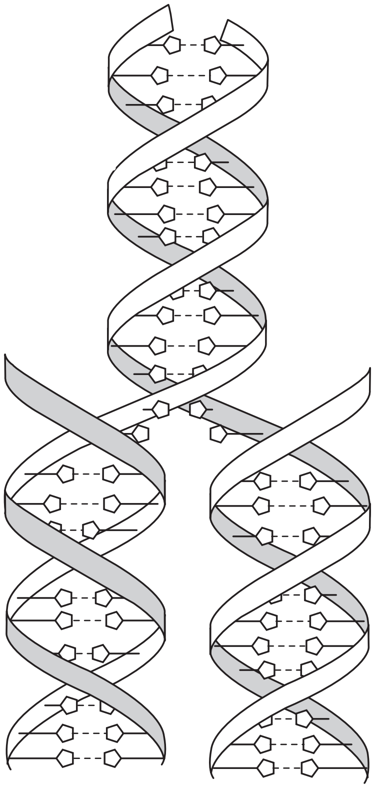
Which statement best describes the process at Step 2 in the diagram?

DNA TACAAACGACCGTTC . . .
ATGTTTGCTGGCAAG . . .
↓ **(1)** DNA serves as a template from which mRNA (messenger RNA) is made.
mRNA AUGUUUGCUGGCAAG . . .
↓ **(2)**
methionine + phenylalanine + alanine + glycine + lysine . . .

A An mRNA molecule signals which nucleotides should be joined to form a nucleic acid.
B The codons of an mRNA molecule signal proteins to create a carbohydrate chain.
C The genetic information coded in an mRNA molecule is translated into an amino acid chain.
D A protein chain acts as a pattern for creating an mRNA molecule with the proper sequence.

Answer Key: page 112

Question 10



Which cellular process is modeled in this diagram?

A Replication, in which DNA is copied before mitosis occurs

B Deletion, in which a chromosome breaks and a piece of DNA is lost

C Transcription, in which the information stored in DNA is copied to mRNA

D Translation, in which the information stored in mRNA is used to synthesize a protein

Answer Key: page 113

Question 11

A group of scientists discover a new species in a rain forest. They take a tissue sample from one of the organisms and look at it under a microscope. The cells making up the tissue have nuclei and cell walls. Next the scientists take several of the organisms and place them in damp soil that is rich in organic material. Half of the organisms are exposed to full sunlight, and half are kept in constant darkness. The group that receives sunlight grows and thrives, but the group that is kept in darkness gradually dies.

In which kingdom should the new species be classified?

A Eubacteria

B Fungi

C Plantae

D Animalia

Answer Key: page 113

Question 12

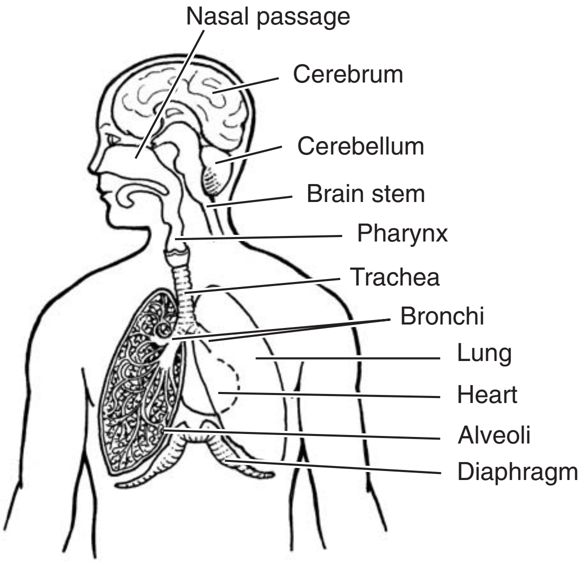
A person drives a car up to a railroad crossing and stops. The driver is startled by the sound of a train blowing its whistle. The driver's heart rate immediately increases, and the driver is more alert. Which body systems are most involved in causing the driver's heart rate and alertness to increase as a result of sudden fright?

A Skeletal and muscular
B Nervous and endocrine
C Circulatory and excretory
D Respiratory and integumentary

Answer Key: page 113

Question 13

An increase in the amount of carbon dioxide in the blood stimulates the respiratory center in the brain. As a result, a message is sent from the brain to the —



A bronchi, causing them to narrow in diameter
B diaphragm, causing an increase in the breathing rate
C alveoli, causing them to actively transport oxygen
D lungs, causing a decrease in the breathing rate

Answer Key: page 113

Question 14

Blood type is determined by marker molecules on the surface of red blood cells. A person's blood plasma may contain antibodies for any marker molecules that his or her blood cells lack. These antibodies recognize blood cells with foreign marker molecules and cause them to clump together. Such clumping can result in serious medical problems. For this reason, accurate blood typing is very important before a patient receives a blood transfusion.

Blood Types, Marker Molecules, and Antibodies

Blood Type	Marker on Red Blood Cells	Potential Antibodies in Plasma
O–	None	Anti-A, Anti-B, Anti-Rh
O+	Rh	Anti-A, Anti-B
A–	A	Anti-B, Anti-Rh
A+	A, Rh	Anti-B
B–	B	Anti-A, Anti-Rh
B+	B, Rh	Anti-A
AB–	A, B	Anti-Rh
AB+	A, B, Rh	None

Which blood types could be safely donated to a person who has a blood type of B–?

A B– or O–

B B– or AB+

C B–, B+, or O–

D B–, B+, AB–, or AB+

Answer Key: page 114

Objective 3

The student will demonstrate an understanding of the interdependence of organisms and the environment.

From your studies in biology, you should be able to demonstrate the interdependence of organisms and the environment.

Wait a minute! What am I supposed to demonstrate?

Organisms don't live in isolation. All living things depend on their environment and other organisms for survival. The environment has an effect on individual organisms and on populations of organisms. You need to be able to show that you know this relationship.

A population of organisms—what's that?

A *population* is a group of organisms that belong to the same species, live in the same area, and breed with other individuals in the group. For example, there are populations of humans, populations of sharks, populations of oak trees, and populations of mosquitoes.

Remember!

A species is a group of organisms that are capable of interbreeding and producing fertile offspring.

I understand how the environment affects individual organisms, but how does the environment affect entire populations?

Good question! Individual organisms have differences, or variations. Factors in the environment such as the amount of food or space can make one variation more favorable than another. Over time the population will have more individuals with the favorable variation. This process is called *natural selection*.

©PhotoDisc ©Paul A. Souders/CORBIS

These bears belong to the same species, but they have different fur colors because of genetic variations. The darker fur color may be more favorable in certain environments, and the lighter fur color may be more favorable in others.

Did you know?

A single swarm of Rocky Mountain locusts was estimated to contain 12.5 trillion insects. That's a large population!

Evolution and natural selection are kind of the same thing, right?

Not exactly. Many students are confused about the difference between evolution and natural selection. To *evolve* means to change over time. Stars evolve, languages evolve, and in biology, living things evolve. Change in the genetic makeup of populations and species over many generations results in evolution. Natural selection is the process that causes these changes.

Can individual organisms evolve?

No, they can't. The genetic makeup of an organism doesn't change during its lifetime, and individual organisms don't develop physical adaptations to their environment. This means that individual organisms can't evolve. However, the genetic makeup of a population does change with each new generation, so populations can evolve.

Can you tell me more about the process of natural selection?

O.K., organisms have differences in inherited characteristics, or traits. Individuals with physical and behavioral traits that are better suited to the environment are more likely to survive, reproduce, and pass those traits on to their offspring. This process is sometimes called *survival of the fittest*.

As those individuals with favorable traits produce more offspring, the favorable traits become more common in the population. Over many generations, the genetic makeup of a population can change, or evolve. The conditions in the environment favor those organisms that are best suited to survive and reproduce. Over time the process of natural selection can lead to changes in a species or to the evolution of a new species.

A new species? How can that happen?

Remember that a species is a group of organisms that are capable of interbreeding and producing fertile offspring. Here's one way a new species can form: two populations of the same species become separated—perhaps by a mountain range, a river, or an ocean. These separate populations are each acted upon by natural selection in their own environment. If the two environments are different, different traits will eventually be present in each population. If the differences are great enough to prevent interbreeding that produces fertile offspring, a new species will evolve. This process is called *speciation*.

Harris's Antelope Squirrel

©CORBIS

White-Tailed Antelope Squirrel

©Charles Ott/Photo Researchers, Inc.

Speciation occurred when two populations of squirrels became separated by the Grand Canyon. Because the squirrels could not cross the canyon to interbreed, the two populations evolved differently, eventually forming two different species. The Harris's antelope squirrel lives on the south side of the Grand Canyon, and the white-tailed antelope squirrel, which is smaller and has a shorter tail, lives on the north side. Unlike that of the white-tailed antelope squirrel, the underside of the Harris's antelope squirrel's tail is dark.

Can you give me an example of some of these traits you keep talking about?

Sure! A *trait* is a physical characteristic of an organism that varies from one individual to another. An *inherited trait* is one that is passed to the next generation in genes. Examples of inherited traits include the color of an animal's fur and the shape of a plant's leaves. All organisms, whether they are humans, plants, or bacteria, have inherited traits. Some of yours are the color of your hair, the shape of your ears, and your height. Although some inherited traits are controlled by a single gene, the inheritance of other traits can be very complex. These traits are often controlled by many different genes.

In a given set of environmental conditions, some inherited traits will be more favorable than others. For example, imagine a population of rabbits, some of which have brown fur and some of which have white fur. The trait of white fur could be advantageous for hiding from predators in a snowy environment, but in another environment it could be detrimental.

What about plants? Do they have traits? Do they undergo natural selection?

Yes, plants also have traits that vary among individuals. For this reason, plants undergo natural selection. Plants with favorable traits are more likely to survive and produce more offspring. This ensures that those traits become more common in the population. Plants have evolved adaptations that allow them to thrive in almost every environment—from deserts to rain forests.

Did you know?

Vascular plants, which are adapted to life on land, are the dominant group of plants today. More than 300,000 species have been identified.

Can you explain how plant species have adapted to their environment?

Sure! Plants were originally aquatic. They relied on an aquatic environment for reproduction and other life functions. As plants adapted to dry land, three organ systems developed: roots, stems, and leaves.

Roots have two primary functions:

- Roots absorb water and minerals.
- Roots anchor a plant firmly in the ground and provide support.

The stem has two primary functions:

- The stem provides a supporting framework for leaves and branches.
- Xylem and phloem run through the stem like a plumbing system and connect the roots to the leaves.

Remember!

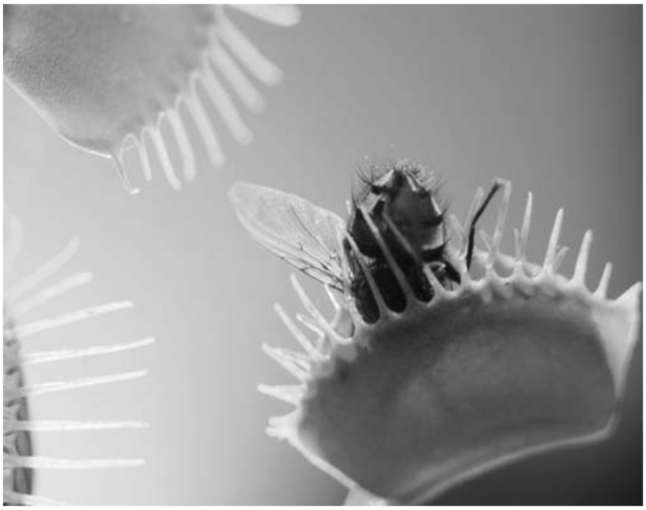
Xylem and phloem are a series of tiny pipes that carry materials throughout the plant. Phloem transports food, and xylem transports water.

The leaves are the main organs of photosynthesis, which means they:

- intercept sunlight
- capture carbon dioxide
- manufacture food for the plant in the form of glucose
- release water vapor through transpiration

Many plant species have evolved specialized roots, stems, and leaves that help the plant adapt to its environment. These include adaptations for protection and defense, water and nutrient storage, trapping and digesting insects, and vegetative (asexual) reproduction.

Plant Adaptations



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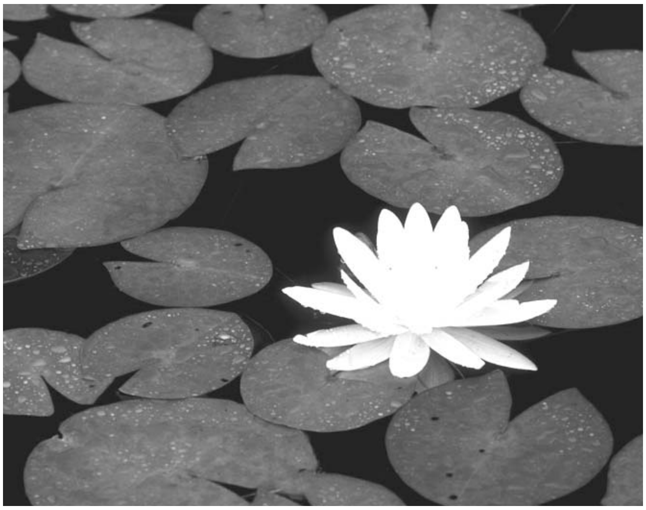
The leaves of a Venus's-flytrap are adapted for trapping and digesting insects.



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The long stems of a water lily connect its floating leaves to its roots at the bottom of a lake or pond.

©Niall Benvie/CORBIS

The spiky leaves of a thistle plant help protect it from herbivores.

©Japack Company/CORBIS

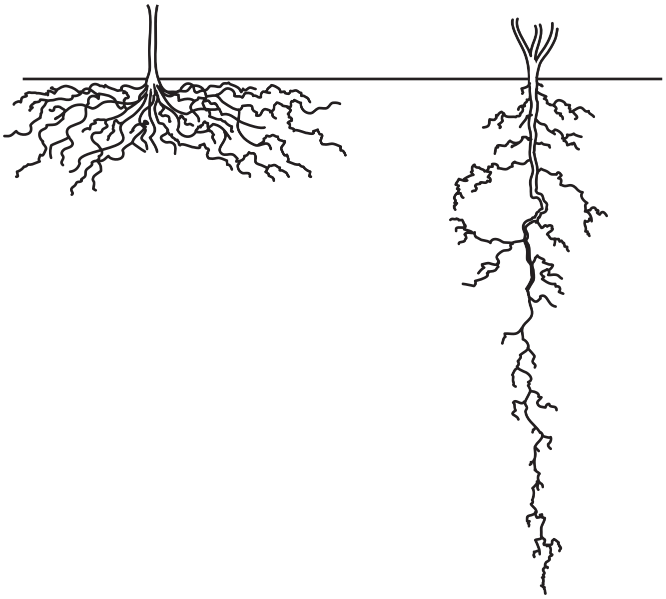
The lightweight seeds of a dandelion are adapted for dispersal by the wind.

Did you know?

The roots of a wild fig tree growing in South Africa grew to an estimated depth of 122 meters—a distance longer than a football field.

Some desert plants, for example, have roots that grow deep into the earth to reach underground water supplies. Other desert plants have roots that extend for long distances just below the surface. These plants can quickly capture occasional rainfall. Both of these adaptations allow desert plants to exist in a dry climate.

Typical Root Structures of Desert Plants



Why do I need to know about plants? Plants don’t even move!

Can you imagine a world without plants? I can’t! Think about the function of plants in the environment. Consider the many uses of plants.

- Plants change the sun’s energy into a form that animals can use, such as glucose.
- Plants are a source of energy and fuel, such as wood and coal.
- Many foods, such as popcorn, bread, and milk, are made from plants or from animals that eat plants.
- Plants provide useful products, such as wood, paper, clothing, and medicines.
- Plants can affect climate and play a role in the water cycle.
- Plants play an important role in the carbon cycle by producing oxygen. (We’ll talk about this later.)

Can plants and animals survive on their own?

All living things—including plants and animals—depend on their environment and on other living things for survival. All the components of an ecosystem are connected.

An ecosystem? What’s that?

An *ecosystem* is an interactive system that includes all parts of the physical environment (*abiotic* factors, such as temperature, soil, and weather). An ecosystem also includes the entire community of organisms that live there (*biotic* factors, such as plants, animals, fungi, and bacteria).

Although it’s easy to think of ourselves as being separate from the environment, we are actually part of an ecosystem. Humans often see themselves as independent of nature, but nothing could be further from the truth. We depend on nature for basic resources such as food and shelter, clean air, and clean water. Life can exist only within an ecosystem.

☞ Remember!

Abiotic means nonliving.

Biotic means living.

What goes on in an ecosystem?

Energy flows through an ecosystem, and matter cycles between living and nonliving things. Without these two processes no life would be possible.

What happens to the energy in an ecosystem?

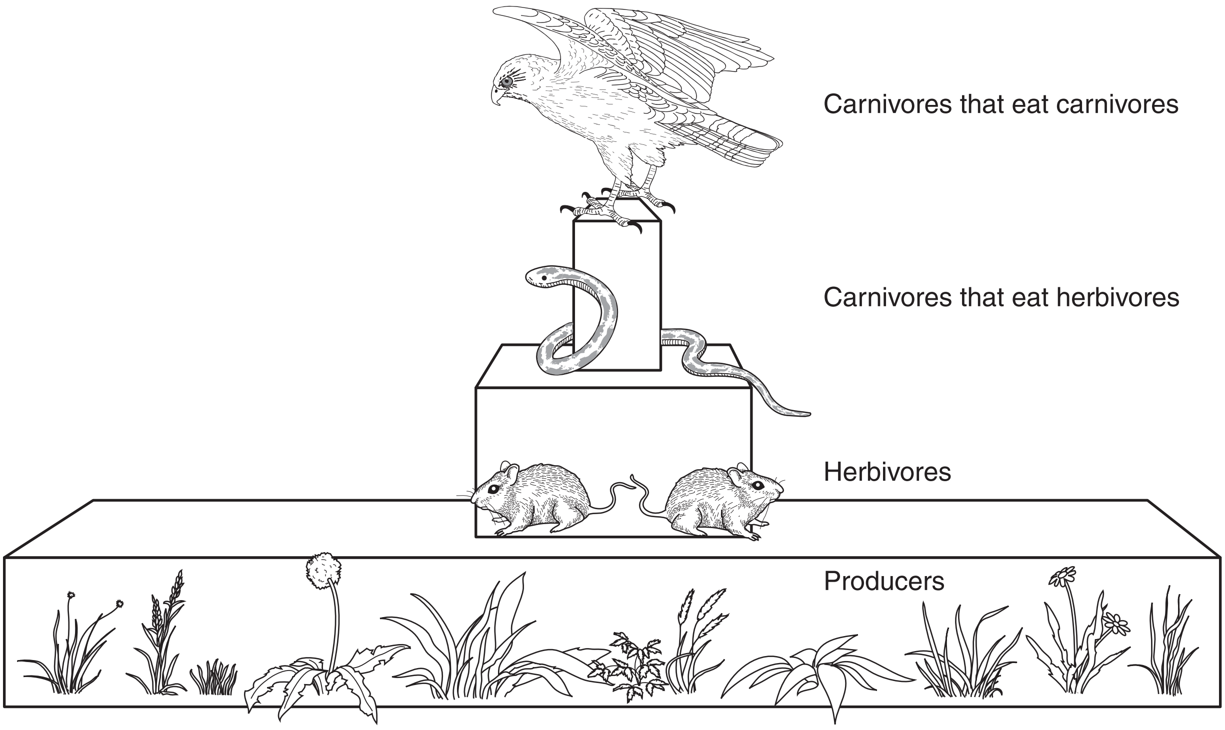
Energy flows in one direction through an ecosystem. Green plants convert the sun's energy to food energy (potential chemical energy). Animals that eat the plants are the next step. These animals are eaten by other animals. At each level in a food chain, consumers convert some food energy to mechanical energy, which is used for activities such as running and breathing. However, much of the energy stored in food is used for *metabolic processes*, such as maintaining a constant body temperature.

In fact, only about 10 percent of the energy at any level in a food chain is transferred to the next level. In mammals, for instance, nearly half of the energy obtained from food is lost to the environment as heat. This is why there are usually only four levels in a food chain. Only rarely is there enough energy available to support a fifth level. An energy pyramid shows the relative amount of energy available at each level.

Remember!

Metabolism refers to all the chemical reactions that take place in an organism.

Energy Pyramid



An energy pyramid shows the energy stored at each trophic (feeding) level in an ecosystem.

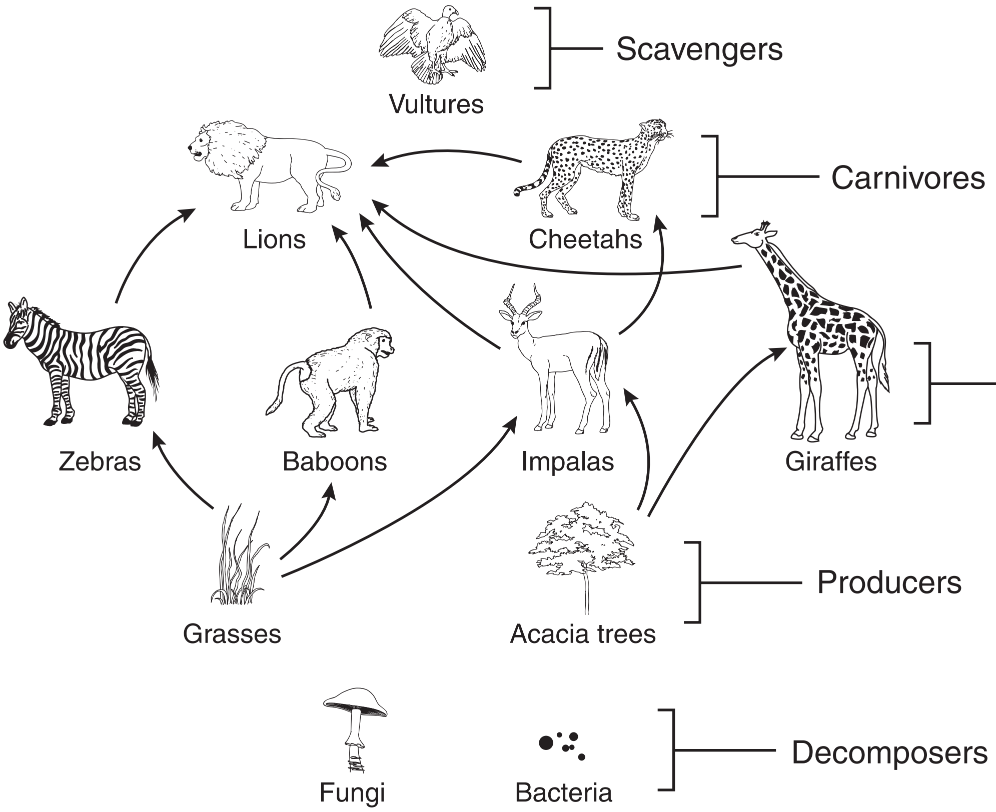
Specific ecosystems can be studied by looking at how energy flows through different feeding levels, such as *producers*, *consumers*, and *decomposers*. These feeding levels are also called *trophic levels*. Listed below are some key concepts about the flow of energy in an ecosystem:

- Organisms contain potential chemical energy stored in organic molecules such as sugars, starches, fats, and proteins.
- The feeding relationships in an ecosystem can be shown in a food web, which consists of many interconnected food chains.
- All food chains and food webs begin with producers.
- Energy moves through ecosystems in food chains and food webs every time an organism eats another organism.
- Energy cannot be recycled.

Remember!

In food chains and food webs, arrows always point from the organism that is consumed to the consumer. Arrows show the flow of matter and energy.

Partial African Grassland Food Web



This grassland food web is made up of producers, consumers (herbivores, carnivores, and scavengers), and decomposers. Scavengers such as vultures feed on the remains of dead animals. Decomposers such as bacteria and fungi decompose dead organisms and their wastes.

O.K., now tell me how matter moves through an ecosystem.

In an ecosystem, matter cycles through both abiotic components, such as water and air, and biotic components, such as plants and animals. As matter is cycled through an ecosystem, it often changes chemically. Carbon compounds are a good example.

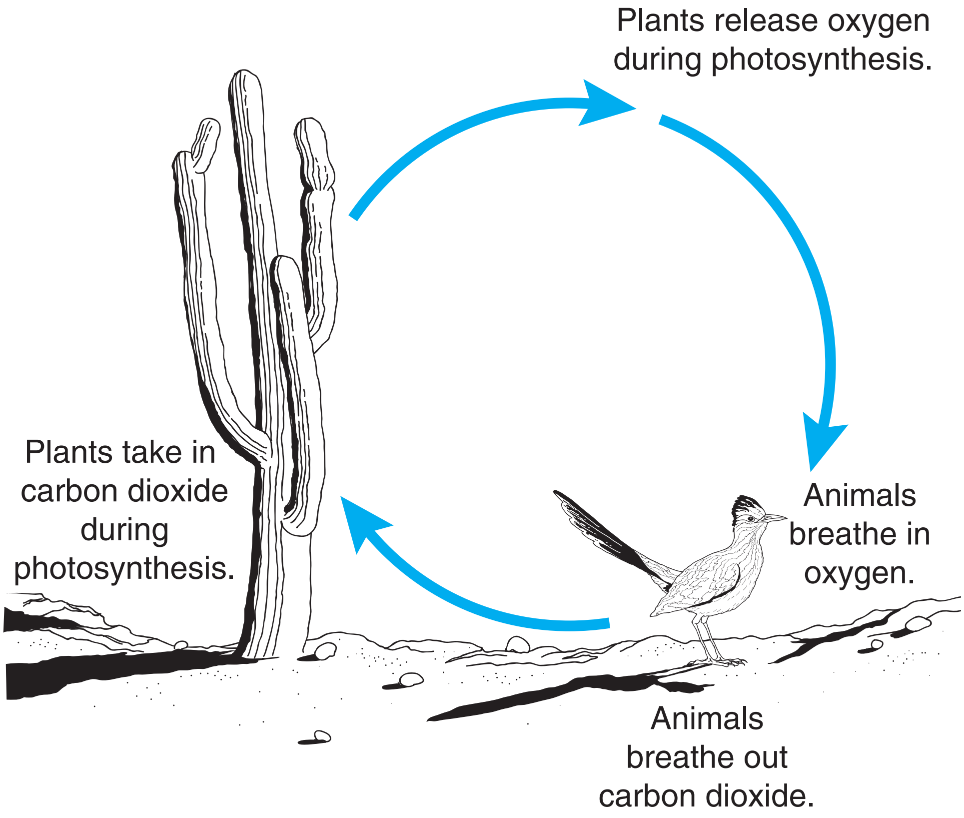
How does carbon get recycled in an ecosystem?

Carbon compounds are found in the cells of all living things. Producers use carbon dioxide from the atmosphere to make sugars and starches, which are carbon-containing molecules. Producers also make proteins and lipids—again, compounds that contain carbon. Consumers that eat plants or other organisms use these carbon compounds for new growth and for cellular respiration. Carbon dioxide is released back to the atmosphere as a waste product of cellular respiration.

Did you know?

More than 90 percent of all known chemical compounds contain carbon. About 18 percent of your body mass is composed of the element carbon.

The Carbon Dioxide–Oxygen Cycle



When an organism dies, decomposers take over. Decomposers such as fungi and certain bacteria use the carbon compounds in dead organisms for their life processes. Decomposers release carbon back into the atmosphere, usually in the form of carbon dioxide or methane. Carbon is always on the move. Think about it: every time you exhale, you are cycling carbon dioxide back to the atmosphere.

So bacteria are actually helpful? I thought they were germs!

Well, some bacteria do cause problems for people. You can blame bacteria if you've ever had a tooth cavity or suffered from acne. Bacteria are also responsible for spoiled food. And of course bacteria cause many human diseases, such as ear infections and bubonic plague. However, most bacteria are important decomposers. They recycle matter, including essential nutrients, through the biosphere. Without bacteria, life as we know it could not exist on Earth.

How many organisms live in an ecosystem?

Each ecosystem is different, and each has a different number of organisms and species. There are a variety of ways that scientists can count the organisms in an ecosystem. They can count the number of species (*biodiversity*), or they can count the number of organisms within each species (*species abundance*).

Scientists can also measure the biomass of an ecosystem.

Did you know?

Scientists have identified more than one million living species, but the majority of species have never been identified. Estimates of the total number of living species fall between 4 and 80 million.

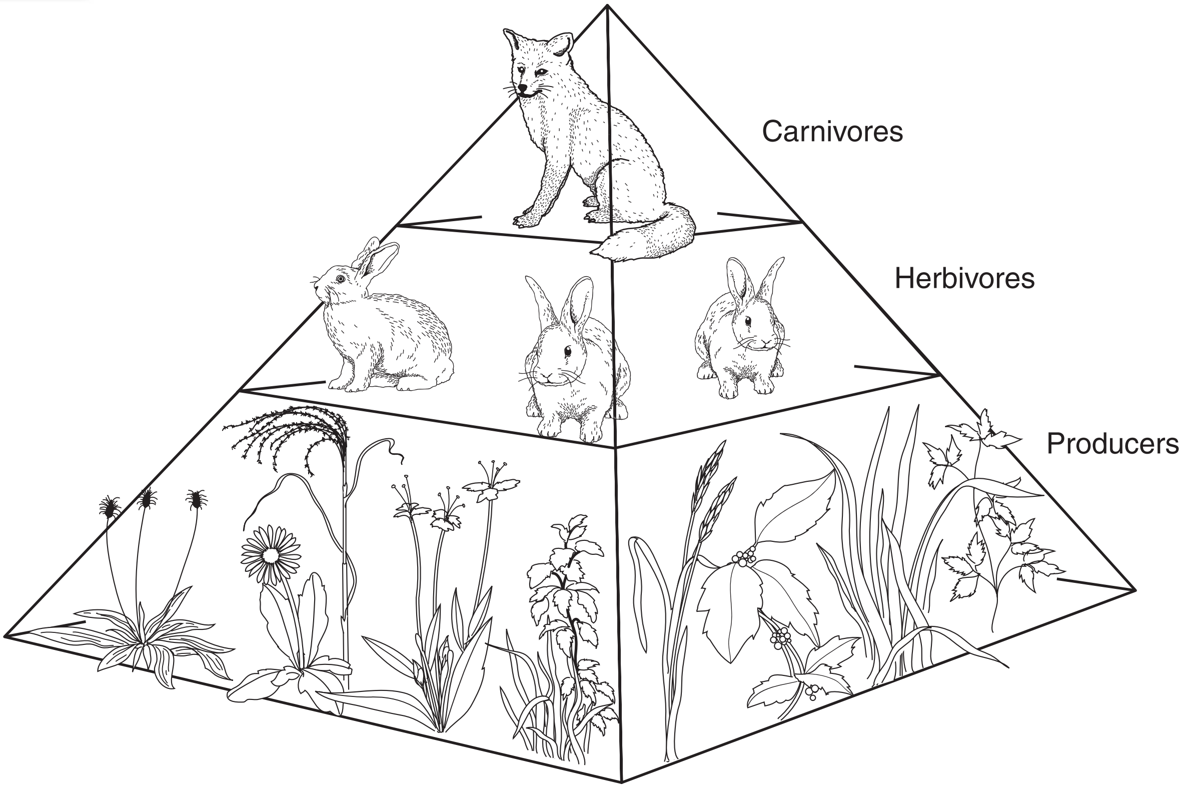
Remember!

Biomass is the total dry mass of a group of organisms living in a given area.

Wait! What's biomass?

Biomass is a measure of the total dry mass of the organisms in an ecosystem. Sometimes biomass measurements are used to determine the amount of living tissue at each trophic level in a food chain. The greatest biomass, representing the producers, is usually at the bottom of the food chain. Each level of consumers tends to have a smaller biomass than the level beneath it. For instance, the biomass of second-level consumers is often much less than that of first-level consumers. A biomass pyramid shows this relationship.

Biomass Pyramid



A biomass pyramid shows the relative dry mass of organisms at each trophic level. In most terrestrial food webs, each trophic level contains about 90 percent less mass than the one below it.

But what determines how many organisms actually live in an ecosystem?

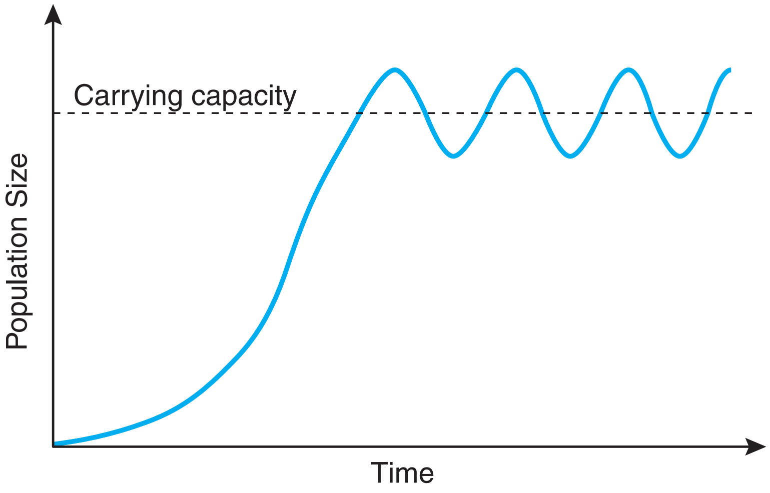
Some of the main factors are the availability of food, water, shelter, and space. Any environmental factor that prevents a population from increasing past a certain point is called a *limiting factor*.

So the number of organisms in an ecosystem is limited?

That's right. The maximum population of a species that can be supported by an ecosystem over a given period of time is called the *carrying capacity*. It's the maximum number of individuals that will have enough resources to survive. Carrying capacity varies for different species. In general, the carrying capacity of species at higher trophic levels is less than the carrying capacity of organisms at lower trophic levels. For example, there would be fewer cheetahs than impalas in an African grassland ecosystem.

No ecosystem can support an unlimited number of organisms. When a population exceeds its carrying capacity, one or more limiting factors act to bring the population back to a size the ecosystem can support.

Population Growth



At first, population growth is slow, but as the number of individuals increases, so does the rate of growth. As the population grows too large, limiting factors act to bring it back down. As more resources are available, the population grows again. The carrying capacity is the average population size that can exist in a given ecosystem.

Did you know?

As many as 30,000 acorn barnacles can live on one square meter of rocky shoreline. For acorn barnacles, space is a limiting factor.

I understand why food and water are limiting factors—but what about space?

Every organism requires a certain amount of space to survive. For example, male mountain lions have an average territory of 280 square kilometers. If food, water, and other resources are plentiful, a smaller territory may be sufficient.

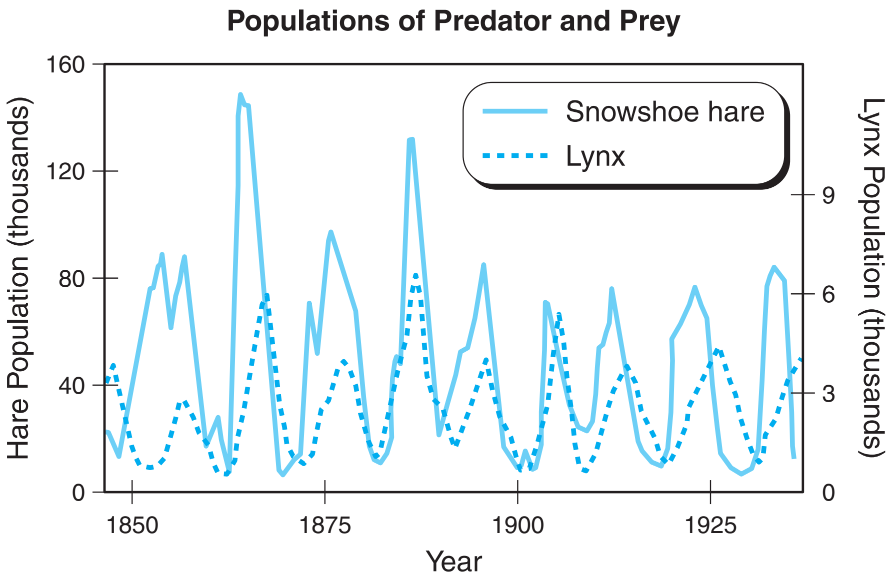
What other factors can limit population size?

Disease can limit population size. As a population approaches carrying capacity, disease is more likely to strike. This is because the individuals in the population may not be getting the nutrients, water, and space required for good health. Also, as a population increases in size and organisms become more crowded, it is easier for contagious diseases to spread.

Are there other limiting factors I should know about?

Yes. *Predation* is a limiting factor for many populations. When two populations have a predator-prey relationship, organisms of one population (predators) feed on organisms of the other population (prey). The sizes of these populations affect each other in a predictable way. When the population of predators increases, the population of prey will decrease (as more of them are eaten). The declining prey population represents a shrinking food supply for the predators. As a result, there may then be a decrease in the size of the predator population if another food source is not available.

As the number of predators declines, the prey population will likely start to increase again. The cycle may repeat if the population of predators increases in response to greater availability of food (prey organisms). Although there are natural fluctuations in the size of any population, the numbers usually stay within the carrying capacity of the ecosystem. Remember, predator-prey interactions are just one of many factors that affect the numbers and kinds of organisms in an ecosystem.



Lynx are predators of snowshoe hares. The population sizes of these two species follow cycles. It is likely that the lynx population cycle is dependent (at least in part) on the snowshoe hare population cycle.

Now It's Your Turn

After you answer the practice questions, you can check your answers to see how you did. If you chose the wrong answer to a question, carefully read the answer explanation to find out why your answer is incorrect. Then read the explanation for the correct answer.

Question 15

Plants and animals are dependent on some bacteria because these bacteria —

A help recycle simple nutrients to the soil

B get energy from fermentation rather than respiration

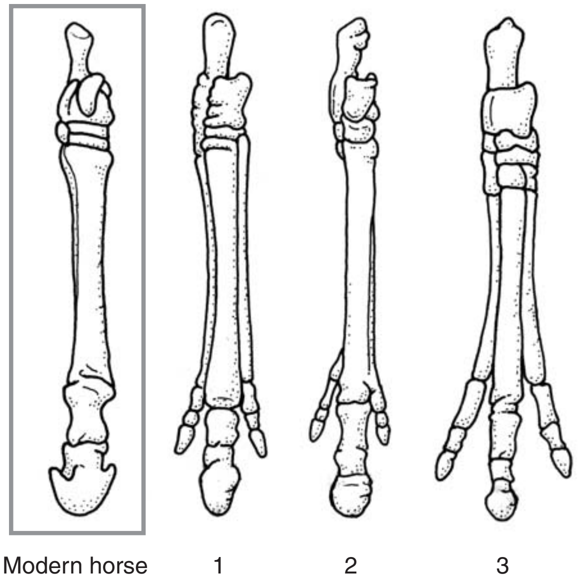
C are able to make their own food by using energy from sunlight

D are engineered to remove hazardous wastes from the environment

Answer Key: page 114

Question 16

The illustration in the box shows the bones in the hind foot of a modern horse. The other illustrations show the bones in the hind feet of three extinct species. Each of these extinct species is an ancestor of the modern horse. (The illustrations have been scaled so that all of the species seem to be the same size.)



Which lists the extinct species in order from most closely related to the modern horse to most distantly related to the modern horse?

A 1, 3, 2

B 2, 1, 3

C 2, 3, 1

D 3, 2, 1

Answer Key: page 114

Question 17

Since the 1940s, chemical insecticides have been used to control insects in an effort to limit crop damage and the spread of insect-carried diseases. Chemical control efforts fail, however, when insect pests become resistant to insecticides. The increase in the number of insecticide-resistant insect species is mainly a result of —

A natural selection

B learned behavior

C geographic isolation

D asexual reproduction

Answer Key: page 114

Question 18

Golden-cheeked warblers are an endangered species of bird that nest only in central Texas. They build their nests using bark from ash juniper trees and feed on spiders and insects. Brown-headed cowbirds sometimes lay eggs in warblers' nests. Blue jays are known to eat young birds, including the golden-cheeked warblers' offspring.

The survival of golden-cheeked warblers would be most threatened by an increase in the —

A spread of a virus fatal to blue jays

B predation of cowbirds by red-tailed hawks

C clearing of ash juniper trees for farmland

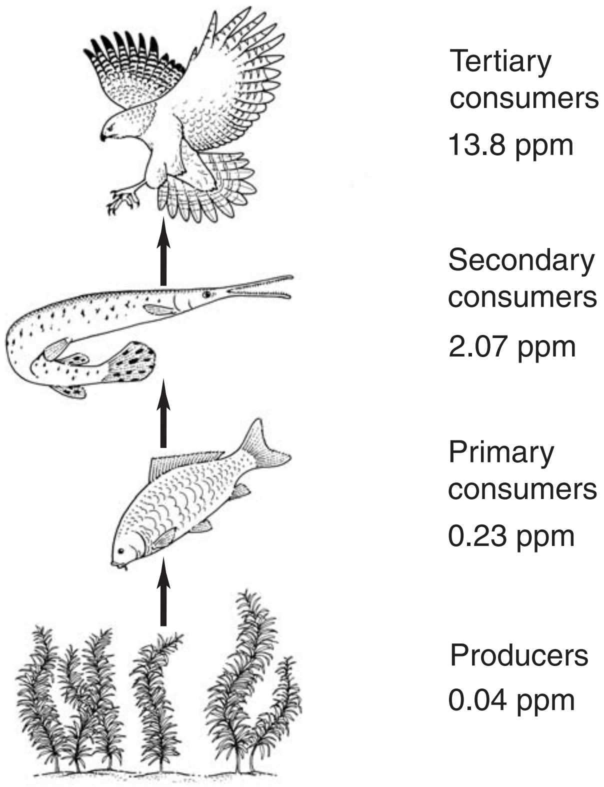
D local spider population because of mild winters

Answer Key: page 114

Question 19

DDT is a pesticide that, beginning in the 1940s, was widely used to control insect pests. The use of DDT was banned in the United States in 1971 because of the harmful effects it was having on animals other than insect pests.

Concentration of DDT in Body Tissues
(parts per million)



Which best describes the movement of DDT through the food chain shown in the diagram?

A DDT builds up in the tissues of organisms at higher trophic levels.

B The level of DDT in a population has little relation to its trophic level.

C The amount of DDT transferred follows the same pattern as the amount of energy transferred.

D DDT is passed from predator populations to the organisms on which they prey.

Answer Key: page 115

Question 20

Which population in this food chain is most likely to have the greatest biomass?

Grass → White-tailed deer → Mountain lions → Vultures

A Grass

B White-tailed deer

C Mountain lions

D Vultures

Answer Key: page 115

Question 21

An oleander is a type of evergreen shrub. The tissues of oleanders contain chemicals that are poisonous to many mammals, including humans, horses, cattle, and sheep. The production of poisonous chemicals most likely benefits oleanders by deterring or even killing many types of —

A bacteria

B herbivores

C pollinators

D scavengers

Answer Key: page 115

Objective 4

The student will demonstrate an understanding of the structures and properties of matter.

From your studies in chemistry, you should be able to demonstrate an understanding of the structures and properties of matter.

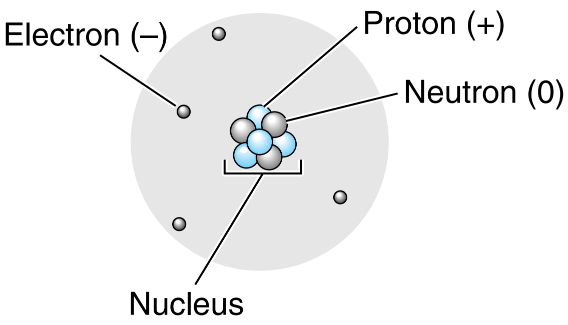
Why does matter matter?

Matter is anything that has mass and takes up space. That includes everything from this study guide, to the chair you're sitting in, to you! Scientists describe matter by describing its properties. For example, matter can be classified as an element, a compound, or a mixture. You need to understand what matter is made of and what some of its properties are.

What is matter made of?

Elements are the building blocks of matter. They cannot be broken down into simpler substances by a chemical reaction. Elements are made up of atoms.

Model of an Atom



The nucleus of an atom is made up of positively charged protons and neutral neutrons. A cloud of negatively charged electrons surrounds the nucleus of an atom.

The atoms of different elements have different numbers of protons. For example, all carbon atoms have six protons, while all chlorine atoms have 17. Ninety-two elements exist naturally on Earth, and about 20 more have been made in laboratories.

Objective 4

That's over 100 different elements! How am I supposed to keep track of all of them?

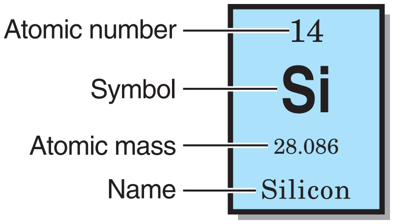
Lucky for you, scientists came up with the periodic table. The periodic table groups elements with similar properties together. That makes them much easier to deal with. Take a look at the periodic table on page 9 of this book.

What are all those numbers and letters on the periodic table?

The elements in the periodic table are arranged in order of atomic number. The *atomic number* is equal to the number of protons in the atoms of an element. The periodic table also shows the chemical symbol for each element. The *chemical symbol* is a one- or two-letter abbreviation for the element.

Did you know?

When Dmitri Mendeleev devised the periodic table in 1869, he used it to predict the properties of three elements not yet discovered. His predictions turned out to be correct.



This diagram shows an example from the periodic table.

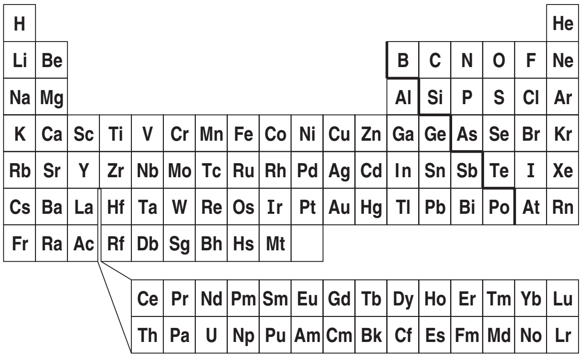
The *atomic mass* of an element is the average mass of one atom measured in atomic mass units (amu). The atomic mass of a single atom is approximately equal to its number of protons plus its number of neutrons.

How does the periodic table help me make sense of the different elements?

Each column in the periodic table is called a *group*. The elements in each group have similar properties. As a result, *metals*, *nonmetals*, and *metalloids* are clustered together in certain parts of the table.

Notice the heavy bold line on the right half of the periodic table. Metals are found on the left side of this line, and nonmetals are found on the right. Most of the elements that border the heavy bold line are metalloids. Metalloids have properties of both metals and nonmetals.

Periodic Table of the Elements



H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt									
				Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
				Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

Properties of Metals, Nonmetals, and Metalloids

Metals	Nonmetals	Metalloids
• Shiny • Malleable (can be flattened into sheets) • Ductile (can be shaped into wires) • Good conductors of heat and electricity • Most are solids at room temperature	• Mostly dull • Brittle; not malleable or ductile • Poor conductors of heat and electricity • Many are gases at room temperature	• Varying ability to conduct electricity • Can be used to make semiconductors (materials that conduct electricity only under certain conditions)

Did you know?

Metalloids such as silicon are very important to the electronics industry.

The real power of the periodic table, though, is that it can help you easily figure out how many valence electrons many elements have.

Valence electrons? What are those?

Most of chemistry is about the movement of electrons. In a chemical reaction, bonds between atoms are formed or broken. These bonds involve the transfer or sharing of electrons between atoms.

Valence electrons are the outermost electrons in the electron cloud surrounding an atom's nucleus. Different elements have different numbers of valence electrons. Because valence electrons are the farthest from the nucleus, they can move from one atom to another much more easily. For this reason, the valence electrons are the electrons that are involved in chemical bonding.

So how does the periodic table help me figure out how many valence electrons an atom has?

All the elements in some groups of the periodic table have the same number of valence electrons. There is a pattern that can be observed.

Group Number	1	2	13	14	15	16	17	18
Number of Valence Electrons	1	2	3	4	5	6	7	8

Elements in Group 1 have one valence electron, and elements in Group 2 have two valence electrons. For Groups 13 through 18, the number of valence electrons is the group number minus 10. The exception to this rule is helium (He). Helium is in Group 18. However, helium atoms have only two electrons, so they have two valence electrons, rather than eight.

Objective 4

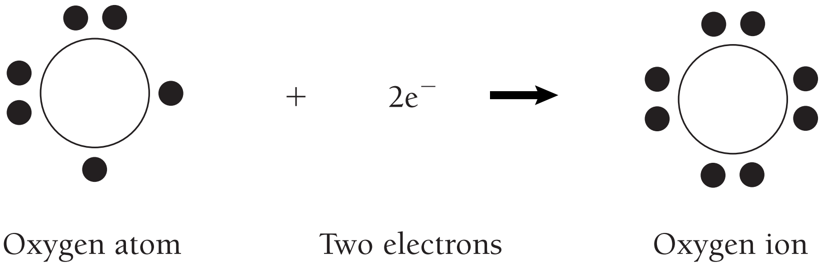
Remember!

The octet rule states that, in general, atoms in compounds have eight valence electrons.

What good does it do me to know how many valence electrons an atom has?

Knowing the number of valence electrons can help you make predictions about chemical reactions. When atoms react with one another, they tend to do so in a way that either fills up their valence shell or empties it. This ensures that their outer shell stays filled with eight electrons (this is called the octet rule). Elements in Group 17, for example, have seven valence electrons. When they react, they gain one electron to fill up their valence shell. Elements in Group 2 have two valence electrons. When they react, they lose these two electrons to empty their valence shell.

When an atom gains or loses electrons, it becomes an ion. When an atom gains an electron, it becomes a negative ion with a charge of 1−. For example, an oxygen atom gains two electrons to fill its valence shell.



8 protons (8+)
+ 8 electrons (8−)
Net charge = 0

8 protons (8+)
+ 10 electrons (10−)
Net charge = 2−

The atomic number of oxygen is 8, so a neutral oxygen atom has eight protons and eight electrons. Because oxygen is in Group 16, only six of its electrons are valence electrons. It must gain two electrons to fill its valence shell.

Objective 4

When an atom loses an electron, it becomes a positive ion with a charge of 1+. A calcium atom that empties its valence shell by losing two electrons forms a calcium ion (Ca^{2+}).

$$\bullet\mathrm{Ca}\bullet \longrightarrow \mathrm{Ca}^{2+} \quad + \quad 2e^{-}$$

Calcium atom	Calcium ion	Two electrons

$$\begin{array}{rlr} & \text{20 protons} & (20+) \\ + & \text{20 electrons} & (20-) \\ \hline & \text{Net charge} = 0 & \end{array} \qquad \begin{array}{rlr} & \text{20 protons} & (20+) \\ + & \text{18 electrons} & (18-) \\ \hline & \text{Net charge} = 2+ & \end{array}$$

The atomic number of calcium is 20, so a neutral calcium atom has 20 protons and 20 electrons. Because calcium is in Group 2, only two of its electrons are valence electrons. It must lose two electrons to empty its valence shell.

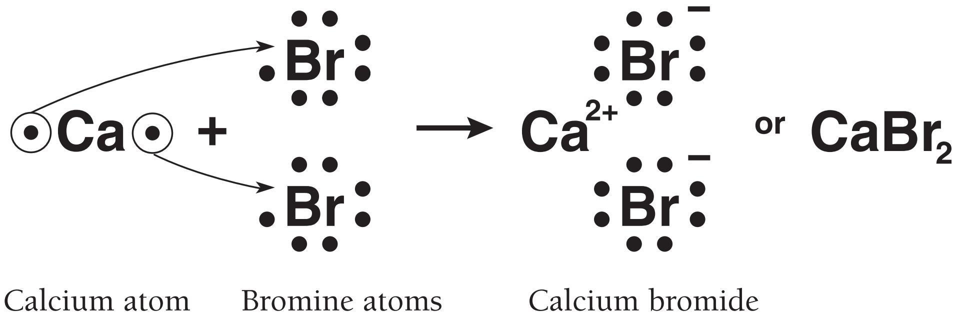
How do ions bond?

When a metal and a nonmetal react, they usually form ions. For example, when sodium reacts with chlorine, the sodium atoms give up their one valence electron to become sodium ions (Na^{+}). The chlorine atoms fill their valence shell by gaining the electrons lost by sodium, becoming chloride ions (Cl^{-}). Because the sodium and chloride ions have opposite charges, they are attracted to each other. The force of attraction that holds the ions together is called an *ionic bond*.

Ionic compounds have no net charge. In other words, the positive and negative charges on the ions always cancel out. For example, when calcium reacts with bromine, the product is calcium bromide ($CaBr_2$), which has two bromide ions for every calcium ion. The 2+ charge on the calcium ion (Ca^{2+}) balances the two 1− charges on the bromide ions (Br^{-}).

Objective 4

$Ca + Br_2 \longrightarrow CaBr_2$



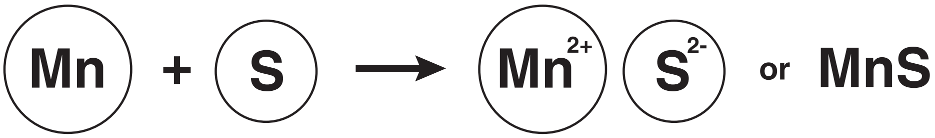
Calcium ion (2+)
Bromide ion (1−)
\+ Bromide ion (1−)
Net charge = 0

What about the metals that aren’t in Groups 1 or 2? Do they form ionic compounds, too?

Yes, they do. The metals in the middle of the periodic table, such as manganese (Mn), also react with nonmetals to form ionic compounds. However, the charge of the ions formed by these metals can vary, depending on the conditions. For example, manganese atoms can give up two electrons to form Mn^{2+}, or they can give up four electrons to form Mn^{4+}.

The name of an ionic compound containing one of these metals tells you what the charge on the metal ion is. The name of the metal is followed by a Roman numeral equal to the charge of the metal ion. For example, manganese(II) sulfide is made up of Mn^{2+} ions and S^{2-} ions. The chemical formula of this compound is MnS.

$Mn + S \rightarrow MnS$



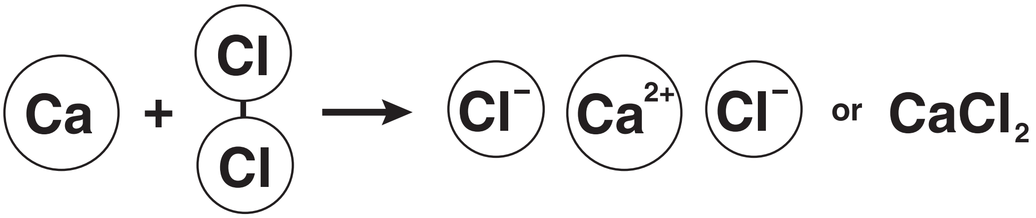
Manganese(II) ion (2+)
+ Sulfide ion (2−)

Net charge = 0

Can we try another one? What's the chemical formula of calcium chloride?

Calcium is a metal, and chlorine is a nonmetal. When these two elements combine, they will form an ionic compound. Calcium is in Group 2, so the calcium ion will have a charge of 2+. Chlorine is in Group 17, so the chloride ions will have a charge of 1−. The net ionic charge of the formula has to be zero, so there must be two Cl^- to balance one Ca^{2+}. The chemical formula of calcium chloride is therefore $CaCl_2$.

Ca	+	Cl_2	→	$CaCl_2$
Calcium		Chlorine		Calcium chloride



Calcium ion (2+)
Chloride ion (1−)
+ Chloride ion (1−)

Net charge = 0

Objective 4

Remember!

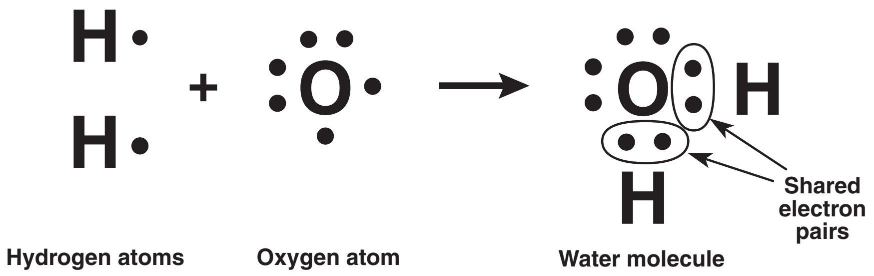
The noble gases are the elements in Group 18. Because they already have eight valence electrons (except for helium, which has only two), they are very stable and rarely participate in chemical reactions.

What's a covalent bond?

When two nonmetals react, they both need to gain electrons to fill their valence shells. To do this, they share electrons. When atoms share electrons, they form a *covalent bond*. Each covalent bond contains two shared electrons (one from each atom).

Water (H_2O) is one example of a compound that contains covalent bonds. An oxygen atom has six electrons in its valence shell, so it needs two more to fill its shell to be stable. A hydrogen atom has one electron in its valence shell. It needs one more electron in its valence shell to have the same electron structure as helium, one of the stable noble gases.

In a water molecule, the oxygen atom forms one covalent bond with each of two hydrogen atoms. As a result of these bonds, the oxygen atom has eight valence electrons, and each hydrogen atom has two.



What happens when compounds and elements react with one another?

A *chemical change* occurs. A chemical change is a change in which new substances are formed. The atoms of the original substances are rearranged to form the new substances. The new substances often have properties that are very different from those of the original substances.

For example, nitrogen gas and hydrogen gas can react to form ammonia (NH_3) under certain conditions. This reaction is a chemical change. The atoms of nitrogen gas and hydrogen gas are rearranged to form ammonia molecules. Ammonia has very different properties from either nitrogen or hydrogen. Nitrogen and hydrogen are both odorless, for instance, while ammonia has a very strong smell.

N_2 Nitrogen gas	+	$3H_2$ Hydrogen gas	→	$2NH_3$ Ammonia

How can I spot a chemical change?

One sign of a chemical change (or chemical reaction) is a change in temperature. Some chemical changes produce heat; others absorb heat from their surroundings. When firewood burns, for instance, you can feel the heat produced by the chemical change.

Remember!

An exothermic reaction is one that produces heat.

An endothermic reaction is one that absorbs heat.

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The heat and light given off by exploding fireworks are signs of a chemical change.

Another sign of a chemical change is a change in color. When an iron nail rusts, the color changes from gray to reddish brown. The iron has reacted with oxygen and water in a chemical change to produce rust.

The production of a gas or a precipitate also signals a chemical reaction. For example, a precipitate forms when calcium nitrate, $Ca(NO_3)_2$, mixes with sodium carbonate, Na_2CO_3, in water. The precipitate, calcium carbonate, $CaCO_3$, is a new substance formed from a chemical change. Calcium carbonate is one of the compounds that cause calcium buildup on shower walls and faucets.

Remember!

A precipitate is a solid that settles out of a solution as a result of a chemical reaction.

Objective 4

It is important to remember that if you observe only one of these signs, a chemical reaction may not necessarily have taken place. For example, when you stir a packet of grape drink mix into a pitcher of water, the solution turns purple. However, no chemical change is occurring as the drink mix dissolves, because no new substances are formed.

To be sure you're seeing a chemical change, look for more than one sign. For example, a chemical change takes place when iodine comes into contact with starch. Not only is there a color change (the appearance of dark blue), but the mixture also gives off heat. Both of these signs indicate that a chemical change has taken place. Remember, however, that the only sure sign of a chemical change is the production of a new substance.

Can you help me with chemical equations?

No problem! A chemical equation is a shorthand way of writing down what happens during a chemical reaction. For example, a chemical equation can be used to describe the reaction of potassium with chlorine gas.

$$\underbrace{K + Cl_2}_{\text{Reactants}} \rightarrow \underbrace{KCl}_{\text{Product}} \quad \text{(unbalanced)}$$

A chemical equation contains a lot of information. Let's go through it part by part.

The equation shows one atom of potassium reacting with one molecule of chlorine gas to form one formula unit of the ionic compound potassium chloride. The left side of the equation shows what you started with (the *reactants*). In this example, the reactants are potassium (K) and chlorine gas (Cl_2). The right side of the equation shows what you ended up with (the *products*). In this example, the product is potassium chloride (KCl).

Remember!

The subscript numbers in a chemical formula tell you how many atoms of an element are in one molecule or formula unit. One molecule of chlorine gas (Cl_2) contains two atoms of chlorine (Cl).

This chemical equation, however, isn't quite finished. To complete the equation, we need to balance it.

Balance it? How do we do that?

When we balance an equation, we make sure that the left side of the equation has the same number and types of atoms as the right side of the equation. We need to balance the equation to show that it follows the *law of conservation of mass*.

The law of what?

The law of conservation of mass. This scientific law states that matter cannot be created or destroyed in a chemical reaction. All the atoms of the reactants of a chemical reaction are still present in the products; they've just been rearranged. In other words, what goes into the reaction must come out of the reaction. We need to balance the equation to show this.

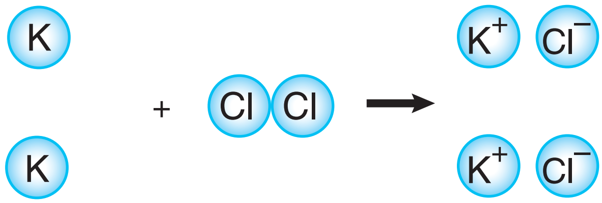
So how exactly do we do that?

First let's look at chlorine. The left side of the equation has two atoms of chlorine, but the right side has one atom of chlorine. That means that we'll have to add a coefficient of "2" in front of the "KCl". The symbol "2KCl" means "two formula units of potassium chloride," which indicates two atoms of chlorine. Now the chlorine is the same on both sides.

$$\mathrm{K} + \underset{\substack{\uparrow \\ \text{subscript}}}{\mathrm{Cl}_2} \longrightarrow \underset{\substack{\uparrow \\ \text{coefficient}}}{2}\mathrm{KCl} \quad \text{(unbalanced)}$$

Next look at potassium. The left side of the equation has one atom of potassium, but the right side now has two atoms of potassium. To get two potassium atoms on the left side, we'll have to add a "2" in front of the "K". The symbol "2K" means "two atoms of potassium." Now the potassium is the same on both sides.

$$2\mathrm{K} + \mathrm{Cl}_2 \longrightarrow 2\mathrm{KCl} \quad \text{(balanced)}$$



Recheck to make sure everything follows the law now. The left side of the equation has two potassium atoms and two chlorine atoms. So does the right side. Everything balances.

Remember!

Suppose you had two molecules of chlorine gas, $2\mathrm{Cl}_2$. Multiply the coefficient $\textcircled{2}\mathrm{Cl}_2$ by the subscript $2\mathrm{Cl}_{\textcircled{2}}$ to get the total number of atoms ($2 \times 2 = 4$ Cl atoms).

Objective 4

Remember!

A solution of two metals is an alloy. Bronze, for example, is an alloy of tin dissolved in copper. An alloy is a mixture that has metallic properties and contains at least one metallic element.

Does a chemical reaction take place when one substance dissolves in another?

No, dissolving is a physical change because no new substances are formed. When one substance dissolves in another, the resulting mixture is called a *solution*. A solution has two parts: the solute and the solvent. The *solute* is the substance that dissolves, and the *solvent* is the substance that the solute dissolves in. The solute breaks up into tiny particles that spread evenly throughout the solvent. In a solution of sugar water, sugar is the solute, and water is the solvent.

Are all solutions liquids?

No! Many types of solutions are possible. Here are a few examples.

Examples of Solutions

Solute	Solvent	Example
Gas	Gas	Air (oxygen and other gases dissolved in nitrogen)
Gas	Liquid	Soda water (carbon dioxide dissolved in water)
Liquid	Liquid	Rubbing alcohol (water dissolved in isopropyl alcohol)
Solid	Liquid	Sugar water (sugar dissolved in water)
Solid	Solid	Bronze (tin dissolved in copper)

How much solute can dissolve in a solvent?

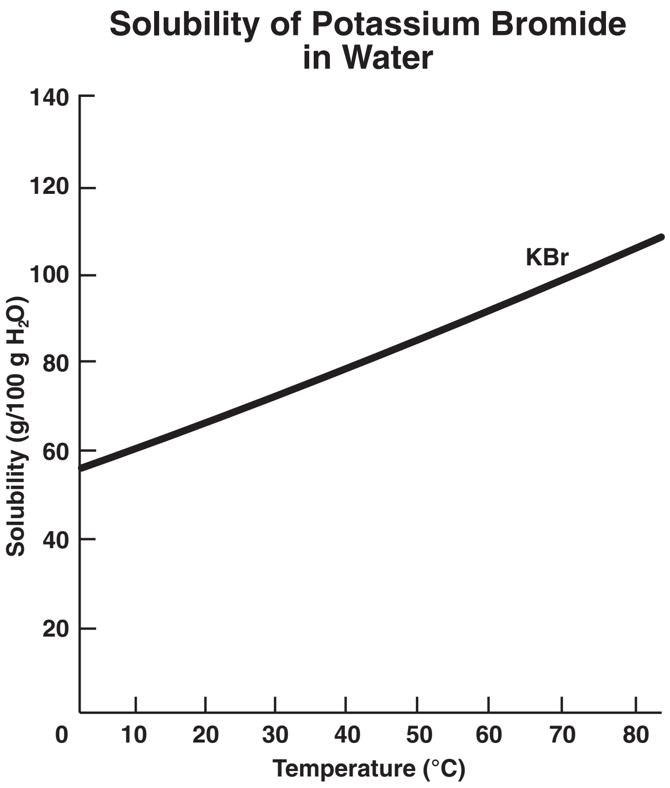
That depends on the solubility of the solute. *Solubility* is how much solute you can dissolve before the solution becomes saturated. A *saturated solution* is one that cannot dissolve any more solute. For example, at 0°C the solubility of table salt in water is 35.7 grams of salt per 100 grams of water. If you added 37 grams of salt to 100 grams of water at 0°C, only 35.7 grams of the salt would dissolve. The rest of the salt would settle to the bottom of the container. Several factors can affect the solubility of a solute, such as temperature and pressure.

How does temperature affect solubility?

When solids dissolve in liquids, solubility usually increases as the temperature of the solution increases. For example, more sugar will dissolve in hot water than in cold water. At higher temperatures, the solute and solvent molecules have more kinetic energy, and the solute molecules are more likely to move throughout the solvent. For this reason, more of the solute can dissolve. (See Example 1 on page 67.)

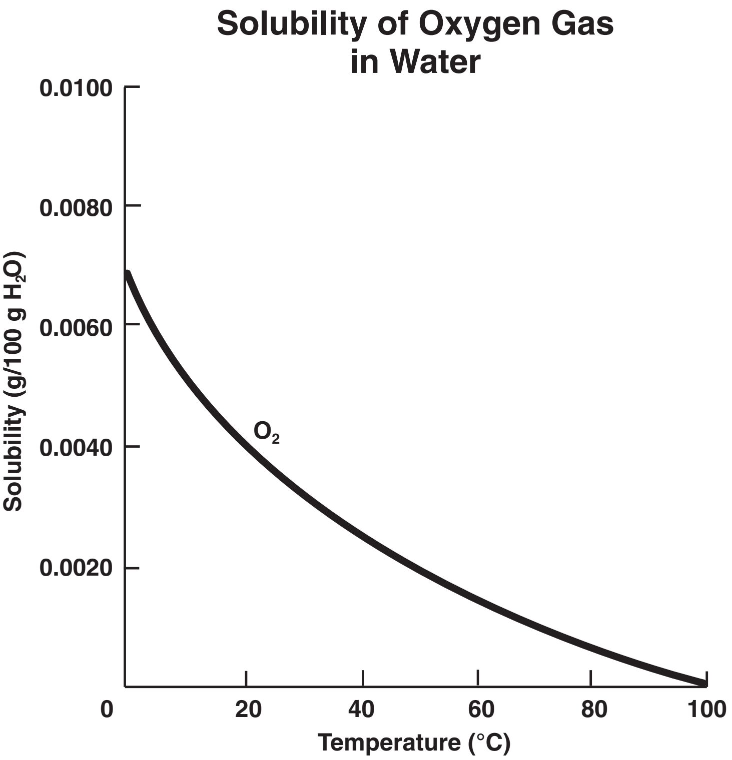
However, temperature has the opposite effect on the solubility of gases in liquids. Gases dissolve better at lower temperatures. If you think about it, this makes sense—as the temperature increases, more of the gas molecules have enough energy to leave the solution. The dissolved gases come out of solution and form bubbles that rise to the surface. (See Example 2 on page 67.) If you've ever opened a warm can of soda, you may have noticed that it fizzed more than a cold soda. This is because warm soda can hold less dissolved carbon dioxide than cold soda. The carbon dioxide leaves the warm soda in the form of fizzing bubbles.

Example 1



The solubility of potassium bromide, a solid ionic compound, increases as the temperature of the water increases.

Example 2



The solubility of oxygen gas decreases as the temperature of the water increases.

When an industrial plant pumps warm wastewater into a lake, the temperature of the lake rises. This type of temperature change is known as thermal pollution. Thermal pollution causes the solubility of gases in the lake to decrease. A decrease in the lake's oxygen level can negatively affect organisms that live there.

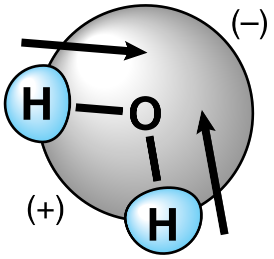
What about the effect of pressure on solubility?

Pressure also affects the solubility of gases in liquids. As the pressure on the gas above the solution increases, more of the gas will dissolve in the solvent. For example, the high pressure in a bottle of soda keeps carbon dioxide gas dissolved in the liquid. Once the bottle is open, the pressure on the soda decreases. Bubbles of carbon dioxide begin to come out of solution and rise to the surface. That's why soda eventually goes flat once you open the bottle. Flat soda contains very little dissolved carbon dioxide.

I know that water is polar. What does that mean?

In a water molecule, the oxygen atom tends to pull the shared electrons away from the hydrogen atoms. So the oxygen end of a water molecule has a partial negative charge, and the hydrogen end has a partial positive charge. Molecules with a slightly negative end and a slightly positive end are called *polar molecules*.

Water Molecule



The unequal sharing of electrons in a water molecule gives the molecule a slightly negative end and a slightly positive end.

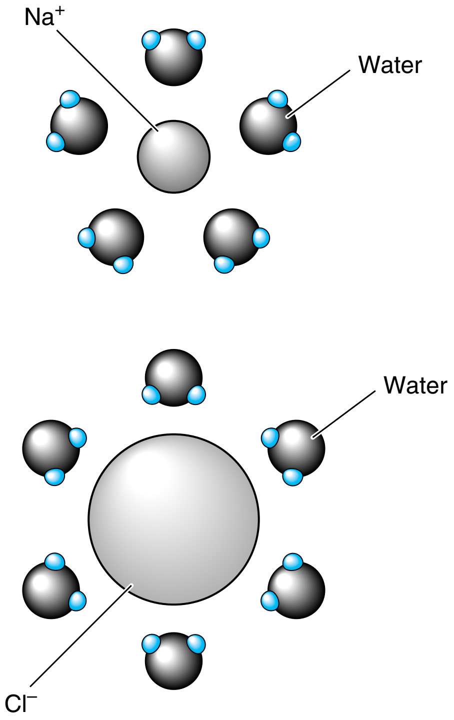
Objective 4

Does the fact that water is polar affect the way it acts in solutions?

Yes, because water is polar, it tends to dissolve other polar compounds. For example, many ionic compounds dissolve in water. When ionic compounds dissolve, they break up into positive and negative ions.

The negative end of water molecules is attracted to the positive ions, and the positive end of water molecules is attracted to negative ions. Each solute ion becomes surrounded by a "shell" of water molecules. This helps keep the solute ions in solution.

Sodium Chloride Dissolved in Water



When sodium chloride (NaCl) dissolves in water, it breaks up into sodium ions (Na^+) and chloride ions (Cl^-). The negative end of water molecules is attracted to sodium ions, and the positive end of water molecules is attracted to chloride ions.

What are some properties of water?

Because water molecules are polar, they have a tendency to stick to other polar substances. This property is called *adhesion*. For example, glass may carry a partial charge along its surface. That's why rain droplets stick to windows.

Cohesion is another property of water. *Cohesion* is the tendency of water molecules to stick together. It is caused by the attraction of the positive end of one water molecule for the negative end of another.

To see cohesion in action, gently lay a paper clip on top of a glass of water. As long as you don't break the surface, the paper clip will remain on top of the water. The attraction of the water molecules to one another is strong enough to keep the paper clip from sinking.

Objective 4

A third property of water is viscosity. *Viscosity* is the resistance of a liquid to flow. Water is less viscous than honey, for example, because water flows more easily.

Two factors that help determine a liquid's viscosity are its cohesiveness and the size of its molecules. The tendency of water molecules to stick together—water's cohesiveness—makes water more viscous than it would be if it were composed of nonpolar molecules. One reason that water is less viscous than honey, however, is that the molecules in honey are much larger than water molecules and flow past one another less easily.

The polar nature of water also causes ice to float. To understand why, you first have to understand density and buoyancy.

O.K., what is density?

Density is a measure of a substance's mass per unit of volume. A dense object has much more mass in a given space than an object that isn't very dense.

You can calculate an object's density by dividing its mass by its volume.

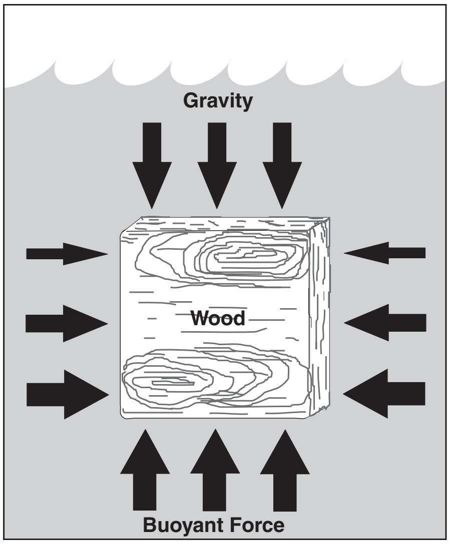
$$\text{Density} = \frac{\text{mass}}{\text{volume}} \qquad D = \frac{m}{v}$$

Suppose you have two identical balloons. You fill one with air and one with water. The water-filled balloon will be much heavier than the air-filled balloon, even though they're the same size. That's because water has a much greater density than air.

And what about buoyancy? What's that?

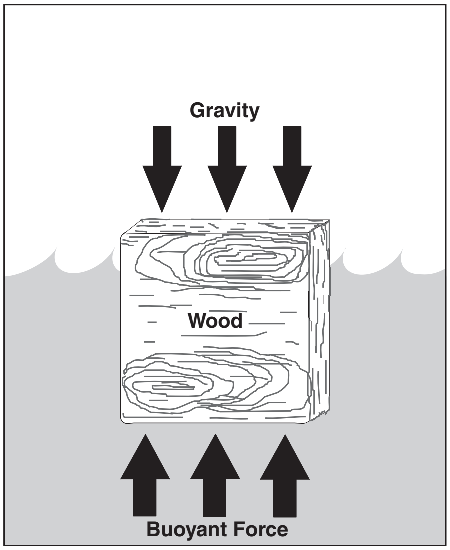
When an object is submerged in water, the water exerts a force on all sides of the object. This force increases with depth, so the force at the top of the object is lower than the force at the bottom of the object. This means that the overall direction of the force is upward. This upward force is called the *buoyant force*.

Before



The force at the bottom of a submerged object is greater than the force at the top. The net force—the buoyant force—is upward.

After



When wood floats, the buoyant force on the wood is greater than the force of gravity on the wood.

When the buoyant force pushing up on the object is greater than the force of gravity pulling down on the object, the object rises to the surface. If the buoyant force is less than the force of gravity, the object sinks to the bottom.

Remember!

The force of gravity on an object is equal to the object's weight.

Remember!

Vegetable oil is insoluble in water, so the two liquids do not form a solution.

How do we know which is greater, the force of gravity or the buoyant force?

We can determine which force is greater by comparing the density of the object to the density of water. If the density of the object is greater than the density of water, the force of gravity on the object will be greater than the buoyant force, and the object will sink.

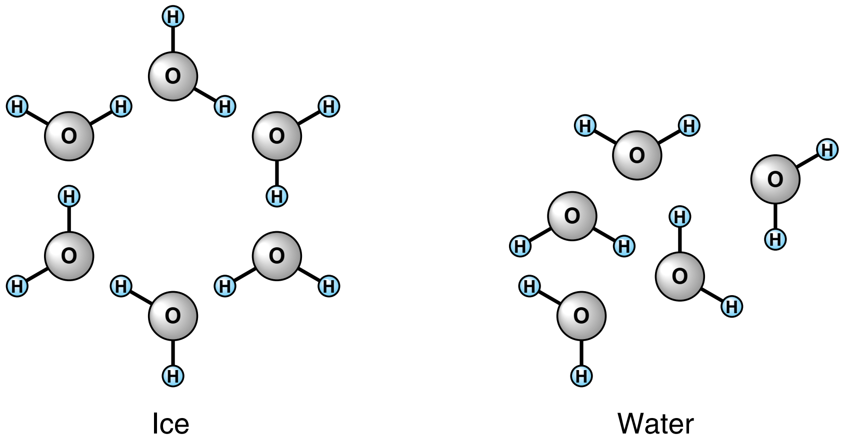
If the density of the object is less than the density of water, the force of gravity on the object will be less than the buoyant force, and the object will float. For example, vegetable oil with a density of 0.93 g/cm^3 will float on water, which has a density of 1.0 g/cm^3.

Now tell me, why does ice float in water? Shouldn't the solid form of water be more dense than the liquid form of water?

When most substances freeze, the molecules making up the substance get closer together. That means that the density of the solid form is greater than the density of the liquid form. For example, solid aluminum is more dense than liquid aluminum, so solid aluminum does not float on liquid aluminum.

But water is different. When water freezes, the partial charges line up, positive to negative, forming a crystalline structure. This pattern causes the molecules to spread slightly apart. This means that ice is less dense than water. Therefore, it floats.

Structure of Ice and Water



Ice has a more orderly arrangement of molecules than liquid water does. This orderly arrangement, or crystalline structure, keeps the molecules in ice from packing as closely together as the molecules in liquid water.

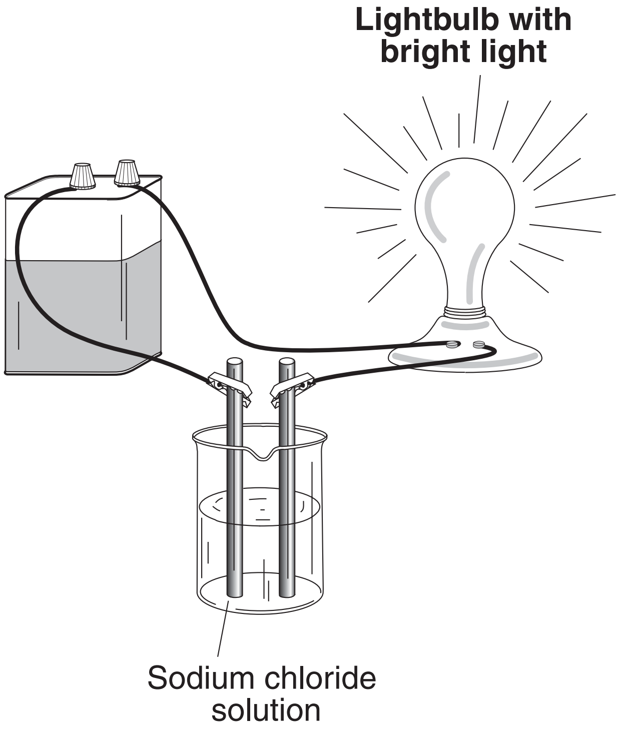
Because ice is less dense than water, lakes begin to freeze from the top down. The layer of ice that forms on a surface of a lake helps shield the water underneath from cold air temperatures. This tends to keep lakes from freezing solid and killing the organisms that live there.

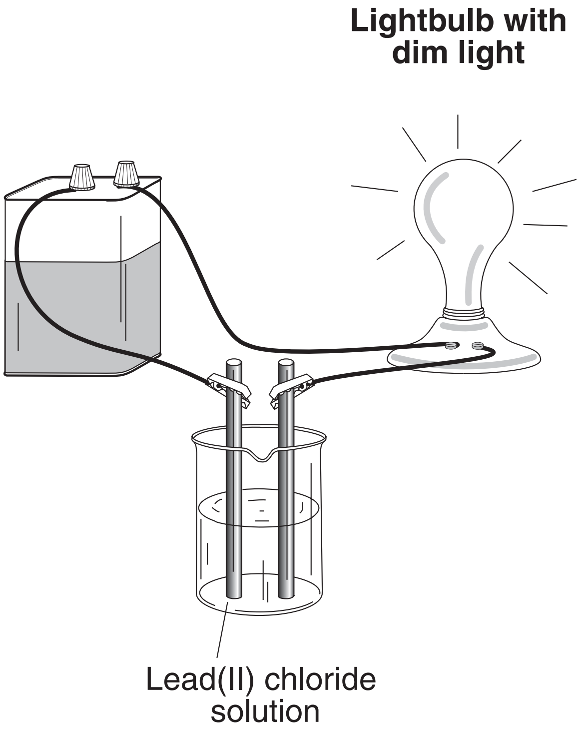
I've heard that water conducts electricity. Is this true?

You might be surprised to learn that pure water doesn't conduct electricity! However, most water isn't pure. Lake water, ocean water, rainwater, and even tap water all contain dissolved substances, including ions such as Ca^{2+}, Mg^{2+}, Na^{+}, and Cl^{-}. Water that contains dissolved ions can conduct electricity.

Substances that can conduct an electric current when they are dissolved in water are called *electrolytes*. Sodium chloride (NaCl) is an electrolyte because it separates into sodium ions (Na^{+}) and chloride ions (Cl^{-}) in solution.

The concentration of ions in a water solution determines how much electric current the solution can conduct. Usually, the higher the concentration of ions, the more current the solution can carry.





Sodium chloride (NaCl) is very soluble in water, so the concentration of ions in the NaCl solution is high. Because the NaCl solution is a strong conductor of electricity, the lightbulb shines brightly. Lead(II) chloride ($PbCl_2$) is only slightly soluble in water, so the concentration of ions in the $PbCl_2$ solution is low. Because the $PbCl_2$ solution is a weak conductor of electricity, the lightbulb is not very bright.

Objective 4

Doesn’t pH have something to do with the concentration of ions?

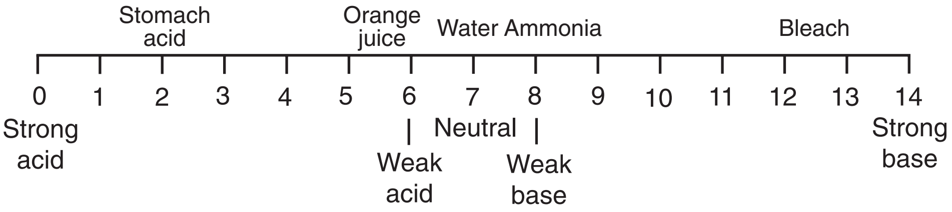
Yes! Specifically, pH is a measure of the concentration of hydrogen ions in a solution. The pH scale goes from 0 to 14. A solution with a low pH is acidic, which means that it has a high concentration of hydrogen ions (H^+). A solution with a high pH is basic, which means that it has a low concentration of hydrogen ions and a high concentration of hydroxide ions (OH^-). A solution with a pH of 7 is said to be neutral; it is neither acidic nor basic. Pure water has a pH of 7.

Suppose you had a solution of hydrochloric acid (HCl), which is a strong acid. What would happen if you added a small amount of a solution of sodium hydroxide (NaOH), a strong base? The hydroxide ions (OH^-) from the base would react with some of the hydrogen ions (H^+) from the acid to form water.

$$OH^- + H^+ \longrightarrow H_2O$$

The overall concentration of hydrogen ions would decrease as a result of this reaction. The solution would become less acidic, and the pH would increase.

pH Scale



Now It's Your Turn

After you answer the practice questions, you can check your answers to see how you did. If you chose the wrong answer to a question, carefully read the answer explanation to find out why your answer is incorrect. Then read the explanation for the correct answer.

Question 22

Two steel plates can be joined by a process called arc welding. In this process, tiny droplets of molten metal are deposited on the joint between the plates. The droplets then cool and harden, joining the plates together.

Many metals will react with oxygen when they are exposed to the high temperatures of arc welding. Therefore, the droplets of molten metal are often shielded from oxygen in the surrounding air by a layer of argon gas.

Why would argon gas be a more suitable shield for arc welding than hydrogen gas?

A Unlike hydrogen, argon is a nonmetal.

B Unlike hydrogen, argon is an inert gas.

C Argon has a larger atomic radius than hydrogen does.

D Argon has a greater atomic mass than hydrogen does.

Answer Key: page 115

Question 23

Which best explains why sodium is more reactive than magnesium?

A Sodium has only one valence electron, while magnesium has two.

B Sodium atoms typically have one more neutron than magnesium atoms do.

C Sodium forms ions with a charge of 2+, but magnesium forms ions with a charge of 1+.

D Sodium atoms tend to attract the electrons of other atoms more than magnesium atoms do.

Answer Key: page 115

Question 24

Hydrogen and nitrogen gas react in a sealed container kept at a constant temperature. The pressure in the container is less at the end of the reaction than at the beginning.

$$\underset{\text{Hydrogen}}{3H_2(g)} \quad + \quad \underset{\text{Nitrogen}}{N_2(g)} \quad \longrightarrow \quad \underset{\text{Ammonia}}{2NH_3(g)}$$

Which is the most likely reason that the pressure in the container decreased?

A There are fewer atoms at the end of the reaction than at the beginning.

B There are fewer molecules at the end of the reaction than at the beginning.

C The mass of the reactants is less than the mass of the products in the reaction.

D The volume of the reactants is less than the volume of the products in the reaction.

Answer Key: page 116

Question 25

What is one way to distinguish a solution of salt (NaCl) and water from a solution of sugar ($C_6H_{12}O_6$) and water without tasting them?

A The salt can be recovered by evaporating the water, but the sugar cannot.

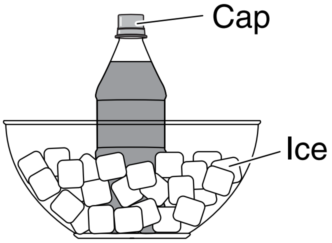
B The salt solution will conduct electric current, but the sugar solution will not.

C The sugar can be separated from the water by filtration, but the salt cannot.

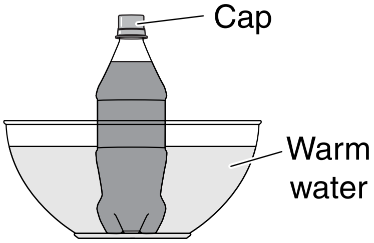
D A beam of light passing through the sugar solution will be visible, but a beam of light passing through the salt solution will not.

Answer Key: page 116

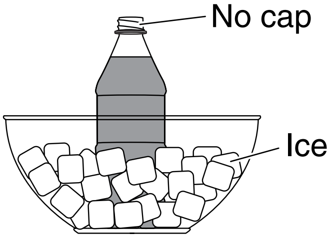
Question 26



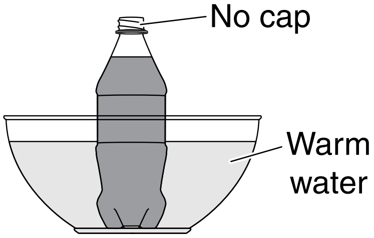
Bottle 1



Bottle 2



Bottle 3



Bottle 4

If each of these bottles of carbonated water initially contained the same amount of dissolved carbon dioxide, which bottle will contain the least amount of dissolved carbon dioxide after 15 minutes?

A Bottle 1

B Bottle 2

C Bottle 3

D Bottle 4

Answer Key: page 116

Question 27

Scuba divers are exposed to greater pressure the deeper they dive. Which is most likely to occur as a result of this increased pressure?

A Glucose will become much more soluble in divers' cells.

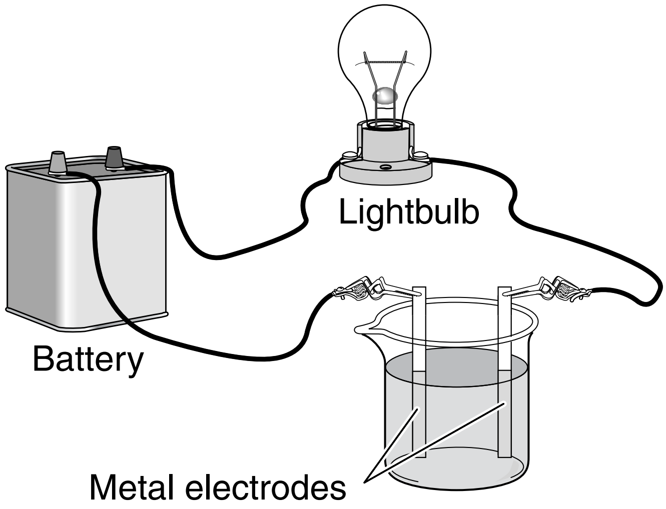
B A high level of nitrogen gas will dissolve in divers' bloodstream.

C Small bubbles of carbon dioxide will form in divers' bloodstream.

D The amount of oxygen dissolved in divers' cells will sharply decrease.

Answer Key: page 116

Question 28



When added to the beaker, which liquid would cause the lightbulb to glow the brightest?

A A concentrated solution of water and table sugar

B A concentrated solution of water and nitrogen gas

C A dilute solution of water and ammonia

D A dilute solution of water and sulfuric acid

Answer Key: page 117

Objective 5

The student will demonstrate an understanding of motion, forces, and energy.

From your studies in physics, you should be able to demonstrate an understanding of motion, forces, and energy.

What's so important about motion, forces, and energy?

Look around you. What do you see that's moving? Leaves fall from trees; cars move along roads; your hands turn the pages of this book. Physicists use the ideas of force and energy to describe motions in the world around us, from the vibrations of tiny atoms to the orbiting of planets in our solar system.

How are motion and forces related?

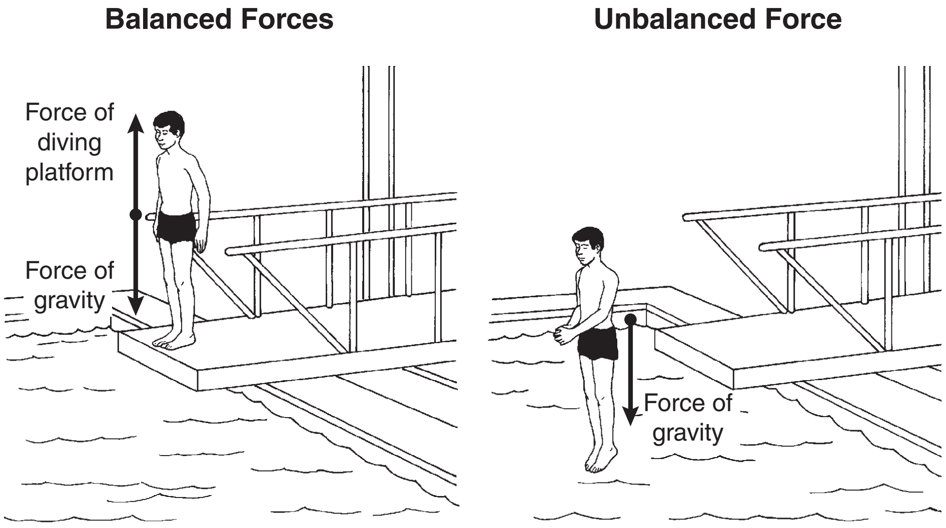
All motion is caused by forces. We can use our knowledge of forces to explain why things move and to predict how they will move. For example, a highway designer needs to understand how forces work on a moving car in order to create safe roads for drivers.

There are often many different forces acting on an object. For instance, when you stand on a diving platform, gravity pulls you down toward the pool, but the diving platform holds you up. These two forces balance each other. As a result, you stay put.

If you step off the end of the diving platform, however, the force of the platform is no longer there to balance the force of gravity. The unbalanced force of gravity causes you to fall into the water.

Remember!

The overall force on an object is called the net force. An object will move when the net force acting on it is greater than zero.



When the forces on the diver are balanced, the diver doesn't move. When the force is unbalanced, the diver falls.

Didn’t Isaac Newton have something to do with explaining forces and motion?

Yes. Isaac Newton proposed the laws of motion in the seventeenth century. They were based on his observations of the world around him. Newton’s laws describe how forces and motion are related.

Newton’s Laws of Motion

- First law: Any object in motion will stay in motion, and any object at rest will stay at rest, until it is acted on by an unbalanced force. Newton’s first law is also referred to as the law of inertia.
- Second law: The net force on an object equals the object’s mass multiplied by its acceleration (Force = mass × acceleration).
- Third law: When one object exerts a force on a second object, the second object exerts an equal but opposite force on the first object.

These laws sound a bit complicated at first, but they make sense when you think about them carefully.

Remember!

Acceleration is the rate at which velocity changes. Changing direction and slowing down are examples of acceleration.

If I kick a soccer ball along the ground, the ball eventually stops. But Newton's first law says that a moving object should keep moving. How does that make sense?

A soccer ball rolling across the ground does eventually stop. But it doesn't break Newton's first law. To find out why, look more closely at the law. It states that a moving object will keep moving unless there is an unbalanced force on it. There must be a force acting on the soccer ball that causes it to slow down and stop.

What is that force?

It's friction! *Friction* is an unbalanced force that changes the ball's motion. If there were no friction between the ball and the ground, the ball would keep rolling on, and on, and on . . .

The second law is really just an equation. What's so important about that?

Newton's second law ($F = ma$) is a powerful tool for making predictions about motion. For example, if you know how big a force is and what size mass it acts on, you can predict how fast an object will accelerate.

How can I understand the second law without using math?

It's easy! First, let's look at force and acceleration. According to Newton's second law, a greater force produces a greater acceleration. For example, if you kick a soccer ball as hard as you can, it will accelerate more than if you just tap it lightly. The greater the force you exert, the greater the ball's acceleration. That makes sense, right?

We can also think about mass and acceleration. The greater the mass, the less the acceleration will be under the same force. If you use the same force to kick a soccer ball that you use to kick a bowling ball (ouch!), which rolls a shorter distance? The bowling ball, of course! It accelerates less because it has more mass than the soccer ball.

Did you know?

The average human head weighs about nine pounds, the same weight as an average bowling ball.

Could you explain the third law too?

Sure! Newton's third law states that all forces come in pairs. Have you ever hit a baseball? When the bat hit the baseball, the bat exerted a force on the ball, causing it to change direction. But the ball also exerted a force on the bat. You probably felt this force as a vibration in the bat's handle. The bat's force on the baseball was exactly the same size as the baseball's force on the bat, but the two forces acted in opposite directions.

Remember!

An object's momentum is equal to its mass multiplied by its velocity. Velocity is an object's speed in a particular direction, so a greater speed means a greater velocity, which means more momentum.

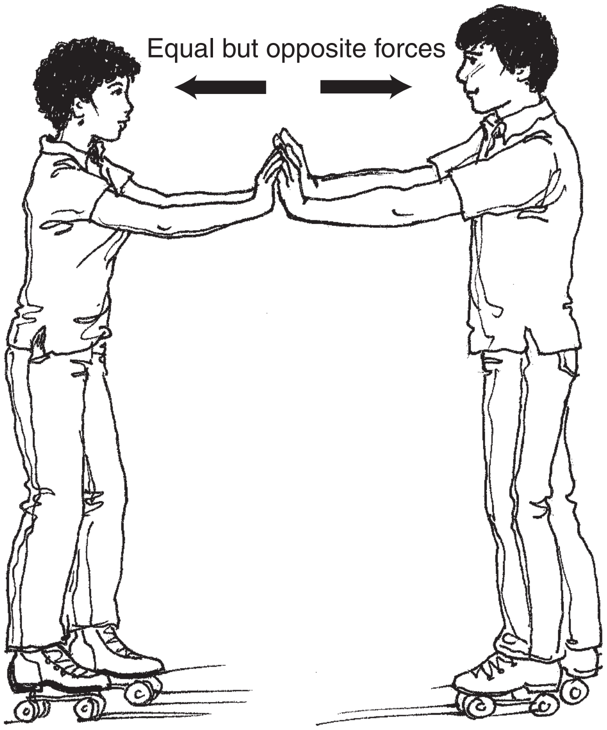
Does the speed of the ball affect the size of these forces?

Yes, it does. The faster the ball is moving, the greater the force it exerts on the bat. A faster ball exerts a greater force because it has more momentum than a slower ball. And because a ball with more momentum exerts a greater force on the bat, the bat will also exert a greater force on the ball, and the batter will be more likely to hit a home run.

Do these pairs of equal and opposite forces cancel out?

No! You might think that since the forces are equal and opposite, they would cancel each other out, but they don't. This is because they are acting on different objects. In order to cancel each other, two opposite forces must act on the same object.

For example, suppose that you and I are wearing roller skates and facing each other. If I push on you, you will push back on me with an equal but opposite force even if you aren't aware of it. My force on you will cause you to move backward, and your force on me will cause me to move backward. Even though the forces are equal but opposite, they do not cancel out because one acts on me and one acts on you.



When one skater pushes on the other, the second skater pushes back with an equal but opposite force. There is a net force on each skater, and each rolls backward.

Are there any other equations I need to know?

Many ideas in physics, such as Newton's second law, can be written as equations, or formulas. You can use these formulas to solve problems and make predictions. Take a look at the formula chart on page 8. To use a formula, you need to know what each variable represents. The words on the left side of the formula chart tell you this. For example, look at the formula.

$$P = \frac{W}{t}$$

The left side of the chart shows that this is the formula for power. P represents power, W represents work, and t represents time.

After the formulas there is a table called "Constants/Conversions." What is this?

This table gives you extra information you might need in order to solve problems. Constants are values for things that don't change. For example, the speed of light (c) and acceleration due to gravity (g) are constants.

A conversion tells you how to change from one unit to another. The table shows some common conversions. For instance, the table shows that 1 newton (N) is equal to 1 kgm/s^2. You can use this conversion to change a problem's answer from 8 kgm/s^2 to 8 N.

Can you show me how to use the formula chart to solve a problem?

Of course! Here's a problem: A roller coaster has a velocity of 3 m/s and an acceleration of 15 m/s^2. How many seconds will it take the roller coaster to reach its maximum velocity of 27 m/s?

First let's list what we know and what we want to find out.
We know:

The current (or initial) velocity: 3 m/s, v_i

The acceleration: 15 m/s^2, a

The maximum (or final) velocity: 27 m/s, v_f

We want to find out how much time it will take the roller coaster to accelerate from 3 m/s to 27 m/s.

Objective 5

Look at the formula chart on page 8 to see which formula includes velocity, acceleration, and time.

The acceleration formula has all three of these variables. Can we use that one?

Yes, we can!

$$\text{Acceleration} = \frac{\text{final velocity} - \text{initial velocity}}{\text{change in time}} \qquad a = \frac{v_f - v_i}{\Delta t}$$

Remember!

The symbol Δ means "change in," so Δt means "change in time."

We want to use this formula to solve for the change in time. We'll need to rearrange the formula so that change in time (Δt) is on one side of the equation by itself. First, multiply each side of the equation by change in time.

$$\text{Acceleration} \times \text{change in time} = \text{final velocity} - \text{initial velocity}$$

$$a \times \Delta t = v_f - v_i$$

Next, divide each side of the equation by acceleration.

$$\text{change in time} = \frac{\text{final velocity} - \text{initial velocity}}{\text{acceleration}} \qquad \Delta t = \frac{v_f - v_i}{a}$$

Now we're ready to use the formula. Let's substitute the values we know and solve for what we want to find out.

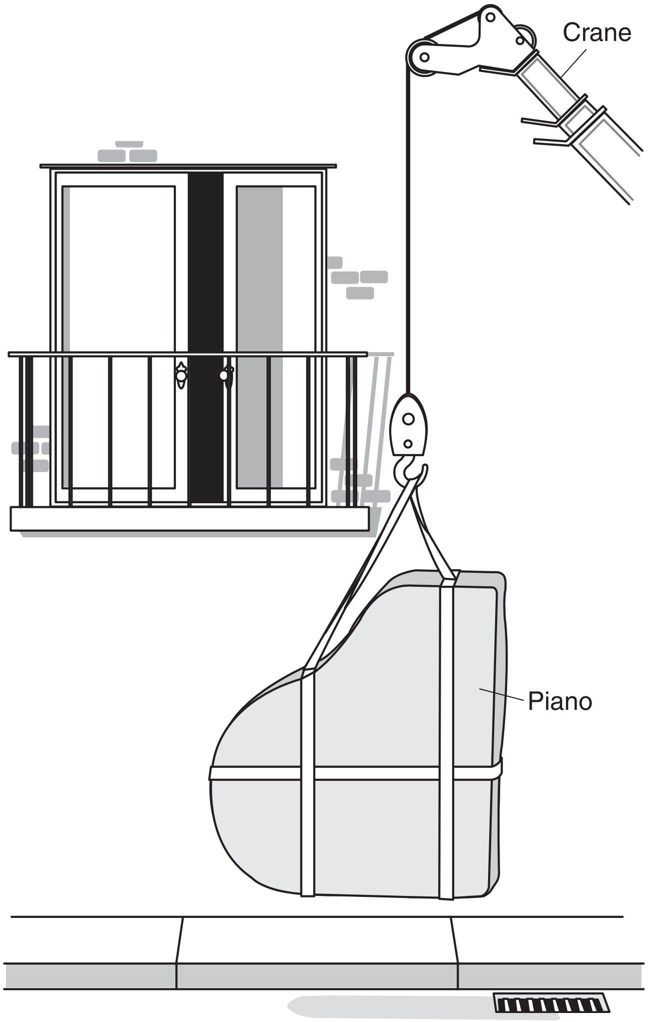
$$\Delta t = \frac{v_f - v_i}{a}$$

$$\begin{aligned} \text{change in time} &= \frac{\text{final velocity} - \text{initial velocity}}{\text{acceleration}} \\ &= \frac{27 \text{ m/s} - 3 \text{ m/s}}{15 \text{ m/s}^2} \\ &= \frac{24 \text{ m/s}}{15 \text{ m/s}^2} \\ &= 1.6 \text{ s} \end{aligned}$$

The roller coaster will reach its maximum velocity in 1.6 seconds.

Cool! We used physics to solve a problem! Can you show me how to do a two-part problem—one with two formulas?

How about this one? Furniture movers use a crane to lift a grand piano with a weight of 2,970 newtons to a height of 5 meters. If the crane does 28,018 joules of work, what is its efficiency?



First, let's write down what we know and what we want to know.

We know:

The piano's weight: 2,970 N, F

The distance the piano is moved (height): 5 m, d

The work done by the crane (the work input): 28,018 J, W_1

We want to find the efficiency of the crane.

Remember!

Weight is the effect of gravity on an object.

Next look at the formula chart; we need to use the percent efficiency formula.

$$\% \text{ efficiency} = \frac{\text{work output}}{\text{work input}} \times 100 \qquad \% = \frac{W_O}{W_I} \times 100$$

Wait! We don't know the work output. What do we do now?

Because we weren't given the work output, we'll have to calculate it using the information we do have. Look back at the formula chart for a formula that we can use to calculate work.

$$\text{Work} = \text{force} \times \text{distance} \qquad W = Fd$$

The work output is the work done on the piano. To calculate the work output, we need the distance the piano moved (which we know) and the force used to lift the piano. To lift the piano, the crane must pull on it with a force equal to the piano's weight, so we can substitute the piano's weight for force in the work formula.

Let's solve for work first.

$$\begin{aligned} W &= Fd \\ \text{Work} &= \text{force} \times \text{distance} \\ &= 2{,}970 \text{ N} \times 5 \text{ m} \\ &= 14{,}850 \text{ Nm} \end{aligned}$$

The work output is 14,850 Nm. But we want the work output to be in units of joules so that it will match the units of the work input. The constants/conversions chart shows that 1 joule (J) is equal to 1 Nm. So, 14,850 Nm = 14,850 J.

Remember!

Friction is present in every machine. Because of friction, not all the work input can be converted to work output. As a result, the efficiency of machines is always less than 100%.

Now we're ready to use the efficiency formula, right?

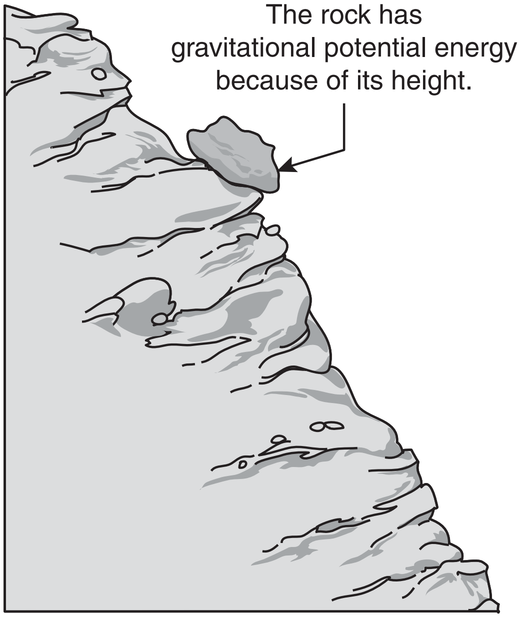
Right! Now we can solve for efficiency.

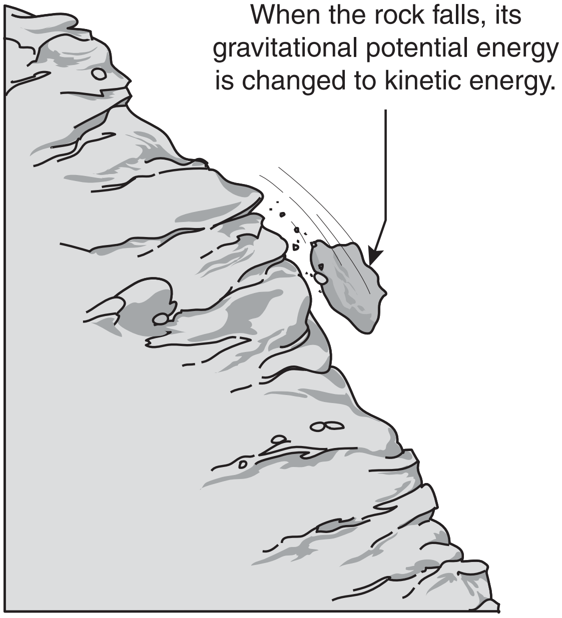
$$\begin{aligned} \% &= \frac{W_O}{W_I} \times 100 \\ \% \text{ efficiency} &= \frac{\text{work output}}{\text{work input}} \times 100 \\ &= \frac{14{,}850 \text{ J}}{28{,}018 \text{ J}} \times 100 \\ &\approx 53 \end{aligned}$$

The efficiency of the crane is about 53%.

O.K., we've talked about motion and forces. How does energy fit into all this?

Great question! *Energy* is the ability to change or move matter. All objects have energy. For example, a falling rock has energy of motion, or *kinetic energy*. But that's not all. An object can also have stored energy, or *potential energy.* A rock at the edge of a steep slope has potential energy because of its height. This energy is changed into kinetic energy if the rock falls down the slope.


The rock has gravitational potential energy because of its height.


When the rock falls, its gravitational potential energy is changed to kinetic energy.

What happens to the rock's energy when it stops at the bottom of the slope? Does it just disappear?

No, it doesn't. Energy can never be destroyed. The *law of conservation of energy* states that energy can never be created or destroyed; it can only change form. As the rock moves down the slope, its mechanical energy is changed into other forms. For example, the rock makes noise as it hits other rocks on its way downhill, so some of its energy is changed into sound energy. In addition, friction between the rock and the ground generates heat, so the rock's mechanical energy is also changed into heat energy.

Remember!

Mechanical energy is the energy an object has as a result of its position or motion.

Objective 5

In the last example, you said that mechanical energy could be changed into sound energy. I know that sound travels in waves. Are waves and energy the same thing?

Not exactly. *Waves* are disturbances that transfer energy from one place to another. Imagine a beach ball floating in a swimming pool. If you were to push your arm up and down in the water over and over again, you would make waves at the surface of the water that would spread out through the pool. Eventually the waves would cause the beach ball to move up and down, too. The waves would transfer some of your energy to the beach ball.

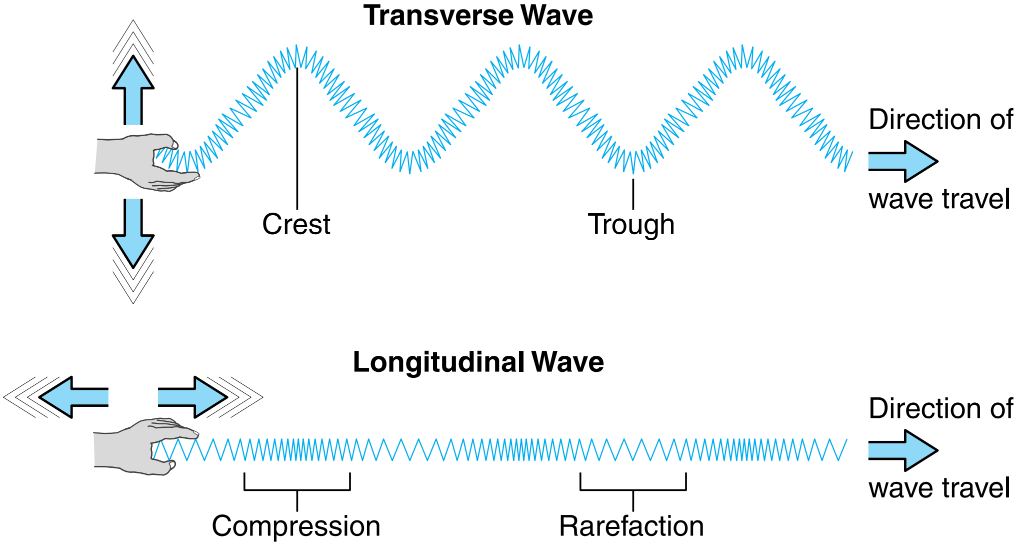
Remember!

A medium is the material or matter through which a wave travels.

How do waves travel?

All waves are produced by some kind of vibration. In a *transverse wave*, the vibration of the wave is perpendicular to the direction in which the wave travels. For example, if a transverse wave travels from left to right, the *medium* vibrates up and down.

In a *longitudinal wave*, such as a sound wave, the vibration of the wave is parallel to the direction in which the wave travels. If a longitudinal wave travels from left to right, the medium vibrates left and right as well.

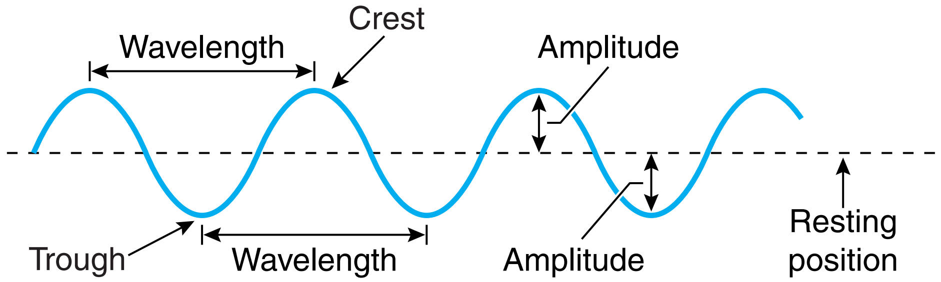


Both waves travel from left to right. In a transverse wave, the medium vibrates up and down, and in a longitudinal wave, the medium vibrates back and forth.

How do scientists measure waves?

Scientists measure waves by describing their properties. Some of the properties of waves are wavelength, amplitude, speed, and frequency. Look at the transverse wave shown below. The *wavelength* is the distance from one *crest* (or high point) to the next, or from one *trough* (or low point) to the next. Because wavelength is a distance, it can be measured in meters (m).

The *amplitude* of the wave is the distance from the resting position to a crest or from the resting position to a trough. Amplitude can also be measured in meters.



The greater the amplitude of a wave, the more energy the wave transfers. If you think about it, this makes sense. Huge waves produced by hurricanes have much larger amplitudes than tiny ripples. They also have more energy. A tiny ripple doesn't have enough energy to do much damage to the shoreline, but a huge ocean wave might.

What's the difference between speed and frequency?

The *speed* of a wave is the distance the wave travels in one unit of time. The speed of a wave can be measured in units of meters per second (m/s). A wave's velocity is its speed in a particular direction.

Frequency is a measure of how many wavelengths pass a particular point in one unit of time. It is measured in units called hertz (Hz). One *hertz* is equal to one wave per second. For example, if four complete wavelengths pass you every second, the frequency is four waves per second, or four hertz.

Objective 5

The following formula relates a wave's velocity to its frequency.

$$\text{Velocity of a wave} = \text{frequency} \times \text{wavelength} \qquad v = f\lambda$$

Suppose a sound wave has a frequency of 440 hertz and a wavelength of 0.78 meter. To find the velocity of the wave, substitute the values for frequency and wavelength into the velocity formula.

$$\begin{aligned} v &= f\lambda \\ \text{Velocity of a wave} &= \text{frequency} \times \text{wavelength} \\ &= 440 \text{ waves/s} \times 0.78 \text{ m} \\ &\approx 343 \text{ m/s} \end{aligned}$$

The sound wave has a velocity of about 343 meters per second.

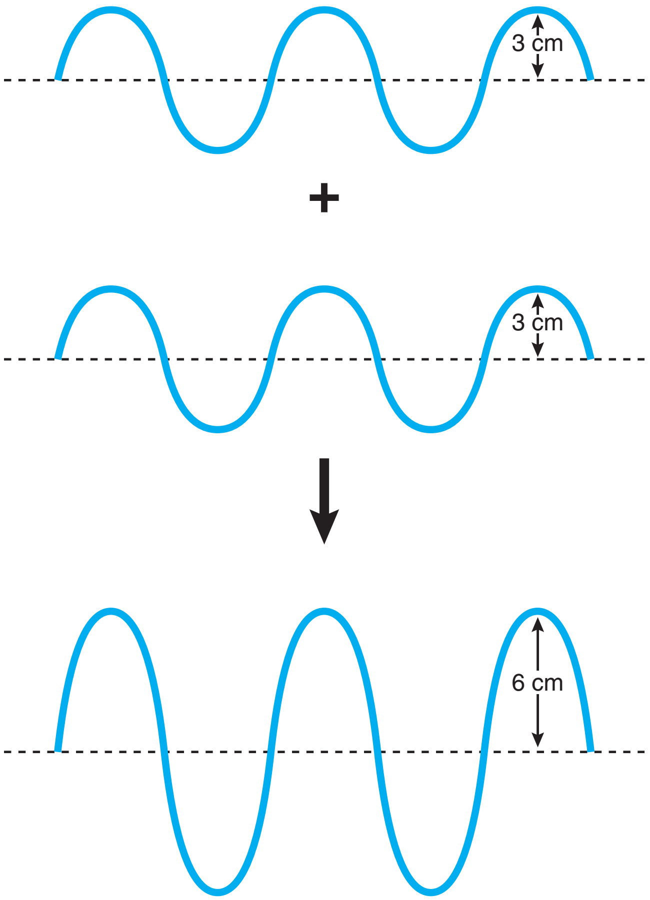
What happens when one wave meets another?

When two waves meet, they occupy the same space at the same time. When this happens, the waves combine to form a new wave with different properties. This is called *interference*. This interaction is different from what occurs when most objects meet. For example, when two marbles meet, they collide and bounce off each other. Two marbles can't occupy the same space at the same time.

How is the new wave that is produced different from the original waves?

That depends on the properties of the original waves. If the crests of the original waves line up with one another, the resulting wave will have a larger amplitude than either of the original waves. The amplitude of the combined wave will be equal to the sum of the amplitudes of the original waves. This type of interference is called *constructive interference*.

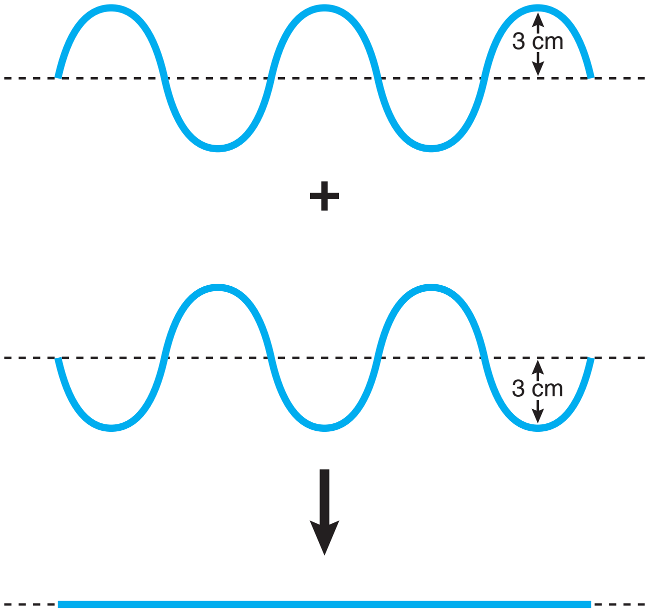
Constructive Interference



The crests of the original waves line up, so the amplitude of the combined wave is equal to the sum of the amplitudes of the original waves: 3 cm + 3 cm = 6 cm.

Another kind of interference is *destructive interference*. Destructive interference can occur when the crests of one wave line up with the troughs of another wave. In this case, the amplitude of the combined wave is equal to the larger wave's amplitude minus the smaller wave's amplitude. If the waves have the same amplitude, then the waves cancel each other out.

Destructive Interference



The crests of the first wave line up with the troughs of the second wave. The amplitude of the combined wave is equal to the difference of the amplitudes of the original waves. In this case, the amplitudes cancel each other out: 3 cm − 3 cm = 0 cm.

Can waves travel through solids?

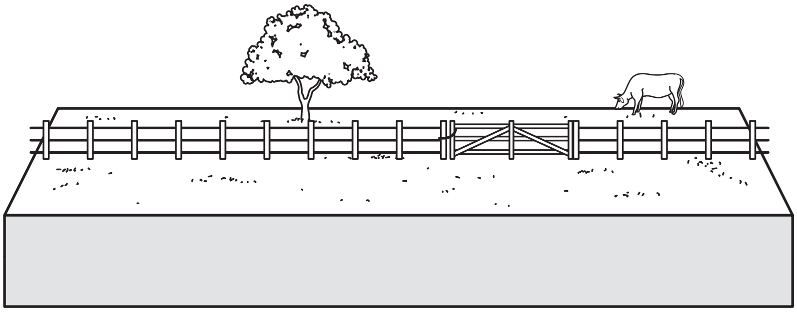
Yes! Seismic waves, for instance, can travel through rock. *Seismic waves* are produced by earthquakes. There are three types of seismic waves: primary waves, secondary waves, and surface waves.

Primary waves (or P waves) are longitudinal waves. They travel faster than the other types of seismic waves. *Secondary waves* (or S waves) are transverse waves. Like P waves, S waves can travel through solid rock, but unlike P waves, they cannot pass through Earth's liquid core. *Surface waves* travel along the boundary between the ground and the air. They are the slowest type of seismic wave, but they can do the most damage.

Did you know?

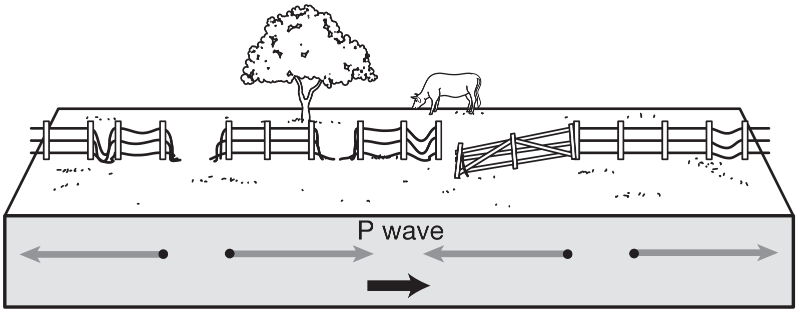
A water wave is a type of surface wave. Surface waves occur at the boundary of two different materials, such as the boundary between water and air.

Before Earthquake



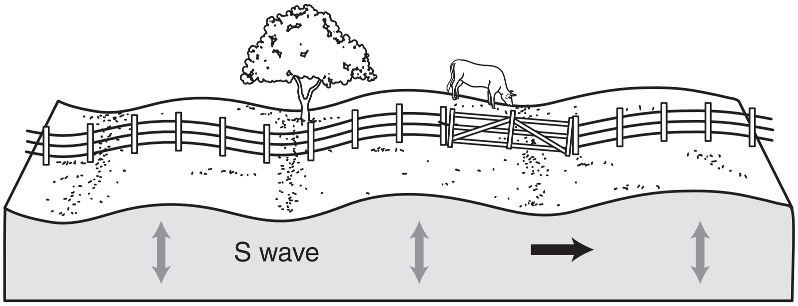
A straight fence provides a reference for future movement.

Motion Caused by a P Wave



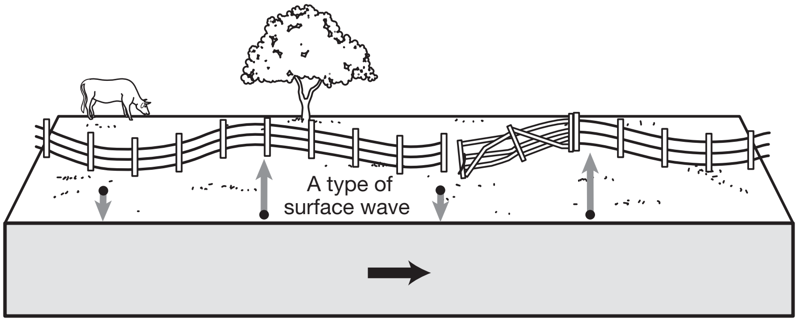
Particles are compressed and expanded in the direction of P-wave travel.

Motion Caused by an S Wave



Particles move up and down at a 90° angle to the direction of S-wave travel.

Motion Caused by a Type of Surface Wave



Particles move side to side at a 90° angle to the direction that this surface wave travels.

Remember!

A vacuum is a region with no matter in it.

Are there any other types of waves I should know about?

Yes. *Electromagnetic waves* include radio waves, infrared waves, visible light, ultraviolet rays, X rays, and gamma rays. Electromagnetic waves are different from other waves because they can travel through a vacuum. They don't require a medium like other waves do. Instead, they travel in the form of changing electric and magnetic fields.

All electromagnetic waves travel through space at the same speed. This constant speed is often called the speed of light. The speed of light is equal to 3×10^8 meters per second.

Just like seismic waves, water waves, and sound waves, electromagnetic waves transfer energy. And it's a good thing they do! We wouldn't be able to survive without the energy that the sun transfers to Earth through light waves.

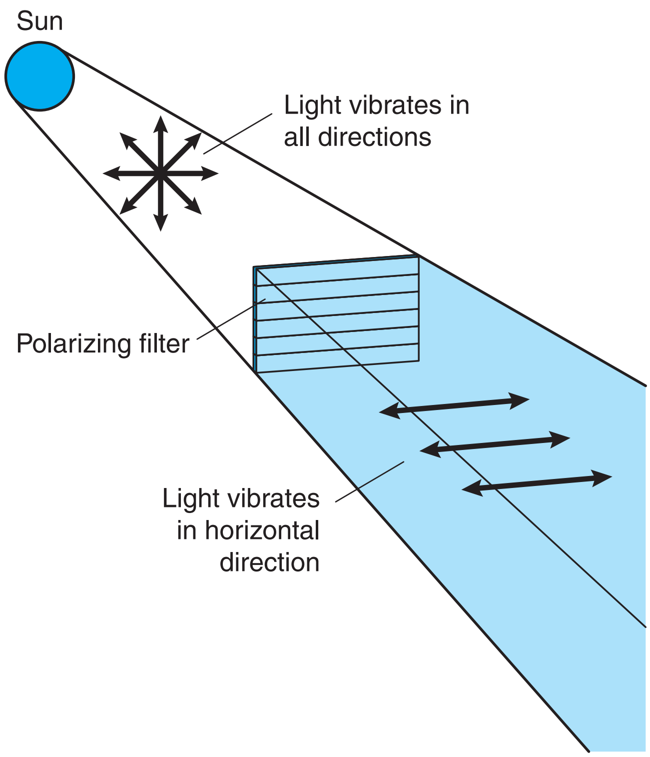
Remember!

The color of visible light depends on its frequency. Of visible light, red light has the lowest frequency, and violet light has the highest.

Do light waves behave like transverse waves or longitudinal waves?

They behave like transverse waves. This means that light can be polarized by passing it through a polarizing filter. Let me explain.

A polarizing filter is made up of long molecules arranged parallel to one another. Between the molecules are narrow slits. The only light that passes through a polarizing filter is light that vibrates parallel to the filter's slits. The light that passes through a polarizing filter is called *polarized light*. Polarized light vibrates in only a single direction, such as a horizontal plane.



Sunlight is unpolarized, meaning that it vibrates in all directions. When sunlight strikes a polarizing filter with horizontal slits, the only light that passes through the filter is light that vibrates in a horizontal direction.

Earlier you said that energy can't be created or destroyed. If energy can't be destroyed, why is there so much talk about conserving energy?

When people talk about conserving energy, they're usually talking about conserving usable energy. After all, even though energy can't be destroyed, it can be converted into a form that we can't easily use anymore. When gasoline is burned in a car's engine, for instance, chemical energy stored in the gasoline is converted to other forms. Only some of this energy is used to move the car forward. Much of the rest is wasted as heat.

Some useful energy sources exist only in limited supplies. Once these sources are used up, they cannot be replaced in a short amount of time. These resources are called *nonrenewable resources*. Fossil fuels, such as coal, oil, and natural gas, are nonrenewable resources. Although fossil fuels are widely used around the world, their supply is limited. Once they are used up, we will not be able to make more.

What are some other energy sources besides fossil fuels?

Some examples of alternative energy sources include solar energy, wind energy, and hydroelectric energy. Solar power plants use energy from sunlight to heat water to steam. The steam is used to turn a turbine and generate electricity. Solar cells, such as those in solar-powered calculators, are able to change light energy directly into electrical energy.

Electricity can also be produced from wind energy. A wind farm consists of a large number of wind turbines (or windmills). As the blades of the wind turbines move, they turn electric generators. In a similar way, hydroelectric power plants use the energy of moving water to turn turbines and generate electricity. Hydroelectric power plants are built near dams or waterfalls.

Alternative energy sources offer an alternative to fossil fuels. Many alternative energy sources are *renewable*—that is, they can be replaced in a short amount of time. In addition, alternative energy resources often cause less pollution than fossil fuels do.

Did you know?

Some two billion people in the world use wood, cow dung, crop residues, and grass for heating and cooking.

Are alternative energy sources used to produce most of our energy?

No. Right now, fossil fuels are the major source of energy in the United States. One reason for this is that alternative energy sources aren't always practical. For example, hydroelectric power plants can be built only in certain spots. Many suitable rivers have already been dammed, so the number of new hydroelectric power plants that can be built is limited. Another disadvantage of hydroelectric power plants is that they can have a negative impact on some types of river wildlife. For example, the damming of a river changes the river's depth and rate of flow. These changes can affect the types of plants that can live in the river, and changes in the river's plant life can affect the animal life as well.

One problem with solar power is that it can't be used to produce electricity at night or on cloudy days. Solar power plants also require a large area of land where mirrors can be set up to focus the sun's rays. Wind power has similar problems: electricity can be produced only when the wind is blowing, and wind farms take up a large amount of space.

Are there any alternative energy sources for cars?

Hybrid cars are cars that use two or more power sources. For example, hybrid electric cars use both a gasoline engine and an electric motor. Because hybrid cars use two different power sources, they can operate more efficiently than regular cars.

In a hybrid electric car, the electric motor is powered by rechargeable batteries. These batteries are recharged with energy that would otherwise be wasted by the gasoline engine. Because less of the gasoline's energy is wasted, hybrid electric cars tend to get better gas mileage than regular cars. And because they use less gas, they produce less pollution.

Fuel cells might someday be used to power cars as well. Fuel cells are devices that produce electrical energy from a chemical reaction between oxygen and hydrogen.

$$\underset{\text{Hydrogen}}{H_2} + \underset{\text{Oxygen}}{O_2} \longrightarrow \underset{\text{Water}}{H_2O} + \text{Electricity}$$

Fuel cells are very efficient because they do not produce much waste heat. Some fuel cells are also nonpolluting. Although fuel cells have been used on spacecraft and in submarines, they are currently too expensive for widespread use.

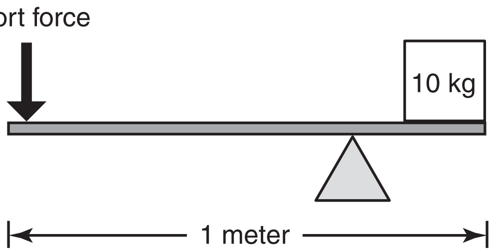
Now It's Your Turn

After you answer the practice questions, you can check your answers to see how you did. If you chose the wrong answer to a question, carefully read the answer explanation to find out why your answer is incorrect. Then read the explanation for the correct answer.

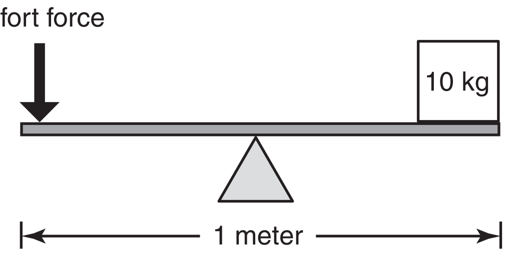
Question 29

Which lever would require the least force to lift a box with a mass of 10 kilograms?

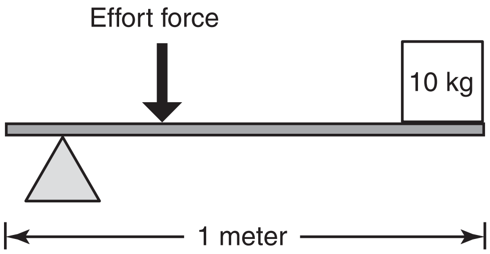
A



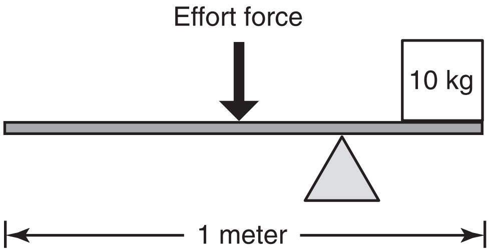
B



C



D



Answer Key: page 117

Question 30

Sunlight strikes a polarizing filter with horizontal slits. What will happen when the light that passes through this filter strikes a second polarizing filter with vertical slits?

A The second filter will block all of the light that passes through the first filter.

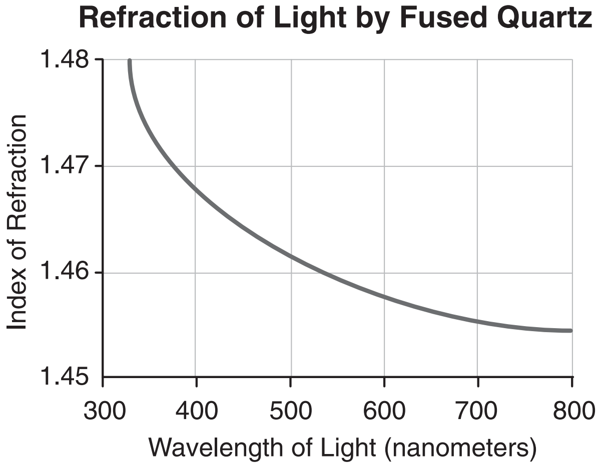
B The second filter will allow light to vibrate in all directions.

C The second filter will allow light to vibrate only in a vertical direction.

D The light that passes through the second filter will vibrate only in a horizontal direction.

Answer Key: page 117

Question 31


Refraction of Light by Fused Quartz

What does the graph indicate about the relationship between the index of refraction of fused quartz and the light being refracted?

A The index of refraction does not depend on the wavelength of the light.

B The frequency of the light has no effect on the index of refraction.

C Light with short wavelengths is refracted less than light with long wavelengths.

D The index of refraction increases as the frequency of the light increases.

Answer Key: page 117

Question 32

A student throws a tennis ball with a mass of 5.7×10^{-2} kilograms into the air. What is the downward force on the ball due to gravity?

A 9.8 N

B 0.56 N

C 0.17 N

D 0.057 N

Answer Key: page 117

Question 33

A machine lifts a crate 6.0 meters in 3.5 seconds. The weight of the crate is 490 newtons. How many watts of power does the machine use to lift the crate? Record and bubble in your answer.

				.			
⓪	⓪	⓪	⓪		⓪	⓪	⓪
①	①	①	①		①	①	①
②	②	②	②		②	②	②
③	③	③	③		③	③	③
④	④	④	④		④	④	④
⑤	⑤	⑤	⑤		⑤	⑤	⑤
⑥	⑥	⑥	⑥		⑥	⑥	⑥
⑦	⑦	⑦	⑦		⑦	⑦	⑦
⑧	⑧	⑧	⑧		⑧	⑧	⑧
⑨	⑨	⑨	⑨		⑨	⑨	⑨

Answer Key: page 118

Question 34

A 5.0-kilogram stone falls off a cliff from a height of 20 meters. If the effects of air resistance are ignored, what will be the stone's kinetic energy the instant it strikes the ground?

A 100 joules

B 490 joules

C 980 joules

D 1000 joules

Answer Key: page 118

Question 35

Batteries produce electricity by means of a chemical reaction. Some batteries are disposable. The reactants of a disposable battery are eventually used up. At that point the battery is dead and can no longer be used. Other batteries are rechargeable. A rechargeable battery can be inserted into a device that uses electric current to convert the products of the reaction back to the reactants. As a result, a rechargeable battery can be used over and over again.

What is an advantage of rechargeable batteries over disposable batteries?

A Rechargeable batteries have a lower initial purchase price.

B Rechargeable batteries produce a stronger electric current.

C Rechargeable batteries result in less pollution of the environment.

D Rechargeable batteries convert chemical energy directly to electricity.

Answer Key: page 119

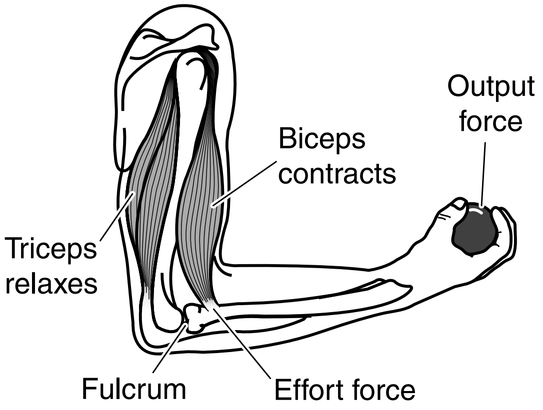
Cluster 1

Use the information below and your knowledge of science to answer questions 36–39.

Skeletal muscles allow you to perform voluntary movements, such as walking and jumping. Skeletal muscles are attached to bones by connective tissue called tendons. When the muscles contract (or shorten), they move the bones to which they are connected. Skeletal muscles can only pull bones when they contract, so each particular muscle is able to move bones in only one direction.

Under certain conditions, the biceps and triceps obtain energy by the process of lactic-acid fermentation. This type of fermentation produces less energy than cellular respiration but does not require oxygen.

The diagram below shows how the muscles and bones of the arm can serve as a lever. The fulcrum of the lever is located at the elbow joint. The pull of the biceps on the bones of the forearm is the effort force. This effort force generates an output force that moves the hand upward.



Question 36

How does the lever formed by the biceps and the bones of the arm make the work of lifting the ball easier?

A It changes the direction in which the effort force acts.

B It multiplies the distance over which the effort force acts.

C It generates an output force that is less than the ball's weight.

D It produces an output force that is greater than the effort force.

Answer Key: page 119

Question 37

Based on the passage and the diagram, what is the main function of the triceps?

A To straighten the arm

B To serve as the fulcrum of a lever

C To assist the biceps in bending the arm

D To attach the biceps to the bones of the arm

Answer Key: page 119

Question 38

One way in which the muscles in an insect's leg differ from the muscles in a human arm is that insect muscles are not —

A composed of cells

B attached to bones

C dependent on glucose

D involved in movement

Answer Key: page 119

Question 39

Which best explains why natural selection might favor carnivores whose muscle cells could use lactic-acid fermentation as well as cellular respiration?

A On high mountains where oxygen levels are low, the carnivores could use carbon dioxide as an energy source.

B During winter months when prey is difficult to find, the carnivores could produce their own food from their muscle cells.

C The carnivores could obtain energy faster during a high-stress situation, such as fighting off a predator's attack.

D The carnivores could continue to chase prey even if their breathing rate could not keep pace with their muscles' demand for oxygen.

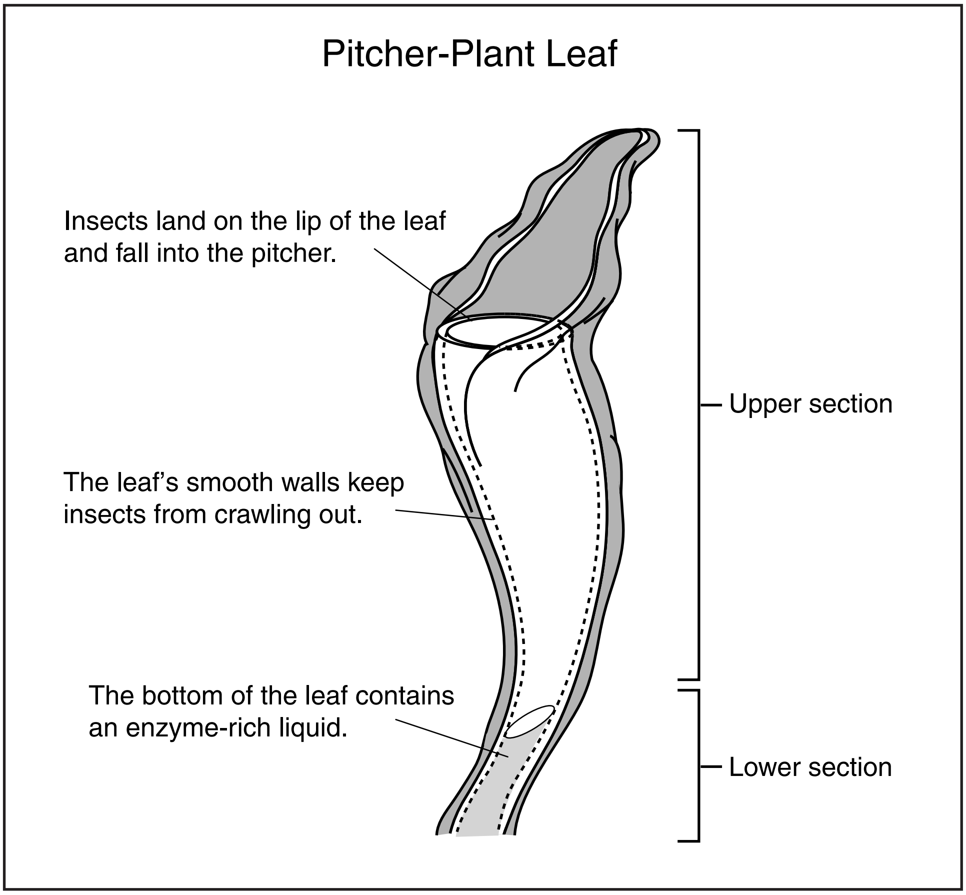
Answer Key: page 119

Cluster 2

Use the information below and your knowledge of science to answer questions 40–42.

Pitcher plants are named for their characteristic pitcher-shaped leaves. The "pitchers" are an adaptation for trapping insects. Most pitcher plants grow in marshy areas where the soil is poor in nutrients such as nitrogen. Pitcher plants obtain nutrients by digesting the insects and other organisms that they trap.

Pitcher plants attract insects by secreting nectar or by releasing a distinctive odor. The lip of the pitcher is very slippery. Insects that land on it fall into the interior and are unable to crawl out. The bottom of the leaf holds an enzyme-rich liquid. These enzymes dissolve the soft parts of the insects' bodies. The nutrients are then absorbed into the plant's tissues.



Pitcher-Plant Leaf

Question 40

The students in a science class are performing an experiment with pitcher plants. They follow the procedure described below.

- The students take pitcher plants of the same species and age and separate them into two groups.
- They plant the groups in the same type of soil and the same size of pots.
- They place one group in a dark closet and the other near a sunny window.
- They give each group the same amount of water and fertilizer.
- Twice a week the students place a dead housefly inside the pitchers of each plant.

Which question are the students most likely trying to answer?

A Can pitcher plants obtain nutrients from soil?

B Do pitcher plants rely on photosynthesis?

C What types of insects are commonly trapped in pitcher plants?

D What happens to pitcher plants if they do not trap enough insects?

Answer Key: page 119

Question 41

The lower section of a pitcher-plant leaf serves the same main function as which human organ?

A Bladder

B Kidney

C Esophagus

D Small intestine

Answer Key: page 120

Question 42

Many pitcher-plant species grow well in soil with a low pH. Soil pH could be decreased by adding a solution of —

A carbonic acid

B potassium hydroxide

C ammonia

D sodium chloride

Answer Key: page 120

Climbing Mount Everest

The peak of Mount Everest is the world's highest point. Reaching this peak is no small accomplishment. Climbers must face extremely cold temperatures, harsh winds, and low oxygen levels. It takes determination and a lot of hard work to conquer Mount Everest.

How much work does it take? Let's find out. According to the scientific definition, work is done when a force causes an object to move. We can calculate work with this formula.

$$\text{Work} = \text{force} \times \text{distance} \qquad W = Fd$$

W is the work done, F is the amount of force acting on the object, and d is the distance the object moves.

Did you know?

The peak of Mount Everest wasn't reached until 1953. Edmund Hillary of New Zealand and Tenzing Norgay of Nepal were the first to reach its summit.

©CORBIS

A Practice Climb

Before we tackle Mount Everest, let's start with something smaller—a lot smaller. Let's determine how much work it takes to climb a flight of stairs.

First of all you'll need supplies: a bathroom scale and a meter stick. You'll also need a flight of stairs. If there isn't a flight of stairs in or near your home, look for one at school, at a library, or at another public building.

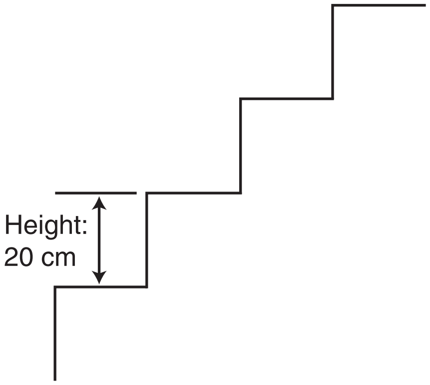
Going the Distance

There are two quantities we need to determine: the distance from the bottom of the stairs to the top and the force needed to climb the stairs. Let's start with the distance.

Follow the steps below and record your answers on the lines provided.

1. Count the number of stairs you're going to climb. ____________
2. Measure the height of one of the stairs as shown in the diagram. Be sure to include units (centimeters or meters) with your measurement.

   ____



3. Find the total height of the stairs by multiplying the height of one stair by the number of stairs.

   ____

4. If your answer to Step 3 is in centimeters, divide it by 100 to change it to meters. Round to two decimal places.

   ____

The height of the stairs that you calculated in Step 4 is the upward distance you will travel. You can use this distance in the work formula.

May the Force Be with You

Before you can use the work formula, you need to know how much force will be required to go up the stairs. To move upward, you need to overcome the force of gravity on your body. The force of gravity on your body is your weight. If you know your weight, you know the force required to go up the stairs.

Follow the steps below and record your answers on the lines or in the space provided.

1. Measure your weight using a bathroom scale. Be sure to include the units with your measurement.

   ____

2. More than likely, you measured your weight in pounds. If so, you need to change this measurement to metric units. Divide your answer from Step 1 by 2.2 to change it to metric units of kilograms. Round to one decimal place.

____

3. Kilograms are units of mass, not force. To determine your weight in metric units, you will need to use the force formula.

$$\text{Force} = \text{mass} \times \text{acceleration} \qquad F = ma$$

You know your mass from Step 2. But what acceleration should you use? You want to know the force of gravity on your body, so you should use acceleration due to gravity, which is 9.8 m/s^2. Use the force formula to calculate the force of gravity on your body. Round to one decimal place and show your work.

4. When you calculated force in Step 3, you should have gotten units of kgm/s^2. This unit is called the newton (N). What is the force of gravity on your body (your weight) in newtons?

____

Ready, Set, Go!

O.K.! You're ready. Climb up the stairs! When you return, use the work formula to calculate how much work you did on your way up. Show your calculations in the space below.

$$\text{Work} = \text{force} \times \text{distance} \qquad W = Fd$$

How much work did you do? Give your answer in units of joules (J).

(Hint: 1 Nm = 1 J) ____________________________________

Note: When you climb a flight of stairs, not only do you move upward, but you also move forward. You do work as you go up, and you do work as you go forward. In order to keep things simple, we calculated only the work of going up, not the work of going forward.

Did you know?

When a basketball player with a mass of 100 kilograms jumps 1 meter off the floor to slam-dunk the ball, he or she does about 1,000 joules of work.

Work Faster!

Power is the rate at which work is done. The faster you do work, the more power you use. Look at the formula chart on page 8. What is the formula for calculating power?

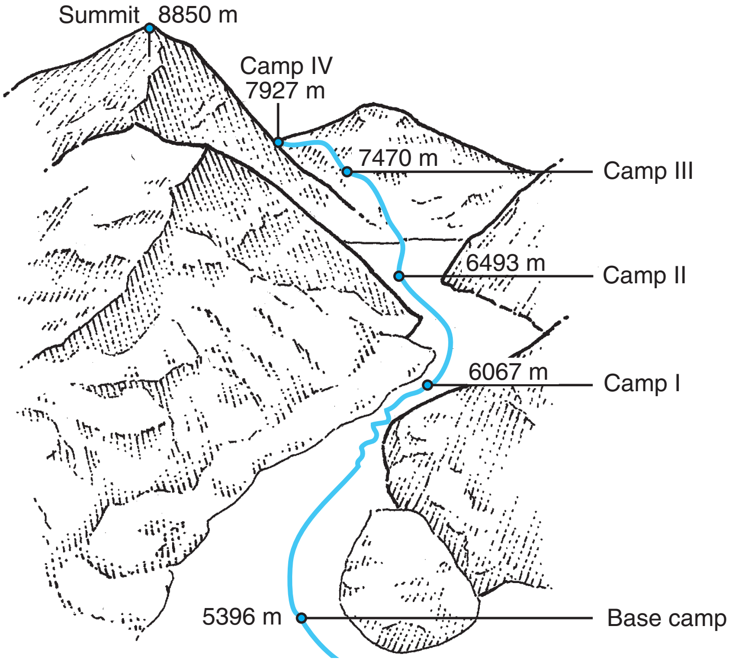
If it takes you 15 seconds to walk up the flight of stairs, how many watts of power do you use? (Hint: 1 J/s = 1 watt.) Show your calculations in the space below. Round to the nearest watt.

How much power do you use if it takes you 7 seconds to run up the stairs? Round to the nearest watt.

Reaching the Top

Now that you've practiced with a flight of stairs, it's time to take on Mount Everest. The diagram shows the most common route to Mount Everest's summit. The elevations given in the diagram represent meters above sea level.

South Route up Mount Everest



Calculate the change in elevation from the base camp to the summit. This is the upward distance you must travel to climb the mountain.

Did you know?

The oxygen level near the top of Mount Everest is so low that many climbers rely on bottled oxygen.

Now determine the amount of work you must do to climb from the base camp to the summit. (Remember, you are calculating only the work you do as you move upward, not the work you do as you move forward.)

Explain how you found your answer. ______________________________

____

Going Further

You won't be able to make it up Mount Everest without any gear. You're going to need clothing, food, a tent and sleeping bag, climbing tools, and other equipment. Suppose your gear has a mass of 40 kilograms. How much work will you do as you carry your gear from the base camp to the summit?

Which requires more work, climbing from Camp I to Camp II or from Camp III to Camp IV? Explain.______________________________

____

If you climbed up Mount Everest a second time but reached the top 2 hours faster, would you have done more work than the first time you climbed the mountain? Would you have used more power? Explain.

____

____

Science Answer Key

Objective 1

Question 1 (page 19)

A Incorrect. Parasites do not always affect two species in the same way, so mosquitoes could be carriers of *Plasmodium* but not develop malaria. Therefore, mosquitoes could be involved in the transmission of malaria to humans, yet show no signs of the disease.

B Incorrect. It might be possible to show that mosquitoes are capable of carrying *Plasmodium* by injecting them with the organism. Ross's hypothesis would be better supported if it could be shown that mosquitoes actually do carry *Plasmodium* in the wild.

C Correct. If *Plasmodium* could be found in the tissues of wild mosquitoes, this would suggest that mosquitoes were involved in spreading *Plasmodium* (and malaria) to humans.

D Incorrect. This information would suggest only that animals are susceptible to malaria and may carry it to humans. But this discovery would not have helped Ross determine whether mosquitoes are involved in the spread of malaria.

Question 2 (page 19)

A Incorrect. The ventilation rate of the fish decreases as the temperature rises above 23°C. Because the ventilation rate would decrease, the level of oxygen in the fish's blood would also decrease. Fish, like all animals, need oxygen to live. This change would likely produce many ill effects in the fish.

B Correct. The graph shows that the ventilation rate of the fish decreases as the temperature rises above 23°C. As the ventilation rate slows, the level of oxygen in the fish's blood decreases. If the level of oxygen falls too low, the fish will die.

C Incorrect. Oxygen levels in the fish's blood would decrease as a result of the decrease in ventilation rate that occurs at higher temperatures. The data shown in the graph suggest that this change would not result in an increased ventilation rate.

D Incorrect. The line of the graph descends sharply as it approaches a temperature of 27°C. There is no evidence to suggest that the line will flatten out at temperatures above 27°C. Instead, the line will likely continue to descend, and the rate of ventilation will continue to decrease.

Question 3 (page 20)

A Incorrect. In this reaction the chemical potential energy of the products is the same as the chemical potential energy of the reactants, so there is no net release or absorption of energy at the end of this reaction.

B Incorrect. In this reaction the chemical potential energy of the products is the same as the chemical potential energy of the reactants, so there is no net release or absorption of energy at the end of this reaction.

C Correct. In this reaction the chemical potential energy of the products is less than the chemical potential energy of the reactants. This reaction results in an overall release of energy. This would be called an exothermic reaction.

D Incorrect. In this reaction the chemical potential energy of the products is greater than the chemical potential energy of the reactants. Therefore, this reaction results in an overall absorption of energy. This would be called an endothermic reaction.

Question 4 (page 21)

A Incorrect. The graph does not show the respiration rate of the two plants. Instead, it shows the net amount of carbon dioxide taken in by the plants (which is affected by photosynthesis as well as respiration). The graph does not tell us which plant requires more energy from respiration.

B Incorrect. The graph shows the levels of light intensity at which the two plants grow well. However, the light level of an environment is not related to its amount of rainfall. For example, not all sunny areas are dry, and not all dry areas are sunny. Therefore, the graph cannot be used to draw conclusions about the dryness or wetness of the environment to which the plants would be well suited.

C Incorrect. The rate at which the plants grow and mature depends on many factors. The intensity of the light in which the plants are grown is only one factor and does not give enough information about maturation rate.

D Correct. A shady environment has low intensities of light. The graph shows that at low light intensities, Plant 2 takes in more carbon dioxide and grows faster than Plant 1. Plant 2 is likely to be better suited to growing in a shady environment than Plant 1.

Question 5 (page 21)

A Incorrect. If the student had mixed the two types of food together, it would have been much more difficult for him to tell which birds were eating which type of food. By keeping the two types of food in separate containers, he could tell which type of food the birds were eating just by noticing which feeder they visited.

B Incorrect. The finches are likely to prefer sunflower seeds to millet no matter what height the feeders are hung. The only extra information the student could get from placing feeders on the ground is whether or not finches will come to the ground to eat.

C Incorrect. Not all investigations need to be conducted in a laboratory. Data gathered in field experiments are often just as valid as data gathered in laboratory experiments.

D Correct. It is possible and perhaps likely that most of the local finch population was finding food elsewhere than at the feeders. It is possible that the finches' primary food source is neither sunflower seeds nor millet, but instead one that the student did not use in his experiment. One method that could help the student determine the finches' primary food source is to observe what they eat in the wild.

Question 6 (page 22)

A Incorrect. If only one group of cats had been used, the researchers would not have been able to determine whether the new food affected the cats' health in any way. There needs to be at least one other group that is fed a diet that is known not to cause health problems in cats. This group will be the control group. In that way, researchers can compare the data obtained for the two groups.

B Incorrect. By measuring more than one indicator of health, the researchers obtain a better overall picture of the cats' health. If they had measured only one indicator of health, their results would have been less valid.

C Correct. If there were a fifth group fed only the new food, researchers could compare the results of this group to the results of Group 1. Group 1 received a diet that does not cause health problems. If the health of cats fed only the new food were poorer than the health of cats in Group 1, researchers could conclude that the new food caused health problems in cats.

D Incorrect. Adding a set of groups that are fed the new food for only one month would not reveal any health problems that were not apparent after the first six-month investigation.

Question 7 (page 22)

A Correct.

Step 1: Find the number of Calories in the bar that come from protein. To do so, multiply the number of grams of protein (19 g) by the number of Calories in one gram of protein $\left(\frac{4 \text{ Cal}}{\text{g}}\right)$.

$$19 \text{ g of protein} \times \frac{4 \text{ Calories}}{\text{g of protein}} =$$

$$19 \text{ g} \times \frac{4 \text{ Cal}}{\text{g}} = 76 \text{ Calories}$$

Step 2: Find the percentage of Calories that come from protein. To do so, divide the number of Calories that come from protein (76 Cal) by the total number of Calories (210 Cal). Then multiply by 100.

$$(76 \text{ Calories from protein} \div 210 \text{ total Calories}) \times 100$$
$$= (76 \text{ Cal} \div 210 \text{ Cal}) \times 100$$
$$= 0.36 \times 100$$
$$= 36\%$$

About 36% of the Calories in this bar come from protein. A greater percentage of Calories comes from protein in this bar than in any of the other bars.

Objective 2

Question 8 (page 33)

A Incorrect. The endoplasmic reticulum helps transfer materials from one part of a cell to another. Organelles called mitochondria transfer energy to ATP.

B Incorrect. Proteins are manufactured by organelles called ribosomes.

C Incorrect. The endoplasmic reticulum transports materials from one part of a cell to another, not from one part of the body to another.

D Correct. The endoplasmic reticulum does help transport hormones to the cell membrane, where they can be secreted. Hormones are chemical messengers that control many of the body's activities.

Question 9 (page 33)

A Incorrect. Both DNA and RNA are nucleic acids. They are made up of units called nucleotides. The information in an mRNA molecule is not used to produce a nucleic acid. It is used to produce a protein made up of units called amino acids.

B Incorrect. The information in an mRNA molecule is used to produce protein chains rather than carbohydrate chains.

C Correct. Step 2 represents the process by which the genetic information coded in an mRNA molecule is translated into the amino acids of a protein chain. Sequences of three letters (called codons) on the model of an mRNA molecule specify particular amino acids.

D Incorrect. A protein chain does not act as a pattern for making an mRNA molecule. Instead, an mRNA molecule acts as a pattern for making a protein chain.

Question 10 (page 34)

A Correct. A DNA molecule has the shape of a double helix, which looks like a twisted ladder. During replication the two strands of the DNA molecule unwind. Then each strand acts as a pattern for a new nucleotide chain. The result is two DNA molecules identical to the original DNA.

B Incorrect. The model shows a DNA molecule unwinding and each of its two strands acting as a template for a new nucleotide chain. As a result, two identical DNA molecules are produced from the original DNA molecule. None of the DNA in the original molecule is lost.

C Incorrect. A DNA molecule consists of two strands of nucleotides coiled into a double helix. An mRNA molecule consists of only a single strand of nucleotides. The molecules in the model, however, are all double-stranded. The model does not represent the transcription of information from DNA to mRNA.

D Incorrect. An mRNA molecule consists of a single strand of nucleotides. The molecules in the model are all double-stranded and represent DNA. The model does not represent the translation of information from mRNA to a protein.

Question 11 (page 34)

A Incorrect. Eubacteria are single-celled organisms, so they do not have tissues. Eubacteria are also prokaryotes and therefore lack nuclei.

B Incorrect. The cells of fungi do have nuclei and cell walls. However, fungi are heterotrophs that obtain food by absorbing nutrients from their environment. Many fungi obtain nutrients from dead organic material—such as that found in rich soil. Fungi do not use sunlight to make their own food, so a lack of sunlight would probably not cause them to die.

C Correct. The cells of plants have nuclei and cell walls and are organized into tissues. Green plants are autotrophs, which make their own food (glucose) by using sunlight as a source of energy. If a green plant were kept in complete darkness for an extended period, it would probably die from lack of glucose. The data support the conclusion that the organism is a plant.

D Incorrect. Animal cells do not have cell walls.

Question 12 (page 35)

A Incorrect. Sudden stress can trigger a "fight-or-flight" response. During such a response, the body prepares to move quickly if necessary. These two systems do not directly cause the driver's increased heart rate and alertness.

B Correct. When a person is startled, the nervous system and the endocrine system work to prepare the body for "fight or flight." The adrenal glands of the endocrine system release stress hormones, and the sympathetic nervous system becomes more active. Both of these changes get the body ready to take sudden action. Among the effects of these changes are an increase in heart rate and level of alertness.

C Incorrect. Although the heart is part of the circulatory system, changes in heart rate during stress are triggered by the nervous and endocrine systems, not by the circulatory system. The excretory system is not involved in causing an increase in heart rate and alertness. The main function of the excretory system is removing wastes from the body.

D Incorrect. The respiratory and integumentary systems are affected by sudden stresses. However, they are not directly involved in causing increased heart rate and level of alertness during a "fight-or-flight" response.

Question 13 (page 35)

A Incorrect. A narrowing of the bronchi would result in less airflow to and from the lungs. As a result, less carbon dioxide would be exhaled, and the level of carbon dioxide in the blood would continue to increase.

B Correct. One of the muscles involved in breathing is the diaphragm. When the level of carbon dioxide increases in the blood, the brain sends signals to the diaphragm and other breathing muscles, resulting in an increase in the breathing rate. When the breathing rate increases, more carbon dioxide can be exhaled. As a result, the level of carbon dioxide in the blood returns to normal levels.

C Incorrect. Oxygen passes from the alveoli to the bloodstream by diffusion, not by active transport.

D Incorrect. A decrease in breathing rate would result in less carbon dioxide being exhaled. As a result, carbon dioxide levels in the blood would increase.

Question 14 (page 36)

A Correct. A person with B− blood may have antibodies against A markers and may have antibodies against Rh markers. A person with B− blood cannot safely receive blood from people with either A or Rh markers. The only two blood types listed in the table that have neither A nor Rh markers are types B− and O−.

B Incorrect. A person with B− blood may have antibodies against A markers and may have antibodies against Rh markers. Type AB+ blood carries both of these markers. A person with B− blood cannot safely receive blood from people who are AB+.

C Incorrect. A person with B− blood may have antibodies against Rh markers. Type B+ blood carries Rh markers. A person with B− blood cannot safely receive blood from people who are B+.

D Incorrect. A person with B− blood may have antibodies against A markers and may have antibodies against Rh markers. Type AB+ blood carries both of these markers, type AB− carries A markers, and type B+ carries Rh markers. A person with B− blood cannot safely receive blood from people who are AB−, AB+, or B+.

Objective 3

Question 15 (page 51)

A Correct. Some bacteria are decomposers. Decomposers break down organic materials and return nutrients such as carbon, nitrogen, and sulfur to the soil. Plants need these nutrients in order to grow. Animals, in turn, get these nutrients by eating plants or by eating other animals.

B Incorrect. Some bacteria do get energy from the process of fermentation. During fermentation, energy is released from sugar molecules without the use of oxygen. Most plants and animals are not dependent for their survival on bacteria that use fermentation.

C Incorrect. Some bacteria do make their own food using the energy from sunlight. However, so do green plants. Green plants, rather than bacteria, are the producers in most terrestrial food chains.

D Incorrect. People have used certain types of bacteria to clean up hazardous wastes. However, there are usually better ways to remove such wastes.

Question 16 (page 51)

B Correct. Species 2 is the most closely related to modern horses, and it should be listed first. The bones of Species 3 have the least resemblance to those of the modern horse. Species 3 is the most distantly related to modern horses, and it should be listed last. The correct order is 2, 1, 3.

Question 17 (page 52)

A Correct. An insecticide never kills all the targeted insects in a population. A few insects have genetic variations that allow them to resist the effects of the insecticide. These insects produce some offspring that are also resistant to the insecticide. These offspring have a better chance of surviving and reproducing.

B Incorrect. Insecticide resistance is due to genetic variations rather than learned behavior.

C Incorrect. Geographic isolation occurs when a population of organisms becomes separated from the rest of its species by a physical barrier, such as a river, an ocean, or a mountain range.

D Incorrect. Species that reproduce asexually tend to have less genetic variation than species that reproduce sexually. For this reason, species that reproduce asexually would be less likely to have genetic variations that allow resistance to insecticides.

Question 18 (page 52)

A Incorrect. The spread of a virus fatal to blue jays would lead to a decrease in the blue jay population. As a result, there would be fewer blue jays to prey on young golden-cheeked warblers. This might cause the population of golden-cheeked warblers to increase.

B Incorrect. Cowbirds harm golden-cheeked warblers by laying eggs in the warblers' nests.

The warbler parents feed the young cowbirds along with their own offspring. As a result, the warblers' offspring receive less food and are less likely to survive. If there were fewer cowbirds as a result of increased predation, the population of golden-cheeked warblers might increase.

C Correct. The clearing of ash juniper trees would mean fewer trees from which the warblers could get bark for their nests. If the birds could not find enough bark, they might not build nests or reproduce. As a result, their population might decrease.

D Incorrect. Golden-cheeked warblers feed on spiders, so an increase in the spider population would likely mean more food for the warblers. As a result, the population of golden-cheeked warblers might increase.

Question 19 (page 53)

A Correct. Organisms at higher trophic levels accumulate a higher concentration of DDT in their tissues than organisms at lower trophic levels do.

B Incorrect. The concentration of DDT in a population increases as its trophic level increases.

C Incorrect. The diagram shows that the concentration of DDT increases at each level in the food chain. By contrast, some energy is lost as heat at each level in a food chain.

D Incorrect. DDT passes from prey to predators, not from predators to prey.

Question 20 (page 54)

A Correct. In most cases, only a small fraction of biomass is passed from one trophic level to another. In general, most of the biomass in a terrestrial community consists of producers, such as grass. White-tailed deer, mountain lions, and vultures are consumers, which have less biomass.

Question 21 (page 54)

A Incorrect. Chemicals that are poisonous to many types of mammals might not necessarily be poisonous to many types of bacteria. In addition, it would not benefit oleanders to kill some types of bacteria, such as those that add nitrogen compounds to the soil.

B Correct. Herbivores are animals that feed on plants. Oleanders have a better chance of surviving and reproducing if they deter or kill animals that might feed on them.

C Incorrect. Pollinators help many types of plants reproduce by transferring the plants' pollen. It would not benefit oleanders to deter or kill the animals that help them reproduce.

D Incorrect. Scavengers are carnivores that feed on dead animals. Scavengers are not likely to have any harmful effect on oleanders, so it would not benefit oleanders to harm scavengers.

Objective 4

Question 22 (page 75)

A Incorrect. Argon is on the far right of the periodic table. Therefore, it is a nonmetal. However, hydrogen is also a nonmetal even though it appears in Group 1 of the periodic table.

B Correct. The purpose of the shield is to prevent the molten metal from undergoing chemical reactions. Argon is in Group 18 of the periodic table, which means that it is a noble gas. Noble gases are extremely inert, meaning that they are unreactive, so argon will not react with the molten metal. Hydrogen, however, is in Group 1 of the periodic table and is very reactive. In fact, hydrogen gas would likely explode if it were used in arc welding.

C Incorrect. Hydrogen has only a single electron and has the smallest atomic radius of any element. It is true that argon has a larger atomic radius than hydrogen. However, this fact does not explain why argon makes a better shield for arc welding.

D Incorrect. According to the periodic table, the atomic mass of hydrogen is 1.008, and the atomic mass of argon is 39.948, so it is true that argon has a greater atomic mass than hydrogen. However, this fact does not explain why argon makes a better shield for arc welding.

Question 23 (page 75)

A Correct. Sodium is in Group 1 of the periodic table, so it has one valence electron. When sodium reacts, it loses its valence electron to form a positive ion with a charge of 1+. Magnesium is in Group 2 of the periodic table, so it has two valence electrons. When magnesium reacts, it loses both of its valence electrons to form an ion with a charge of 2+. It takes more energy to remove two electrons from magnesium than to remove one electron from sodium. For this reason, sodium is more reactive than magnesium.

B Incorrect. The periodic table shows that the atomic number (number of protons) of sodium is 11 and its mass number (number of protons and neutrons) is usually 23, so most sodium atoms have 12 neutrons (because 23 − 11 = 12). The atomic number of magnesium is 12, and its mass number is usually 24, so most magnesium atoms also have 12 neutrons (because 24 − 12 = 12). Even if the typical number of neutrons in the atoms of these elements did differ, it is the number of electrons, not the number of neutrons, that affects an element's chemical properties.

C Incorrect. Sodium is in Group 1 of the periodic table. Therefore, it has one valence electron and forms ions with a charge of 1+. Magnesium is in Group 2 of the periodic table, so it has two valence electrons and forms ions with a charge of 2+.

D Incorrect. Sodium and magnesium are both on the left side of the periodic table. Therefore, they have a tendency to give up their valence electrons and form cations (positive ions) rather than attract electrons and form anions (negative ions).

Question 24 (page 76)

A Incorrect. The number of atoms in the reactants of a chemical reaction is the same as the number of atoms in the products. Atoms are neither created nor destroyed in a chemical reaction.

B Correct. The pressure in a sealed container depends on the number of gas molecules it contains. The number of molecules in the products of the reaction (2) is less than the number of molecules in the reactants (4). This caused the pressure in the container to decrease.

C Incorrect. According to the law of conservation of mass, mass is neither created nor destroyed during a chemical reaction. Therefore, the mass of the reactants in a chemical reaction will equal the mass of the products.

D Incorrect. Gases expand to fill the volume of the container they occupy. The reaction between hydrogen and nitrogen takes place inside a sealed container, so any gases produced by the reaction will occupy the same volume as the reactants did.

Question 25 (page 76)

A Incorrect. Salt and sugar both dissolve in water to form solutions. One way to separate a solid solute from a liquid solvent is by evaporating the liquid, so both salt and sugar can be separated from water by evaporation.

B Correct. Salt is an ionic compound, so when salt dissolves in water, the solute (salt) exists as ions. For this reason, a salt solution will conduct an electric current. By contrast, sugar is a covalent compound. When sugar dissolves in water, the solute (sugar) exists as neutral molecules. As a result, a sugar solution will not conduct an electric current.

C Incorrect. Salt and sugar both dissolve in water to form solutions. The dissolved particles in a solution are very small and can pass through a filter. Therefore, neither salt nor sugar can be separated from water by filtration.

D Incorrect. Salt and sugar both dissolve in water to form solutions. A beam passing through either solution will not be visible.

Question 26 (page 77)

D Correct. Bottle 4 is uncapped, so the carbon dioxide in Bottle 4 is under less pressure than the carbon dioxide in Bottles 1 and 2. Because the solubility of a gas decreases as the pressure decreases, Bottle 4 will contain less carbon dioxide than Bottles 1 and 2. In addition, Bottle 4 sits in warm water, unlike Bottle 3, which is chilled. Because the solubility of a gas decreases as the temperature increases, Bottle 4 will contain less carbon dioxide than Bottle 3.

Question 27 (page 78)

A Incorrect. The solubility of solids and liquids does not change much with changes in pressure. Sugars such as glucose are normally solids. Therefore, an increase in pressure will have little effect on the solubility of glucose in the divers' cells.

B Correct. The solubility of gases increases with an increase in pressure. Therefore, the solubility of nitrogen gas in the divers' blood will increase as the divers are exposed to high pressure underwater.

C Incorrect. Carbon dioxide gas would bubble out of the bloodstream only if the solubility of carbon dioxide in blood decreased. The solubility of gases increases with increasing pressure. Therefore, carbon dioxide will be more soluble in the divers' blood the deeper the divers go.

D Incorrect. The solubility of gases increases with increasing pressure. Therefore, oxygen will be more soluble in the divers' cells the deeper the divers go.

Question 28 (page 78)

A Incorrect. Sucrose dissolves in water but does not form ions. For this reason, sucrose is a nonelectrolyte and will not conduct an electric current.

B Incorrect. Nitrogen dissolves in water but does not form ions. For this reason, nitrogen is a nonelectrolyte and will not conduct an electric current.

C Incorrect. Because ammonia is a weak base, few ammonia molecules break up into ions when it is added to water. Electric current will be able to pass from one electrode to the other because there are some ions in the ammonia solution. However, the lightbulb in this circuit will glow less brightly than a lightbulb in a circuit with a solution having a higher concentration of ions.

D Correct. The lightbulb will glow only if electric current can pass from one electrode to the other. The solution will conduct electricity from one electrode to another only if it contains ions. The more ions the solution contains, the better it can conduct electricity. When a strong acid such as sulfuric acid is added to water, almost all of the acid molecules break up into ions, so a solution of sulfuric acid is a good conductor of electricity. The lightbulb in this circuit should glow brightly when a solution of sulfuric acid is added to the beaker.

Objective 5

Question 29 (page 97)

A Correct. The fulcrum of this lever is closer to the box than to the effort force. As a result, less force will be needed to lift the box than if the lever were not used. This lever is the only one that multiplies force.

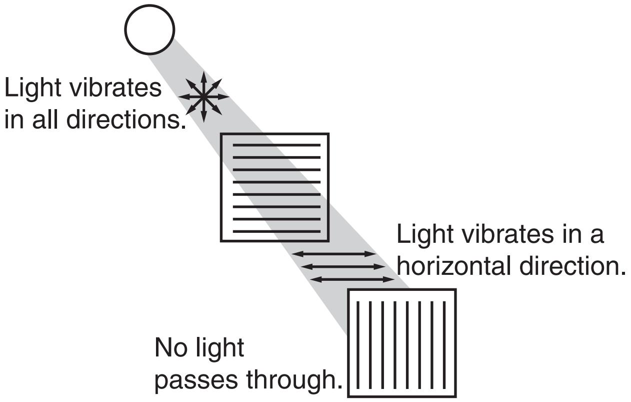
B Incorrect. The fulcrum of this lever is halfway between the box and the effort force. As a result, the amount of force needed to lift the box will be the same as if the lever were not used.

C Incorrect. Because of the location of the fulcrum and the direction of the effort force, it would not be possible to lift the box.

D Incorrect. The fulcrum of this lever is halfway between the box and the effort force. As a result, the amount of force needed to lift the box will be the same as if the lever were not used.

Question 30 (page 98)

A Correct. The only light that passes through the first filter is light that vibrates in a horizontal direction. The only light that can pass through the second filter is light that vibrates in a vertical direction, so none of the light that passes through the first filter will be able to pass through the second filter.



Question 31 (page 98)

A Incorrect. If the index of refraction were independent of wavelength, the index of refraction would not change as the wavelength of light changed.

B Incorrect. Light with longer wavelengths has lower frequencies, and light with shorter wavelengths has higher frequencies, so a change in the frequency of light means a change in the wavelength, which means a change in the index of refraction of fused quartz.

C Incorrect. The graph shows that as the wavelength of light decreases, the index of refraction increases, so light with shorter wavelengths is refracted more than light with longer wavelengths.

D Correct. The graph shows that the index of refraction is higher for light with shorter wavelengths. The shorter the wavelength of light, the higher its frequency is, so the index of refraction is higher for light with higher frequencies.

Question 32 (page 99)

B Correct. You know the mass of the ball (5.7×10^{-2} kg) and want to find the force on the ball due to gravity.

Step 1: Look at the formula chart on page 8 for the formula that relates mass to force.

$$\text{Force} = \text{mass} \times \text{acceleration}$$

The acceleration of the ball is the acceleration due to gravity. This value is listed in the constants/conversions chart. The acceleration due to gravity is 9.8 m/s^2.

Step 2: Substitute the values you know into the formula and solve for force.

$$\begin{aligned}\text{Force} &= \text{mass} \times \text{acceleration}\\ \text{Force} &= (5.7 \times 10^{-2}\text{ kg}) \times 9.8\text{ m/s}^2\\ &= 0.057\text{ kg} \times 9.8\text{ m/s}^2\\ &= 0.56\text{ kgm/s}^2\\ &= 0.56\text{ N}\end{aligned}$$

The force on the ball due to gravity is 0.56 N.

Question 33 (page 99)

This problem involves two steps. First find the work done by the machine. Then use the work to find the power of the machine.

Step 1: Look at the formula chart on page 8 to find the formula for work.

$$\text{Work} = \text{force} \times \text{distance}$$

You know the force used to lift the crate (490 N) and the distance the crate was moved (6 m). Substitute these values into the formula and solve for work.

$$\begin{aligned}\text{Work} &= \text{force} \times \text{distance}\\ \text{Work} &= 490\text{ N} \times 6\text{ m}\\ &= 2940\text{ Nm}\\ &= 2940\text{ J}\end{aligned}$$

The machine did 2940 joules of work.

Step 2: Look at the formula chart on page 8 to find the formula for power.

$$\text{Power} = \frac{\text{work}}{\text{time}}$$

You know the work done to lift the crate (2940 J) and the time needed to move the crate (3.5 s). Substitute these values into the formula and solve for power.

$$\begin{aligned}\text{Power} &= \frac{\text{work}}{\text{time}}\\ \text{Power} &= \frac{2940\text{ J}}{3.5\text{ s}}\\ &= \frac{840\text{ J}}{\text{s}}\\ &= 840\text{ W}\end{aligned}$$

The machine used 840 watts to lift the crate.

	8	4	0	.			
⓪	⓪	⓪	●		⓪	⓪	⓪
①	①	①	①		①	①	①
②	②	②	②		②	②	②
③	③	③	③		③	③	③
④	④	●	④		④	④	④
⑤	⑤	⑤	⑤		⑤	⑤	⑤
⑥	⑥	⑥	⑥		⑥	⑥	⑥
⑦	⑦	⑦	⑦		⑦	⑦	⑦
⑧	●	⑧	⑧		⑧	⑧	⑧
⑨	⑨	⑨	⑨		⑨	⑨	⑨

If you added a zero after the decimal or before the 8, the answer would still be correct.

Question 34 (page 100)

C Correct. The kinetic energy of the stone at the end of its fall will equal its gravitational potential energy at the beginning of its fall.

Step 1: Look at the formula chart on page 8 to find the formula for gravitational potential energy (*GPE*).

$$GPE = \text{mass} \times \text{acceleration due to gravity} \times \text{height}$$

The mass of the stone is 5.0 kilograms, and its height at the beginning of its fall is 20 meters. The constants/conversions chart lists the acceleration due to gravity as 9.8 m/s^2.

Step 2: Substitute the values you know into the formula and solve for gravitational potential energy.

$$GPE = \text{mass} \times \text{acceleration due to gravity} \times \text{height}$$

$$\begin{aligned}GPE &= 5.0\text{ kg} \times 9.8\text{ m/s}^2 \times 20\text{ m}\\ &= 49\text{ kgm/s}^2 \times 20\text{ m}\\ &= 49\text{ N} \times 20\text{ m}\\ &= 980\text{ Nm}\\ &= 980\text{ J}\end{aligned}$$

The stone's gravitational potential energy at the beginning of the fall is 980 joules. By the end of the fall, this potential energy will have changed to 980 joules of kinetic energy.

Question 35 (page 100)

A Incorrect. Rechargeable batteries usually cost more than disposable batteries when first purchased. The use of rechargeable batteries requires the purchase of a recharging device as well.

B Incorrect. Batteries of the same voltage will produce the same amount of current regardless of whether the batteries are rechargeable or disposable.

C Correct. Disposable batteries must be thrown away once they are dead. They often end up in landfills, and the metals they contain can pollute the environment. Because rechargeable batteries do not need to be replaced as often, fewer rechargeable batteries end up in landfills.

D Incorrect. Both disposable and rechargeable batteries convert chemical energy directly to electrical energy.

Cluster 1

Question 36 (page 103)

A Incorrect. The effort force and the output force act in the same direction. Both are upward forces.

B Correct. When the arm bends, the point at which the biceps meets the forearm moves only a short distance, but the hand and the ball move a much larger distance.

C Incorrect. If the output force were less than the ball's weight, the person would not be able to lift the ball, and the ball would not move.

D Incorrect. For this lever, it is not possible for the output force to be greater than the effort force because of the law of conservation of energy.

Question 37 (page 103)

A Correct. A muscle can pull a bone in only one direction. When the biceps contracts, it pulls on the forearm, and the arm bends at the elbow. To straighten the arm, a different muscle must contract. This muscle is the triceps. When the triceps contracts and the biceps relaxes, the arm straightens.

B Incorrect. A fulcrum is a fixed point on which a lever turns. The elbow joint acts as a fulcrum when the biceps or triceps exerts an effort force to bend or straighten the arm.

C Incorrect. If both the biceps and triceps worked to bend the arm at the elbow, there would be no way to straighten the arm. Skeletal muscles are often found in pairs: one muscle bends a joint, and the other straightens it.

D Incorrect. Muscles are attached to bones by tendons.

Question 38 (page 103)

A Incorrect. All living things, including insects and their muscles, are composed of cells.

B Correct. Insects do not have an internal skeleton made of bones. Instead, they have an exoskeleton. Insect muscles are attached to their exoskeleton.

C Incorrect. Insects are animals, and animal tissues are dependent on glucose as an energy source. During cellular respiration, glucose is broken down through a series of chemical reactions to release energy.

D Incorrect. Human muscles and insect muscles have the same general functions. One of these functions is body movement.

Question 39 (page 103)

A Incorrect. Animals do not use carbon dioxide as an energy source. Carbon dioxide is a waste product of both cellular respiration and fermentation. The energy source for both of these processes is glucose.

B Incorrect. Only producers can make their own food. Carnivores are not producers; they are consumers that eat other animals.

C Incorrect. Fermentation is a less efficient way of obtaining energy from glucose because it produces less energy than cellular respiration does.

D Correct. If the carnivores' muscle cells could no longer obtain energy because of low oxygen, the animals might have to slow down and could lose their prey. However, if their muscle cells could use fermentation to produce energy in this situation, they could continue to run for a short time and would have a better chance of a successful hunt. Natural selection is likely to favor carnivores that are better able to obtain food.

Cluster 2

Question 40 (page 105)

A Incorrect. To answer this question, the students probably would have grown one group of plants in nutrient-rich soil and kept insects (dead or alive) away from the plants. If the plants remained healthy, this evidence would suggest that the plants could obtain nutrients from the soil and were not dependent on insects as a nutrient source.

B Correct. The only difference between the two groups of plants is whether they receive light. If the group kept in the dark did not survive, this evidence would suggest that the plants are dependent on sunlight to make their own food by the process of photosynthesis.

C Incorrect. To answer this question, the students probably would have made observations of pitcher plants in the wild. The students could observe the number and types of insects trapped in the plants' pitchers.

D Incorrect. To answer this question, the students probably would have prevented insects (dead or alive) from falling into the pitchers of one group of plants. If the plants did not survive, this evidence would suggest that pitcher plants are dependent on the nutrients they get from insects.

Question 41 (page 105)

A Incorrect. The bladder is a storage organ for urine (a waste fluid). The fluid in the lower section of a pitcher-plant leaf is not made up of wastes; its purpose is to digest insects.

B Incorrect. The main function of the kidneys is to filter waste from blood. The lower section of a pitcher-plant leaf does not have a similar function.

C Incorrect. The esophagus is used to transport largely undigested food from the mouth to the stomach. The lower section of a pitcher-plant leaf is not used to transport undigested insects.

D Correct. Most digestion in humans occurs in the small intestine, and nutrients are absorbed through its surface. Similarly, the lower section of a pitcher-plant leaf contains an enzyme-rich fluid that digests insects. The insects' nutrients are then absorbed into the plant through the leaf's surface.

Question 42 (page 105)

A Correct. Adding an acid will increase the acidity of the soil. As the acidity of the soil increases, its pH will decrease.

B Incorrect. Potassium hydroxide is a strong base. It produces hydroxide ions in solution. Adding a base will decrease the acidity of the soil. As the acidity of the soil decreases, its pH will increase.

C Incorrect. Ammonia is a weak base. It produces hydroxide ions in solution. Adding a base will decrease the acidity of the soil. As the acidity of the soil decreases, its pH will increase.

D Incorrect. Sodium chloride is a salt. Adding sodium chloride will not change the soil's hydrogen-ion concentration. Therefore, it will not change the soil's acidity or pH.

Science Activity

Going the Distance (page 107)

1. Answers will vary. Sample: 14
2. Answers will vary. Sample: 20 cm
3. Answers will vary. You should have multiplied your answer for Step 1 by your answer for Step 2. Sample: 14 × 20 cm = 280 cm
4. Answers will vary. If your answer to Step 3 was in centimeters, you should have divided it by 100. Sample: 280 cm ÷ 100 = 2.80 m

May the Force Be with You (page 107)

1. Answers will vary. Sample: 140 pounds
2. Answers will vary. You should have divided your answer for Step 1 by 2.2. Sample: 140 pounds ÷ 2.2 = 63.6 kilograms.
3. Answers will vary. You should have multiplied your mass by 9.8 m/s^2. Sample:

$$\begin{aligned} F &= ma \\ &= 63.6 \text{ kg} \times 9.8 \text{ m/s}^2 \\ &= 623.3 \text{ kgm/s}^2 \end{aligned}$$

4. Answers will vary. Sample: 623.3 N

Ready, Set, Go! (page 108)

The amount of work will vary depending on your mass and the height of the stairs. Sample:

$$\begin{aligned} W &= Fd \\ &= 623.3 \text{ N} \times 2.80 \text{ m} \\ &= 1745 \text{ Nm} \\ &= 1745 \text{ J} \end{aligned}$$

Work Faster! (page 109)

$$\text{Power} = \frac{\text{work}}{\text{time}} \qquad P = \frac{W}{t}$$

The power used to walk up the stairs will vary depending on your mass and the height of the stairs. Sample:

$$\begin{aligned} P &= \frac{W}{t} \\ &= \frac{1745 \text{ J}}{15 \text{ s}} \\ &= 116 \text{ J/s} \\ &= 116 \text{ watts} \end{aligned}$$

The power used to run up the stairs will vary depending on your mass and the height of the stairs. Sample: 1745 J ÷ 7 s = 249 watts.

Reaching the Top (page 109)

The change in elevation from the base camp to the summit is 3,454 meters:

8,850 m (summit) − 5,396 m (base camp) = 3,454 m

The amount of work will vary depending on your mass. Sample:

$$\begin{aligned} W &= Fd \\ &= 623.3 \text{ N} \times 3{,}454 \text{ m} \\ &= 2{,}152{,}878 \text{ Nm} \\ &= 2{,}152{,}878 \text{ J} \end{aligned}$$

Sample explanation: To find the amount of work needed to climb from the base camp to the summit, I multiplied my weight in newtons by the change in elevation.

Going Further (page 110)

Add 40 kilograms of gear to your mass in kilograms. Sample: 40 + 63.6 = 103.6 kilograms

Find the force of gravity on this mass. Sample:

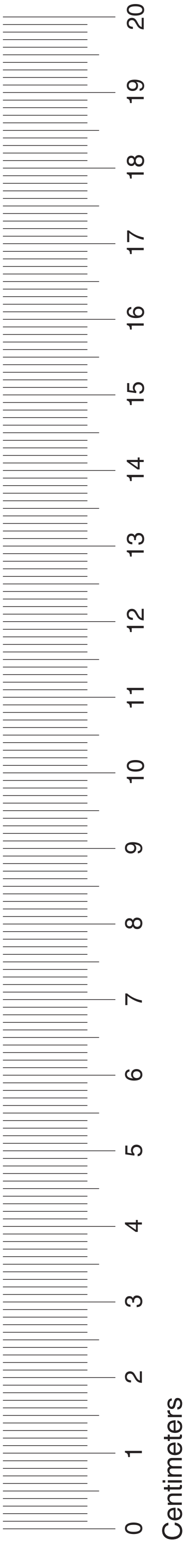
$$\begin{aligned} F &= ma \\ &= 103.6 \text{ kg} \times 9.8 \text{ m/s}^2 \\ &= 1{,}015 \text{ kgm/s}^2 \\ &= 1{,}015 \text{ N} \end{aligned}$$

Find the work needed to move this weight 3,454 meters. Sample:

$$\begin{aligned} W &= Fd \\ &= 1{,}015 \text{ N} \times 3{,}454 \text{ m} \\ &= 3{,}505{,}810 \text{ Nm} \\ &= 3{,}505{,}810 \text{ J} \end{aligned}$$

The change in elevation from Camp I to Camp II is 426 meters, and the change in elevation from Camp III to Camp IV is 457 meters. It requires more work to climb from Camp III to Camp IV because the change in elevation is greater. Climbing faster does not decrease the upward distance or the force of gravity that you must work against, so the amount of work does not change even if you do it faster. However, climbing faster does increase the power you must use because the same amount of work is done in a shorter period of time.

FORMULA CHART
for Grades 10–11 Science Assessment



$\text{Density} = \dfrac{\text{mass}}{\text{volume}}$	$D = \dfrac{m}{v}$
$\left(\begin{matrix}\text{heat gained or}\\ \text{lost by water}\end{matrix}\right) = \left(\text{mass}\right)\left(\begin{matrix}\text{change in}\\ \text{temperature}\end{matrix}\right)\left(\begin{matrix}\text{specific}\\ \text{heat}\end{matrix}\right)$	$Q = (m)(\Delta T)(C_p)$
$\text{Speed} = \dfrac{\text{distance}}{\text{time}}$	$v = \dfrac{d}{t}$
$\text{Acceleration} = \dfrac{\text{final velocity} - \text{initial velocity}}{\text{change in time}}$	$a = \dfrac{v_f - v_i}{\Delta t}$
$\text{Momentum} = \text{mass} \times \text{velocity}$	$p = mv$
$\text{Force} = \text{mass} \times \text{acceleration}$	$F = ma$
$\text{Work} = \text{force} \times \text{distance}$	$W = Fd$
$\text{Power} = \dfrac{\text{work}}{\text{time}}$	$P = \dfrac{W}{t}$
$\%\ \text{efficiency} = \dfrac{\text{work output}}{\text{work input}} \times 100$	$\% = \dfrac{W_O}{W_I} \times 100$
$\text{Kinetic energy} = \dfrac{1}{2}(\text{mass} \times \text{velocity}^2)$	$KE = \dfrac{mv^2}{2}$
$\text{Gravitational potential energy} = \text{mass} \times \text{acceleration due to gravity} \times \text{height}$	$GPE = mgh$
$\text{Energy} = \text{mass} \times (\text{speed of light})^2$	$E = mc^2$
$\text{Velocity of a wave} = \text{frequency} \times \text{wavelength}$	$v = f\lambda$
$\text{Current} = \dfrac{\text{voltage}}{\text{resistance}}$	$I = \dfrac{V}{R}$
$\text{Electrical power} = \text{voltage} \times \text{current}$	$P = VI$
$\text{Electrical energy} = \text{power} \times \text{time}$	$E = Pt$

Constants/Conversions

g = acceleration due to gravity = 9.8 m/s^2

c = speed of light = 3×10^8 m/s

speed of sound = 343 m/s at 20°C

1 cm^3 = 1 mL

1 wave/second = 1 hertz (Hz)

1 calorie (cal) = 4.18 joules

1000 calories (cal) = 1 Calorie (Cal) = 1 kilocalorie (kcal)

newton (N) = kgm/s^2

joule (J) = Nm

watt (W) = J/s = Nm/s

volt (V) ampere (A) ohm (Ω)

Periodic Table of the Elements

Atomic number — 14
Symbol — **Si**
Atomic mass — 28.086
Name — Silicon

	Group 1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIII	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 **H** 1.008 Hydrogen																	2 **He** 4.0026 Helium
2	3 **Li** 6.941 Lithium	4 **Be** 9.012 Beryllium											5 **B** 10.81 Boron	6 **C** 12.011 Carbon	7 **N** 14.007 Nitrogen	8 **O** 15.999 Oxygen	9 **F** 18.998 Fluorine	10 **Ne** 20.179 Neon
3	11 **Na** 22.990 Sodium	12 **Mg** 24.305 Magnesium											13 **Al** 26.982 Aluminum	14 **Si** 28.086 Silicon	15 **P** 30.974 Phosphorus	16 **S** 32.066 Sulfur	17 **Cl** 35.453 Chlorine	18 **Ar** 39.948 Argon
4	19 **K** 39.098 Potassium	20 **Ca** 40.08 Calcium	21 **Sc** 44.956 Scandium	22 **Ti** 47.88 Titanium	23 **V** 50.942 Vanadium	24 **Cr** 51.996 Chromium	25 **Mn** 54.938 Manganese	26 **Fe** 55.847 Iron	27 **Co** 58.933 Cobalt	28 **Ni** 58.69 Nickel	29 **Cu** 63.546 Copper	30 **Zn** 65.39 Zinc	31 **Ga** 69.72 Gallium	32 **Ge** 72.61 Germanium	33 **As** 74.922 Arsenic	34 **Se** 78.96 Selenium	35 **Br** 79.904 Bromine	36 **Kr** 83.80 Krypton
5	37 **Rb** 85.468 Rubidium	38 **Sr** 87.62 Strontium	39 **Y** 88.906 Yttrium	40 **Zr** 91.224 Zirconium	41 **Nb** 92.906 Niobium	42 **Mo** 95.94 Molybdenum	43 **Tc** (98) Technetium	44 **Ru** 101.07 Ruthenium	45 **Rh** 102.906 Rhodium	46 **Pd** 106.42 Palladium	47 **Ag** 107.868 Silver	48 **Cd** 112.41 Cadmium	49 **In** 114.82 Indium	50 **Sn** 118.71 Tin	51 **Sb** 121.763 Antimony	52 **Te** 127.60 Tellurium	53 **I** 126.904 Iodine	54 **Xe** 131.29 Xenon
6	55 **Cs** 132.905 Cesium	56 **Ba** 137.33 Barium	57 **La** 138.906 Lanthanum	72 **Hf** 178.49 Hafnium	73 **Ta** 180.948 Tantalum	74 **W** 183.84 Tungsten	75 **Re** 186.207 Rhenium	76 **Os** 190.23 Osmium	77 **Ir** 192.22 Iridium	78 **Pt** 195.08 Platinum	79 **Au** 196.967 Gold	80 **Hg** 200.59 Mercury	81 **Tl** 204.383 Thallium	82 **Pb** 207.2 Lead	83 **Bi** 208.980 Bismuth	84 **Po** (209) Polonium	85 **At** (210) Astatine	86 **Rn** (222) Radon
7	87 **Fr** (223) Francium	88 **Ra** 226.025 Radium	89 **Ac** 227.028 Actinium	104 **Rf** (261) Rutherfordium	105 **Db** (262) Dubnium	106 **Sg** (263) Seaborgium	107 **Bh** (262) Bohrium	108 **Hs** (265) Hassium	109 **Mt** (266) Meitnerium	110 (269)								

Mass numbers in parentheses are those of the most stable or most common isotope.

Lanthanide Series	58 **Ce** 140.12 Cerium	59 **Pr** 140.908 Praseodymium	60 **Nd** 144.24 Neodymium	61 **Pm** (145) Promethium	62 **Sm** 150.36 Samarium	63 **Eu** 151.97 Europium	64 **Gd** 157.25 Gadolinium	65 **Tb** 158.925 Terbium	66 **Dy** 162.50 Dysprosium	67 **Ho** 164.930 Holmium	68 **Er** 167.26 Erbium	69 **Tm** 168.934 Thulium	70 **Yb** 173.04 Ytterbium	71 **Lu** 174.967 Lutetium
Actinide Series	90 **Th** 232.038 Thorium	91 **Pa** 231.036 Protactinium	92 **U** 238.029 Uranium	93 **Np** 237.048 Neptunium	94 **Pu** (244) Plutonium	95 **Am** (243) Americium	96 **Cm** (247) Curium	97 **Bk** (247) Berkelium	98 **Cf** (251) Californium	99 **Es** (252) Einsteinium	100 **Fm** (257) Fermium	101 **Md** (258) Mendelevium	102 **No** (259) Nobelium	103 **Lr** (262) Lawrencium

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