Florida Review Panel

The Florida Review Panel provided valuable input and feedback on the design, content, and development of *Science in Review: Mastering the FCAT, Grade 11*. Glencoe thanks the members of the panel for their help.

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### Benchmarks Tested on Grade 11 FCAT

**Sunshine State Standards Benchmark**

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<thead>
<tr>
<th>STRAND A: THE NATURE OF MATTER</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SC.A.1.4.1</strong> The student knows that the electron configuration in atoms determines how a substance reacts and how much energy is involved in its reactions. CS; MC, GR</td>
</tr>
</tbody>
</table>
| **SC.A.1.4.2** The student knows that the vast diversity of the properties of materials is primarily due to variations in the forces that hold molecules together. CS; MC  
  *Also covers A.1.4.5* |
| **SC.A.1.4.3** The student knows that a change from one phase of matter to another involves a gain or loss of energy. CS; MC, GR |
| **SC.A.1.4.4** The student experiments and determines that the rates of reaction among atoms and molecules depend on the concentration, pressure, and temperature of the reactants and the presence or absence of catalysts. AA; MC, GR, SR |
| **SC.A.1.4.5** The student knows that connections (bonds) form between substances when outer-shell electrons are either transferred or shared between their atoms, changing the properties of substances. *Covered as A.1.4.2* |
| **SC.A.2.4.1** The student knows that the number and configuration of electrons will equal the number of protons in an electrically neutral atom and when an atom gains or loses electrons, the charge is unbalanced. CS; MC, GR |
| **SC.A.2.4.2** The student knows the difference between an element, a molecule, and a compound. CS; MC |
| **SC.A.2.4.3** The student knows that a number of elements have heavier, unstable nuclei that decay, spontaneously giving off smaller particles and waves that result in a small loss of mass and release a large amount of energy. CS; MC  
  *Also covers A.2.4.4* |
| **SC.A.2.4.4** The student knows that nuclear energy is released when small, light atoms are fused into heavier ones. *Covered as A.2.4.3* |
| **SC.A.2.4.5** The student knows that elements are arranged into groups and families based on similarities in electron structure and that their physical and chemical properties can be predicted. AA; MC |
| **SC.A.2.4.6** The student understands that matter may act as a wave, a particle, or something else entirely different with its own characteristic behavior. CS; MC |

<table>
<thead>
<tr>
<th>STRAND B: ENERGY</th>
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</thead>
</table>
| **SC.B.1.4.1** The student understands how knowledge of energy is fundamental to all the scientific disciplines (e.g., the energy required for biological processes in living organisms and the energy required for the building, erosion, and rebuilding of the Earth). AA; MC, GR, SR  
  *Also covers B.1.4.2* |
| **SC.B.1.4.2** The student understands that there is conservation of mass and energy when matter is transformed. *Covered as B.1.4.1* |
| SC.B.1.4.3 | The student knows that temperature is a measure of the average translational kinetic energy of motion of the molecules in an object. CS; MC, GR |
| SC.B.1.4.4 | The student knows that as electrical charges oscillate, they create time-varying electric and magnetic fields that propagate away from the source as an electromagnetic wave. CS; MC, GR |
| SC.B.1.4.5 | The student knows that each source of energy presents advantages and disadvantages to its use in society (e.g., political and economic implications may determine a society’s selection of renewable or nonrenewable energy sources). Covered as G.2.4.2 |
| SC.B.1.4.6 | The student knows that the first law of thermodynamics relates the transfer of energy to the work done and the heat transferred. Covered as B.1.4.7 |
| SC.B.1.4.7 | The student knows that the total amount of usable energy always decreases, even though the total amount of energy is conserved in any transfer. CS; MC, GR Also covers B.1.4.6 |
| SC.B.2.4.1 | The student knows that the structure of the universe is the result of interactions involving fundamental particles (matter) and basic forces (energy) and that evidence suggests that the universe contains all of the matter and energy that ever existed. CS; MC |

**STRAND C: FORCE AND MOTION**

| SC.C.1.4.1 | The student knows that all motion is relative to whatever frame of reference is chosen and that there is no absolute frame of reference from which to observe all motion. CS; MC, GR |
| SC.C.1.4.2 | The student knows that any change in velocity is an acceleration. CS; MC, GR |
| SC.C.2.4.1 | The student knows that acceleration due to gravitational force is proportional to mass and inversely proportional to the square of the distance between the objects. AA; MC, GR |
| SC.C.2.4.2 | The student knows that electrical forces exist between any two charged objects. Covered as C.2.4.3 |
| SC.C.2.4.3 | The student describes how magnetic force and electrical force are two aspects of a single force. CS; MC Also covers C.2.4.2 |
| SC.C.2.4.4 | The student knows that the forces that hold the nucleus of an atom together are much stronger than electromagnetic force and that this is the reason for the great amount of energy released from the nuclear reactions in the sun and other stars. CS; MC |
| SC.C.2.4.5 | The student knows that most observable forces can be traced to electric forces acting between atoms or molecules. CS; MC |
| SC.C.2.4.6 | The student explains that all forces come in pairs commonly called action and reaction. CS; MC |
### STRAND D: PROCESSES THAT SHAPE THE EARTH

**SC.D.1.4.1** The student knows how climatic patterns on Earth result from an interplay of many factors (Earth’s topography, its rotation on its axis, solar radiation, the transfer of heat energy where the atmosphere interfaces with lands and oceans, and wind and ocean currents). AA; MC, SR

**SC.D.1.4.2** The student knows that the solid crust of Earth consists of slow-moving, separate plates that float on a denser, molten layer of Earth and that these plates interact with each other, changing the Earth’s surface in many ways (e.g., forming mountain ranges and rift valleys, causing earthquake and volcanic activity, and forming undersea mountains that can become ocean islands). AA; MC, SR

**SC.D.1.4.3** The student knows that changes in Earth’s climate, geological activity, and life forms may be traced and compared. CS; MC

**SC.D.1.4.4** The student knows that Earth’s systems and organisms are the result of a long, continuous change over time. Covered as F.2.4.3

### STRAND E: EARTH AND SPACE

**SC.E.1.4.1** The student understands the interconnectedness of the systems on Earth and the quality of life. AA; MC, SR  
Also covers G.2.4.4

**SC.E.1.4.2** The student knows how the characteristics of other planets and satellites are similar to and different from those of the Earth. Covered as E.1.4.1

**SC.E.1.4.3** The student knows the various reasons that Earth is the only planet in our Solar System that appears to be capable of supporting life as we know it. Covered as E.1.4.1

**SC.E.2.4.1** The student knows that the stages in the development of three categories of stars are based on mass: stars that have the approximate mass of our sun, stars that are two-to-three-stellar masses and develop into neutron stars, and stars that are five to-six-stellar masses and develop into black holes. CS; MC

**SC.E.2.4.2** The student identifies the arrangement of bodies found within and outside our galaxy. CS; MC

**SC.E.2.4.3** The student knows astronomical distance and time. CS; MC, GR

**SC.E.2.4.4** The student understands stellar equilibrium. Not Covered

**SC.E.2.4.5** The student knows various scientific theories on how the universe was formed. Not Covered

**SC.E.2.4.6** The student knows the various ways in which scientists collect and generate data about our universe (e.g., X-ray telescopes, computer simulations of gravitational systems, nuclear reactions, space probes, and supercollider simulations). Covered as H.1.4.1
<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC.E.2.4.7</td>
<td>The student knows that mathematical models and computer simulations are used in studying evidence from many sources to form a scientific account of the universe. <em>Covered as H.1.4.1</em></td>
</tr>
</tbody>
</table>

**STRAND F: PROCESSES OF LIFE**

<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC.F.1.4.1</td>
<td>The student knows that the body processes involve specific biochemical reactions governed by biochemical principles. AA; MC, SR <em>Also covers F.1.4.3, F.1.4.5</em></td>
</tr>
<tr>
<td>SC.F.1.4.2</td>
<td>The student knows that body structures are uniquely designed and adapted for their function. <em>Covered as F.2.4.3</em></td>
</tr>
<tr>
<td>SC.F.1.4.3</td>
<td>The student knows that membranes are sites for chemical synthesis and essential energy conversions. <em>Covered as F.1.4.1</em></td>
</tr>
<tr>
<td>SC.F.1.4.4</td>
<td>The student understands that biological systems obey the same laws of conservation as physical systems. CS; MC</td>
</tr>
<tr>
<td>SC.F.1.4.5</td>
<td>The student knows that complex interactions among the different kinds of molecules in the cell cause distinct cycles of activity governed by proteins. <em>Covered as F.1.4.1</em></td>
</tr>
<tr>
<td>SC.F.1.4.6</td>
<td>The student knows that separate parts of the body communicate with each other using electrical and/or chemical signals. <em>Covered as F.1.4.7</em></td>
</tr>
<tr>
<td>SC.F.1.4.7</td>
<td>The student knows that organisms respond to internal and external stimuli. CS; MC <em>Also covers F.1.4.6, F.1.4.8</em></td>
</tr>
<tr>
<td>SC.F.1.4.8</td>
<td>The student knows that cell behavior can be affected by molecules from other parts of the organism or even from other organisms. <em>Covered as F.1.4.7</em></td>
</tr>
<tr>
<td>SC.F.2.4.1</td>
<td>The student understands the mechanisms of asexual and sexual reproduction and knows the different genetic advantages and disadvantages of asexual and sexual reproduction. CS; MC, GR</td>
</tr>
<tr>
<td>SC.F.2.4.2</td>
<td>The student knows that every cell contains a “blueprint” coded in DNA molecules that specify how proteins are assembled to regulate cells. CS; MC</td>
</tr>
<tr>
<td>SC.F.2.4.3</td>
<td>The student understands the mechanisms of change (e.g., mutation and natural selection) that lead to adaptations in a species and their ability to survive naturally in changing conditions and to increase species diversity. AA; MC, SR <em>Also covers D.1.4.4, F.1.4.2</em></td>
</tr>
</tbody>
</table>

**STRAND G: HOW LIVING THINGS INTERACT WITH THEIR ENVIRONMENT**

<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC.G.1.4.1</td>
<td>The student knows of the great diversity and interdependence of living things. AA; MC, SR <em>Also covers G.1.4.2</em></td>
</tr>
<tr>
<td>SC.G.1.4.2</td>
<td>The student understands how the flow of energy through an ecosystem made up of producers, consumers, and decomposers carries out the processes of life and that some energy dissipates as heat and is not recycled. <em>Covered as G.1.4.1</em></td>
</tr>
<tr>
<td>SC.G.1.4.3</td>
<td>The student knows that the chemical elements that make up the molecules of living things are combined and recombined in different ways. CS; MC</td>
</tr>
<tr>
<td>SC.G.2.4.1</td>
<td>The student knows that layers of energy-rich organic materials have been gradually turned into great coal beds and oil pools (fossil fuels) by the pressure of the overlying earth and that humans burn fossil fuels to release the stored energy as heat and carbon dioxide. CS; MC</td>
</tr>
</tbody>
</table>
| SC.G.2.4.2 | The student knows that changes in a component of an ecosystem will have unpredictable effects on the entire system but that the components of the system tend to react in a way that will restore the ecosystem to its original condition. AA; MC, SR, ER  
**Also covers B.1.4.5, G.2.4.5** |
| SC.G.2.4.3 | The student understands how genetic variation of offspring contributes to population control in an environment and that natural selection ensures that those who are best adapted to their surroundings survive to reproduce. CS; MC |
| SC.G.2.4.4 | The student knows that the world ecosystems are shaped by physical factors that limit their productivity. *Covered as D.2.4.1* |
| SC.G.2.4.5 | The student understands that the amount of life any environment can support is limited and that human activities can change the flow of energy and reduce the fertility of the Earth. *Covered as G.2.4.2* |
| SC.G.2.4.6 | The student knows the ways in which humans today are placing their environmental support systems at risk (e.g., rapid human population growth, environmental degradation, and resource depletion). CS; MC |

**STRAND H: THE NATURE OF SCIENCE**

| SC.H.1.4.1 | The student knows that investigations are conducted to explore new phenomena, to check on previous results, to test how well a theory predicts, and to compare different theories. AA; MC, GR, SR, ER  
**Also covers H.1.2.1, H.1.2.2, H.2.4.2, E.2.4.6, E.2.4.7** |
| SC.H.1.4.2 | The student knows that from time to time, major shifts occur in the scientific view of how the world works, but that more often the changes that take place in the body of scientific knowledge are small modifications of prior knowledge. CS; MC  
**Also covers H 1.3.2, H.1.4.3, H.1.4.6** |
| SC.H.1.4.3 | The student understands that no matter how well one theory fits observations, a new theory might fit them as well or better, or might fit a wider range of observations, because in science, the testing, revising, and occasional discarding of theories, new and old, never ends and leads to an increasingly better understanding of how things work in the world, but not to absolute truth. *Covered as H.1.4.2* |
| SC.H.1.4.4 | The student knows that scientists in any one research group tend to see things alike and that therefore scientific teams are expected to seek out the possible sources of bias in the design of their investigations and in their data analysis. CS; MC |
| SC.H.1.4.5 | The student understands that new ideas in science are limited by the context in which they are conceived, are often rejected by the scientific establishment, sometimes spring from unexpected findings, and usually grow slowly from many contributors. CS; MC |
| SC.H.1.4.6 | The student understands that, in the short run, new ideas that do not mesh well with mainstream ideas in science often encounter vigorous criticism and that, in the long run, theories are judged by how they fit with other theories, the range of observations they explain, how well they explain observations, and how effective they are in predicting new findings. *Covered as H.1.4.2* |
| SC.H.1.4.7 | The student understands the importance of a sense of responsibility, a commitment to peer review, truthful reporting of the methods and outcomes of investigations, and making the public aware of the findings. CS; MC |
| SC.H.2.4.1 | The student knows that scientists assume that the universe is a vast system in which basic rules exist that may range from very simple to extremely complex, but that scientists operate on the belief that the rules can be discovered by careful, systemic study. AA; MC |
| SC.H.2.4.2 | The student knows that scientists control conditions in order to obtain evidence, but when that is not possible for practical or ethical reasons, they try to observe a wide range of natural occurrences to discern patterns. *Covered as H.1.4.1* |
| SC.H.3.4.1 | The student knows that performance testing is often conducted using small-scale models, computer simulations, or analogous systems to reduce the chance of system failure. CS; MC |
| SC.H.3.4.2 | The student knows that technological problems often create a demand for new scientific knowledge and that new technologies make it possible for scientists to extend their research in a way that advances science. AA; MC, SR *Also covers H.3.4.5, H.3.4.6* |
| SC.H.3.4.3 | The student knows that scientists can bring information, insights, and analytical skills to matters of public concern and help people understand the possible causes and effects of events. CS; MC |
| SC.H.3.4.4 | The student knows that funds for science research come from federal government agencies, industry, and private foundations and that this funding often influences the areas of discovery. *Not Covered* |
| SC.H.3.4.5 | The student knows that the value of a technology may differ for different people and at different times. *Covered as H.3.4.2* |
| SC.H.3.4.6 | The student knows that scientific knowledge is used by those who engage in design and technology to solve practical problems, taking human values and limitations into account. *Covered as H.3.4.2* |
How to Complete the Response Grids

Science test questions that have the gridded response symbol require you to fill in the grid to the right of the question. Sometimes there is more than one way to complete the response grid. In this section, you will learn the correct ways to complete the grids.

Parts of a Response Grid
Response grids contain the following:

- Answer boxes
- Fraction bar
- Decimal point
- Number bubbles

Directions
1. Read the question, and work the problem. For gridded response questions, your answer will always be a number.
2. Once you have your answer, write it in the answer boxes.
   - Write your answer with the first digit in the left box OR with the last digit in the right box.
   - Use only one digit or symbol in each box. Do NOT leave a blank answer box in the middle of an answer.
   - If your answer is a decimal or fraction, be sure to include the decimal point or the fraction bar in the correct answer box.
3. Under each answer box, fill in the correct bubble for the number you wrote.
   - Fill in one bubble for each answer box. Do NOT fill in a bubble under an unused answer box.
   - Each bubble must be filled in completely.
   - You MUST correctly fill in the bubbles for your answer in order to receive credit.

**Examples**

**Whole Number**

95 – 15 =

Whole Number

95

80

0

1

2

3

4

5

6

7

8

9

0

OR

Whole Number

95

80

0

1

2

3

4

5

6

7

8

9

0


**Decimal**

Show the decimal equivalent of \( \frac{8}{100} \).

Decimal

Show the decimal equivalent of \( \frac{8}{100} \).

Decimal

Show the decimal equivalent of \( \frac{8}{100} \).

Decimal

Show the decimal equivalent of \( \frac{8}{100} \).

Decimal

Show the decimal equivalent of \( \frac{8}{100} \).

Decimal

Show the decimal equivalent of \( \frac{8}{100} \).

Decimal

Show the decimal equivalent of \( \frac{8}{100} \).

Decimal

Show the decimal equivalent of \( \frac{8}{100} \).

Decimal

Show the decimal equivalent of \( \frac{8}{100} \).

Decimal
**Fraction**

NOTE: You cannot give a mixed number as an answer. If you have a mixed number, you must convert your answer to an improper fraction or a decimal number. For example, if you fill in $17\frac{1}{2}$, it would be read as $\frac{171}{2}$. This is not a correct answer, and you will not receive credit.

\[17\frac{1}{2}\] INCORRECT

\[\frac{171}{2}\]

\[17\frac{1}{2}\] CORRECT

\[\frac{35}{2}\]

OR

\[17.5\]

**Decimal or Fraction**

Many answers may be shown as either a decimal or a fraction.
How to Answer "Read, Inquire, Explain" Questions

You can receive full or partial credit for your answers to short response and extended response questions. Even if you do not feel that you can find the complete answer for these types of questions, you should write as much as you can and show all your work. This way, you can receive credit for a portion that is correct.

When you see this symbol next to a question, it signals a short response question. For these types of questions, you should use about 5 minutes to write your answers.

You will receive 2 points for an answer that is completely correct and 1 point for an answer that is partially correct.

When you see this symbol next to a question, it signals an extended response question. The answers for these questions will be longer than those for short response. You will see questions with a Part A and a Part B. You should use about 10–15 minutes to answer extended response questions.

You will receive 4 points for an answer that is completely correct and 1, 2, or 3 points for an answer that is partially correct.

When you see this symbol next to a question, it signals a gridded response question. For this type of question you will need to fill in a grid. There is more than one correct way to record your answer on the grid. You MUST write your numerical answer in the answer boxes and then fill in the correct bubbles for all the digits and symbols.

You will receive 1 point for a correct answer. There are no partial points for incomplete gridded response questions.
# FCAT Science Reference Sheet

## Equations

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceleration ($\bar{a}$)</td>
<td>$\bar{a} = \frac{v_f - v_i}{t_f - t_i}$</td>
</tr>
<tr>
<td>Average speed ($\bar{v}$)</td>
<td>$\bar{v} = \frac{d}{t}$</td>
</tr>
<tr>
<td>Density ($D$)</td>
<td>$D = \frac{m}{V}$</td>
</tr>
<tr>
<td>Percent efficiency ($e$)</td>
<td>$%e = \frac{\text{Work out (J)}}{\text{Work in (J)}} \times 100$</td>
</tr>
<tr>
<td>Force in newtons ($F$)</td>
<td>$F = ma$</td>
</tr>
<tr>
<td>Frequency in hertz ($f$)</td>
<td>$f = \frac{n \text{ of events}}{t}$</td>
</tr>
<tr>
<td>Momentum ($p$)</td>
<td>$p = mv$</td>
</tr>
<tr>
<td>Pressure ($p$)</td>
<td>$p = \frac{F}{A}$</td>
</tr>
<tr>
<td>Wavelength ($\lambda$)</td>
<td>$\lambda = \frac{v}{f}$</td>
</tr>
<tr>
<td>Work ($W$)</td>
<td>$W = Fd$</td>
</tr>
</tbody>
</table>

## Units of Measure

- cm = centimeter
- Hz = hertz
- kg = kilogram
- N = newton
- g = gram
- J = joule (newton-meter)
- m = meter
- s = second
- AU = Astronomical Unit (distance between Earth and the Sun; approximately 150 million km)
Using a Calculator

This is a diagram of a generic calculator and its parts.

**Helpful Hints for Using a Calculator on the FCAT Science Test**

1. Decide if you need a calculator to solve the problem by reading the question very carefully.
2. Always clear your calculator by pressing the clear key before starting a new problem.
3. If you see an **E** in the display, clear the error before you begin.
4. If you see an an **M** in the display, clear the memory before you begin.
5. If you get an answer that does not match an answer choice or seems unreasonable, check your work and re-enter the problem into the calculator.
6. Remember to enter your problem into the calculator using the correct order of operations. The calculator will NOT do this automatically.
7. Take your time using the calculator. Make sure you are pressing the correct keys.
8. Always check your answer and your work before writing or selecting your final answer.
### Periodic Table of the Elements

(based on $^{12}_{6}\text{C} = 12.0000$)

<table>
<thead>
<tr>
<th>Group</th>
<th>Representative Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>H</td>
</tr>
<tr>
<td>2A</td>
<td>Li</td>
</tr>
<tr>
<td>3B</td>
<td>Na</td>
</tr>
<tr>
<td>4B</td>
<td>K</td>
</tr>
<tr>
<td>5B</td>
<td>Sc</td>
</tr>
<tr>
<td>6B</td>
<td>V</td>
</tr>
<tr>
<td>7B</td>
<td>Mn</td>
</tr>
<tr>
<td>8B</td>
<td>Co</td>
</tr>
<tr>
<td>1B</td>
<td>Cu</td>
</tr>
<tr>
<td>18</td>
<td>Ga</td>
</tr>
<tr>
<td>19</td>
<td>As</td>
</tr>
<tr>
<td>20</td>
<td>Br</td>
</tr>
<tr>
<td>24</td>
<td>Rb</td>
</tr>
<tr>
<td>25</td>
<td>Cs</td>
</tr>
<tr>
<td>26</td>
<td>Ba</td>
</tr>
<tr>
<td>27</td>
<td>Ce</td>
</tr>
<tr>
<td>28</td>
<td>Nd</td>
</tr>
<tr>
<td>29</td>
<td>Sm</td>
</tr>
<tr>
<td>30</td>
<td>Gd</td>
</tr>
<tr>
<td>31</td>
<td>Dy</td>
</tr>
<tr>
<td>32</td>
<td>Er</td>
</tr>
<tr>
<td>33</td>
<td>Yb</td>
</tr>
<tr>
<td>34</td>
<td>Hf</td>
</tr>
<tr>
<td>35</td>
<td>W</td>
</tr>
<tr>
<td>36</td>
<td>Os</td>
</tr>
<tr>
<td>37</td>
<td>Pt</td>
</tr>
<tr>
<td>38</td>
<td>Hg</td>
</tr>
<tr>
<td>39</td>
<td>Th</td>
</tr>
<tr>
<td>40</td>
<td>U</td>
</tr>
<tr>
<td>57</td>
<td>Cm</td>
</tr>
<tr>
<td>58</td>
<td>Cf</td>
</tr>
<tr>
<td>59</td>
<td>Am</td>
</tr>
<tr>
<td>60</td>
<td>Cm</td>
</tr>
<tr>
<td>61</td>
<td>Bf</td>
</tr>
<tr>
<td>62</td>
<td>Es</td>
</tr>
<tr>
<td>63</td>
<td>Rf</td>
</tr>
<tr>
<td>64</td>
<td>No</td>
</tr>
<tr>
<td>65</td>
<td>Db</td>
</tr>
<tr>
<td>66</td>
<td>Mt</td>
</tr>
<tr>
<td>67</td>
<td>Ds</td>
</tr>
<tr>
<td>68</td>
<td>Rn</td>
</tr>
<tr>
<td>69</td>
<td>Fr</td>
</tr>
<tr>
<td>70</td>
<td>Rg</td>
</tr>
<tr>
<td>71</td>
<td>Cn</td>
</tr>
</tbody>
</table>

#### Group Numbers
- Group 1: Alkaline Earth Metals
- Group 2: Transition Metals
- Group 13: Alkaline Metals
- Group 14: Carbon Group
- Group 15: Nitrogen Group
- Group 16: Oxygen Group
- Group 17: Halogen Group
- Group 18: Noble Gases

### Elements
- **Helium** (He), **Lithium** (Li), **Boron** (B), **Carbon** (C), **Nitrogen** (N), **Oxygen** (O), **Fluorine** (F), **Neon** (Ne), **Sodium** (Na), **Magnesium** (Mg), **Aluminum** (Al), **Silicon** (Si), **Phosphorus** (P), **Sulfur** (S), **Chlorine** (Cl), **Arsenic** (As), **Potassium** (K), **Calcium** (Ca), **Scandium** (Sc), **Titanium** (Ti), **Vanadium** (V), **Chromium** (Cr), **Manganese** (Mn), **Iron** (Fe), **Cobalt** (Co), **Nickel** (Ni), **Copper** (Cu), **Zinc** (Zn), **Gallium** (Ga), **Germanium** (Ge), **Arsenic** (As), **Selenium** (Se), **Bromine** (Br), **Krypton** (Kr), **Rubidium** (Rb), **Strontium** (Sr), **Yttrium** (Y), **Zirconium** (Zr), **Niobium** (Nb), **Molybdenum** (Mo), **Technetium** (Tc), **Rhenium** (Re), **Osmium** (Os), **Iridium** (Ir), **Platinum** (Pt), **Gold** (Au), **Mercury** (Hg), **Thallium** (Tl), **Lead** (Pb), **Bismuth** (Bi), **Polonium** (Po), **Astatine** (At), **Radon** (Rn), **Francium** (Fr), **Radium** (Ra), **Rutherfordium** (Rf), **Dubnium** (Db), **Seaborgium** (Sg), **Bohrium** (Bh), **Meitnerium** (Mt), **Nihonium** (Nh), **Oganesson** (Og), **Ununnilium** (Uu), **Ununbium** (Uub), **Upuq** (Uup)

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Pretest

1. It once was thought that Earth was the center of the universe and the other planets orbited around it. In the 16th century, Nicolaus Copernicus suggested that the Sun was the center of the universe and the planets, including Earth, orbit around the Sun. Why were Copernicus’s ideas not accepted by many people?
   A. Copernicus was not well respected in his lifetime.
   B. They felt that Copernicus had not done enough testing to prove his ideas.
   C. They thought Copernicus suggested his ideas only to become rich and famous.
   D. Copernicus’s ideas contradicted what the church of that day taught about the universe.

2. Trophic levels show the flow of energy through an ecosystem. Which food chain shows the correct flow of energy through trophic levels?
   F. grass → human → snake → hawk
   G. human → grass → grasshopper → toad → snake → hawk
   H. grasshopper → weed → snake → human → bacteria of decay
   I. grass → grasshopper → toad → snake → hawk → bacteria of decay

3. The process that creates energy in the Sun and other stars is nuclear fusion. Which describes the energy from fusion?
   A. the energy created when nuclei are bombarded by radioactive rays
   B. the energy produced when two or more nuclei combine to form a larger one
   C. the energy created by the breakdown of a large, unstable nucleus into smaller nuclei
   D. the energy created when two or more elements combine explosively into a compound

4. A strong nuclear force holds protons and neutrons together in the atomic nucleus, yet atomic nuclei with too many protons and neutrons are unstable. Which correctly accounts for this?
   F. The electromagnetic force is stronger than the nuclear force.
   G. The weak nuclear force becomes more important for large nuclei.
   H. The range of the strong nuclear force is too small for large nuclei.
   I. The range of the electromagnetic force is too great for large nuclei.
The graph shows a sample of the population of diamondback rattlesnakes and jackrabbits in an Arizona county. For most years, the two populations seem interconnected. However, in 1975, the two populations seem independent. Which is a possible reason for this difference?

A. The snakes no longer wanted to hunt jackrabbits.
B. Snakes migrated from the area to search for easier prey.
C. The rabbits were scarce, so the snakes had nothing to eat.
D. A negative outside factor, like disease, affected only the snake population.

A tsunami is a large wave produced by an underwater earthquake or volcano. The wave can reach a height of 15 m. Oceanographers have developed a system for detecting tsunamis and providing real-time warnings. Which best illustrates the role of scientific research in such efforts?

F. Scientific research poses risks to Earth’s natural balance.
G. Scientific research can lead to technology to help warn people about natural disasters.
H. There has been a decrease in natural disasters because technology helps us control them.
I. Scientific research has helped people living in coastal areas by limiting the number of tsunamis that occur there.
Chaparral is a biome where brushfires frequently occur. Certain species of plants rely on the brushfires for reproduction. The seeds of the plants will not germinate unless they are heated by fire. How did the plants develop this adaptation?

A. Local animals feed on the burned seeds, while the unburned seeds survive.
B. Seeds that germinate before brushfires start are more likely to reproduce.
C. The plants burned by brushfires produce offspring with seeds that look burnt.
D. Plants with traits that allow them to withstand brushfires survive and reproduce.

Of the following, which element has the highest electronegativity?

F. carbon (C)
G. fluorine (F)
H. nitrogen (N)
I. oxygen (O)

Ade did an experiment with pure water. He took a beaker of ice and placed it on a hot plate. Every 2 min he took the temperature and made observations. In minutes, when did the water start turning into a gas?
Venus is approximately 0.7 astronomical units (AU) from the Sun. Mars is 1.5 AU from the Sun. Light from the Sun takes 8.3 min to reach Earth, which is 1 AU from the Sun. How many more minutes will it take light to reach Mars than to reach Venus?

Science seeks to understand how natural events occur. Many natural events can be studied and better understood when scientists use controlled experiments that can be repeated many times. Some natural events, such as earthquakes, cannot readily be studied with controlled experiments.

**Part A** Explain why earthquakes are difficult to study with controlled experiments.

**Part B** Describe how geologists still could study earthquakes and their effects without performing controlled experiments.
This reaction between two amino acids to form a polypeptide, known as peptide-bond formation, is missing one of the products. What is the missing product?

A. ammonia (NH₃)  
B. carbon dioxide (CO₂)  
C. enzyme  
D. water (H₂O)

The table below shows the natural gas consumption of three countries in 2001. Iran, Nigeria, and Russia also burn off large amounts of natural gas that is not used for energy. Which would be a reason for burning off this excess gas?

<table>
<thead>
<tr>
<th>Country</th>
<th>Natural Gas Consumption (billion cubic meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iran</td>
<td>65.59</td>
</tr>
<tr>
<td>Nigeria</td>
<td>7.85</td>
</tr>
<tr>
<td>Russia</td>
<td>408.1</td>
</tr>
</tbody>
</table>

F. These countries have too many nonrenewable resources.  
G. These countries burn off the excess gas to keep prices reasonable.  
H. These countries find it too difficult to transport and export the excess gas.  
I. These countries are trying to switch to renewable resources and need to use the nonrenewable ones quickly.
14. Which explains the concept of entropy?
   A. The amount of usable energy within a system will increase along with the total amount of energy.
   B. The amount of usable energy within a system will decrease along with the total amount of energy.
   C. The amount of usable energy within a system will increase, though the total energy stays the same.
   D. The amount of usable energy within a system will decrease, though the total energy stays the same.

15. Applied research is used specifically to solve a problem noted by a scientist. Which is an example of applied research?
   F. A geologist studies the effects of climate on glacier size.
   G. Chemists discover a new refrigerant through years of researching coolants.
   H. Biologists discover a protozoan in the water supply and run tests to determine if it can harm humans.
   I. Scientists discover an unknown substance as a product in a reaction, so they run tests to find out its properties.

16. Computer models help scientists study many events without risking personal injury. What could not be studied with a computer model?
   A. the location and timing of earthquakes
   B. the strength of materials used for bridges
   C. the effect of masses of cold air on hurricanes
   D. the way birds select mates during breeding season

17. The diagram below shows a section of rings from the trunk of a tree that has been cut down. The number of tree rings can tell you the age of a tree. The thickness of the rings also can provide clues about climate conditions during the tree’s lifetime. Based on the diagram, which correctly explains the reason for the different thickness of the rings?
   F. Cutting down a tree changes the shape of its rings.
   G. The brightness of the Sun changed from year to year.
   H. The tree has become infested with insects since it was cut.
   I. The tree received differing amounts of rainfall from year to year.
Pretest

Covalent molecular compounds exhibit low melting points, low conductivity of electricity, and are soft or brittle in the solid state. These properties are determined by the weak intermolecular forces. Which would exhibit the lowest conductivity of electricity?

A. ammonium chloride (NH₄Cl)
B. methane (CH₄)
C. potassium bromide (KBr)
D. sodium sulfate (Na₂SO₄)

The chemistry of metals and nonmetals in the periodic table is highly predictable. The behavior and properties of the transition metals are not so predictable. What best explains the unpredictable chemistry of the transition metals?

F. Transition metals are radioactive and unstable.
G. Transition metals have a complete outer shell of electrons.
H. The number of electrons in a transition metal cannot be predicted.
I. Transition metals have more complex electronic configurations.

The monarch butterfly looks like the viceroy butterfly in its wing pattern and colors, but they are quite different otherwise. The monarch is distasteful to predatory birds, while the viceroy is not distasteful. It is believed the similarity in coloration is an adaptation. Briefly identify which butterfly has adapted, and describe the adaptation.

____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________

Go on
Pretest

21  A snowboard sits on a snow slope and does not move. Why is the snowboard not moving?
   A. No forces are acting on the snowboard.
   B. The electromagnetic force on the snowboard equals its weight.
   C. The force of friction on the snowboard equals the gravitational force that would pull it down the slope.
   D. The gravitational force of Earth on the snowboard is greater than the force that would pull it down the slope.

22  Locusts have the ability to avoid colliding with other locusts when traveling in huge swarms. Their brains contain sensors that detect when they are on a crash course with another object. How could scientists use this knowledge for humans in everyday life?
   F. The information is not helpful because humans already are capable of avoiding crashes.
   G. They can use locusts to train drivers on how to avoid other cars by practicing on locust swarms.
   H. By studying the locusts’ sensors, they can design sensors that help cars avoid each other to reduce accidents.
   I. Scientists can examine a locust’s brain to determine the location of the sensor and place it in humans to help them avoid crashes.

23  Keisha is creating a research team. The table shows the results of questions she asked of applicants. How can Keisha reduce bias on her research team?

<table>
<thead>
<tr>
<th>Applicants</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you expect a bonus for successful research?</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Have you worked for the company for whom we are doing research?</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Do any family members have ties to the company for whom we are doing research?</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

A. remove applicant 1
B. remove applicant 3
C. remove applicants 1 and 3
D. remove applicants 2 and 4
Mosquitoes commonly are seen as pests because they are annoying and are potential disease carriers. However, all insect species are important parts of their ecosystems.

**Part A** What effects, both positive and negative, can be predicted if mosquitoes were removed from the ecosystem?

**Part B** How might the ecosystem react in order to restore balance?

Maria is testing a plant’s response to environmental stimuli by measuring its root growth. She plants it in a pot and waters it daily on the edges of the pot, away from the plant. She then measures the angle from the horizontal and length of the root growth. Based on her results, what was the plant’s strongest response to the stimuli?

<table>
<thead>
<tr>
<th>Number of days</th>
<th>Root growth (cm)</th>
<th>Angle of root growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>30° angle</td>
</tr>
<tr>
<td>2</td>
<td>2.3</td>
<td>45° angle</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>vertical</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>vertical</td>
</tr>
</tbody>
</table>

F. geotropism  
G. hydrotropism  
H. phototropism  
I. thigmotropism
26. Andrew is observing the changes of state in an ice cube that is heated slowly from \(-10 \, ^\circ\text{C}\) to \(110 \, ^\circ\text{C}\). What happens to the ice cube as it begins to melt and its temperature rises to \(5 \, ^\circ\text{C}\)?
   A. The ice becomes water vapor.
   B. The molecules escape the liquid state and become a gas.
   C. The molecules in the water stay fixed, and the ice is solid.
   D. The ice changes to liquid, and the molecules in the water move faster.

27. Light displays the property of diffraction; it bends slightly around a barrier. Based on this property, how does light behave?
   F. as a wave
   G. as a particle
   H. as a light source
   I. as a wave and a particle

28. In all chemical reactions, energy must be added to reactants to break bonds in atoms. Based on the law of conservation of energy, what must happen when atoms form new bonds in reactions?
   A. Energy must be absorbed again.
   B. Energy is released as thermal energy or light.
   C. More atom bonds must form than were broken.
   D. Fewer atom bonds are formed than were broken.

29. When an object slides across the floor, it is slowed down by friction, and the floor surface gets warmer. What energy conversion process takes place in this situation?
   F. Kinetic energy is converted into thermal energy.
   G. Potential energy is converted into kinetic energy.
   H. Kinetic energy is converted into potential energy.
   I. Potential energy is converted into thermal energy.
Seasonal climate differences are more extreme in some places than in others. Far to our north in Canada, for example, there is a much larger difference between summer temperatures and winter temperatures than in Florida, which is closer to the equator. What are the causes of these seasonal climate differences, and why are they more extreme in some places?

Mercury and Venus are the only planets with no moons. What is one hypothesis that explains this phenomenon?
A. Their gravity is too weak.
B. Venus is the moon of Mercury.
C. The planets are too small to attract moons.
D. The planets are too close to the Sun’s gravity.

Nucleotides in DNA molecules always form the same complementary pairs. Based on the data, which is true?
F. Each nucleotide pairs with an identical nucleotide.
G. A and T, and C and G are complementary pairs.
H. A and G, and C and T are complementary pairs.
I. A and C, and G and T are complementary pairs.

### Analysis of Nucleotides in DNA of Two Plant Species

<table>
<thead>
<tr>
<th>Plant</th>
<th>Percent of DNA Nucleotides</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Cotton</td>
<td>32.8</td>
</tr>
<tr>
<td>Peanut</td>
<td>29.3</td>
</tr>
</tbody>
</table>
The graph below shows the energy sources that produce electricity. Why are nonrenewable fossil fuels used to generate so much of the nation’s electricity?

**A.** They are cheaper to use than alternative sources.
**B.** They are more readily available than alternative sources.
**C.** They are more fuel efficient than alternative sources.
**D.** They are cleaner sources of energy than alternative sources.

Jonathan is standing still watching a train go by at 20.0 m/s. Shelly is inside that train walking at 2.0 m/s toward the front of the train. How many meters per second does Shelly appear to be moving relative to Jonathan?

An electric generator induces a voltage when a coil is rotated in a magnetic field. An electric motor does the opposite—it induces rotation of a coil when a voltage is applied in a magnetic field. Which describes the energy transfer in an electric motor?

**F.** Mechanical energy in gives electrical energy out.
**G.** Mechanical energy in gives chemical energy out.
**H.** Chemical energy in gives mechanical energy out.
**I.** Electrical energy in gives mechanical energy out.
Magnesium (Mg) in solid form will chemically react with oxygen (O₂) gas to form magnesium oxide (MgO). The following balanced equation describes this reaction.

$$2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$$

Explain how raising the temperature of the reactants will speed up the reaction.

Bacteria are some of the smallest yet most important organisms on earth. As decomposers, they play a significant role in cycling nutrients within Earth’s ecosystems. Which is true of bacteria?

A. Bacteria only decompose dead organisms in the soil.
B. Bacteria do not decompose dead organisms in frozen areas.
C. Decomposers like bacteria turn once-living organisms into proteins for use in the food chain.
D. Bacteria decompose organisms into nutrients which are used by other organisms in the food chain.

Scientists wanted to test the effect of disease-causing bacteria (A), vulnerable to heat, on live, harmless bacteria (B). They heated one set of A to inactivate it and kept another set of A activated. Then they mixed both sets of A with an equal amount of B and injected the mixture into healthy white mice. The mice developed disease and died. The scientists studied the mice and found live bacteria of the disease-causing strain. What DNA process occurred with the two bacteria?

F. replication
G. transcription
H. transformation
I. translation
A 25-kg mass falling from a cliff on Mars experiences a force of 92.7 N. What is the free-fall acceleration at the surface of Mars in meters per second squared?

The graph below plots stars according to their luminosity and temperature. You can see that supergiant and giant stars fall above and to the right of the main sequence, and white dwarfs fall below and to the left of the main sequence. Where would you expect to find a star that is just entering the supernova phase?

A. in the main sequence  
B. below and to the left of the main sequence  
C. above and to the right of the main sequence  
D. at the intersection of the x-axis and the y-axis
41 A scientist has discovered a reliable way to predict earthquakes. What step should the scientist take next?
   F. Describe the evidence to other geologists to spread the news faster.
   G. Notify the media about the discovery so they can warn people.
   H. Educate communities in earthquake-prone areas about preparedness.
   I. Report to the scientific community so the results can be retested.

42 Kudzu vine was introduced to the United States in 1876. It was used in the 1930s to help with erosion control. Unfortunately, the climate of the southeast United States is ideal for kudzu, and it has grown out of control. What is one possible reason for the expansive growth of kudzu?
   A. Kudzu is popular, and people planted acres of it.
   B. Kudzu is resistant to all herbicides and cannot be killed.
   C. Kudzu is an endangered species, so an eradication program is not allowed.
   D. Kudzu is not a natural food source for native animals, so it is not threatened.

43 Substances that belong to the carbonyl group are found in living things. It is a functional group having a carbon (C) atom and an oxygen (O) atom joined by a double bond.

        O

            ||

        (C)

What is the term for a substance in the carbonyl group?
   F. compound
   G. hydrocarbon
   H. isotope
   I. mixture

44 A pendulum bob swings back and forth in an arc. Which describes the energy conversion process as the pendulum moves from left to right?
   A. kinetic energy to chemical energy to potential energy
   B. kinetic energy to potential energy back to kinetic energy
   C. potential energy to kinetic energy back to potential energy
   D. potential energy to kinetic energy to electromagnetic energy
There are four seasons each year as Earth orbits the Sun. Which characteristic of the solar system causes this?

- F. the solar winds
- G. the tilt of Earth’s axis
- H. Earth’s orbital rotation
- I. the changing distance from Earth to the Sun

Asexual reproduction is a method of reproduction that does not require sex cells. From the selections below, choose a method that is **not** an example of asexual reproduction.

- A. angiosperms undergoing the process of pollination
- B. a host culture growing in a glass container
- C. a small daughter bud falling from a large mother bud
- D. cells originating from one host and dividing into equal halves

One of the first experiments designed to measure the speed of light recorded the time it took for a person to turn on a light after seeing another light turned on a certain distance away. Scientists calculated the speed of light using the time and distance recorded. However, because light travels so fast, they measured only their reaction time.

The speed of light in air is around 300,000 km/s. How long (in seconds) does it take for light to travel across a 300 km path between the two hills?
The top vector represents Sydney’s initial velocity. Choices A through D represent her final velocity. In which situation did Sydney not accelerate?

A. A
B. B
C. C
D. D

Along the western coast of South America, the oceanic Nazca Plate collides with the continental South American Plate. As this collision occurs, the very dense Nazca Plate is forced beneath the less dense South American Plate.

What type of tectonic boundary is this? Describe the geological features you might expect to see on the South American plate near this boundary.

________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________
The sodium (Na) atom is found in table salt (NaCl) and is necessary for the function of the human body. How many electrons does sodium lose when it forms ionic bonds with other atoms?
Electron Configuration and Stability

**Key Questions:**

1. **How does the arrangement of electrons in the atoms of an element determine how atoms of the element react?**
2. **How does an atom attain a more stable electron configuration?**

Scientists suspect that electrons within an atom’s electron cloud have different amounts of energy. Energy differences are shown by placing the electrons in energy levels. Each electron’s energy level in an atom is shown by an atomic orbital, a three-dimensional region around the atom’s nucleus that describes the electron’s probable location.

Each energy level has several orbitals. Each orbital can hold two electrons. The first energy level has one orbital, called 1s. The second energy level has four orbitals: 2s, 2p_x, 2p_y, and 2p_z. One or two electrons can occupy the first energy level, and up to eight electrons can occupy the second energy level. Table 1 shows the orbital diagrams and electron configurations of the ten elements in the first two periods of the periodic table.

**Table 1**

Orbital Diagrams and Electron Configurations for Elements in the First Two Periods

<table>
<thead>
<tr>
<th>Element</th>
<th>Atomic Number</th>
<th>1s</th>
<th>2s</th>
<th>2p_x</th>
<th>2p_y</th>
<th>2p_z</th>
<th>Electron Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>1</td>
<td>↑</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1s^1</td>
</tr>
<tr>
<td>Helium</td>
<td>2</td>
<td>↑↑</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1s^2</td>
</tr>
<tr>
<td>Lithium</td>
<td>3</td>
<td>↑↑</td>
<td>↑</td>
<td></td>
<td></td>
<td></td>
<td>1s^22s^1</td>
</tr>
<tr>
<td>Beryllium</td>
<td>4</td>
<td>↑↑</td>
<td>↑</td>
<td></td>
<td></td>
<td></td>
<td>1s^22s^2</td>
</tr>
<tr>
<td>Boron</td>
<td>5</td>
<td>↑↑</td>
<td>↑</td>
<td>↑</td>
<td></td>
<td></td>
<td>1s^22s^22p^1</td>
</tr>
<tr>
<td>Carbon</td>
<td>6</td>
<td>↑↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td></td>
<td>1s^22s^22p^2</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>7</td>
<td>↑↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>1s^22s^22p^3</td>
</tr>
<tr>
<td>Oxygen</td>
<td>8</td>
<td>↑↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>1s^22s^22p^4</td>
</tr>
<tr>
<td>Fluorine</td>
<td>9</td>
<td>↑↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>1s^22s^22p^5</td>
</tr>
<tr>
<td>Neon</td>
<td>10</td>
<td>↑↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>1s^22s^22p^6</td>
</tr>
</tbody>
</table>

A filled energy level is more stable than a partially filled energy level. An atom is chemically stable when its outer energy level is complete. The noble gases, which are found in the column at the far right end of the periodic table, are stable because they each have a complete outer energy level.
Consider the stable substance sodium chloride (NaCl), which you know as salt. **Figure 1** shows electron dot diagrams for sodium (Na) and chlorine (Cl). When they combine, sodium loses one electron, and chlorine gains one electron. You can see from the electron dot diagram that chlorine now has a stable outer energy level similar to a noble gas. Sodium, on the other hand, had only one electron in its outer energy level, which it lost to combine with chlorine in sodium chloride. After the reaction, the sodium atom’s outermost energy level is filled with eight electrons. Sodium and chlorine are stable now because of the exchange of an electron.

In general, an atom reacts in one of three ways to attain a more stable electron configuration:

1. **Losing electrons in orbitals related to the atom’s highest energy level.** This occurs until the atom’s electron configuration is the same as the closest noble gas with fewer electrons. A lithium (Li) atom (1s²2s¹) has a single 2s electron. Little ionization energy is required to remove the 2s electron from a lithium atom. As a result, a lithium atom is most likely to react with an atom of another element by losing its 2s electron, forming an ion (Li⁺) with the electron configuration of helium (He):

   \[
   \text{Li} + \text{energy} \rightarrow \text{Li}^+ + 1e^- 
   \]

2. **Sharing electrons to fill orbitals related to the atom’s highest energy level.** The ionization energy required to remove an electron from a carbon (C) atom (1s²2s²2p²) is greater than for lithium. For that reason, carbon atoms are less likely to lose electrons than lithium atoms. Carbon atoms most often react by sharing the four electrons related to their second energy levels (2s²2p²) with electrons of other atoms to attain the noble-gas configuration of neon (Ne).

3. **Gaining electrons to fill orbitals related to the atom’s highest energy level.** The ionization energy required to remove an electron from a fluorine (F) atom (1s²2s²2p⁵) is much greater than for either lithium or carbon. Because the fluorine atom has a high attraction for its electrons, it usually reacts with an atom of another element by gaining one electron to form a fluoride ion (F⁻) with the noble-gas configuration of neon.
1 When reacting with atoms of other elements, sulfur (S) atoms often gain electrons. When a sulfur atom undergoes such a reaction, what ion and noble-gas electron configuration would you expect to result?

A. S⁺⁺, krypton (Kr)  
B. S²⁺, argon (Ar)  
C. S, helium (He)  
D. S²⁻, argon (Ar)

2 Find aluminum (Al) on the periodic table. Aluminum has three electrons in its highest energy level. When aluminum reacts with chlorine (Cl), how many electrons does each aluminum atom lose to attain a stable electron configuration?
Chemical Bonding and Properties of Compounds

Key Questions:

1. What are three types of bonds which hold together molecules?
2. What is the difference between the electron arrangement of ionic bonds and covalent bonds?

Why do chemical compounds have such widely varying chemical and physical properties? Consider, for example, the properties of lithium fluoride (LiF), water (H₂O), and carbon dioxide (CO₂), as shown in Table 1.

Table 1
Properties of LiF, H₂O, and CO₂

<table>
<thead>
<tr>
<th>Formula</th>
<th>Physical State at 0°C</th>
<th>Melting Point at 1 Atm Pressure</th>
<th>Boiling Point at 1 Atm Pressure</th>
<th>Density at 0°C</th>
<th>Type of Bond</th>
<th>Electron-Dot Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>LiF</td>
<td>white, cubic crystals</td>
<td>845°C</td>
<td>1676°C</td>
<td>2.6 g/mL</td>
<td>ionic</td>
<td>Li:F:</td>
</tr>
<tr>
<td>H₂O</td>
<td>colorless liquid</td>
<td>0°C</td>
<td>100°C</td>
<td>1.0 g/mL</td>
<td>polar</td>
<td>:O:</td>
</tr>
<tr>
<td>CO₂</td>
<td>colorless gas</td>
<td>does not exist as a liquid at 1 atm pressure</td>
<td>sublimes at −78.5°C</td>
<td>0.00075 g/mL</td>
<td>covalent</td>
<td>:O:C:O:</td>
</tr>
</tbody>
</table>

The vastly different properties of lithium fluoride, water, and carbon dioxide can be understood best by examining the types of bonding between the atoms that make up the compounds. Compare each elements’ electron-dot structures, shown in Table 2. Recall that valence electrons, also called outer-shell electrons, are shown as dots.

Table 2
Electron-Dot Structures

<table>
<thead>
<tr>
<th>Group</th>
<th>1A</th>
<th>2A</th>
<th>3A</th>
<th>4A</th>
<th>5A</th>
<th>6A</th>
<th>7A</th>
<th>8A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagram</td>
<td>Li·</td>
<td>Be·</td>
<td>B·</td>
<td>C·</td>
<td>N·</td>
<td>O·</td>
<td>F·</td>
<td>Ne·</td>
</tr>
</tbody>
</table>
Refer back to the final column of Table 1, which illustrates the electron-dot structure of the bonded atoms in each molecule. When lithium (Li) and fluorine (F) atoms react to form lithium fluoride, each lithium atom loses its single valence electron to form the lithium ion (Li\(^+\)). Simultaneously, each fluorine atom accepts an electron from lithium to complete an octet, as in neon (Ne). A fluoride ion (F\(^-\)) results. The strong attractions between lithium ions and fluoride ions are called ionic bonds. Ionic bonding produces crystalline solids, which have higher densities than gases and most liquids. Because significant energy is required to overcome the strong bonds holding the ions together, ionic compounds have relatively high melting and boiling points.

The bonding in water is different from the bonding in lithium fluoride. Consider the similarities by noting the location of each element in the periodic table. Lithium atoms and hydrogen (H) atoms have a single one-electron valence orbital. The oxygen (O) atom, with six valence electrons, has room for two more electrons in its valence shell.

In the lithium fluoride molecule, the fluorine atom “transferred” an electron to lithium, and the molecule is held together by the opposite charge on each ion. Water is formed when two hydrogen atoms combine with one oxygen atom by sharing electrons. Electrons shared between two atoms are called covalent bonds. Because the oxygen nucleus has a greater attraction for the shared electrons, they are drawn closer to the oxygen nucleus. This covalent bond is said to be polar because the molecule has two poles: negative at one end and positive at the other end.

A molecule whose bond is polar covalent has an unequal balance of power, as in tug-of-war. In tug-of-war, the stronger team can pull harder on the rope than the weaker team. In polar molecules, electrons are attracted more strongly by one type of atom in the molecule than another. Because of this unequal sharing of electrons, polar molecules have a slightly negative end and a slightly positive end. In the case of water, polar covalent bonding causes the water molecule to have a net polarity, called a dipole. The strong attractions between the dipoles of adjacent water molecules are called hydrogen bonds. Figure 1 shows how these bonds attract each molecule to surrounding molecules.
Each molecule of carbon dioxide also contains two polar covalent bonds. Unlike the two bonds in the water molecule, however, the carbon-oxygen bonds are oriented on opposite sides (180° angles) of the central carbon (C) atom. As a result, the molecule is nonpolar. Attractions between molecules are weak. The carbon dioxide molecules are separated easily, and carbon dioxide has a relatively low boiling point and low density.

1 Several compounds are crystalline solids at room temperature and have high melting and boiling points. What types of bonds likely exist between the particles that make up each compound?
   A. ionic
   B. covalent
   C. hydrogen
   D. polar covalent

2 Compare and contrast the arrangement of electrons in ionic and covalent bonds.
Phase Changes

**Standard SC.A.1.4.3:** The student knows that a change from one phase of matter to another involves a gain or loss of energy.

**Key Question:**

What is involved when matter changes from one state to another?

The three most common states of matter are solids, liquids, and gases. The state of matter of a substance is determined by the motion of its particles and the strength of the attraction between the particles. Particles that move quickly have more kinetic energy than particles that move slowly. Not all the particles in a sample of matter have the same amount of energy. The average kinetic energy of the individual particles in a substance is the temperature of the substance.

**Thermal energy** is the total kinetic energy and potential energy of all the particles in a sample of matter. When a warm object is brought near a cooler object, thermal energy is transferred from the warmer object to the cooler one. The transfer of thermal energy from a substance at a higher temperature to one at a lower temperature is called heat. When a substance is heated, it gains thermal energy. Therefore, its particles move faster, and its temperature rises. When a substance is cooled, it loses thermal energy. Then its particles move more slowly, and its temperature drops. When thermal energy is gained or lost, matter can change from one state to another. **Figure 1** shows the relationship of changing energy levels to the states of water.

---

**The Heating Curve of Water**

![The Heating Curve of Water](image-url)

**Figure 1**
Melting is the process by which the solid state changes to the liquid state. The temperature at which a substance changes from a solid to a liquid is called the melting point. The heat of fusion is the amount of energy required to change 1 kg of a substance from a solid to a liquid at its melting point. Not all substances have the same melting point. Water has a melting point of 0°C.

Freezing is the process by which a liquid changes to a solid. As a liquid cools, the particles move more slowly because they have less kinetic energy. In a solid, the attracting forces are strong enough to hold the particles in an ordered arrangement. Thermal energy is released when a liquid freezes. The heat of fusion is the amount of energy released when a liquid freezes, just as it is the amount of energy absorbed when a substance melts. The temperature of the freezing point is the same temperature as the melting point.

The process by which a liquid changes to a gas is called vaporization. Particles in a liquid stay together because of attractive forces, but as the particles in a liquid move faster, they can overcome attractive forces and spread out. When this happens, the liquid becomes a gas. The temperature of a substance does not change during vaporization, but the substance gains, or absorbs, thermal energy.

The two forms of vaporization are evaporation and boiling. Evaporation occurs when particles at the surface of a liquid leave the liquid and become a gas. For example, when the air is warmer than the water in a rain puddle, the water at the surface of the puddle evaporates.

Unlike evaporation, boiling occurs throughout a liquid. It occurs only at a certain temperature, depending on the pressure at the surface of the liquid. The boiling point of a liquid is the temperature at which the pressure of the vapor in the liquid is equal to the outside pressure acting on its surface. This outside pressure is a force that pushes down on the liquid and keeps the particles from escaping. The heat of vaporization is the amount of energy required for 1 kg of a liquid at its boiling point to become a gas. The boiling point of water is 100°C.

Condensation, the opposite of vaporization, occurs when a substance changes from a gas state to a liquid state. During condensation, thermal energy is released, and water droplets or fog form. The heat of vaporization is the amount of energy released during condensation, just as it is the amount of energy absorbed during the change from a liquid to a gaseous state.

The changing state of water is important to the citrus farmers of Florida and elsewhere. When temperatures fall below 0°C, the liquid in the cells of oranges can freeze and expand. This causes cells to break, making the oranges mushy and the crops useless for sale. To prevent this, farmers spray the oranges with water just as the air temperature reaches 0°C. As the water freezes, it releases thermal energy. Some of this energy flows into the orange, making it warmer. This method is one way to save oranges during hard winters.
1. Which describes the process of the forming of water vapor?
   A. At the heat of vaporization point, absorbed thermal energy changes water from a gaseous state to a solid state.
   B. At the heat of fusion point, released energy changes water from a gaseous state to a solid state.
   C. At the heat of fusion point, released energy changes water from a liquid state to a solid state.
   D. At the heat of vaporization point, absorbed energy changes water from a liquid state to a gaseous state.

2. How can the formation of ice on an orange prevent the orange from freezing?
   F. The thermal energy released by the freezing water can keep the temperature of the orange above freezing.
   G. The thermal energy gained by the freezing water causes the orange to gain thermal energy.
   H. The thermal energy lost by the freezing water causes the orange to lose thermal energy.
   I. The thermal energy gained by the freezing water causes the orange to lose thermal energy.
Rates of Chemical Reactions

Key Questions:

1. What factors influence the rate at which atoms and molecules undergo reactions?
2. How does kinetic theory describe the interaction of atoms and molecules during a chemical reaction?

A match, when struck, bursts into flame, but an iron wheel exposed to the weather might take years to rust. Although both changes are chemical reactions, why does one reaction occur quickly and the other slowly? The following are factors that affect rate of reaction, or the speed at which reactants are consumed and products are produced in a given reaction:

- **concentration** of the reactants, which is the relative amount of a particular substance, solute, or mixture
- **pressure** of the reactants
- **temperature** of the reactants, commonly described in kelvin (K), which is a fundamental SI unit of temperature where 0 K is equal to absolute zero (1 K equals 1°C)
- the presence or absence of catalysts
- **surface area, solubility, and pH**

**Concentration** Kinetic theory states that reactant atoms, ions, and molecules must collide in order to react. The **reactant** is any substance or molecule that participates in a chemical reaction. The **product** is a substance or compound resulting from a chemical reaction. Increasing the concentration of one or more reactants will speed up a reaction, because collisions among reactants occur more during a given time period if there are more reactants moving in a given volume.

**Pressure** When the pressure of a gas increases, the reactants in the gas move closer together and travel more quickly, which means that more collisions will occur among reactants in a given time. Thus higher pressure increases the rate of a reaction in gaseous form. Note the similarity to increased concentration.

**Temperature** also affects the rates of chemical reactions. The following graph shows the same reaction performed at varying temperatures.
**Figure 1** shows that only a small increase in temperature (10 K) is needed to double the reaction rate for this particular reaction. Why? Kinetic theory states that the reactant particles must collide with sufficient energy to form a transitional state called the activated complex, which then forms the products. The crest in the energy diagram shown in Figure 2 represents activation energy, which is the least amount of energy required to start a particular chemical reaction.

**Figure 1** shows that increasing the temperature by 10 K increases the number of molecular collisions with sufficient energy to form the activated complex by a factor of approximately two. This is why such an increase in temperature doubles the rate of reaction.

**Catalysts** A catalyst decreases the activation energy for a reaction. When the activation energy is lowered, a greater percentage of collisions results in the activated complex, so the reaction rate increases. In general, a catalyst is a substance that speeds up or slows down the rate of a reaction without being consumed or altered.

**Surface Area, Solubility, and pH** If surface area increases, reactant particles have more opportunity to collide. If solubility increases, there are more reactant particles which can collide. The pH of a solution can affect the reaction rate, because pH is related to the concentration of hydrogen ions (H\(^+\)), which lower pH, and hydroxide ions (OH\(^-\)), which increase pH. If one of these ions is consumed in the reaction, increasing the number of ions will increase the reaction rate while altering the pH. In general, kinetic theory relates how increasing the number of collisions between reactants, increasing the energy of collisions between reactants, or increasing the number of reactant particles will increase the rate of reaction.

---

1. How does a catalyst increase the rate of a chemical reaction?
   A. by increasing the concentrations of the reactants
   B. by increasing the speed of the molecules
   C. by lowering the energy of the products
   D. by lowering the activation energy

2. For a particular chemical reaction, the rate doubles for each temperature increase of 10 K. At what temperature, in kelvin, is the rate of the reaction eight times what it was at 298 K?

3. Use kinetic theory to explain how increasing temperature can increase the rate of a chemical reaction.
Mastering the FCAT, Grade 11

Atoms, Electrons, and Ions

Key Questions:

1. What types of particle make up an atom, and what is the charge and relative mass of each of these particles?

2. What happens when an atom gains or loses electrons?

An element is matter that is composed of one type of atom. An atom is the smallest piece of matter that still retains the property of the element. Atoms are composed of particles called protons, neutrons, and electrons. Table 1 summarizes the properties of these building blocks from which all atoms are made.

Table 1

<table>
<thead>
<tr>
<th>Particle</th>
<th>Symbol</th>
<th>Location</th>
<th>Relative electrical charge</th>
<th>Relative mass</th>
<th>Actual mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electron</td>
<td>e⁻</td>
<td>In the space surrounding the nucleus</td>
<td>1⁻</td>
<td>( \frac{1}{1840} )</td>
<td>( 9.11 \times 10^{-28} )</td>
</tr>
<tr>
<td>Proton</td>
<td>p⁺</td>
<td>In the nucleus</td>
<td>1⁺</td>
<td>1</td>
<td>( 1.673 \times 10^{-24} )</td>
</tr>
<tr>
<td>Neutron</td>
<td>n⁰</td>
<td>In the nucleus</td>
<td>0</td>
<td>1</td>
<td>( 1.675 \times 10^{-24} )</td>
</tr>
</tbody>
</table>

Figure 1 shows the arrangement of these particles in an atom. The nucleus contains virtually all the atom’s mass but occupies only about one ten-thousandth the volume of the atom. The nucleus is extremely dense and contains two types of particles—protons, which have positive charge, and neutrons, which are neutral, or have zero charge. Outside the nucleus is a “cloud” of fast-moving, negatively charged electrons.

Atomic charge Atoms have a net electric charge of zero. All atoms are electrically neutral, because they contain identical numbers of negatively charged electrons and positively charged protons. For example, an atom of the element carbon (C) contains six protons and six electrons. Six positive charges and six negative charges balance to make a net charge of zero.
**Atomic mass** The atom’s protons and neutrons, found in the nucleus of the atom, contribute to the mass of the atom. The nucleus occupies a very small volume, as shown in Figure 1. The electrons account for nearly all of the atom’s volume by occupying a negatively charged “cloud” around the nucleus.

**Making an ion** If an atom loses or gains electrons, it is called an ion. An ion is a charged particle because it has either more or fewer electrons than protons. The positive and negative charges are not balanced. Figure 2 shows how atoms of sodium (Na) and chlorine (Cl) form ions that combine to make salt (NaCl).

\[ \text{Na}^+ + \text{Cl}^- \rightarrow \text{NaCl} \]

A sodium atom loses an electron to become a sodium ion (Na\(^+\)). At the same time, a chlorine atom gains an electron to become a chloride ion (Cl\(^-\)). An ionic compound, sodium chloride (NaCl), is formed.

**Figure 2**

a. Sodium atom + energy → Sodium ion (Na\(^+\)) + electron

b. Chlorine atom + electron → Chloride ion (Cl\(^-\)) + energy

**Why are atoms electrically neutral?**

A. They contain more neutrons than protons.
B. They contain more electrons than protons.
C. They contain equal numbers of protons and neutrons.
D. They contain equal numbers of protons and electrons.

**How many electrons does an aluminum (Al\(^{3+}\)) ion contain?**
Key Questions:

1. What is the difference between an element and a molecule?
2. What is the difference between a compound and a mixture?

Chemistry is the science of matter. Because of the diversity of matter, chemists categorize substances as elements, molecules, compounds, and mixtures.

All matter is made of atoms, which are the smallest particles of an element that retain the properties of the element. If all the atoms in a substance have the same identity, that substance is an element. An element is a substance that cannot be broken down into simpler substances by physical or chemical means. Consider a diamond, one form of the element carbon (C). Suppose you could grind a pure diamond into smaller and smaller pieces, without limit. The smallest possible piece you could produce that would still be carbon would be a single atom. Elements are categorized in the periodic table of the elements.

The arrangement of electrons surrounding the nucleus of an atom is responsible for the element’s properties. Elements can exist as atoms, as in the case of the noble gases neon (Ne) and argon (Ar). The electron arrangement of some elements causes two atoms of an element to combine and create a molecule, which is a neutral particle that forms as a result of electron sharing, or covalent bonding. A molecule can be made of atoms of the same element or of atoms of different elements. For instance, the elements nitrogen (N) and oxygen (O) naturally exist as the diatomic molecules nitrogen (N₂) and oxygen (O₂).

![Figure 1](image1.png)

Figure 1 These chemical equations show how atoms share electrons to become stable. The electron-dot structures for the molecules show that all atoms in the molecules are stable according to the octet rule.
Two or more elements can combine to form substances called compounds. A **compound** is a substance in which the atoms of two or more elements are combined in a fixed proportion. For example, water (H₂O) is a compound in which two atoms of the element hydrogen (H) combine with one atom of the element oxygen. **Figure 1** shows three reactions where atoms share electrons to form compounds.

Compounds also can be ionic, as in the case of salt, which is known to chemists as sodium chloride (NaCl). Sodium (Na) and chlorine (Cl) atoms react by losing and gaining electrons, to make sodium ions (Na⁺) and chlorine ions (Cl⁻). The opposite charges on these ions attract each other to form an ionic compound, which is made up of positive and negative ions.

**Figure 2** illustrates the fact that the number of each type of atom is the same before and after a reaction occurs, whatever the type of reaction.

Molecules can be made of the same element, an example of which is oxygen, or of different elements, an example of which is water. Molecules made of different elements are called molecular compounds. Compounds must be made of combinations of different elements, as in the case of water or salt.

When elements are joined to form compounds, the atoms lose their individual properties. A compound has new and different properties from its constituent elements. Compounds can be broken down into elements by chemical means, but not by physical means. For example, the compound water can be separated into the elements hydrogen and oxygen by electrolysis, which is a chemical process where an electric current is passed through the water.

Electrolysis results in the following chemical change:

$$2\text{H}_2\text{O}_{(\text{liquid})} \rightarrow 2\text{H}_2\text{O}_{(\text{gas})} + \text{O}_2\text{(gas)}$$

A physical change such as boiling water, on the other hand, does not change the identity of the compound:

$$\text{H}_2\text{O}_{(\text{liquid})} \rightarrow \text{H}_2\text{O}_{(\text{gas})}$$
A mixture is matter that is made by combining two or more different elements or compounds in any proportion by physical means. In a mixture, elements and/or compounds are physically intermingled but are not chemically joined. A mixture can be separated into its components by physical means. Additionally, a mixture often will retain many of the properties of its components. Some examples of mixtures are air, dirt, and salt water.

Suppose a mixture of salt water consists of a cup of water and a teaspoon of salt. The mixture will still be salt water if another teaspoon of salt is added. The water, which is a compound, must have two hydrogen atoms for each oxygen atom, or it will not be water. If another oxygen atom is added to each water molecule, the substance will become hydrogen peroxide \((H_2O_2)\), which is poisonous if swallowed.

1. A compound containing elements A and B has the formula \(A_3B\). If a jar contains 100 molecules of the compound \(A_3B\), how many atoms of type A are in the jar?
   A. 100
   B. 200
   C. 300
   D. 400

2. Why is air a mixture?
   F. Air is a gas.
   G. Air contains only molecules.
   H. The gases in air are physically intermingled.
   I. At extremely cold temperatures, air becomes a liquid.
Nuclear Reactions

Key Questions:
1. What is nuclear radiation?
2. How does nuclear fission produce energy?

When atoms form chemical bonds in substances such as hydrogen dioxide (H\(_2\)O\(_2\)), carbon dioxide (CO\(_2\)), or sodium chloride (NaCl), the electrons of each atom interact. Chemical reactions do not involve atomic nuclei, which contain the atoms’ protons and neutrons. Chemical bonds between atoms involve only electrons.

A nuclear reaction occurs when the nucleus of an atom changes. When two small atomic nuclei combine to form an atom with a nucleus that has a larger mass, energy is released in a process called nuclear fusion. The most common fusion reactions occur in the Sun and other stars, as shown in Figure 1. In this process, four hydrogen (H) nuclei fuse in several steps to form one helium (He) nucleus. The energy released by this reaction reaches Earth in the form of heat and light.

![Figure 1](image)

\[
\begin{array}{c}
\text{H-1} \\
\rightarrow \\
\text{He-3} \\
+ \\
\text{H-2} \\
\rightarrow \\
\text{energy}
\end{array}
\]

Figure 1 The fusion of hydrogen to form helium takes place in several stages in the Sun. One of these stages is shown here. An isotope of helium is produced when a proton and the hydrogen isotope H-2 undergo fusion.

The nuclei of atoms of most elements that you encounter in daily life are stable and unlikely to change. However, the nuclei of some atoms are unstable. All the elements with an atomic number greater than 83 are unstable and decay spontaneously.
When an unstable nucleus decays, the process is called **radioactive decay**. Radioactive decay emits particles and energy called **nuclear radiation**. Three types of nuclear radiation are alpha, beta, and gamma radiation. The properties of each are described in **Table 1**. Alpha and beta radiation are composed of particles, while gamma radiation consists of electromagnetic waves.

**Table 1**

<table>
<thead>
<tr>
<th></th>
<th>Alpha Particles</th>
<th>Beta Particles</th>
<th>Gamma Rays</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Symbol</strong></td>
<td>$^4_2\text{He}$</td>
<td>$^0_{-1}\text{e}$</td>
<td>$\gamma$</td>
</tr>
<tr>
<td><strong>Mass</strong></td>
<td>$4\mu$</td>
<td>$0.0005\mu$</td>
<td>$0$</td>
</tr>
<tr>
<td><strong>Charge</strong></td>
<td>$+2$</td>
<td>$-1$</td>
<td>$0$</td>
</tr>
</tbody>
</table>

An alpha particle consists of two protons and two neutrons, the same as a helium nucleus. When a nucleus decays and emits an alpha particle, it loses two protons and becomes a different element. For example, radium-226 ($^{226}\text{Ra}$) emits an alpha particle and decays into radon-222 ($^{222}\text{Rn}$), as shown in **Figure 2**.

A beta particle is a high energy electron that is emitted from a nucleus when a neutron changes into a proton. When a nucleus decays and emits a beta particle, the charge of the nucleus increases by one, the identity of the element changes, and the mass number remains unchanged. Iodine-131 ($^{131}\text{I}$), for example, emits a beta particle and decays into xenon-131 ($^{131}\text{Xe}$), as shown in **Figure 3**.

Gamma rays are a form of electromagnetic radiation, so they have neither mass nor charge. The emission of a gamma ray does not change the identity of the element, although gamma rays generally accompany either alpha or beta decay of the nucleus.

The process of splitting a nucleus into several smaller nuclei is **nuclear fission**. Only large nuclei, such as the nuclei of uranium and plutonium atoms, can undergo nuclear fission. The total mass of the products is slightly less than the mass of the original nucleus. This small amount of missing mass is converted to a tremendous amount of energy during the fission reaction.
The first reaction that was observed to involve nuclear fission was the fission of uranium-235 ($^{235}\text{U}$). As shown in Figure 4, when a neutron from another nuclear reaction strikes a uranium-235 nucleus, it can cause the nucleus to break apart into smaller nuclei. This reaction yields many possible products, including krypton-91 ($^{91}\text{Kr}$) and barium-142 ($^{142}\text{Ba}$).

![Figure 4](image)

**Figure 4**

Figure 4 illustrates that the fission reaction produces neutrons. Because more neutrons are produced than are absorbed, a fission chain reaction can occur when some of the emitted neutrons start new fission reactions. Nuclear fission chain reactions in nuclear power plants release large amounts of energy, some of which is captured and converted to electricity.

1. A lead-214 ($^{214}\text{Pb}$) atom undergoes radioactive decay and releases a beta particle according to the following equation:

$$^{214}\text{Pb} \rightarrow ^{209}\text{Bi} + ^{0}\text{e} + ^{0}\overline{\text{v}}$$

When the lead-214 atom decays to a bismuth (Bi) atom, what is the total number of protons and neutrons in the bismuth atom?

A. 210 ($^{210}\text{Bi}$)
B. 212 ($^{212}\text{Bi}$)
C. 214 ($^{214}\text{Bi}$)
D. 218 ($^{218}\text{Bi}$)

2. When a radioactive atom emits an alpha particle, how much mass does it lose?

F. 1 amu
G. 2 amu
H. 3 amu
I. 4 amu
The periodic table organizes all known elements by atomic number and by chemical and physical properties. The atomic number of an element is the number of protons in the nucleus of each atom belonging to a given element.

The horizontal rows of the periodic table are called periods. The vertical columns of the table are called groups, or families. Elements in the same vertical column are similar because of the arrangement of electrons in each atom of a given element. The electrons in an atom have different amounts of energy and belong to different energy levels. In general, an electron has more energy the farther it is from its nucleus, and the outermost electron level of an atom is called its valence shell. Elements in a given group have the same number of electrons in the valence shell, so they are said to contain the same number of valence electrons. This similarity in electron arrangement means that the elements in a given group have similar chemical properties.

Figure 1 shows that atoms of all Group 1 elements have one electron in their valence shell, while atoms of all Group 2 elements have two electrons in their valence shell.
For most elements, the valence shell can hold up to eight electrons. An atom is most stable when its valence shell is filled, or when it contains eight electrons. For this reason, elements with seven valence electrons, like those in Group 17, are likely to accept an additional electron to fill the valence orbital. The eight electrons which fill the orbital are called an octet. When an atom accepts an addition electron, it becomes negatively charged.

Similarly, elements with one valence electron, such as those in Group 1, are likely to lose their valence electron. When an atom loses one electron, it takes on a charge of +1 because it has one more positively charged proton than negatively charged electron.

How does electron configuration affect the chemical properties of the elements in a group? An atom is likely to lose or gain electrons so that its valence shell has an octet. In molecules, charges are balanced so the positive and negative charges in a molecule must add to zero. For this reason, Group 1 elements are prone to attach to Group 17 elements, as in lithium fluoride (LiF), potassium bromide (KBr), and sodium iodide (NaI).

Valence electrons also affect the physical properties of elements. Atoms of elements with few valence electrons share electrons in a way that gives the pure elements metallic properties. In general, metallic elements are good conductors of heat and electricity, solids at room temperature, malleable, and ductile. Elements with these properties include titanium (Ti), iron (Fe), and copper (Cu). On most periodic tables, a “staircase” line appears on the right side of the table. Metals are found to the left of the line.

Atoms of the elements to the right of the staircase line (except for the Group 18 elements) share their valence electrons in a way that gives the pure elements nonmetallic properties. For the most part, nonmetallic elements are either gases at room temperature or dull, brittle solids that are poor conductors of heat and electricity. Elements with these properties include carbon (C), oxygen (O), sulfur (S), and chlorine (Cl).

Metalloids border the staircase line and have chemical and physical properties of both metals and nonmetals. Metalloids can conduct electricity better than nonmetals but not as well as metals and sometimes are called semiconductors because of their in-between nature.

Group 18 of the periodic table contains the noble gases. These elements are unreactive and sometimes are called inert gases. These gaseous elements are very stable because their outer energy sublevels are filled. The noble gases are nonflammable. Argon, for example, is used in some fire extinguishers. Helium has a very low density, which is why it commonly is used in toy balloons, as well as in large airships.
Which property is consistent with the location of the element magnesium (Mg), which is in Group 2?

A. malleable  
B. gas at room temperature  
C. poor conductor of electricity  
D. atoms have many valence electrons

Of the following elements, which has the same number of valence electrons as nickel (Ni), which has atomic number 28?

F. gold (Au), atomic number 79  
G. neon (Ne), atomic number 10  
H. copper (Cu), atomic number 29  
I. platinum (Pt), atomic number 78
Behavior of Light and Matter

Key Questions:

1. What are some properties of a particle? A wave?
2. How can light and matter exhibit properties of both waves and particles?

In everyday life, you see some matter behave as a particle and some matter behave as a wave. A particle is an object with a position in space, such as a cup sitting on a kitchen counter or a molecule of water inside the cup. A wave is not as simple to visualize, but you encounter many different kinds of waves every day. For example, radio waves transmit sounds from one point on Earth to another, and ocean waves disturb the water and transfer energy through it. A wave is a repeating disturbance or movement that transfers energy.

Electromagnetic waves are made by vibrating electric charges and can travel through space where matter is not present. Visible light, microwaves, radio waves, and X rays are examples of electromagnetic waves. Water and sound waves propagate through matter by transferring energy from one particle to another. An electromagnetic wave does not require matter to propagate. It is a combined electric and magnetic field that travels through space. Figure 1 shows how a vibrating electric charge creates an electromagnetic wave that travels outward in all directions from the charge. In the figure, the wave is shown only in one direction.

One type of electromagnetic wave is an X ray, which doctors and dentists use to form images of internal organs, bones, and teeth. X rays have a short distance between wave peaks, which means that they have high energy. Because of its high energy, a beam of X rays can damage living tissues. The doctor or dentist gives the patient a lead apron to cover parts of the body that are not being imaged, because the X ray does not have enough energy to penetrate a metal object.

All matter can exhibit properties of both particles and waves. The electron is a particle that can behave like a wave. If a beam of electrons is sprayed at two tiny slits, you might expect the electrons to strike only the area behind the slits, like the spray paint in Figure 2. Instead, experimentalists observe that the electrons form an interference pattern. This type of pattern is produced by waves when they pass through two slits and interfere with each other, as do the water waves in Figure 2.

Likewise, a wave can behave like a particle. In 1921, Albert Einstein won the Nobel Prize in Physics for demonstrating this phenomenon. He showed that an electromagnetic wave can behave as a particle called a photon.
When light shines on metal, electrons can be ejected from the metal. Einstein explained that this happens because the energy of photons is related to the distance between the peak of each wave. The smaller the distance between each wave peak, the higher the energy of the associated photon.

It is convenient to say that an electron is a particle because it can be thought of as an object, and it is convenient to say that light is a wave because it moves through space. In certain situations, however, an electron exhibits wave-like behavior, as illustrated by the experiment shown in Figure 2, and light exhibits particle-like behavior, as illustrated by light ejecting electrons from a metal surface.

1 Photons associated with which electromagnetic wave have the highest energy?
   A. X rays with 0.000000005 m between each wave peak
   B. visible light with 0.0000005 m between each wave peak
   C. a microwave with 0.05 m between each wave peak
   D. a radio wave with 50.0 m between each wave peak

2 Which is not a characteristic of a wave?
   F. It is a repeating movement.
   G. It transfers energy or matter.
   H. It can cause electrons to be ejected.
   I. It cannot travel through empty space.
Energy

**Key Questions:**

1. **What are some of the forms in which energy can exist?**
2. **How do energy levels change if energy always is conserved?**

*Energy* is the ability of an object to produce change in itself or in its surroundings. Every change that occurs—large or small—involves energy. Energy has several different forms, such as electrical, mechanical, chemical, radiant, and thermal. Radiant energy comes from the Sun to grow plants from which we make our food. Our food contains chemical energy, which our bodies digest and use.

Energy can change from one form to another, but the total amount of energy never changes. This principle is recognized as a law of nature. The **law of conservation of energy** states that energy cannot be created or destroyed. A system can lose or gain energy, but the total energy of a system and the system’s surroundings does not change.

In the process of photosynthesis, for example, the Sun provides radiant energy to plants. The plants convert the radiant energy to chemical energy that is stored in molecules of the plants and eventually in other types of organisms when the plant is eaten. If we consider the Sun to be the system, it appears that the system loses energy. That energy, however, has not been destroyed. It simply left the system and now can be found in another system.

The energy for most living organisms comes directly or indirectly from the Sun. The Sun’s energy is transformed and then is used in living systems. The Sun also is the source of energy in Earth’s atmosphere that provides warmth and enables processes such as the water cycle to continue.

Two forms of mechanical energy are kinetic and potential energy. The **kinetic energy** of an object depends on the mass and speed of the object. For this reason, kinetic energy also is called energy of motion.

The complex chemical and physical processes going on in your body also obey the law of conservation of energy. Your body stores energy in the form of fat and other chemical compounds. This chemical potential energy is used to fuel the processes that keep you alive, such as making your heart beat and digesting the food you eat. Your body also converts this energy to heat that is transferred to your surroundings, and you use this energy to make your body move.
Potential energy is energy stored in the position, composition, or structure of an object. In the case of a rock sitting at the top of a cliff, potential energy depends on the rock’s mass, the height of the cliff, and the gravity of the planet. Suppose that the rock falls from the cliff. The total kinetic and potential energy just before it falls and just before it touches the ground is the same. On the cliff, the rock has only potential energy, and its kinetic energy is zero because it is not moving. Halfway down, it has equal kinetic and potential energy. Just before it strikes the ground, all of its potential energy has been converted into kinetic energy.

Figure 1 shows the relationship between kinetic and potential energy in the case of a baseball flying through the air. Note that potential energy is highest when the ball reaches its maximum height, and that kinetic energy is highest when the ball is moving fastest—the moment it is hit and the moment before it lands.

**Figure 1** Kinetic energy and gravitational potential energy are converted into each other as the ball rises and falls.
1. The muscles of a runner transform chemical potential energy into __________
   A. mass energy.
   B. solar energy.
   C. kinetic energy.
   D. electrical energy.

2. The pendulum in the figure below swings back and forth between points A and C. State the law of conservation of energy. Explain how this law can be applied to the pendulum to describe the change in potential and kinetic energy of the ball. (Ignore friction and the mass of the string.)

   Energy v. Position

   Figure 2 The motion of a pendulum demonstrates conservation of mechanical energy.
**Temperature**

**Standard SC.B.1.4.3:** The student knows that temperature is a measure of the average translational kinetic energy of motion of the molecules in an object.

**Key Questions:**

1. **What does temperature measure?**
2. **What are the three most common scales for measuring temperature?**

Kinetic energy is the energy of an object resulting from its motion. A ball, for example, has kinetic energy if it is moving. Even if an object is sitting still, however, its particles always are moving and have an internal kinetic energy. **Figure 1** shows water molecules in their solid state, as ice. Even though a solid ice cube doesn’t look like it is moving, its molecules are vibrating in place.

**Figure 1**

**Temperature** is a measure of the average kinetic energy of the particles in a substance. Because temperature depends on average kinetic energy, it does not depend on the number of atoms in the substance. To understand this, consider two bottles of soda. The first bottle has a mass of 1 kg, and the second bottle has a mass of 2 kg. If the 1-kg bottle of soda is at the same temperature as the 2-kg bottle, the average kinetic energy of the particles in each bottle is the same. However, the 2-kg bottle has twice the mass, and therefore twice the number of particles, of the 1-kg bottle. Thus, the total amount of kinetic energy of the particles in the 2-kg bottle is twice that of the 1-kg bottle. The average kinetic energy is the total kinetic energy divided by the total number of particles. Temperature, therefore, is not dependent on the number of particles in an object and is independent of the mass of the system.
The temperature of an object can change if thermal energy moves into or out of the object. Consider, for example, a hot frying pan and a cold egg. The particles of the frying pan are moving faster and have more kinetic energy than the particles of the egg. If the egg is cracked into the frying pan, particles on the surface of the frying pan will collide with particles on the bottom of the egg. Some energy will be transferred from the more energetic particles of the frying pan to the less energetic particles of the egg. **Heat** is the transfer of thermal energy between two objects in contact with one another. It flows from a hotter object to a colder object. Over time, the average kinetic energy of the particles in the egg will increase, so the temperature of the egg will rise.

Not all particles in an object have the same energy. Some energy is transferred in both directions, but overall there is a net transfer of energy from the warmer to the cooler object. Thermal equilibrium helps explain how a liquid thermometer works. Heat flows between the object being measured and the thermometer. When they are in thermal equilibrium, there is no longer a net transfer of thermal energy; the temperature of the thermometer is the same as that of the object.

Celsius, Kelvin, and Fahrenheit are three common temperature scales, as shown in **Figure 2**. The Celsius scale is based on the normal freezing point of water, defined as 0°C, and the normal boiling point of water, defined as 100°C, both at standard atmospheric pressure.

The Kelvin scale begins at absolute zero, the point at which all particle motion is at a minimum. Absolute zero, 0 K, is approximately –273°C. The SI system defines the Kelvin scale by adding –273.15 to the Celsius temperature. Note that no degree symbol is used with the Kelvin scale.

The Fahrenheit temperature scale commonly is used in thermometers and weather reports in the United States. The Fahrenheit scale places the freezing point of water at 32°F and the boiling point of water at 212°F, making the freezing and boiling points of water 180°F apart.

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**Figure 2**

Mastering the FCAT, Grade 11  55
Use the graph below to answer questions 1 and 2.

The graph above represents the changes in a 20-kg sample of a substance as it is heated at a constant rate of 15 kJ/min. During which two intervals on the graph is the average kinetic energy of the molecules in the sample increasing?

A. AB and CD
B. BC and DE
C. BC and EF
D. DE and EF

According to the graph, at what temperature, in degrees Celsius (°C), does the sample change from a liquid to a gas?
A cellular phone communicates with satellites and telephone towers via electromagnetic waves in the radio frequency range. What makes it possible to generate and communicate via electromagnetic waves?

Electric fields and magnetic fields are closely related. Every charged particle is surrounded by an **electric field**, an area in which another charged particle experiences a force. Magnets are surrounded by a **magnetic field**, an area in which another magnet experiences a force.

A moving charge creates circular magnetic fields in a plane perpendicular to the motion of the charge. For example, electric charge that flows as current in a wire is surrounded by a magnetic field. A changing electric current produces a changing magnetic field. However, a stationary charge is not surrounded by a magnetic field.

Likewise, a changing magnetic field produces a changing electric field; the motion of charged particles relative to a magnetic field produces an electric field. If the electric field is in a wire that is part of a complete circuit, a current will result.

When electric charges vibrate periodically, or oscillate, they produce an **electromagnetic wave**. As the electric field oscillates up and down, it produces a magnetic field that oscillates at right angles to the electric field. Both of the fields are at right angles to the wave direction. **Figure 1** shows a representation of an electromagnetic wave.

---

**Figure 1**

*a.* The diagram above shows what an electromagnetic wave might look like at a given point in time.  *b.* The electric field, magnetic field, and wave velocity all are perpendicular to each other.
Electromagnetic waves can travel through space and matter. The speed of an electromagnetic wave through a vacuum is approximately $3.0 \times 10^8$ m/s, which is the speed of light ($c$). This speed is slightly reduced when traveling through matter because of interactions with particles in the matter. In this case, it is called $v$. The wavelength ($\lambda$), speed ($v$), and frequency ($f$) of electromagnetic waves are related as follows, where $c$ is the speed of light in a vacuum:

$$\lambda = \frac{c}{f} \text{ (in vacuum)} \quad \text{and} \quad \lambda = \frac{v}{f} \text{ (in matter)}$$

If a radio station broadcasts radio waves at 98.6 MHZ $(9.86 \times 10^7$ Hz), it is possible to calculate the wavelength in meters, if we assume that the waves travel at the speed of light $(3.0 \times 10^8$ m/s):

$$\lambda = \frac{3.0 \times 10^8 \text{ m/s}}{9.86 \times 10^7 \text{ Hz}} = 3.04 \text{ m}$$

**Figure 2**, which summarizes the different types of electromagnetic waves, shows that an electromagnetic wave with a wavelength of approximately 3 m is a radio wave. The electromagnetic spectrum consists of radio waves, microwaves, infrared radiation, visible light, ultraviolet light, X rays, and gamma rays, all of which travel at the speed of light in a vacuum.

The energy propagated by an electromagnetic wave depends on its frequency. Waves with higher frequencies have greater energy. If you examine the wavelength-frequency relationship equation, you can see that this implies that waves with shorter wavelengths have greater energies. If an electromagnetic wave has high energy, it could damage living tissues. Radio waves, which have long wavelengths, are not harmful. X rays, on the other hand, have short wavelengths, which could damage a person’s internal organs after repeated exposure. For this reason, technicians who run X-ray equipment wear lead jackets to partially shield their body from repeated exposure.

![Electromagnetic Spectrum Diagram](image-url)
According to Figure 2, which type of electromagnetic wave would you expect to have the greatest energy?

A. red light  
B. violet light  
C. radio waves  
D. gamma waves

A new radio station broadcasts your favorite band at a wavelength of 2.9 m. If the electromagnetic radio wave propagates at $3.0 \times 10^8$ m/s, to what frequency should you tune your radio to hear the broadcast? Answer in three significant digits.
Transfer of Energy

**Key Questions:**
1. What do the first and second laws of thermodynamics tell us?
2. What is the relationship between entropy and usable energy?

You can warm your hands on a cold day by placing them near a fire. Heat is added to your hands by radiation; the heat transferred from the fire increases the thermal energy of your hands.

**Thermal energy** is the sum of the kinetic and potential energy of the particles in an object. While heat radiation is one way to transfer thermal energy, it is not the only possibility. If you do not have a warm fire, and your hands are cold, you can rub your hands together to warm them. When rubbing your hands together, you do work to convert mechanical energy to thermal energy. Your hands become warmer, and their thermal energy and temperature increase, even though there is no heat flowing into them from an outside source. However, not all the work you do by rubbing your hands together warms them. Some heat is transferred into the air surrounding your hands. This means that some energy is lost as heat.

Thermodynamics studies the relationship between thermal energy, heat, and work. The **first law of thermodynamics** states that the increase in thermal energy of a system equals the work done on the system plus the heat transferred to the system. This is a way of describing the law of conservation of energy, which states that energy is neither created nor destroyed, but can be changed from one form into another. If the heat of a system changes, or if work is done on a system, there will be a change in the internal energy of the system. No energy transfer is entirely efficient; some energy is always emitted as heat.

If two objects are touching, heat flows from the warmer object to the cooler one. The **second law of thermodynamics** states that heat always flows spontaneously from warmer areas to cooler areas. Another way of stating this is to say that nature has a tendency to proceed toward a state of greater disorder. **Entropy** is a measure of the disorder and refers to the amount of energy in a physical system that cannot be used to do work. If heat in a system always flows spontaneously from warmer areas to cooler areas, then the entropy in the system increases, and the amount of energy that can be used to do work decreases. In other words, the amount of usable energy in a system decreases spontaneously as the disorder, or entropy, of the system increases.
One way to understand the second law is to consider a container that is divided into two compartments by a partition. The left compartment contains helium (H), and the right compartment is a vacuum. If the partition is removed, the helium will fill both compartments. No matter how long we observe the container, the helium will never collect spontaneously in the left compartment. Before the partition was removed, the gas particles were all in the left compartment. Of course, a gas always can be compressed to get it back into its original chamber. This involves doing work on the gas, which will increase entropy of the universe, so the second law is not violated.

Particles of gas cannot spontaneously arrange themselves in specific ordered patterns. In particular, thermal energy transfers spontaneously from a hotter object or gas to a colder one, as illustrated in Figure 1. The transfer of energy from the colder object to the hotter one cannot be spontaneous because this process would reduce entropy.

**Figure 1** A spontaneous process must obey the first and second laws of thermodynamics.

**Figure 1** also illustrates that when a cold object is placed next to a hot object, the system has the ability to do work by the transfer of thermal energy. After heat flows from the warmer to the cooler object, the energy no longer is in a form that can be used to do work. As the entropy of the system increases, the amount of usable energy decreases, even though the total amount of energy is conserved.
If heat always flows spontaneously from warmer areas into cooler areas, then how do we keep our bodies at a constant temperature? After exercising on a warm day, you might feel hot and sweaty. Your body uses evaporation to keep its internal temperature constant. When a liquid changes to a gas, energy is absorbed from the liquid's surroundings. As you exercise, your body generates sweat from tiny glands within your skin. As the sweat evaporates, it carries away heat, as shown in Figure 2.

As thermal energy moves away from your body, the entropy of the universe increases. While the total amount of energy in the universe remains constant, the usable amount of energy in the universe decreases a tiny bit each time you sweat.

**Figure 2** As perspiration evaporates from your skin, it carries away heat, cooling your body.

Consider ice cubes floating in a glass of water. Which explains why heat flows from the water to the ice and not from the ice to the water?

A. The entropy of the system will decrease.
B. The total heat of the system will increase.
C. The internal energy of the system will increase.
D. The total amount of usable energy will decrease.

What is the term for energy that is transferred from warmer to cooler materials?

F. heat
G. entropy
H. usable energy
I. mechanical energy
Key Questions:

1. What are the four fundamental forces?
2. What are some fundamental particles that make up all matter?

The standard model of physics is a theory that describes four forces which influence the behavior of all matter and energy. These four fundamental forces of nature are the strong nuclear force, the electromagnetic force, the weak nuclear force, and the gravitational force. The two nuclear forces act only on particles in the nuclei of atoms.

The strong nuclear force, which sometimes is called the strong force, is an attractive force that holds the nuclei of atoms together. The strong force is the strongest of the four fundamental forces. It is 100 times more powerful than the second strongest force, the electromagnetic force. Figure 1 shows the strong force operating between particles that are found in the nucleus of an atom.

![Figure 1](image1.png)

**Figure 1** The particles in the nucleus are attracted to each other by the strong force.

The strong force is a short-range force that quickly becomes extremely weak as protons and neutrons get farther apart. Because protons are positively charged, the electromagnetic force repels two protons at the same time that they are attracted by the strong nuclear force. The electromagnetic force is a long-range force, so protons that are far apart still are repelled by the electromagnetic force, as shown in Figure 2.

Electricity and magnetism are caused by the electromagnetic force. Chemical interactions between atoms and molecules also are due to the electromagnetic force. Similarly charged particles are repelled by the electromagnetic force, and oppositely charged particles are attracted. The electromagnetic force is both attractive and repulsive, depending on the interacting particles.

![Figure 2](image2.png)

**Figure 2** The gravitational force between two objects depends on their masses and the distance between them. a. If the mass of either of the objects increases, the gravitational force between them increases. b. If the distance between them decreases, the gravitational force between them increases.
The weak nuclear force is a repulsive force acting in atomic nuclei. Imbalances between the strong and weak nuclear forces are responsible for radioactive decay and fusion reactions, which is how the Sun emits heat and light that provides much of the energy on Earth. A weak decay is the process of decomposing a heavier particle into lighter particles by the weak force. Such decay emits energy in the form of gamma radiation, the source of radioactivity.

The weakest of the four fundamental forces is the gravitational force. Gravity, an attractive force between any two objects, depends on the masses of the objects and the distance between them. Figure 2 shows how the magnitude of the force caused by gravitation changes as the distance and mass of the objects change.

A piece of matter must be very large to exert a noticeable gravitational force on you. This force keeps things on Earth, and it must be overcome to leave the planet. The Sun and Earth exert a gravitational force on each other. This is why Earth continues to circle the Sun; gravity perpetually attracts Earth toward the Sun just enough to maintain Earth’s orbit.

In addition to describing the four fundamental forces of nature, the standard model describes particles that compose all matter. Figure 3 illustrates particles of the standard model.

At the top, Figure 3 shows quarks, which compose protons and neutrons. Every proton and neutron contains three quarks, in a manner such that the sum of the charges of the quarks is +1 for a proton and 0 for a neutron.

In the bottom half of the figure are leptons, which include the electrons that surround the nuclei of atoms. Unlike neutrons and protons, electrons cannot be thought of as compositions of smaller particles, but as fundamental particles in and of themselves.

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**Particles of the Standard Model**

<table>
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<th>Quarks</th>
<th>Symbol</th>
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<tbody>
<tr>
<td>up</td>
<td>u</td>
<td>up</td>
<td>+(\frac{2}{3})e</td>
</tr>
<tr>
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<table>
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<tr>
<td>tau</td>
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</table>

Note: For each particle, there is a corresponding antiparticle with a charge opposite that of its associated particle.

**Figure 3** Quarks and leptons are the building blocks of matter.

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1. What is the fundamental force that holds the nucleus of an aluminum (Al) atom together?
   A. gravitational force
   B. weak nuclear force
   C. strong nuclear force
   D. electromagnetic force

2. What is the net charge on a particle composed of two up quarks (charge +\(\frac{2}{3}\)e) and one down quark (charge +\(\frac{1}{3}\)e)?
Relative Motion

Key Questions:

1. What is the difference between distance and displacement, and between speed and velocity?
2. How can you choose a frame of reference?

Motion is movement from one place to another. A description of motion depends on the point of view of the observer. For example, if you stand on the side of the road and watch a car go by, you would describe the car as moving. However, if you were a passenger in the car, a person standing on the side of the road and the ground outside the car would appear to be moving. To accurately describe motion, you must first specify a frame of reference.

**Distance** describes how far an object is from the origin of your frame of reference. The change in an object’s position, having both magnitude and direction, is its **displacement**. Displacement is a measure of the difference between the object’s final position, \( d_f \), and its initial position, \( d_i \).

\[
\text{Displacement} = d = d_f - d_i
\]

**Figure 1** illustrates the difference between distance and displacement. The runner’s displacement is 20 m north of the starting line, but the total distance traveled is 80 m.

If you think of distance as the change in position, then speed is the rate at which distance is traveled or the rate of change in position.

\[
\text{Speed} = \text{speed} = \frac{\text{distance}}{\text{time}}
\]

The speed of an object is just a number; it does not tell us anything about where the object is going, only how quickly it will get there. **Velocity**, on the other hand, includes the speed of an object and the direction of its motion. Velocity is based on the displacement, rather than the distance, of an object.

\[
\text{Velocity} = \text{velocity} = \frac{\text{displacement}}{\Delta \text{time}}
\]

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Velocity and displacement are both vectors, which specify a direction. Displacement is a vector because it describes the distance traveled by an object and the direction of the motion. Velocity is a vector because it tells us the speed and direction in which an object moves. In order to describe a vector, it must have a reference frame. All reference frames begin with choosing a single point. After a reference point is chosen, a frame of reference can be created. A frame of reference is a coordinate system in which the position of the objects is measured. Figure 2 shows a vector in a reference frame consisting of an x-axis and y-axis. The x-axis and y-axis of the reference frame are drawn so that they intersect at the reference point or origin.

All motion is relative to the frame of reference chosen to describe the motion. Suppose, for example, that you are in a school bus traveling at a velocity of 8 m/s in a positive direction. You walk with a velocity of 3 m/s toward the front of the bus. In the reference frame of the road, your speed is the speed of the bus plus the speed you walk, or 11 m/s. In the reference frame of the bus, your speed is 3 m/s.

Whenever an automobile travels down a road, its motion is along the same path, so we describe its relative motion in one dimension. When astronomers observe the motion of planets, they must consider more dimensions, because each planet does not follow the same path. Furthermore, our reference point on Earth is just one of many possible positions from which to choose a reference frame.

---

1. A cyclist and a jogger are moving toward each other along a straight path. If the cyclist is moving at 12 m/s, and the jogger is moving at 2.0 m/s, what is the speed, in m/s, of the jogger in the cyclist’s frame of reference?

2. An airplane flies due north relative to the Earth, while a passenger on the airplane walks toward the eastern side of the airplane. Relative to the earth, in what direction is the passenger moving?
   A. northeast
   B. northwest
   C. southeast
   D. southwest
Key Questions:
1. **What is the relationship between velocity and acceleration?**
2. **What is the difference between positive and negative acceleration?**

You are sitting in a car at a stoplight when the light turns green. You step on the gas pedal, and the car starts moving faster. Just as speed is the rate of change in position, **acceleration** is the rate of change in velocity. When the velocity of an object changes, the object is accelerating. Acceleration occurs when an object changes its speed, its direction, or both.

When you think of acceleration, you probably think of something speeding up. However, an object that is slowing down also is accelerating.

Imagine a car traveling through a city. If the speed is increasing, the car has positive acceleration. When the car slows down, its speed is decreasing, and the car has negative acceleration. In both cases, the car is accelerating, because its speed is changing.

How is the acceleration of a car speeding up different from that of a car slowing down? **Figure 1** shows both situations.

If the acceleration is in the same direction as the velocity, as in the upper half of **Figure 1**, the speed increases, and the acceleration is positive. If the acceleration is in the direction opposite the velocity, then the car experiences a negative acceleration, as shown in the lower portion of **Figure 1**.

Any time an object changes direction, its velocity changes, and it is accelerating. Think about a horse on a carousel, as shown in **Figure 2**. Although the horse’s speed remains constant, the horse is accelerating, because it is changing direction constantly as it travels in a circular path. In the same way, Earth is accelerating constantly as it orbits the Sun in a nearly circular path.

It is possible to calculate acceleration from a graph of velocity v. time. Why is this the case? When an object’s velocity is constant (it changes neither speed nor direction), it has zero acceleration. However, when an object is changing speed, it has either positive or negative acceleration.
Figure 3 plots the velocity of a car traveling north along a straight road. At the initial and final times shown in the figure, the car has zero velocity, but it speeds up and slows down in between. Between time \( t_0 \) and time \( t_1 \) seconds, designated as 1 in the figure, the velocity is increasing. Thus the vehicle has positive acceleration during time 1. For further consideration of the figure, continue to the first question.

**Figure 3**

1. **Figure 3** shows the velocity of a car traveling in one direction along a straight road. Which portion of the figure shows the car traveling with negative acceleration?
   - A. 1
   - B. 2
   - C. 3
   - D. Graph does not provide enough information.

2. Describe the motion of an object that has an acceleration of 0 m/s\(^2\).

   ______________________________________________________
   ______________________________________________________
   ______________________________________________________
Gravity is one of the four fundamental forces. Gravity is always an attractive force. There is a gravitational force between you and every other object in the universe, but the gravitational force is so weak that it is easy to detect only between masses which are either very close or very massive, such as your body and Earth. Where do the criteria of distance and mass come from? It has been rumored that in 1687 Isaac Newton was sitting under an apple tree when an apple hit him on the head. Between the falling apple and his analysis of planetary motion in the night sky, Newton formulated the law of universal gravitation, which can be written as the following equation:

\[
F = G \frac{m_1 m_2}{d^2}
\]

In this equation, \( G \) is a constant called the universal gravitational constant, and \( d \) is the distance between the two masses, \( m_1 \) and \( m_2 \). The law of universal gravitation enables the force of gravity to be calculated between any two objects if their masses and the distance between them are known. Figure 1 shows objects with various masses and the gravitational forces between them.

In space, planets and stars circle each other because of gravitational force. Less massive astronomical bodies form orbits around more massive bodies, such as the Moon around Earth or Earth around the Sun. Figure 2 illustrates how the Moon is pulled toward Earth because of gravity. If Earth were not attracting the Moon with gravity, the Moon would travel in a straight line through space.

**Key Questions:**

1. **What factors influence the magnitude of the gravitational force between two objects?**
2. **How does gravitational force create gravitational acceleration on Earth’s surface?**

**Law of Universal Gravitation**

Gravitational force = (constant) \( \frac{(mass \ 1) \times (mass \ 2)}{(distance)^2} \)

\[
F = G \frac{m_1 m_2}{d^2}
\]
On Earth, the law of universal gravitation is experienced differently than on the Moon. All objects near Earth’s surface are attracted to Earth with the same acceleration. Remember that acceleration is the rate of change of velocity, which occurs when an object changes speed or direction. In other words, Earth’s gravitational pull exerts a change in speed or direction on an object near Earth’s surface.

In many ways, this idea seems obvious. What happens when you throw a baseball in the air? The Earth exerts a change in the speed and direction of the ball by pulling it back toward the ground. What happens when you jump off a tall diving board into a swimming pool? As you get closer to the water, you fall more and more quickly, because the acceleration of gravity increases your velocity.

What is the relationship between the law of universal gravitation and the force of Earth’s gravity on a falling object? Refer to the equation for universal gravitation. If the mass of Earth and the distance between Earth’s center and surface are inserted for \( m_1 \) and \( d \), respectively, and the universal gravitational constant is calculated, we find an equation for the force of Earth’s gravity.

\[
F = \frac{G \cdot (\text{mass of Earth}) \times m_2}{(\text{radius of earth})^2}
\]

\[
= m_2 \text{ (kg)} \times \text{ acceleration of gravity (m/s}^2)\]

\[
F = mg
\]

\[
F \text{ (N)} = m \text{ (kg)} \times 9.8 \text{ (m/s}^2)\]

The radius of Earth is large compared to the distance between the surface of Earth and the height a baseball is thrown, or even the height at which airplanes fly. For this reason, calculations of the acceleration of gravity on Earth neglect changes in the distance between Earth and the object accelerating toward Earth.

**Figure 2** The Moon would move in a straight line if Earth’s gravity did not pull it toward Earth. This gives the Moon a nearly circular orbit.
As written in the equation box, the acceleration of a falling object near Earth is about 9.8 m/s\(^2\). This acceleration is given the symbol \(g\) and sometimes is called the acceleration of gravity. The simple equation \(F = mg\) allows us to use the acceleration of gravity to calculate the gravitational force on an object on Earth.

For example, the gravitational force on a sky diver with a mass of 60 kg would be calculated in the following way:

\[
F = mg (60 \text{ kg})(9.8 \text{ m/s}^2) = 588 \text{ N}
\]

When you throw a ball, as illustrated in Figure 3, the force exerted by your hand pushes the ball forward. This force gives the ball horizontal motion. When you let go of the ball, gravity pulls it downward, giving it vertical motion. Gravitational acceleration changes the direction of its path from forward to forward and downward.

![Figure 3](image)

**Figure 3** As a ball is thrown in a horizontal motion, gravity pulls down on the ball. The combination of these two motions causes the ball to move in a curved path.

Every mass in the universe experiences gravitational acceleration created by the attractive force to every other mass. Two freight cars, each of mass \(3.0 \times 10^5 \text{ kg}\), are located on adjacent train tracks. Their centers are 9.0 m apart. What gravitational force exists between them?

\[
F = G \frac{m_1 m_2}{d^2} = (6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2) \left( \frac{(3.0 \times 10^5 \text{ kg})(3.0 \times 10^5 \text{ kg})}{(9.0 \text{ m})^2} \right) = 0.074 \text{ N}
\]

Notice that the force of gravity decreases as the distance between the masses squared increases. This is called an inverse square law.
If the distance between two objects is doubled, how does the acceleration due to gravitational force between the objects change?

A. divided by 2  
B. divided by 4  
C. multiplied by 2  
D. multiplied by 4

Suppose Earth’s mass increased but Earth’s diameter didn’t change. How would the acceleration of gravity near Earth’s surface change?
Key Questions:

1. How can the electric force be repulsive and attractive?
2. What is the relationship between the electric force and the magnetic force?

The standard model of physics describes four fundamental forces of nature: the strong nuclear force, the electromagnetic force, the weak nuclear force, and the gravitational force. The electromagnetic force is related to electricity and magnetism, and it governs chemical interactions between atoms and molecules.

The electric force exists between charged particles. Unlike the gravitational force, which is attractive in all situations, the electric force can be either attractive or repulsive. It also can be positive or negative. For instance, protons have a positive charge, and electrons have a negative charge. Figure 1 shows that unlike charges attract each other, and like charges repel each other. The force between electric charges also depends on the distance between charges. The force decreases as the distance between charges increases.

An electric field surrounds every charged particle, exerting the force that attracts or repels other electrically charged particles. We cannot see electric fields, but we see how charged particles behave when placed in an electric field. We draw electric field diagrams, like the ones shown in Figure 2, using arrows to represent how the electric field would make a positively charged particle move. For this reason, electric field lines point toward negatively charged particles and away from positively charged particles.

Figure 1 Positive and negative charges exert forces on each other.

Figure 2 Surrounding every electric charge is an electric field that exerts forces on other electric charges. The arrows point in the direction a positive charge would move.
While an electric field surrounds an electrically charged particle and exerts a force on other particles with electric charges, a **magnetic field** surrounds a magnet and exerts a force on other magnets and objects made of magnetic materials. **Figure 3** illustrates the magnetic field of a bar magnet, which has two poles. For every magnet, one is called the south pole, and the other is called the north pole. As with the electric force, like poles repel each other, and unlike poles attract each other.

A changing electric field produces a magnetic field. Current in a wire, for example, is surrounded by a magnetic field. **Figure 4** shows that the current passing through a long coil wire with many loops creates a magnetic field. Such a wire is called a solenoid. If an electric current flows in the wire, the coil has a field similar to a permanent magnet with north and south poles. An **electromagnet** that is created when current flows through a wire coil is useful because the magnetic field it produces can be controlled by varying the current.

The practical applications of electromagnets are numerous. **Figure 5** illustrates how a loudspeaker uses an electromagnet connected to a moveable cone to produce sound in audio devices. When you turn on the speaker, current flows through the electromagnet, producing a magnetic field that is attracted to or repelled by the field of a permanent magnet. The strength of the electromagnet’s field varies depending on the current. The electromagnet and the cone vibrate in response to the varying force caused by the interaction of the electromagnet and the permanent magnet. These vibrations are transmitted through the air as sound waves.

**Figure 3** A magnet’s magnetic field is represented by magnetic field lines.

**Figure 4** In a solenoid, the magnetic fields from all loops are combined into a single field.

**Figure 5** The electromagnet in a speaker converts electrical energy into mechanical energy to produce sound.
The electric force between two charged objects depends on which of the following?
A. their speeds
B. their masses and their charge
C. their charge and their separation
D. their masses and their separation

When current flows in an electromagnet, a
F. magnetic field of a permanent magnet produces an electric field.
G. changing electric field produces a magnetic field around a wire coil.
H. magnetic field around one coil produces a field around another coil.
I. spinning wire coil produces a magnetic field in a permanent magnet.
**The Four Fundamental Forces**

**Standard SC.C.2.4.4:** The student knows that the forces that hold the nucleus of an atom together are much stronger than electromagnetic force and that this is the reason for the great amount of energy released from the nuclear reactions in the sun and other stars.

**Key Questions:**

1. **How are atomic nuclei held together?**
2. **What forces govern the interaction of matter over a long distance?**

Physicists theorize that four fundamental forces govern the interaction of all matter. These forces can account for interactions between individual particles and the behavior of all matter, so each force is important in its own way. The electromagnetic force and the gravitational force govern the behavior of matter on all scales, such as between electrons in an atom or between distant solar systems. The strong nuclear force and the weak nuclear force govern the behavior of atomic nuclei. **Table 1** compares the strong nuclear force, electric force, and total force in atomic nuclei of two different sizes.

**Table 1**

<table>
<thead>
<tr>
<th>Force</th>
<th>Relative Strength (Compared to Gravitational Force)</th>
<th>Range of Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong nuclear</td>
<td>$10^{38}$</td>
<td>10–15 m</td>
</tr>
<tr>
<td>Electromagnetic</td>
<td>$10^{36}$</td>
<td>unlimited</td>
</tr>
<tr>
<td>Weak nuclear</td>
<td>$10^{31}$</td>
<td>10–17 m</td>
</tr>
<tr>
<td>Gravitational</td>
<td>1</td>
<td>unlimited</td>
</tr>
</tbody>
</table>

The **electromagnetic force** causes electricity and magnetism. This force acts between charged particles, in a manner which is either attractive or repellant. Opposite charges are attracted to each other, as in the case of negatively charged electrons being held to the positively charged nucleus of an atom. Similarly charged particles are repelled. Because the nucleus consists of positively charged protons and neutral neutrons, a repulsive electromagnetic force among the protons might be expected to cause them to fly apart. Because this does not happen, an even stronger attractive force must exist within the nucleus.
While the electromagnetic force can be attractive or repulsive, the **gravitational force** always is attractive, and it is present between any two objects in the universe. We can feel the gravitational pull of Earth on people and objects, because Earth is massive and we are close to it. At the atomic level, however, the gravitational force between particles is negligible. The gravitational force is proportional to the mass of the objects on which it is acting, and sub-atomic particles have very little mass. Thus stronger forces overcome the gravitational attraction between very small particles.

The **strong nuclear force**, which also is called the strong force, is an attractive force that acts between protons and neutrons that are close together in the nucleus of an atom. This force is more than 100 times stronger than the electromagnetic force. While the electromagnetic and gravitational forces can act at any distance, the range of the strong force is very short—only about the radius of a proton, $1.4 \times 10^{-15}$ m. The range of the strong nuclear force relative to an atomic nucleus is illustrated by a white circle in **Table 1**. The strong force holds protons and neutrons together to form atomic nuclei.

Like the strong force, the **weak nuclear force** acts on particles in the atomic nucleus, but it is weaker and has an even more limited range. The weak force is important in certain kinds of radioactive decay in which a nucleus transforms into one or more different nuclei.

**Figure 1a** shows that because a small nucleus has few protons, the repulsive force on a proton due to the other protons is small. **Figure 1b** shows a large nucleus. In large nuclei, only the nearest neighbors experience the attractive strong force, but all the protons exert repulsive electromagnetic forces. The total repulsive force is larger in Figure 1b than in Figure 1a.

The strong force is so powerful that great amounts of energy are released when the force is overcome, which is what happens in the case of nuclear fission or fusion. In nuclear fission, the nucleus divides into two or more fragments, releasing energy. The process of fission is used in nuclear reactors to produce electrical energy. In nuclear fusion, energy is released when nuclei with small masses combine to form a nucleus with a larger mass. The repulsive force between the charged nuclei requires the fusing nuclei to have high energies. Thus, fusion reactions take place only when the nuclei have large amounts of thermal energy, such as that found in the center of the Sun and other stars.
1. Which fundamental force is responsible for binding protons and neutrons in the nucleus of an atom?
   A. electromagnetic
   B. gravitational
   C. strong nuclear
   D. weak nuclear

2. Compare and contrast factors which determine the strength of the electromagnetic and gravitational forces.
Electric Forces

**Standard SC.C.2.4.5:** The student knows that most observable forces can be traced to electric forces acting between atoms or molecules.

**Key Questions:**

1. What are some situations in which electric forces are evident?
2. How does an object become positively or negatively charged?

Electric charge can be positive or negative. Protons have a positive charge, and electrons have a negative charge. An atom is **neutral** because it has the same number of protons and electrons. Any atom with a positive or negative charge is called an ion. If an ion has more protons than electrons, it has a positive charge. If an ion has more electrons than protons, it has a negative charge.

Similarly, objects can be neutral, positively charged, or negatively charged. An object can become charged in different ways. **Charge by conduction** can occur more easily if the electrons are not tightly bound to the atoms that make up a material. One way to charge by conduction is to rub objects together. For example, when wool is rubbed against a rubber surface, electrons transfer from the wool to the rubber, because the electrons are more tightly bound to the rubber molecules than to the wool. The rubber develops an overall negative charge, and the wool develops an overall positive charge.

Suppose you charge a balloon by rubbing it on your shirt, as shown in Figure 1. If you bring the negatively charged balloon near your sleeve, the extra electrons on the balloon repel the electrons in the sleeve. The electrons near the sleeve’s surface move away from the balloon, leaving a positively charged area on the surface of the sleeve. As a result, the negatively charged balloon attracts the positively charged area of the sleeve.

**Charge by induction** is a process that occurs when a charged object is brought near an uncharged object, and electrons move toward the charged object or away from it, causing a separation of charge. The previously uncharged object becomes charged. Figure 2 shows how an object undergoes charge by induction. Notice that the objects do not have to come in contact.

---

**Figure 1** The balloon on the left is neutral. The balloon on the right is negatively charged. It produces a positively charged area on the sleeve by repelling electrons.
Electric charges exert forces on other charges at a distance. The force is repulsive between two like charges and attractive between two different charges. The force is stronger when the charges are closer together. Charges also exert an attractive gravitational force on each other, but the electric force is much stronger.

Electric forces have many everyday applications. One well-known example occurs when you walk across a carpet on a dry day. Your shoes might acquire excess charge from the carpet by conduction. This is an example of static electricity. Your body then has a slight charge. If you move your hand close to a metal door handle, the metal becomes charged by induction. Moisture in the air tends to dissipate the charge before induction occurs. On dry days, however, you might experience a slight shock, caused by static discharge, when your hand approaches the door handle.

You might have noticed another example of static discharge between socks that have tumbled together in a dryer. As the socks rub together, electrons from one sock transfer to the other. This transfer gives the socks opposite charges, causing them to stick together. If you pull apart the socks, they might crackle and even spark because of static discharge.

Lightning is a dramatic example of static charge. Collisions between particles in the air cause charges to transfer. Negative charge collects near the bottom of a cloud, which then causes the nearby ground to develop a positive charge by induction. When the static electricity is great enough, static discharge is seen as a flash of lightning. A similar process causes lightning flashes between clouds.

In some cases, static charge can be helpful. For example, forces between charged particles can be used to collect soot before it is able to leave smokestacks, thereby reducing air pollution. Tiny paint droplets, charged by induction, can be used to paint automobiles and other objects uniformly. Photocopy machines use static electricity to place black toner on a page so that a precise reproduction of the original document is made.
Static charge sometimes can damage objects. Film used in some cameras can be ruined if it attracts dust by static charge. Other electronic devices, such as personal computers, contain components that are easily damaged by static discharges. To prevent damage to these sensitive components during repair, technicians wear conductive straps that conduct charge away from the electronic devices.

1. Elena notices that sometimes socks stick together after tumbling in the dryer. Which force causes the attraction between the socks?
   A. magnetic
   B. electrical
   C. centripetal
   D. gravitational

2. An object becomes positively charged when which occurs?
   F. loses protons
   G. gains neutrons
   H. loses electrons
   I. gains electrons
**Action and Reaction Forces**

**Standard SC.C.2.4.6:** The student explains that all forces come in pairs commonly called action and reaction.

**Key Questions:**

1. What is Newton’s third law of motion?
2. What are some examples of action and reaction forces?

What keeps a kite flying in the air on a windy day? Gravity pulls down on the kite, bringing it back to the ground if the wind is not strong enough. If the wind is sufficient, the large surface area of the kite allows the wind to exert an upward force greater than the force of gravity so there is an upward net force on the kite. This upward net force allows the kite to overcome gravity’s downward pull and fly.

Wind and gravity are not responsible for all the forces on a kite when it is flying in the air. Tension in the string prevents the kite from flying away. This tension is also a force; it pulls the kite toward the string. At the same time, the kite exerts an equal and opposite force on the string. As long as the string holding the kite does not break, these forces are balanced.

These forces are action-reaction pairs described by Newton’s third law of motion, which states that when one object exerts a force on a second object, the second one exerts a force on the first that is equal in strength and opposite in direction. Another way to say this is “to every action force there is an equal and opposite reaction force.”

Consider a wood block sitting on a table, as shown in Figure 1. The weight of the block on the table is in the downward direction. There is also an upward force, called the normal force, which the table exerts on the block. Because these two forces are equal, the block is at rest. Similarly, the table exerts a force on the ground beneath it, and the ground exerts a normal force upward on the table.

![Figure 1](image_url)
Circular motion provides another example of action and reaction forces. Consider the orbit of the Moon around Earth.

The centripetal and centrifugal forces are an interaction pair of forces. Newton’s first law states that an object moving at a constant velocity keeps moving at that velocity unless an unbalanced net force acts on it. Remember that velocity is a measure of speed and direction. The first law might suggest that the Moon has a tendency to continue moving in a straight line. A centripetal force causes an object to move in a circular path. For the Moon, gravity is the centripetal force. According to Newton’s third law, there must be an equal force pointing away from the center of the circle. This “force” is centrifugal, referring to motion away from the center of the circle. It is considered an apparent force because it does not exert a true push on an object.

Rockets use the action-reaction principle to move in the vacuum of outer space. In the rocket engine, burning fuel produces hot gases. The rocket engine exerts a force on these gases and causes them to escape out the back of the rocket. Based on Newton’s third law, the gases exert a force on the rocket and push it forward.

The person shown below is pushing against the couch with force of 50 Newtons.

What is the force of the couch against the man if the couch does not move?
A. 0 Newtons
B. less than 50 Newtons
C. exactly 50 Newtons
D. more than 50 Newtons

When an object moves in a circular path, the net force is called a ________
F. frictional force.
G. centripetal force.
H. centrifugal force.
I. gravitational force.
Climate is the pattern of long-term weather conditions found in an area. Climates differ from place to place as the result of many factors, such as the amount of solar radiation an area receives. Other factors relate to the topography of a location in addition to the winds that occur in the area and nearby large bodies of water.

**Solar Radiation** The amount of solar radiation an area receives largely depends on latitude. Because Earth is a sphere, the rays of the Sun strike different parts of the planet at different angles. Figure 1 illustrates climate zones according to latitude. The tropics—areas just north and south of the equator—receive the most intense solar radiation. The rays of the Sun strike the tropics at nearly 90° angles. Areas north and south of the tropics are the temperate climate zones. These climate zones are cooler than the tropics, because the rays of the Sun strike these areas at lower angles than they do in the tropics. A lower angle means that the energy from the Sun is distributed over a larger area of land. In the polar regions, the rays strike Earth at an even lower angle, which spreads out the energy even more. As a result, polar regions have extremely cold climates.

Short-term seasonal changes in climate relate to the change in the amount of solar radiation an area receives. The change in the amount of solar radiation is caused by the tilt of Earth on its axis and the elliptical path Earth follows as it revolves around the Sun, as shown in Figure 2. Tropical areas do not have as much seasonal temperature change as areas near the middle latitudes.
Topography Another factor that influences climate is topography. Topography is the changing elevation of a place and describes the surface of Earth. For example, mountain regions usually have cooler climates than lower areas. This is because the temperature in the lower atmosphere of Earth generally decreases with altitude. Mountains also affect the climates on either side of them. As air rises along one side of a mountain, it cools, condenses, and eventually drops its moisture. This makes the climate on the windward side of the mountain wet and cool. On the opposite side of the mountain, called the leeward side, the air is warm and dry, resulting in a desert climate.

Prevailing Winds Wind is largely a function of air masses and air pressure. An air mass is a unit of air throughout which heat and moisture are distributed evenly. Air pressure is a measure of the weight of air of a given area. Air pressure is stronger in hot, humid air. When there is a difference between the temperature, humidity, and air pressure in nearby air masses, winds form. The rotation of Earth on its axis causes winds to move in circles and swirls. In the northern hemisphere, the winds blow counterclockwise around low pressure areas and clockwise around high pressure areas. In the southern hemisphere, the directions reverse. Winds that generally blow in the same direction over time are called prevailing winds.

Three large-scale wind systems help balance the heat energy on Earth and produce the three major climate zones shown in Figure 1. The trade winds blow in the tropics and move warm air toward the temperate climate zones. The polar easterlies blow through the polar climate zones and move cold air from the poles toward the temperate climate zones. The prevailing westerlies lie between the trade winds and the polar easterlies.

Large Bodies of Water Nearness to a large body of water also affects the climate of an area. Water heats and cools more slowly than land. Thus, many coastal regions are warmer in the winter and cooler in the summer than inland areas at similar latitudes. The moving waters of ocean currents also affect coastal climates. Surface currents develop in the upper few hundred meters of the water. Currents on the west coast of continents usually are cold, but currents on eastern coasts are warm. West-coast currents begin near the poles, where the waters are colder and flow toward the equator. East-coast currents originate near the equator, where the water is warmer, and flow northward. Ocean surface currents are driven by winds that develop partly from the transfer of heat and moisture from the warm water to the atmosphere.

The Gulf Stream The ocean current that affects the climate of Florida is the Gulf Stream, a warm-water current that originates near the equator. A small-scale wind system called the Bermuda High helps move the Gulf Stream. The Bermuda High is a mass of air located near the islands of Bermuda, which are northeast of Florida. The temperature and the amount of moisture in the air mass are fairly high. Because the winds coming from the Bermuda High move in a clockwise, circular pattern, the western side of this wind system moves the Gulf Stream northward along Florida and the eastern coast of the United States.
Which pair of factors accounts for the differences in the amount of solar radiation from one area to another?
A. prevailing winds and mountain areas
B. prevailing winds and ocean currents
C. prevailing winds and the tilt of Earth on its axis
D. the tilt of Earth on its axis and the path Earth follows as it revolves around the Sun

Which pair of factors contributes to the tropical-like climate of southern Florida?
F. latitude and the Gulf Stream
G. polar easterlies and the tilt of Earth on its axis
H. latitude and the level elevation of Florida
I. the Gulf Stream and the level elevation of Florida

Refer to Figures 1 and 2. Why is it hotter in the northern hemisphere temperate zone in the summer than it is in the winter?
A. Earth is closer to the Sun in the summer than it is in the winter.
B. The rays of the Sun strike at higher angles in the summer than in the winter.
C. The rays of the Sun strike at lower angles in the summer than in the winter.
D. The south pole tilts away from the Sun during summer in the southern hemisphere.
**Theory of Plate Tectonics**

**Standard SC.D.1.4.2:** The student knows that the solid crust of Earth consists of slow-moving, separate plates that float on a denser, molten layer of Earth and that these plates interact with each other, changing the Earth’s surface in many ways (e.g., forming mountain ranges and rift valleys, causing earthquake and volcanic activity, and forming undersea mountains that can become ocean islands).

**Key Questions:**

1. What is involved in the interaction of tectonic plates?
2. How does plate movement change the surface of Earth?

Earth is a dynamic planet. Scientists theorize that the surface of Earth is broken into moving slabs of rock called plates. As the plates move, they interact, resulting in many of Earth’s surface features. This plate movement and resulting features are referred to as **tectonics**. The tectonics on Earth relate to the makeup of the interior of Earth.

**Interior of Earth** Scientists have produced a model of the interior of Earth based on evidence from earthquake waves and exposed rock. The model shows that the interior of Earth has at least four distinct layers—the inner core, the outer core, the mantle, and the crust. The diagram in **Figure 1** shows the arrangement of these layers. The inner core is solid and probably 100 percent iron. The outer core lies above the inner core and is thought to be composed mostly of molten metal (a liquid). The layer above the outer core is the mantle, which is divided into a lower mantle and an upper mantle. The outermost layer of Earth is the crust, which is thin compared to the other layers. **Figure 2** shows a further division of the crust and upper mantle. Plates are made of the crust and a part of the upper mantle called the lithosphere. This rigid layer generally is less dense than material underneath. This material below is plasticlike and called the asthenosphere.

**Plate Movement** Scientists hypothesize that density, temperature, and pressure within Earth, which are lowest in the crust and greatest in the inner core, produce convection currents. A **convection current** is a cycling of material caused by differences in density which cause uneven heating. Heated material rises, cools, and then sinks, as shown in **Figure 3**. One hypothesis relates plate motion directly to the movement of these currents. The rates of plate movements are relatively small—just a few centimeters per year. However, these movements cause major changes on Earth.

A plate is classified by its major feature and named for its general location, as illustrated in **Figure 4**. The North American Plate is named after the North American continent and is made of continental crust and rigid upper mantle. The Pacific Plate is made of oceanic crust and upper mantle. This oceanic plate includes much of the Pacific Ocean floor.
Plate Boundaries  Plates interact at places called plate boundaries. The three types of plate boundaries are divergent, convergent, and transform.

The boundary between two plates that are moving apart is called a divergent boundary, which is shown in Figure 5. Most divergent boundaries are found on the sea floor. As the plates pull apart, long deep cracks called rifts form. Magma wells up into these rifts, cools from the seawater, and then hardens and forms ocean ridges. Many of these ridges snake through the middle of an ocean and often are called mid-ocean ridges. One example is the Mid-Atlantic Ridge, which is located where the South American plate and the African plate move apart.

Divergent boundaries also can form on continents. When plates move apart on land, the movement forms a rift valley. Rift valleys are long, narrow valleys bounded by faults. A fault is a rock feature along which movement or displacement of the crust has taken place. The African continent is separating now along the East African Rift Valley. Both oceanic and continental divergent boundaries are the sites of many shallow earthquakes.

A convergent boundary occurs where two plates are colliding, as illustrated in Figure 6. One type of convergent boundary occurs when two continental plates collide. Scientists suggest that differences in density cause hot, plasticlike rock to be forced upward. Because each continental plate has about the same density, one of the plates eventually overrides the other. This forms an enormous wedge of crust material. As convergence continues, the wedge becomes highly deformed and folded. This produces towering mountain ranges.
When an oceanic plate collides with another oceanic plate or a continental plate, the denser plate plunges underneath the other, forming a deep trench. When one plate sinks underneath another plate, it is called subduction. When a plate subducts, the seafloor cools, becomes denser, and sinks into the mantle. The descending plate partially melts to form magma. Subduction produces large earthquakes. When an earthquake occurs under water, it can cause a giant wave called a tsunami.

A **transform boundary** occurs where two plates slide past one another. The plates move in opposite directions or in the same direction at different rates. When one plate slips past another suddenly, earthquakes occur. Long faults and shallow earthquakes characterize transform boundaries. The San Andreas Fault, a system of numerous faults that runs through much of the western half of California, is part of a transform plate boundary. This boundary is the site of numerous earthquakes. **Figure 7** shows a diagram of a transform boundary and the San Andreas Fault.

**Volcanoes** Occasionally, magma from inside Earth reaches the surface. Magma is then called lava. When hot, molten lava, ash, and sulfurous gases escape through an opening in the surface of Earth, a volcano forms. Volcanoes form in divergent and convergent boundaries. Volcanoes also form on places in plates where deep rocks already are melted. These places are called hot spots. **Figure 8** shows how magma rises at divergent boundaries in the seafloor to form volcanic rock. Sometimes the volcanic eruptions rise above sea level, forming islands such as Iceland. When volcanoes form from colliding plates, magma forms when the plate that is pulled under gets deep enough and hot enough to melt partially. The magma then is forced upward to the surface. Eruptions over hot spots in the seafloor have formed the Hawaiian Islands. Volcanoes that form on convergent plate boundaries tend to erupt more forcefully than do other volcanoes.

**Figure 7** The San Andreas Fault occurs along the transform plate boundary where the Pacific Plate is sliding past the North American Plate.

**Figure 8** This diagram shows how volcanic activity occurs where Earth’s plates move apart.
1. Refer to Figure 3. Suppose that the arrows in the diagram represent patterns of convection in the mantle of Earth. Which type of plate boundary is most likely to occur along the region labeled “A”?
   A. convergent 
   B. divergent 
   C. transform 
   D. volcanic 

2. Plate movements produce many of Earth’s features. Refer to Figure 4. Which feature would you expect to find along the western side of South America?
   F. a rift valley 
   G. a transform fault 
   H. a trench 
   I. mountains with volcanic peaks 

3. Refer to the diagram in Figure 7. Which can be explained by the movement shown?
   A. eruption of a volcano 
   B. formation of a trench 
   C. growth of a mountain range 
   D. shaking of an earthquake
Earth History

Key Questions:

1. What have been some of the major changes in Earth and its life-forms over time?
2. How have these changes been traced and compared?

Scientific evidence suggests that Earth formed about 4.5 billion years ago. Since then, many changes have occurred in the atmosphere, climate, and structure of the surface of Earth. Complex interactions among these physical features have created conditions to make Earth suitable for life. Scientists work to understand the history of Earth and its life-forms.

Atmosphere One factor that has affected life on Earth is change in the gases which surround Earth. Early in its existence, Earth was molten and had no atmosphere. Earth began to cool and develop an outer crust. Over time, volcanic eruptions vented gases from deep inside Earth to form the early atmosphere of Earth. This atmosphere mostly was made up of water vapor (H₂O), carbon dioxide (CO₂), carbon monoxide (CO), and nitrogen (N₂). Because this early atmosphere lacked oxygen (O₂), it was unable to support life, but it did play a major role in the formation of the oceans of Earth. As Earth continued to cool, low-lying areas formed on its surface. Water vapor in the atmosphere gradually condensed and filled these low-lying areas, forming the oceans.

Life is thought to have originated in the oceans. Through photosynthesis, these early aquatic organisms produced oxygen, which gradually changed the composition of the atmosphere. The addition of oxygen allowed the development of organisms that breathe air. The ozone (O₃) layer in the atmosphere began to develop. This important gas also protects organisms from harmful radiation from the Sun.

Climate Another factor that has affected life on Earth is change in climate. Many times in the past 66 million years, Earth was much colder than it is today. These periods of time are called ice ages. During an ice age, a large volume of freshwater on Earth is frozen. Large masses of ice, called glaciers, cause sea levels to fall. A drop in sea levels exposes the continental shelf. This reduces habitats of many marine organisms. Then, as glaciers melt, sea levels rise, turning broad expanses of land into separate islands. These changes in landmasses can cause species to become isolated or extinct (to die out) if they cannot reach proper food sources. However, if geographic isolation produces conditions favorable for survival, species can thrive.
Changes in sea levels can lead to another phenomenon, called overturning. Overturning occurs when seawater from great depths rises to the surface of the ocean. This water lacks oxygen. Marine life-forms that need oxygen for their life processes will die, and some might even become extinct.

**Tectonic Plate Movement** Other factors that have affected life on Earth are changes that relate to movements of tectonic plates. For example, when two tectonic plates collide, mountain ranges, including volcanoes, form. These mountain ranges can cause species to become isolated. Episodes of mountain-building also can produce deserts in areas that once had temperate climates. Intense volcanic action can cause changes in the atmosphere when dust and ash block sunlight. A huge decrease in the amount of sunlight can cause mass extinctions of some plants. Organisms that depend on these plants also can become extinct.

**Asteroids** The physical changes discussed so far have occurred on Earth slowly and gradually over time. However, a major event that caused a mass extinction resulted from an interaction between Earth and an object from space. Much evidence suggests that an asteroid collided with Earth at what is now the Yucatan Peninsula in Mexico. This occurred about 66 million years ago (mya). The impact spewed dust into the atmosphere, reducing the amount of sunlight that reached Earth. As a result, many species of plants became extinct. This led to the extinction of many organisms that depended on the plants for energy.

**Clues to the Past** While physical changes have affected the development of life on Earth, it is the physical evidence of the life-forms that helps scientists trace and compare not only the life-forms but the physical changes as well. The physical evidence of past life on Earth is found in fossils. **Fossils** are the remains, imprints, or traces of prehistoric organisms. **Table 1** lists several types of fossils. Sometimes organisms were preserved when they were frozen or trapped in amber or tar. Most often, fossils formed when plants or animals died in mud, sand, or clay. Over time, they were covered with more mud, sand, or clay and were compressed or packed down. The burial material hardened into a type of rock called sedimentary rock. In a similar way, fossils are forming today at the bottoms of lakes, streams, and oceans.

Fossils have helped scientists determine when life first appeared, when plants and animals first lived on land, and when organisms became extinct. Scientists theorize that about 95 percent of all the species of plants and animals that ever lived on Earth are now extinct.

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permineralized remains</td>
<td>Hard parts of organisms, such as bones, teeth, and shells, combined with minerals</td>
</tr>
<tr>
<td>Carbon (C) films</td>
<td>A silhouette made from a thin film of carbon left from an original organism</td>
</tr>
</tbody>
</table>
| Molds and casts       | Mold: cavity in rock left from organism that has decayed  
                       | Cast: Copy of original object when cavity fills in with minerals or sediment |
| Original remains      | Original organisms that are preserved in various ways, such as in amber, ice, or tar |
| Trace fossils         | A visible sign, such as a footprint, trail, burrow, or claw mark, made or left by the activity of a living organism |
Scientists use fossils to determine what the environment of an area was like in the past. For example, if an area was covered by an ocean, it might be possible to learn its depth, because different organisms live at different depths. Fossils of marine organisms found today in deserts provide evidence that the area was once a sea. Fossils also can give evidence about past climates. For example, rocks in parts of the eastern United States contain fossils of tropical plants. The environment in this part of the United States today is not tropical. Because of the fossils, scientists know that it was tropical when the plants were living.

Fossils also have provided support for the idea of continental drift. This idea was proposed by Alfred Wegener in 1912. Wegener hypothesized that the continents once composed one large landmass and moved slowly to their current locations. Figure 1 shows how the continents were joined to form this landmass, called Pangaea. Fossils of the reptile Mesosaurus have been found in South America and Africa. Because this reptile lived in freshwater and on land and could not swim through seawater, Wegener hypothesized that they lived on both continents when the continents were joined. Fossil remains of other organisms that lived in Pangaea have been found on more than one continent.

**Dating the Clues** There are several ways to determine the age of fossils. One is a method called **relative dating**. Rocks form in layers, with new (younger) layers added on top of older layers. Fossils in lower levels are thought to be older than fossils in higher layers. While this method does not determine the exact age of the fossil, it does determine the age of the fossil in relation to other fossils above or below it. Scientists use index fossils to estimate the ages of rock layers. **Index fossils** are the remains of species that existed on Earth for relatively short periods of time, were abundant, and were widespread. To find the specific age of a fossil or rock, scientists use **radiometric dating** techniques. These methods measure the rate of decay, or breakdown, of radio isotopes within the rocks. Sedimentary rocks cannot be dated this way. For that reason, scientists date other kinds of rocks that are near the sedimentary rocks. A time line of the history of Earth is shown in Figure 2.
Refer to Figure 2. Plants, through photosynthesis, use carbon dioxide (CO₂) for energy and in turn release oxygen (O₂) into the atmosphere. During which time span did the atmosphere contain enough oxygen for organisms that depend on oxygen to live?

A. 544 to 505 mya  
B. 505 to 440 mya  
C. 410 to 360 mya  
D. 360 to 325 mya

Refer to the figure below for questions 2 and 3.

What type of physical change is illustrated?
F. change caused by tectonic activity  
G. change in the composition of the atmosphere  
H. change in the climate  
I. change caused by glaciers

If the folds in the rock layers were not shown, which would help scientists determine the relative age of the layers?
A. index fossils in both layers of the sandstone  
B. marine fossils in the limestone  
C. knowing the age of the layer below the bottom layer of sandstone  
D. marine fossils in the sandstone and coal
Key Question:
How do the movements of Earth and the Moon in relation to each other and to the Sun cause events on Earth?

Certain characteristics of the movement of Earth in relation to the Sun cause events that we rarely consider because they happen so often. For example, Earth rotates on its imaginary axis one complete rotation every 24 h, which causes day and night. The motion of Earth makes the Sun appear to move from east to west. But other factors in the movements of Earth and the Moon result in more complex events. These factors include
- the tilt of Earth on its imaginary axis;
- the time it takes for Earth to revolve around the Sun;
- the time it takes the Moon to revolve around Earth;
- the shape of the orbital paths.

These factors result in seasons, phases of the Moon, eclipses, and tides.

**Seasons** The axis of Earth is tilted 23.5° from an imaginary line drawn perpendicular to the plane of its orbit. This tilt and the revolution of Earth in its yearly orbit around the Sun cause seasons. The orbit of Earth is an ellipse, with the Sun near the center of the ellipse. Because Earth remains tilted in the same direction as it revolves, different hemispheres are tilted toward the Sun at different times of the year. Refer to Figure 1.

![Figure 1](image-url)

**Figure 1** When the north pole of Earth is tilted toward the Sun, the northern hemisphere experiences summer. When the north pole is tilted away from the Sun, the northern hemisphere experiences winter. When the axis of Earth is pointing neither toward the Sun nor away from it, the northern and southern hemispheres experience spring and fall. Seasons in the southern hemisphere are opposite of those in the northern hemisphere.
Another reason the tilt of Earth effects seasons is that it causes the radiation of the Sun to strike the hemispheres at different angles. Sunlight hits the hemisphere tilted toward the Sun at a higher angle (close to 90°) than it does the hemisphere tilted away. This sunlight is intense. Thus, the hemisphere tilted toward the Sun receives more total solar radiation than the hemisphere tilted away. Figure 2 shows the angles of the Sun’s rays for the northern and southern hemispheres when the northern hemisphere is experiencing summer.

Figure 2  During summer, days are longer than nights because radiation strikes a hemisphere at a higher angle and for a longer time.

Another factor related to the tilt of Earth’s axis is the position of the equator relative to the Sun. This tilt and the revolution of Earth cause the position of the Sun over the equator to change daily. This affects the length of days and nights. For most of the year, the Sun appears to be north or south of the equator. But twice a year, the equator appears directly under the Sun. This event is known as the equinox. The equinox occurs during spring and fall. When it occurs, the number of daylight hours equals the number of nighttime hours. The point at which the Sun is at its greatest distance north or south of the equator is called the solstice. During the summer solstice, days are the longest of the year; during the winter solstice, days are the shortest of the year. In the northern hemisphere, the spring equinox falls in March, the summer solstice in June, the fall equinox in September, and the winter solstice in December. Refer to Figure 3.
During the summer solstice in the northern hemisphere, the Sun is directly over the Tropic of Cancer, and the latitude line is at 23.5° N. During the winter solstice, the Sun is directly over the Tropic of Capricorn, and the latitude line is at 23.5° S. During the fall and spring equinoxes, the Sun is directly over the equator.

**Moon Phases**  Just as Earth rotates on its axis and revolves around the Sun, the Moon rotates on its axis and revolves around Earth. Because one rotation and one revolution take the same amount of time, the same side of the Moon always faces Earth, as shown in Figure 4. The Moon seems to shine because its surface reflects light—one half is lighted while the other half is dark. As the Moon revolves around Earth, you see different portions of its lighted side, causing the appearance of the Moon to change. These differences in appearances are called phases and result from the changing position of the Moon relative to Earth and the Sun. When the Moon is located between Earth and the Sun, the Moon is not visible. This phase is called a new moon. When Earth is between the Moon and the Sun, the phase is called a full moon. Figure 5 shows all the phases of the Moon.
Eclipses are other events experienced on Earth that are caused by the relative positions of Earth, the Moon, and the Sun. During a solar eclipse, the Moon passes between Earth and the Sun and casts a shadow on Earth. The darkest part of the Moon’s shadow is called the umbra, as shown in Figure 6. The solar eclipses can occur only during a new moon phase. During a lunar eclipse, Earth is between the Sun and the Moon and casts a shadow on the Moon, as shown in Figure 7. Lunar eclipses occur only during a full moon.

Figure 4 In about 27.3 days, the Moon orbits Earth. It also completes one rotation on its axis during the same period.

Figure 5 The phases of the Moon change during a cycle, called a lunar month, which lasts about 29.5 days. After the new moon, the phases begin waxing. After the full moon, the phases are said to be waning.
Tides are caused by a huge ocean wave produced by the gravitational pull among Earth, the Moon, and the Sun. This giant wave has a height of only 1–2 m but a wavelength of thousands of kilometers. As the crest of the wave nears the shore, the sea level rises. This is called high tide. About 6 h later, as the trough of the wave approaches and the seawater recedes from the shore, low tide occurs. Gravitational pull creates a bulge of water in the ocean on the side of Earth that is facing the Moon and a bulge on the opposite side of Earth. As Earth rotates, the bulges move around the planet, remaining aligned with the Moon. See Figure 8. Most of the gravitational pull comes from Earth because it is closer to the Moon than to the Sun. But when the Sun, the Moon, and Earth form a straight line, high tides are extremely high, and low tides are extremely low. These tides are called spring tides. When the Sun, the Moon, and Earth form a right angle, both high and low tides are weak. These tides are called neap tides.

The time of day in Florida is 3 h later than it is in California and 4 h later than it is in Alaska. Which motion determines the differences in these times?

A. rotation of the Moon  
B. rotation of Earth  
C. revolution of Earth  
D. revolution of the Moon
Which explains why the north pole always experiences daylight during summer in the northern hemisphere?

F. The south pole is tilted toward the Sun; as Earth revolves, the north pole remains pointed toward the Sun.

G. The north pole is tilted toward the Sun; as Earth rotates, the north pole remains pointed toward the Sun.

H. The north pole is tilted toward the Sun; as Earth revolves, the north pole remains pointed toward the Sun.

I. The south pole is tilted toward the Sun; as Earth rotates, the north pole remains pointed toward the Sun.

Which refers to the shadow on Earth during a total solar eclipse or the shadow on the Moon during a total lunar eclipse?

A. full moon

B. new moon

C. penumbra

D. umbra

The figure below lists examples from a tide chart for the outer coast of Naples, Florida, for September 2005, during which neap tides occurred.

<table>
<thead>
<tr>
<th>Date</th>
<th>Highest Tide of the Day (m)</th>
<th>Lowest Tide of the Day (m)</th>
<th>Percent of Moon Visible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sept. 3</td>
<td>0.84</td>
<td>0.5</td>
<td>0</td>
</tr>
<tr>
<td>Sept. 12</td>
<td>0.90</td>
<td>0.06</td>
<td>55</td>
</tr>
<tr>
<td>Sept. 18</td>
<td>1.11</td>
<td>0.12</td>
<td>99</td>
</tr>
<tr>
<td>Sept. 25</td>
<td>0.84</td>
<td>0.21</td>
<td>53</td>
</tr>
<tr>
<td>Oct. 4</td>
<td>0.96</td>
<td>0.09</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: [http://www.saltwatertides.com/cgi-local/floridagulf.cgi](http://www.saltwatertides.com/cgi-local/floridagulf.cgi)

Refer to the figure above and also to Figure 5. In which phase is the Moon at the time of the largest difference between high tide and low tide?

F. first quarter

G. full moon

H. new moon

I. third quarter

How would the tides differ between neap tides and spring tides?

A. The difference between high tide and low tide would be greater during spring tides than during neap tides.

B. The difference between high tide and low tide would be greater during neap tides than during spring tides.

C. The difference between high tide and low tide would be the same during both spring and neap tides.

D. The greatest difference between high tide and low tide would occur during a different phase of the Moon.
Unique Earth

**Key Questions:**

1. How do the characteristics of Earth compare to those of other planets in the solar system?
2. Why is Earth the only planet in our solar system capable of supporting life as we know it?

The planets and moons of the solar system have a number of things in common. They are spherical in shape and, as are all objects in the universe, are held in their orbits by gravity. The planets in the solar system orbit the Sun, and the moons orbit their planets. Some features are common among certain planets and moons, while other features distinguish them. The different characteristics confirm the theory that Earth is the only planet in our solar system that can support life.

**Characteristics of the Planets** The planets of the solar system can be grouped in several ways. One way is to group them by their distance from the Sun—the inner and outer planets. The inner planets, starting with the one closest to the Sun, are Mercury, Venus, Earth, and Mars. The outer planets are Jupiter, Saturn, Uranus, Neptune, and Pluto. Another way to group the planets is by their basic properties. Table 1 displays distinguishing characteristics of the planets and their moons. **Terrestrial planets** are small planetary bodies with solid surfaces. The inner planets are terrestrial planets. The fifth through eighth planets from the Sun are gas giants. The **gas giants**, as their name suggests, are larger, less dense, and more gaseous than the terrestrial planets. The ninth planet, Pluto, is a unique body with a solid surface and does not fit into either category.
### Table 1

**Distinguishing Characteristics of the Planets and Moons of the Solar System**

<table>
<thead>
<tr>
<th>Planet</th>
<th>Relative Size</th>
<th>Type</th>
<th>Distinguishing Characteristics</th>
<th>Moons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>Second-smallest</td>
<td>Terrestrial</td>
<td>Surface has many craters and high cliffs, no atmosphere; temperatures range from 425°C during the day to −170°C at night</td>
<td>None</td>
</tr>
<tr>
<td>Venus</td>
<td>Similar to Earth in size and mass</td>
<td>Terrestrial</td>
<td>Thick atmosphere made mostly of carbon dioxide (CO₂); droplets of sulfuric acid (H₂SO₄) in atmosphere give clouds a yellowish color; surface has craters, faultlike cracks, and volcanoes; surface temperatures range from 450°C to 475°C</td>
<td>None</td>
</tr>
<tr>
<td>Earth</td>
<td>Fourth-smallest</td>
<td>Terrestrial</td>
<td>Atmosphere protects life; surface temperatures that range from −89°C to 58°C, allowing water (H₂O) to exist as solid, liquid, and gas; about 70% of the surface of Earth is liquid water; surface also has mountains, volcanoes, faults, and valleys</td>
<td>One large moon with many craters</td>
</tr>
<tr>
<td>Mars</td>
<td>Third-smallest</td>
<td>Terrestrial</td>
<td>Surface appears reddish-yellow because of iron oxide (Fe₂O₃) in soil; ice caps are made of frozen carbon dioxide and water; channels indicate that water had flowed on the surface; has large volcanoes and valleys (Olympus Mons is largest volcano in solar system); thin atmosphere composed mostly of carbon dioxide; surface temperatures range from −125°C to 35°C</td>
<td>Two small moons with many craters</td>
</tr>
<tr>
<td>Jupiter</td>
<td>Largest</td>
<td>Gaseous</td>
<td>Atmosphere is mostly hydrogen (H) and helium (He); continuous storms swirl on the planet (the largest, the Great Red Spot, has faint rings)</td>
<td>Four large moons and at least 57 smaller moons; one of its moons, Io, has active volcanoes</td>
</tr>
<tr>
<td>Saturn</td>
<td>Second-largest</td>
<td>Gaseous</td>
<td>Thick atmosphere is mostly hydrogen and helium; has a complex ring system with several broad rings that are composed of thousands of thin ringlets; rings are composed of countless ice and rock particles</td>
<td>At least 31; the largest, Titan, is larger than Mercury</td>
</tr>
<tr>
<td>Uranus</td>
<td>Third-largest</td>
<td>Gaseous</td>
<td>Has thin, dark rings; atmosphere is hydrogen, helium, and methane (CH₄); axis of rotation is nearly parallel to plane of its orbit</td>
<td>At least 21</td>
</tr>
<tr>
<td>Neptune</td>
<td>Fourth-largest</td>
<td>Gaseous</td>
<td>Has rings that vary in thickness; is sometimes farther than Pluto from the Sun; methane atmosphere causes bluish-green color; has dark-colored storms in atmosphere</td>
<td>At least 11; Triton is largest moon</td>
</tr>
<tr>
<td>Pluto</td>
<td>Smallest</td>
<td>Icy rock</td>
<td>Thin atmosphere</td>
<td>Single moon, Charon, is half the diameter of the planet</td>
</tr>
</tbody>
</table>

*Source: Adapted from Time Almanac 2005.*
**Conditions that Support Life**  The most significant way Earth differs from the other planets in our solar system is that it can support life as we know it, while other planets cannot. Several factors contribute to this difference. Earth’s distance from the Sun and its nearly circular orbit allow water (H₂O) to exist on its surface in all three states: solid, liquid, and gas. The vast abundance of liquid water on Earth is important for the development and existence of life. In addition, the makeup of the atmosphere helps support life. Earth has a moderately dense atmosphere, which is composed primarily of nitrogen (N) and oxygen (O). Refer to Figure 1. Other gases in the atmosphere also are important because they affect the temperature on Earth. These gases, such as water vapor, carbon dioxide (CO₂), and methane (CH₄), are known as greenhouse gases. They create a mild greenhouse effect, which is a natural heating process that occurs when these gases trap heat from Earth. Radiation from the Sun strikes the surface of Earth and causes it to warm. Some of this heat is radiated back toward space. The greenhouse gases absorb a portion of this heat. The heat then radiates back toward Earth. This keeps Earth warmer than it would be otherwise. Ozone is another greenhouse gas that is found mostly in the ozone layer. It absorbs most of the ultraviolet radiation from the Sun that enters the atmosphere, forming a protective barrier against rays that can damage skin and cause skin cancer.

**Figure 1**  Atmospheric Composition of Earth
1. Which group of planets is most similar to Earth?
   A. Jupiter, Venus, and Pluto
   B. Mercury, Venus, and Mars
   C. Neptune, Saturn, and Mars
   D. Pluto, Saturn, and Mars

2. Based on the information in Table 1, which group of features describes how Mars is different from Earth?
   F. thinner atmosphere, warmer temperatures, and large volcanoes
   G. denser atmosphere, colder temperatures, and ice caps
   H. denser atmosphere, warmer temperatures, and ice caps
   I. thinner atmosphere, colder temperatures, and abundance of iron oxide (Fe$_2$O$_3$) in its soil

3. Which group of conditions helps support life on Earth?
   A. abundant water (H$_2$O), moderate temperatures, ozone (O$_3$) layer in the atmosphere
   B. abundant water (H$_2$O), cold temperatures, and lack of greenhouse gases
   C. abundant water (H$_2$O), warm temperatures, and lack of greenhouse gases
   D. abundant water (H$_2$O), moderate temperatures, and large volume of greenhouse gases
Star Life Cycles

Key Question:
What are the stages of star evolution, and what is involved in the evolution?

The life cycle of a star begins when the star forms, continues through a period when the star is stable, and ends when the star dies. The lifetimes of stars range from millions to billions of years, because the mass of a star determines how quickly it evolves. Stars with greater mass evolve more quickly than stars with less mass. The Sun is an average star. It has a stable life span of about 10 billion years, about half of which is still in the future. Stars can be classified by their stage in the star cycle.

New Star
All stars form when a cloud of interstellar gas and dust called a nebula collapses on itself as the result of its own gravity. Gravitational forces cause instability within the nebula. It can break apart into smaller and smaller pieces. As smaller pieces of the nebula move closer together, the temperature in each nebula piece increases. As the cloud continues to contract, its rotation forces it to form a disk. At the center of this disk is a hot, condensed object called a protostar. Nuclear fusion, a process in which one element is converted into another, results from the formation of the protostar. The first fusion reactions that occur within the core of the protostar convert hydrogen (H) into helium (He). Heat from the fusion causes pressure to increase. This pressure balances the attraction due to gravity, and the protostar has evolved into a star.

Mature Star
Once the fusion of hydrogen into helium begins and pressure balances, a star becomes more stable, continuing to use its hydrogen fuel and changing slowly for billions of years. This mature star falls on the main sequence of the H-R diagram, a graph developed by Ejnar Hertzsprung and Henry Russell in the early 1900s. This graph, illustrated in Figure 1, shows the relationship of the temperature of a star to its absolute magnitude. Absolute magnitude is the measure of the brightness (luminosity) of a star. The brightness and color of a star depend on its temperature, which in turn depends on its mass. About 90 percent of all stars are main sequence stars, and most of them are small, red stars found in the lower right of the H-R diagram. These small, red stars evolve the slowest and so remain on the main sequence the longest.

Figure 1
Stars in the upper left are hot, blue, bright stars, and stars in the lower right are cool, red, dim stars. Yellow main sequence stars, like the Sun, fall in between.
**Old Stars** Stars that have evolved to the point of becoming unstable leave the main sequence. How a star evolves and the rate at which it evolves and leaves the main sequence depend on its mass, expressed in terms of the mass of the Sun. The mass of the Sun is one solar mass (one stellar mass). The more massive a star, the greater the gravity pressing inward, and the hotter and denser the star must be inside to balance gravity. In stars that are more than eight times the mass of the Sun, the stages of evolution occur more quickly and more violently. **Figure 2** shows the pattern of development based on mass.

![Figure 2](image)

**Figure 2** The life of a star depends on its mass. Massive stars eventually become neutron stars or black holes.

A star that is one solar mass takes about 10 billion years to convert its hydrogen into helium. At this point, the star leaves the main sequence, because energy at the edge of the core forces the outer layers of the star to expand and cool. The star then becomes a **red giant**, which is an extremely large star. Because of its size, a red giant has a low surface gravity, which causes the star to lose gases from its outer layers. In the core of a red giant, nuclear fusion causes the helium to convert to carbon (C). However, the core never becomes hot enough for carbon to react. The red giant then loses energy and eventually becomes a small, hot object about the size of Earth. Such a star is called a white dwarf. A **white dwarf** has no way to sustain heat, so it cools over time. It radiates its remaining heat into space for millions of years. When a white dwarf has completely cooled, it becomes a black dwarf—a cold, dark object that does not radiate any energy.
A star with a mass of about five solar masses evolves into a **supergiant**. Nuclear fusion in the core of a supergiant produces the element iron (Fe). Over time, the core of a supergiant shrinks due to gravity, and becomes hotter and denser until all fusion ceases. At this time, the star begins its final phase of collapse. The core of the supergiant recoils in an explosive shock wave. This tremendous burst of energy causes an explosion called a **supernova** and can happen in a second. The explosion sends the outer layers of the star far into space. If the collapsed core of a supernova is between 1.4 and 3 solar masses, it will shrink to approximately 20 km in diameter. Only neutrons can exist in the dense core, so a **neutron star** is formed. On the other hand, if the remaining dense core from a supernova is more than three solar masses, probably nothing can stop the core from collapsing into a point. The gravity near this mass is so strong that nothing can escape from it, not even light. Because light cannot escape, the region is called a **black hole**.
1. As the Sun ages, into which will it eventually evolve?
   A. black hole  
   B. supergiant  
   C. supernova  
   D. white dwarf

2. Refer to the figure below which shows the composition of the Sun.

![Circle graph showing composition of the Sun]

How will the circle graph change while the Sun remains on the main sequence?
   F. The hydrogen (H) slice will get smaller.  
   G. The hydrogen (H) slice will get larger.  
   H. The helium (He) slice will get smaller.  
   I. Both the hydrogen (H) slice and the helium (He) slice will get smaller.

3. Refer to Figure 1. Which type of star will age fastest?
   A. a yellow star in the middle of the main sequence  
   B. a blue star in the upper left hand of the main sequence  
   C. a red star in the lower right hand of the main sequence  
   D. a blue star in the lower right hand of the main sequence

4. Which will take the longest to evolve?
   F. black hole  
   G. neutron star  
   H. supernova  
   I. white dwarf
Early Greek scientists thought that Earth was at the center of the solar system and that the planets and stars circled Earth. Today, people know that objects in the solar system revolve around the Sun. Mercury, Venus, Earth, and Mars are referred to as the inner planets. These planets are small, rocky planets. The outer planets are Jupiter, Saturn, Uranus, Neptune, and Pluto. Pluto is a small, icy planet, but the other outer planets are large, gaseous planets. Scientists today also know that there are millions of bodies beyond the solar system in the universe.

The Solar System The solar system includes an area extending billions of kilometers in all directions from the Sun. The Sun is a star—an enormous sphere of fiery gases—that lies in the center of the solar system. The solar system is made up of nine planets, their moons, and many smaller objects. The diameter of the Sun is equal to about 109 diameters of Earth, positioned side by side. Jupiter is the largest planet in the solar system and has a diameter about 10 times that of Earth. Pluto is the smallest planet. More than five Plutos side by side would span the diameter of Earth. Refer to Table 1 for the approximate diameters of the Sun and its planets.

The mass of the Sun is enormous compared to the mass of other objects in the solar system. It is about 330,000 times the mass of Earth. The Sun makes up more than 99 percent of the mass in the solar system. Because of this, the gravity of the Sun is immense. The gravity of the Sun holds the solar system together, just as the gravity of Earth holds the Moon in its orbit around Earth. Figure 1 shows how the planets are arranged around the Sun. Refer to Table 2 for approximate distances between the planets and the Sun. These distances are given in astronomical units (AU). One AU is equal to the average distance between Earth and the Sun.
Figure 1 shows how the planets are arranged around the Sun. It also shows the asteroid belt between Mars and Jupiter. **Asteroids** are rocky objects formed from material similar to that of planets. They range from a few kilometers to about 1000 km in diameter. Comets are other objects that exist in or near the solar system but farther from the Sun than asteroids. **Comets** are made of dust and rock mixed with ice, methane, and ammonia and range from 1 to 10 km in diameter. They are located mostly in the Kuiper Belt near the orbit of Neptune or in the Oort Cloud, which completely surrounds the solar system. **Meteoroids** are other rocky objects orbiting throughout the solar system. They might have formed when asteroids collided or when comets broke up as they passed close to the Sun, leaving a trail of debris. When Earth passes through these trails, meteoroids can enter the atmosphere of Earth and usually burn. These are called meteors. Those that do not burn up completely land on Earth and are called meteorites. Another object in the solar system that is smaller than Pluto but larger than asteroids and comets has puzzled scientists for some time. It is called **Sedna** unofficially and labeled a planetoid.

**Beyond the Solar System** Although it seems very large, our solar system is only a very small part of another system in the universe—the Milky Way galaxy. A galaxy is a large group of stars, gas, and dust held together by gravity. The entire Milky Way is about 100 billion times the mass of the Sun. It is shaped like a disk, as shown in Figure 2. The Milky Way might contain one trillion stars. However, as shown in Figure 2, not all of them are located in the disk. The Milky Way is about 130,000 light-years (ly) in diameter. A light-year is based on the speed of light. One **light-year** is equal to the distance light travels in one year. The Sun is located about 28,000 ly from the center of the galaxy. A view from above or below the galaxy shows the spiral arms that wind around the galactic center, as shown in Figure 3.
Beyond the Milky Way are billions of other galaxies. Each of these contains the same elements, forces, and types of energy as the Milky Way. Most of these enormous collections of stars and interstellar matter are located in groups. The Milky Way belongs to a small cluster of about 45 galaxies called the Local Group. The Local Group is approximately 2 million ly in diameter. Galactic clusters larger than the Local Group might have hundreds of members. They might range in diameter from about 5 to 30 million ly. Clusters of galaxies are organized into even larger groups called superclusters. These gigantic formations can be hundreds of millions of light-years in size.

In 1929, all galaxies in the universe were discovered to be moving away from Earth. The farther a galaxy is from Earth, the faster it is moving away. This discovery has shown that the enormous universe is getting even larger over time.
1. Which group orders the objects in the universe from largest to smallest?
   A. superclusters, stars, galaxies, groups
   B. superclusters, galaxies, solar systems, planets
   C. groups, clusters, superclusters, asteroids
   D. galaxies, planets, stars, asteroids

2. The symbols below represent the Milky Way galaxy, the solar system, the Sun, and the universe.

   Which arrangement below is an accurate representation of the symbols above?
   F. (1)  
   G. (2)  
   H. (3)  
   I. (4)

3. Which describes how you would change the figures in question 2 to reflect the idea that the universe is expanding?
   A. Make the symbols for the universe and the Sun larger.
   B. Make the symbols for everything but the Sun larger.
   C. Make the symbols for the universe but not anything else larger.
   D. Makes the symbols for everything but the Milky Way galaxy larger.
Astronomical Distance and Time

**Key Question:**
What units do astronomers use to measure vast distances in the solar system?

The solar system spans billions of kilometers from end to end. Even planets within the solar system are millions of kilometers apart. The distances among bodies in the solar system are relatively small when compared to other distances in space. Two stars in a constellation might appear to be close to each other, but one might be 1 trillion km away from Earth, and the other might be 2 trillion km away from Earth. Distances to even the closest stars, aside from the Sun, are too large to measure in kilometers. Because of this, astronomers use other measures to describe the distances. One measure is based on distance; the other is based on time.

**Astronomical Unit** One unit astronomers use to describe distances within the solar system is called an **astronomical unit** (AU). One AU is the average distance between Earth and the Sun. This is approximately 1.5 million km. The AU makes it easier to compare distances between planets and other objects in the solar system. Pluto, for example, is 5,869,660,000 km from the Sun. This can be expressed as 39 AU from the Sun. In other words, the distance from the Sun to Pluto is 39 times the distance from the Sun to Earth.

**Light-year** Another unit astronomers use to measure long distances is called a light-year (ly). The light-year is based on the speed of light. This is because light travels faster than anything else in the universe. The speed of light is 300,000,000 m/s. A **light-year** is the distance light travels in one year, which is equal to about 9.5 trillion km. Light from the Sun takes approximately eight minutes to reach Earth. When people observe that light, they are seeing the Sun as it was eight minutes earlier. The light that people see when they look at stars other than the Sun left those stars many years ago. The nearest star to Earth besides the Sun is Proxima Centauri. This star is 4.2 ly away, or about 40 trillion km. Light from this star takes 4.2 y to reach Earth. It can take millions of years for light to reach Earth from stars in galaxies besides the Milky Way. A star could die before its light reaches Earth.
Use the table below to answer questions 1 and 2.

### Distances Within the Solar System

<table>
<thead>
<tr>
<th>Planet</th>
<th>Average Distance from Sun (km)</th>
<th>Average Distance from Sun (AU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>57,910,000</td>
<td>0.387</td>
</tr>
<tr>
<td>Venus</td>
<td>108,210,000</td>
<td>0.723</td>
</tr>
<tr>
<td>Earth</td>
<td>149,600,000</td>
<td>1.000</td>
</tr>
<tr>
<td>Mars</td>
<td>227,920,000</td>
<td>1.523</td>
</tr>
<tr>
<td>Jupiter</td>
<td>778,570,000</td>
<td>5.204</td>
</tr>
<tr>
<td>Saturn</td>
<td>1,433,530,000</td>
<td>9.582</td>
</tr>
<tr>
<td>Uranus</td>
<td>2,872,460,000</td>
<td>19.201</td>
</tr>
<tr>
<td>Neptune</td>
<td>4,495,060,000</td>
<td>30.047</td>
</tr>
<tr>
<td>Pluto</td>
<td>5,869,660,000</td>
<td>39.236</td>
</tr>
</tbody>
</table>

1. Which statement describes Neptune’s distance from the Sun?
   A. Neptune is 30 times farther from Earth than Earth is from the Sun.
   B. Neptune is 30 times farther from the Sun than Earth is from the Sun.
   C. Neptune is 29 times farther from the Sun than Earth is from the Sun.
   D. Neptune is 25 times farther from the Sun than Jupiter is from the Sun.

2. Sunlight reaches Earth in 8.33 min. How long, in minutes, does it take sunlight to reach Mars? Record your answer in significant digits.
Biochemical Reactions

Key Questions:

1. What are the chemical reactions involved in photosynthesis and cellular respiration?
2. What are some tasks performed by carbohydrates, proteins, and lipids in cell functioning?

Cells, including those in your body, can undergo chemical reactions that release energy from carbon-containing (organic) compounds such as food. There are three major classes of organic molecules: carbohydrates, proteins, and lipids. Each type of molecule is important for biochemical reactions in its own way. Carbohydrates, which include the sugar glucose (C₆H₁₂O₆), are formed from the Sun’s energy in a process called photosynthesis and are broken down in the process of cellular respiration to harness energy for living cells. Proteins are needed to access the energy stored in cells, build cell structures, and regulate the rate of chemical reactions. Lipids, commonly known as fats and oils, create the membranes of cells that provide the sites for essential energy conversions. This cell barrier is a lipid bilayer, illustrated in Figure 1.

The cell membrane, formed by lipids, allows only certain substances to cross. Proteins embedded in the cell membrane allow molecules required for cell function to move across the membrane. Because the membrane selects what molecules can enter the cell, the lipid wall creates a biochemical environment inside the cell that differs from the outside.

Two biochemical cycles related to sugars are photosynthesis and cellular respiration. Table 1 compares these cellular processes. The left-hand side summarizes photosynthesis, the process of storing energy from the Sun in the form of glucose. The right-hand side summarizes cellular respiration, the process of releasing the energy from glucose and storing it in the high energy bond to make adenosine triphosphate (ATP) from adenosine diphosphate and phosphate.

Table 1

<table>
<thead>
<tr>
<th>Comparison of Photosynthesis and Cellular Respiration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photosynthesis</td>
</tr>
<tr>
<td>food accumulated</td>
</tr>
<tr>
<td>energy from Sun stored in glucose</td>
</tr>
<tr>
<td>carbon dioxide taken in</td>
</tr>
<tr>
<td>oxygen given off</td>
</tr>
<tr>
<td>produces glucose from PGAL</td>
</tr>
<tr>
<td>goes on only in light</td>
</tr>
<tr>
<td>occurs in presence of chlorophyll</td>
</tr>
</tbody>
</table>
The general equation for photosynthesis is written as follows:

\[6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2\]

Cellular respiration is summarized in the following equation:

\[\text{P} + \text{ADP} + \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{ATP}\]

Notice that ATP is a product of cellular respiration. On a cellular level, the molecule in a cell that provides a quick source of energy is the molecule ATP. The energy of ATP becomes available to a cell when the molecule loses a phosphate. When ATP loses the phosphate and the energy is released, the energy must be captured and used efficiently by cells. Many proteins have a specific site where ATP can bind. Then, when the ATP bonds are broken and the energy is released, the cell can use the energy for activities such as making a protein or transporting molecules.

This cellular process is similar to the way a radio uses the energy in batteries. Batteries sitting on a table are of little use if the energy stored within the batteries cannot be accessed. When the batteries are snapped into the holder in the radio, the radio then has access to the stored energy. When the energy in the batteries has been used, the batteries can be taken out, recharged, and replaced in the holder. Similarly, in a cell, when ATP has been broken down to release energy, the remaining molecule is released from the binding site in the protein, and the binding site then can be filled by another ATP molecule. Cells use energy, harnessed from ATP, for purposes such as synthesizing new proteins or moving waste out of the cell. These processes are chemical reactions that sometimes rely on proteins called enzymes to regulate the rate of chemical reaction.

1. Which describes the process of cellular respiration?
   A. It produces ATP.
   B. It splits water molecules.
   C. It circulates nutrients to cells.
   D. It uses carbon dioxide and water to synthesize glucose.

2. Which type of carbon-based (organic) compound can change the rate of chemical reactions?
   F. lipid
   G. protein
   H. nucleic acid
   I. carbohydrate
Conservation of Mass and Energy in Biological Systems

Key Questions:

1. How does conservation of mass and energy apply to ecosystems on Earth?
2. How is energy transferred between organisms on Earth?

In physics, conservation laws tell us that particular measurable properties of any system, such as energy and mass, do not change. It is possible to observe these laws within biological processes and ecosystems if we pay attention to all the details. Mass and energy cannot be created or destroyed but can be converted from one form to another.

Energy is conserved as it flows through an ecosystem. Almost all organisms on Earth get energy from the Sun, either directly or indirectly. The energy you get from eating a pizza, for example, can be traced back to the Sun. The flour used to make the dough came from wheat plants, the sauce came from tomatoes, and the cheese was made from milk that came from dairy cattle that ate grass.

Energy moving through an ecosystem changes form from light energy to chemical energy to thermal and mechanical energy. Organisms called producers carry out photosynthesis, which transforms light energy from the Sun into chemical energy in the form of high-energy nutrients. Producers are organisms such as plants and protists, which include certain algae and slime molds. When you eat a plant, such as a potato, your body digests the potato, and the high-energy nutrients undergo cellular respiration. This process converts the energy contained in the nutrients into energy that your body uses to carry out everyday processes. The products of cellular respiration—carbon dioxide and water—are exhaled and excreted. Much of the energy contained in the plant is given off in the form of heat, or thermal energy.

Each organism in a food chain belongs to a trophic level in an energy pyramid. A given organism’s trophic level is positioned above what it eats and below what eats it. Producers make up the lowest, or first, trophic level. These organisms contain molecules that are able to capture energy directly from the Sun. Consumers make up the remaining levels. Consumers include herbivores, carnivores, and omnivores. Herbivores are organisms that consume producers. Horses, elephants, and grasshoppers are just a few examples of the many animals that eat only plant matter. Similarly, a carnivore is an animal whose diet consists only of meat. Snakes, cats, spiders, and polar bears are examples of carnivores. Omnivores, organisms that consume both plants and animals, include pigs, chickens, and many humans. It is important to note that as energy is transferred from producers to herbivores to carnivores, the amount of available energy at each trophic level decreases, as shown in Figure 1 and Figure 2.
When an organism consumes food, it uses some of the food’s energy for its metabolism and building body tissues, while some energy is given off as heat. When that organism is eaten, the energy that was used to build body tissue is again available as energy to be used by the organism that consumes it. Some of the energy transferred at each successive trophic level enters the environment as heat, but the total amount of energy in the ecosystem remains the same.

The law of conservation of energy explains that energy can be converted from one form to another, but it cannot be created or destroyed. An equivalent law exists for mass. Mass changes form, but it cannot be created or destroyed. This principle is illustrated when you consider the movement of individual atoms within an ecosystem.

Consider one path an atom of carbon (C) could take as it flows through the carbon cycle. Start with the carbon in the form of carbon dioxide (CO₂) in the air. From there, it is used by a corn plant and converted into a high-energy molecule of glucose (C₆H₁₂O₆). The plant is then fed to dairy cattle. The carbon atom becomes part of a protein molecule in milk produced by the cows. You then consume the milk with your bowl of breakfast cereal. Each time you inhale oxygen, you exhale carbon dioxide. That carbon atom you ate as a protein ultimately gets disposed of as a waste carbon dioxide molecule, which in turn gets used by a plant to synthesize food.

The reactions in these processes might have altered the physical and chemical properties of the carbon compounds. However, in all of these reactions, mass is neither created nor destroyed. Other substances, such as water (H₂O), nitrogen (N), and phosphorus (P), also cycle through the biosphere, obeying the law of conservation of mass.
Eating a sweet potato can provide energy for human metabolic processes. What is the original source of this energy?

A. vitamins and minerals found in the soil  
B. protein molecules stored within the potato  
C. starch molecules absorbed by the potato plant  
D. light energy that is transformed by photosynthesis

As shown in the energy pyramid of Figure 1, only 10 percent of the energy available within a trophic level is transferred to organisms in the next trophic level. The rest of the energy is used by the organism to perform cell functions or is lost to the environment. These facts support which law of conservation?

F. law of conservation of mass  
G. law of conservation of energy  
H. law of conservation of matter  
I. law of conservation of resources
Response to Stimuli

**Key Questions:**

1. **What are different types of stimuli?**
2. **How can the nervous system respond to stimuli?**

Suppose you’re in a crowded, noisy store and you feel a tap on your shoulder. Turning your head, you see the smiling face of a good friend. How did the shoulder tap get your attention? The touch stimulated sensory receptors located in the skin of your shoulder to produce an impulse. The sensory impulse was carried to the spinal cord and then up to your brain. From your brain, an impulse was sent out to your motor neurons, which then transmitted the impulse to muscles in your neck. Your neck muscles then turned your head. **Figure 1** shows how a stimulus, such as a tap on the shoulder, is transmitted through your nervous system.

A condition that produces a response from an organism is called a **stimulus**. A reaction to a stimulus is a **response**. A stimulus can be external, such as the tap on your shoulder described in **Figure 1**. You respond to this stimulus by turning your head in the direction of the stimulus. A stimulus also can be internal, such as a sensor in the skin alerting the brain that body temperature is increasing. The body responds through a mechanism that returns body temperature to normal levels.

Neurons, or nerve cells, conduct electrical impulses throughout the nervous system. Neurons can be classified in three categories. **Sensory neurons** carry impulses from the body to the spinal cord and brain. **Interneurons**, found within the spinal cord and brain, process incoming impulses and pass on response impulses to motor neurons. **Motor neurons** carry the response impulses away from the brain and spinal cord to a muscle or gland. A nerve impulse travels as an electrical signal through each neuron. Although neurons lie next to each other, they don’t actually touch. A tiny space lies between the ends of each neuron, and the nerve impulse must pass through this space. It does so by chemical transmission.

Sometimes a stimulus results in an automatic, unconscious response within the nervous system. When you touch something hot, you automatically pull away your hand. Such an action is a **reflex**, an automatic response to a stimulus. A reflex impulse travels to the spinal column or brain stem where it causes an impulse to be sent directly back to a muscle. The brain becomes aware of the reflex only after it occurs. **Figure 2** shows the shortened route of a reflex impulse.
When something in an organism’s internal environment causes the organism to react, the response is always involuntary. One way an organism responds to internal stimuli is through the release of hormones. Hormones are produced by endocrine glands and released directly into the bloodstream. Hormones cause changes in the body at specific sites called target cells.

For example, blood glucose levels are controlled by the hormone insulin. When blood glucose levels are high, the endocrine system responds by releasing insulin, which in turn signals the liver and muscle cells to take in glucose, lowering blood glucose levels. When blood glucose levels return to normal, insulin is no longer released. If blood glucose levels become too low, as they might for a runner during a marathon, the pancreas releases another hormone called glucagon. Glucagon signals liver cells to release stored glucose, thus restoring blood glucose levels to normal. Once blood glucose levels are normal, glucagon is no longer released. Blood glucose levels are constantly monitored and adjusted according to this stimulus and response system. When a mammal’s endocrine system malfunctions and fails to release enough insulin as blood glucose levels rise, that organism has a disorder called diabetes. Some forms of diabetes are treated by injecting insulin into the bloodstream when blood glucose levels get too high.

Figure 2  A simple reflex impulse involves one sensory neuron, one interneuron, and one motor neuron.
1. Which type of neuron carries impulses toward the brain?
   A. motor neuron
   B. sensory neuron
   C. stimulus neuron
   D. association neuron

2. When blood glucose levels are high, the pancreas releases the hormone insulin. Insulin signals the liver and muscle cells to take in glucose, lowering blood glucose levels. Which are target cells in this example of an internal stimulus-response system?
   F. cells in the liver
   G. cells in the blood
   H. cells in the pancreas
   I. cells that contain glucose
Asexual and Sexual Reproduction

**Key Questions:**

1. **What is the difference between asexual and sexual reproduction?**
2. **What is the difference between an organism’s genotype and an organism’s phenotype?**

There are two types of reproduction: asexual and sexual. In asexual reproduction, one parent passes copies of all its chromosomes to each of its offspring. An organism which reproduces asexually produces new cells by **mitosis**, the orderly process of nuclear division in which two new daughter cells each receive a complete set of chromosomes. Once the parent produces new cells by mitosis, cell division separates the new cells from the parent to form offspring. Different types of asexual reproduction include binary fission, budding, spore formation, and regeneration, as illustrated in Table 1. In some organisms, asexual reproduction is merely an extension of growth.

**Table 1**

<table>
<thead>
<tr>
<th>Some Types of Asexual Reproduction</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
<td><strong>Example</strong></td>
</tr>
<tr>
<td>Binary fission</td>
<td><em>Paramecium</em></td>
</tr>
<tr>
<td>A one-celled organism divides evenly to form two one-celled offspring.</td>
<td></td>
</tr>
<tr>
<td>Budding</td>
<td><em>Hydra</em></td>
</tr>
<tr>
<td>A cell or group of cells pinches off from the parent to form a new individual.</td>
<td></td>
</tr>
<tr>
<td>Spore formation</td>
<td><em>Moss</em></td>
</tr>
<tr>
<td>Parent produces reproductive cell with a hard outer coat. This cell forms a new organism without the fusion of gametes.</td>
<td></td>
</tr>
<tr>
<td>Regeneration (animals)</td>
<td><em>Planarian</em></td>
</tr>
<tr>
<td>A new organism is produced through the replacement or regrowth of body parts.</td>
<td></td>
</tr>
<tr>
<td>Vegetative propagation (plants)</td>
<td><em>Strawberry</em></td>
</tr>
<tr>
<td>A new plant is produced from existing roots, stems, or leaves.</td>
<td></td>
</tr>
</tbody>
</table>
Offspring formed by asexual reproduction are genetically identical to each other and to the parent unless a mutation occurs. A **mutation** is the process by which a gene undergoes a change in DNA sequence or a change in structure. One advantage of reproducing asexually is that organisms can create offspring rapidly and in large numbers. In an unchanging environment, asexual reproduction is advantageous because successful parents will produce successful offspring. On the other hand, if organisms are not well adapted to a changing environment, asexual reproduction might provide offspring that cannot survive and reproduce. This is one disadvantage of asexual reproduction.

Sexual reproduction usually involves two parents. The offspring receives half of its chromosomes from its father’s sperm and half of its chromosomes from its mother’s egg. The egg and sperm are female and male sex cells, which are called **gametes**. When an organism reproduces sexually, cell division must produce gametes, which contain one of each pair of chromosomes from a parent’s body cell. This process is called **meiosis**, and it occurs in the specialized body cells of each parent that produces gametes.

Upon fertilization, the full number of chromosomes is restored with the formation of the zygote. A zygote contains all the information necessary for growth, development, and eventual reproduction of an offspring. The zygote will develop into an offspring that is similar, but not genetically identical, to its parents.

Sexual reproduction is advantageous because it produces offspring with genetic variation. This variety increases the chance that at least a few offspring will be better adapted to changing environmental conditions. The variability that results from sexual reproduction reduces the chance that a species will become extinct. One disadvantage of sexual reproduction is that male gametes must reach female gametes. For example, for animals that practice external fertilization, such as fish and frogs, reproduction occurs in watery environments in which the sperm must swim to the eggs. If the water is polluted, the gametes might not unite, preventing reproduction of the species in the polluted area.

The genetic characteristics of a sexually produced organism are described by **genotype**, the genes carried by an organism, and **phenotype**, the way an organism looks and behaves. Each organism has two genes that control its traits—one from each parent. These genes are located on chromosomes. Genes exist in alternative forms called **alleles**. The allele combination an organism contains determines its genotype. Some alleles are dominant, while others are recessive. A Punnett square is a shorthand way of finding the expected proportions of possible genotypes in the offspring of two parents.

**Figure 1** is a Punnett square for two pea plants, where each parent has one gene for being tall (T) and one gene for being short (t). The tall characteristic is dominant, which means that if the pea plant’s genotype includes a tall gene (T), the phenotype of the pea plant will be tall. The short characteristic is recessive, which means that a pea plant will be short if, and only if, its genotype is homozygous and has two short genes (tt).

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**Figure 1** This Punnett square predicts the results of a cross between two heterozygous pea plants.
There are three different genotypes for the height of a pea plant: \( TT \), \( Tt \), and \( tt \). However, there are only two different phenotypes: tall and short. The pea plant will have a tall phenotype when its genotype is \( TT \) or \( Tt \). The pea plant’s phenotype will be short only when its genotype is \( tt \). An organism is \textbf{heterozygous} when it has two different alleles for a trait: in the case of the pea plant’s height, \( Tt \). An organism is \textbf{homozygous} when it has two of the same alleles for a trait: \( TT \) or \( tt \). Note that a pea plant can be short only if its genotype is homozygous \((TT\) or \( tt)\), but it can be tall with a homozygous \((TT)\) or heterozygous \((Tt)\) genotype.

1. Which phrases identify the characteristics of asexual reproduction?
   
   A. two parents; no union of gametes; offspring identical to parents
   
   B. one parent; no union of gametes; offspring genetically identical to parent
   
   C. one parent; union of gametes; offspring similar, but not genetically identical, to parent
   
   D. two parents; union of gametes; offspring similar, but not genetically identical, to parents

2. Complete and examine the Punnett square shown below. What percent of the offspring will have a genotype of \( Bb \)?

\[
\begin{array}{ccc}
\text{B} & \text{B} \\
\text{B} & \text{BB} & \text{Bb} \\
\text{b} & \text{Bb} & \text{bb} \\
\end{array}
\]
A cattail, a cat, and a catfish all are different organisms composed of varying amounts of various proteins. If you compare the chromosomes of these organisms, you will find that they all contain deoxyribonucleic acid (DNA) made up of the same four nucleotides with adenine (A), thymine (T), guanine (G), and cytosine (C) as their nitrogenous bases, as shown in Figure 1. A nucleotide is a subunit of nucleic acid, which is a complex biomolecule that stores cellular information in the form of a code. How can organisms be so different from each other if their genetic material is made of the same four nucleotides? Their differences result from the sequence of the four different nucleotides along the DNA strands, as shown in Figure 2.

The sequence of nucleotides forms the unique genetic information of an organism. For example, a nucleotide sequence of A-T-T-G-A-C carries information different from a sequence of T-C-C-A-A-A. In a similar way, two six-letter words made of the same letters but arranged in different orders have different meanings. The closer the relationship between two organisms, the more similar their DNA nucleotide sequences will be. The DNA sequences of a chimpanzee are similar to those of a gorilla, but different from those of a rosebush. Scientists use nucleotide sequences to determine evolutionary relationships among organisms, to determine whether two people are related, and to identify persons at a crime scene.

The sequence of nucleotides in DNA contains information that codes for proteins. Once proteins are produced, they fold into complex, three-dimensional shapes to become key structures and regulators of cell functions. Some proteins become structures, such as the filaments in muscle tissue. Other proteins, such as enzymes, control chemical reactions that perform life functions—breaking down glucose molecules in cellular respiration, digesting food, or making spindle fibers during mitosis. In fact, enzymes control the chemical reactions of an organism. Thus, by encoding the instructions for making proteins, DNA strands control cells.

Proteins are polypeptides, which are long chains of amino acids. The sequence of nucleotides in each gene contains information for assembling the string of amino acids that make up a single protein. DNA strands provide ribonucleic acid (RNA) molecules with the instructions for making proteins. The RNA molecules assemble the protein amino acid by amino acid.
The nucleotide sequence is transcribed from DNA to a strand of messenger RNA (mRNA). Think of this message being written in a language that uses nitrogenous bases as its alphabet. Every three base combination is a letter in the DNA alphabet called a codon. Each codon codes for an amino acid. Because there are only 20 common amino acids, some amino acids correspond to more than one codon. As codons are translated into amino acids by the cell's ribosomes, the chains of amino acids make the polypeptide chains that form proteins used by the cell.

**Figure 2** The structure of DNA

- a. In each chain of nucleotides, the sugar of one nucleotide is joined to the phosphate group of the next nucleotide by a covalent bond.
- b. The two chains of nucleotides in a DNA molecule are held together by hydrogen bonds between the bases. In DNA, cytosine forms three hydrogen bonds with guanine, and thymine forms two hydrogen bonds with adenine.
- c. Complementary base pairing produces a long, two-stranded molecule that often is compared to a zipper. As you can see, the sides of the zipper are formed by the sugar and phosphate units, while the teeth of the zipper are the pairs of bases.

**Why is the presence of DNA important for cellular metabolic activities?**
A. DNA is the major component of cytoplasm.
B. DNA directly increases the solubility of nutrients.
C. DNA is a structural component of cell membranes.
D. DNA directs the production of proteins and enzymes.

**Most sequences of three bases in the DNA of a gene code form a single ________ in a protein.**

- F. gene
- G. strand
- H. mRNA
- I. amino acid
Natural Selection and Species Diversity

Key Questions:
1. What mechanisms influence species diversity?
2. What is some evidence for evolution?

Evolution is the process of change over time as a result of natural selection. British scientist Charles Darwin developed a theory of evolution which provides the basis of modern evolutionary theory. Using his collections and observations from a scientific journey around the world from 1831 to 1836, Darwin identified the process of natural selection, the steps of which are illustrated in Figure 1.

Figure 1  Darwin proposed the idea of natural selection. Over time, offspring with certain variations make up most of the population and can look entirely different from their ancestors.

Natural selection is a mechanism for change in populations. It occurs when organisms with favorable variations survive, reproduce, and pass their variations to the next generation. As a result, each generation largely consists of offspring from parents with these variations that aid survival. Figure 1 illustrates some genetic variations which increase or decrease an organism’s chance of survival in an environment. There are three different types of natural selection that act on variation: stabilizing, directional, and disruptive. Stabilizing selection is natural selection that favors average individuals in a population. Directional selection occurs when natural selection favors one of the extreme variations of a trait, and in disruptive selection, individuals with either extreme of a trait’s variations are selected for survival.

A population that is in genetic equilibrium is not evolving. Any factor that affects the genes in the gene pool disrupts a population’s genetic equilibrium, which results in the process of evolution. One mechanism for genetic change is mutation. Environmental factors, such as radiation or chemicals, cause many mutations, but other mutations occur by chance.
Most of the evidence for evolution is indirect, coming from sources such as fossils and studies of anatomy and biochemistry. An example of anatomical evidence for evolution is illustrated in Figure 2. Although the bones of each forelimb are modified for their function, the basic arrangement of the bones in each limb is similar. Evolutionary biologists view such structural similarities as evidence that organisms evolved from a common ancestor. It would be unlikely for so many animals to have similar structures if each species arose separately. Structural features with a common evolutionary origin are called **homologous structures**. Homologous structures can be similar in arrangement, in function, or in both.

![Figure 2](image)

**Figure 2** The bones of these organisms have similar functions. The whale has a flipper that it uses to swim through the water. The crocodile has an arm that supports its weight as it walks on land. A bird has a wing that it uses to fly through the air.

The structural or functional similarity of a body feature does not always mean that two species are closely related. For example, the wing of a butterfly and the wing of a bird are not similar in structure, but they are similar in function. The body parts of organisms that do not have a common evolutionary origin but are similar in function are called **analogous structures**.

Evidence accumulated by many researchers over time indicates that life on Earth probably began billions of years ago in the form of unicellular organisms. Scientists theorize that the species existing on Earth today developed from earlier species that adapted to changing conditions. Most present-day organisms changed gradually over millions of years.
According to the theory of natural selection, why are some individuals more likely than others to survive and reproduce?

A. Some individuals have adaptations that enable them to produce more offspring.
B. Some individuals have adaptations that allow them to live a long time.
C. Some individuals do not pass new characteristics to their offspring.
D. Some individuals pass mutations to their offspring that are neither harmful nor helpful.

In terms of natural selection and resistance, why do many towns no longer routinely spray insecticides to kill mosquitoes during summer months?
Interdependence in Ecosystems

Key Questions:
1. How are interdependence and biodiversity of organisms related?
2. What is involved in the flow of energy through an ecosystem?

The study of relationships among organisms and their environment is called ecology. An ecosystem is made up of all the communities in an area and the nonliving things with which they interact. Most species in ecosystems survive because of how they relate to other species. When organisms rely on each other, they are interdependent. This interdependence exists in various forms and is also shown in different models of energy transfer. These models include food chains, food webs, and energy pyramids.

**Biodiversity** One of the important ecosystems in Florida is made up of coral reefs. The Florida coral reefs combine into the only major reef system in the continental United States. A coral reef forms from the skeletons of dead coral. Coral spend their entire adult lives in the reef. Thousands of species of sea organisms live in or near the reef using it as a food source and some as protection against others predators. Almost as many species live in the coral reefs of Florida as in the tropical rain forest—the most diverse ecosystem on Earth.

The variety of life in an ecosystem is called **biodiversity**. Biodiversity is important in ecosystems worldwide. When many species lead to the survival of many others, this makes an ecosystem stable. Biodiversity is important for people. Living things provide people with food, medicine, building materials, and fiber for clothing.

**Symbiosis** In ecosystems, many species of organisms have close relationships that are necessary for their survival. **Symbiosis** occurs when two or more different species have a close relationship. One type of symbiosis is called mutualism. **Mutualism** is a relationship in which both species benefit. The coral of Florida provide an excellent example of mutualism. Because coral are animals, they do not make their own food. Coral get most of their food from one-celled algae which live inside them. In turn, the coral help the algae by providing the carbon dioxide (CO₂) the algae need for photosynthesis.
Another type of symbiosis is **commensalism**. It is a relationship in which only one species benefits and the other species is not harmed or helped. When mosses grow on trees, the trees are not harmed, but the mosses get a good living space. **Parasitism** is a form of symbiosis as well. Parasitism is a relationship in which a member of one species benefits at the expense of another species. For instance, when a tick lives on a dog, it is beneficial for the tick but harmful for the dog. The tick—a parasite—gets food and a home, but the dog—the host—could get sick.

**Food Chains**  Most of the interactions between members of different species involve feeding. Feeding transfers the energy stored in the molecules of one organism to another organism. The organism oxidizes food to release energy that it can use for maintenance and growth or is transferred into heat. One model of the transfer of energy is a food chain as shown in **Figure 1**.

![Aquatic plants → Insects → Bluegills → Humans](image)

**Figure 1**  This food chain illustrates the transfer of energy among these organisms.

Organisms can be classified according to their roles in a food chain. The ultimate source of energy for all life is the Sun. Plants use the energy from the Sun to make food in a process called photosynthesis. **Autotrophs**, or producers, are organisms that use light energy or energy stored in chemical compounds to make other energy-rich compounds. Grass, trees, and other plants are the most familiar autotrophs. Some one-celled organisms, such as green algae, also are autotrophs.

Some organisms cannot make their own food. They must eat other organisms to get their food and energy. These organisms are called **heterotrophs**, or consumers. All animals are heterotrophs. Some heterotrophs, such as deer, feed only on autotrophs. They are herbivores. Other heterotrophs, such as panthers, feed only on other heterotrophs. They are carnivores. Still other heterotrophs, such as bears and humans, are omnivores. They feed on both autotrophs and heterotrophs.

**Decomposers** break down the complex compounds of dead and decaying plants and animals. They change these compounds into simpler forms that they can use for fuel. Decomposers also break down energy into molecules that are returned to the environment. Some carbon (C) is returned to the air as carbon dioxide (CO₂). Plants use the carbon to make more high-energy molecules. A form of nitrogen (N) returns to the soil when amino acids are broken down. Plants take in the nitrogen and produce new proteins. Some protozoans, many bacteria, and most fungi are decomposers.
Food Webs  A food chain shows only one possible path for the transfer of matter and energy through an ecosystem. Many other paths may exist because many different organisms can be on each trophic level. For example, many organisms other than bluegill eat insects. Also, many different kinds of organisms eat more than one type of food. This means that a single species, such as humans, may feed at several different trophic levels. For these reasons, scientists also use food webs to illustrate the transfer of energy. Food webs are models that show all possible feeding relationships at each trophic level in a community. A food web is a more realistic model than a food chain because most organisms depend on more than one type of organism for food. Figure 2 shows part of a food web that exists between organisms off the Atlantic Coast.

Energy pyramids  A food chain usually has three or four steps but no more than five. Less energy is available at the last step than is available at the first step. This is because at each transfer of energy, a portion of the energy is lost as heat due to the activities of the organisms. An energy pyramid, like the one shown in Figure 3, shows the amount of energy available at each feeding level in an ecosystem. The bottom of the pyramid, which represents all of the producers, is the first feeding level. It is the largest level because it contains the most energy and the largest number of organisms. As you move up the pyramid, the transfer of energy is less efficient, and each level becomes smaller.

Figure 2  Food webs in the Atlantic Ocean are based on phytoplankton, which are microscopic algae. The algae are eaten by shrimplike krill, which are eaten by baleen whales, squid, and fish. Sharks and people eat the squid and fish.
1. Which is an example of interdependence among organisms?
   A. autotrophy
   B. decomposing
   C. heterotrophy
   D. symbiosis

2. Refer to the food chain below. What is the first effect a decrease in octopi would have on the other organisms in the food chain?

   <food chain image>

   - F. The number of crabs would increase.
   - G. The number of algae would decrease.
   - H. The number of algae would increase.
   - I. The number of crabs would decrease.

3. Which describes the amount of energy available at each trophic, or feeding, level?
   A. the amount of heat available
   B. the amount of energy in an individual organism
   C. the amount of energy in an individual organism and the number of organisms
   D. the number of organisms at that level in the food chain
Key Questions:

1. **What elements are essential to life on Earth?**
2. **How do elements on Earth participate in life cycles?**

Elements such as carbon (C), oxygen (O), and nitrogen (N) make up molecules that are essential to all life on Earth. These elements make up water and macromolecules such as carbohydrates, proteins, fats, and nucleic acids, which are needed by all organisms to survive. Many of these elements are part of natural cycles that occur on Earth, as illustrated in **Figure 1**.

Atoms of carbon form the framework for proteins, carbohydrates, fats, and nucleic acids. The carbon cycle starts with plants and algae. During photosynthesis, as shown in the equation below, plants and algae use energy from the Sun to convert carbon dioxide (CO₂) into energy-rich carbon molecules, such as glucose (C₆H₁₂O₆), that many organisms use for a source of energy. Note that oxygen (O₂) gas is a product of photosynthesis and is released into the atmosphere.

\[
6\text{CO}_2 + 6\text{H}_2\text{O} + \text{light energy} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2
\]

carbon  water  glucose  oxygen
dioxide

**Figure 1**  Many of Earth’s natural processes occur in cycles.
Organisms use glucose molecules for growth and energy. When organisms undergo cellular respiration, energy is released from the carbon-containing molecules in the form of ATP molecules. Carbon dioxide also is released and returned to the atmosphere. The equation for cellular respiration is shown below. Note that oxygen is a reactant in cellular respiration.

\[
P + ADP + C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{ATP molecules}
\]

Plants use nitrogen to make important molecules such as proteins. Though air is about 78 percent nitrogen, most plants cannot use the nitrogen in the air. They use nitrogen in the soil that has been converted into more usable forms by bacteria.

Herbivores eat plants and convert nitrogen-containing plant proteins into nitrogen-containing animal proteins. Your body converts the protein components in food into human proteins in the form of muscle cells, blood cells, and enzymes. Urine, an animal waste, also contains nitrogen compounds. When an animal urinates, nitrogen returns to the soil and eventually to the atmosphere. Plants reuse the nitrogen that has been returned to the soil. Soil bacteria also act on nitrogen-containing molecules and release nitrogen back into the air. Figure 2 shows the nitrogen cycle.

Figure 2 Nitrogen can be cycled from bacteria on plant roots, then to animals, and directly back to plants again as a result of decomposition.
1. Which would most decrease the amount of carbon dioxide in the air?
   A. running dog
   B. burning forest
   C. growing maple tree
   D. person driving a car

2. Which is not essential to life on Earth, according to the passage?
   F. boron (B)
   G. carbon (C)
   H. oxygen (O)
   I. nitrogen (N)
Standard SC.G.2.4.1: The student knows that layers of energy-rich organic materials have been gradually turned into great coal beds and oil pools (fossil fuels) by the pressure of the overlying earth and that humans burn fossil fuels to release the stored energy as heat and carbon dioxide.

Standard SC.B.1.4.5: The student knows that each source of energy presents advantages and disadvantages to its use in society (e.g., political and economic implications may determine a society’s selection of renewable or nonrenewable energy sources).

Key Questions:

1. How are fossil fuels formed?
2. What are the advantages and disadvantages of using fossil fuels for energy?
3. What are the advantages and disadvantages of using sources other than fossil fuels for energy?

Coal, petroleum (crude oil), and natural gas are the forms of energy most used in the United States and elsewhere. These fuels are the remains of once-living organisms that were buried, compressed, and altered over millions of years. They are called fossil fuels. As populations increase, the need for energy also increases. The amount of fossil fuels is limited, however. Because fossil fuels take so long to form, they are considered nonrenewable resources. As sources of fossil fuels become scarce, fossil fuel costs will rise. Eventually, primary energy resources will need to be renewable—able to be replaced within a relatively short time. Other costs of burning fossil fuels involve their effects on the environment. Scientists already are working on ways to make the process of burning fossil fuels cleaner. Social and political action plays a large part in the choice a society makes regarding which sources to develop and use.

**Fossil Fuel Formation**  
Energy in fossil fuels is stored in organic matter in chemical bonds. These bonds form during the process of photosynthesis. Over time, oxygen (O) and hydrogen (H) are lost from the organic matter, concentrating the carbon (C) that was present in the once-living organisms. Three common fossil fuels are coal, petroleum, and natural gas. Coal is a solid, petroleum is a liquid, and natural gas is a vapor. Coal formed from the remains of numerous generations of tropical swamp plants. **Figure 1** shows the four basic stages in the formation of coal. The amount of carbon in coal determines the amount of energy that is produced when the coal burns.

**Figure 1**  
Coal is formed in four basic stages.

a. Dead plant material accumulates in swamps and eventually forms a layer of peat.

b. Over time, heat and pressure cause the peat to change into lignite coal.

c. As the lignite coal is buried by more sediments, heat and pressure change it into bituminous coal.

d. When bituminous coal is heated and squeezed during metamorphism, anthracite coal forms.
**Petroleum** As ancient marine organisms died, they settled on the ocean floor and were covered with sediment. Over millions of years, pressure from the overlying sediment and other changes converted the remains to petroleum. Similar conditions have resulted in the formation of natural gas. Because liquids and gases are fluids, petroleum and natural gas often migrate, or move, from the rocks in which they formed. These fuels continue to migrate until they reach an impermeable layer of rock. Such a barrier prevents the fluids from moving by forming a trap, or reservoir. Wells drilled into these traps allow the fuels to be brought to the surface, where they are processed.

**Figure 2** Oil and natural gas are trapped and accumulate beneath the surface of Earth.

**Effects of Burning Fossil Fuels** Burning fossil fuels releases stored energy as heat, but it also creates pollution, such as smog and acid rain, and releases carbon dioxide (CO₂) into the atmosphere. This important gas is present in small amounts in the atmosphere and helps absorb solar radiation, which keeps our planet warm. Evidence suggests that the burning of fossil fuels adds to this amount of carbon dioxide in the atmosphere. Some scientists hypothesize that this increase in carbon dioxide is raising the average temperatures on Earth, a process called global warming. If these scientists are correct, global warming could result in changes in the climate. For example, higher temperatures could increase the rate at which polar ice melts. This could raise the levels of the oceans. Such increases could have severe impacts on coastal areas.

**Alternative Sources of Energy** Less than 10 percent of the energy used in the United States in 2005 came from sources other than fossil fuels. Some of these alternative energy sources are listed in Table 1.
Another energy source is called biomass energy. It is derived from burning organic material, such as wood, alcohol, and garbage. Florida has waste-to-energy (WTE) facilities that burn garbage to generate electricity. Florida also uses garbage in a landfill-to-fuel process. This process turns garbage into methane gas. Methane is made when a plant or animal dies and bacteria break down its tissues. This natural gas collects in pipes and flows to facilities that can use it as fuel for heating and cooking. It also can be used to heat water to run steam turbines that make electricity.

Florida is a low-lying state with a high water table. Because of this, garbage landfills cannot be dug into the ground. Waste is added above the ground, and landfills grow higher with every layer. In coastal counties, landfills often are the tallest structures. Changing garbage into energy helps solve the problem of waste materials. It also cuts down on the use of fossil fuels. As of 2005, the 13 WTE facilities in Florida produced more electricity from solid waste than any other state produced. The plants burn 20,000 metric tons of solid waste each day. In addition, ten landfill-to-fuel facilities run in Florida.

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<th>How Produced</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<td>Hydroelectric</td>
<td>Energy in running water turns turbines that turn generators that make electricity</td>
<td>Clean, renewable</td>
<td>The building of dams to harness the moving water can displace people and destroy wildlife habitats; upstream lakes in areas behind dams fill with sediment and erosion increases downstream</td>
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<tr>
<td>Nuclear</td>
<td>Atomic reactions (nuclear fission) using a type of uranium as fuel; as each atom splits, heat is released that is used to boil water to make steam; steam drives turbines, which turn a generator that produces electricity</td>
<td>Clean to air</td>
<td>Long-lasting toxic waste that must be kept from water and placed in protected containers for 10,000 years; limited supplies of uranium make nuclear power nonrenewable</td>
</tr>
<tr>
<td>Wind</td>
<td>A large number of windmills placed together generate electricity</td>
<td>Clean, renewable</td>
<td>Needs strong winds on a steady and regular basis; harmful to birds; some people think wind farms are ugly</td>
</tr>
<tr>
<td>Geothermal</td>
<td>Bodies of magma can heat large reservoirs of groundwater; steam from the reservoirs turns turbines that run generators that make electricity</td>
<td>Clean, renewable</td>
<td>So far used only in Hawaii and parts of the western United States</td>
</tr>
<tr>
<td>Solar</td>
<td>1. South-facing windows on buildings act as passive collectors of energy from the Sun, warming exposed rooms; 2. Solar cells actively collect energy from the Sun and transform it into electricity</td>
<td>Clean, renewable</td>
<td>Solar cells work less efficiently on cloudy days and not at all at night; some systems use batteries to store energy, but it is difficult to store large amounts; worn-out batteries must be discarded in ways that will not pollute the environment</td>
</tr>
</tbody>
</table>
1. When fossil fuels burn, they release stored energy. What is the source of this energy?
   A. carbon dioxide (CO₂)
   B. the interior of Earth
   C. hydrogen (H)
   D. the Sun

2. Scientists are working to develop even more alternative sources of energy, such as hydrogen power. They also are working to improve the processes involved in providing energy from the sources already being used. Refer to Table 1. Which of the following describes the advantages of such work to society?
   F. to make the air cleaner and the average temperatures on the surface of Earth warmer
   G. to make alternative energy sources safer and more widely available
   H. to make energy less costly and the average temperatures of the surface of Earth warmer
   I. to make fossil fuels less costly and more widely available
An ecosystem consists of all the organisms living in an area, as well as the nonliving parts of that environment. Living things are affected by other living things. Living things in an environment are called biotic factors. The nonliving things in the environment, the abiotic factors, also affect living things. They include water, air, soil, temperature, light, and space. Anything that limits the ability of an organism to live in a certain place is called a limiting factor. The interaction of living and nonliving things means that the natural world always is changing.

**Succession** The normal, gradual changes that occur in the types of species that live in an area are referred to as succession. There are two types of succession—primary and secondary. Primary succession begins on land that does not have any living organisms. For example, lava flowing from a volcano destroys everything in its path. As the lava cools, it forms new, but barren, land. The forces of weather and erosion begin to break up the rock into soil. Lichens and mosses are among the few producers that can grow in this newly formed soil. As they die and decompose, they provide organic matter, changing the condition of the soil. Water, wind, and animals carry seeds into the area, and new plants begin to grow. Over time, other types of organisms move in and become established. This results in a climax community—a community in which primary succession has slowed and the system has stabilized. Figure 1 shows succession from bare rock to a climax community.
Stability in an ecosystem does not mean that change stops. Biotic and abiotic factors continue to interact. This causes the numbers of species to rise and fall. Over time, however, the changes in ecosystems are balanced. For example, wildfires are unexpected and can cause devastating losses to human life and habitats, but these same wildfires can be helpful to ecosystems. Some trees, such as certain types of willow, will re-grow from their root systems. Some pines have cones that open only when heated. Also, dormant seeds of Peters Mountain mallow depend on fire to crack them to let in water. Some birds, such as woodpeckers, benefit from the increase of open areas between meadows and forests. The ecosystem eventually is restored. Such changes result in secondary succession. Secondary succession occurs in areas that previously contained life and still contain soil. A climax community will take less time to form in a secondary succession than in a primary succession.

Forest services are working to conserve the forest ecosystems. Sometimes the forest service sets controlled fires in declining forests to get rid of the dead brush and trees that easily can catch fire by lightning. These efforts contribute to the beginning of a secondary succession.

Biomes Large regions that have similar climates and similar ecosystems are called biomes. The amount of precipitation and average temperature determine the type of biome. The common land biomes include tundra and taiga in cooler areas. In temperate zones, deciduous forest and rain forest biomes are found. Tropical rain forests are found near the equator. Grasslands are found in temperate and tropical zones. Deserts can be found in all but the polar regions. A summary of these land biomes appears in Table 1. A few examples of the organisms found in the biomes also are included.
Wildfires in Florida destroyed almost 500,000 acres of land in 1998. Not only have people rebuilt in those areas, but the forest areas are re-growing. Which explains this situation?

A. Primary succession will occur; new species will establish themselves.
B. The area will remain barren; no new species will establish themselves.
C. Secondary succession will occur; eventually a climax community will be reached.
D. Secondary succession will occur; the area will turn into a completely different habitat, such as a desert.

Refer to Table 1. What is the relationship between limiting factors and the size of tundra plants?

F. Much sunlight most of the year and cold temperatures make a long growing season.
G. Much sunlight for a short period of the year and warm temperatures make a long growing season.
H. Little sunlight part of the year and warm temperatures make a long growing season.
I. Little sunlight most of the year and cold temperatures make a short growing season.
**Population Genetics**

**Key Questions:**

1. **What is genetic variation?**
2. **What is involved in natural selection?**

A population is all of the individuals of one species that live in the same area at the same time. Change in a population is based on different traits in the species. Change also depends on the process that ensures that those individuals best adapted to the surrounding environment will survive to reproduce.

**Genetic Variation** Within any species, a wide variety of physical characteristics exists. An inherited trait that makes an individual different from other members of its species is called a **variation**. Each member of a population has the genes that characterize the traits of the species. These genes exist as pairs of alleles. An **allele** is an alternative form of a gene for each trait of an organism. All the genes of the individuals in a population make up the gene pool of the population. Traits that are advantageous in a population are passed to the offspring. An organism that is poorly adapted to its environment might be unable to survive and reproduce.

The major way genetic variation in traits occurs is through a process called crossing over. Crossing over takes place when cells begin meiosis. At that time, the duplicated homologous chromosomes line up and exchange parts. **Homologous chromosomes** are paired chromosomes with genes for the same traits arranged in the same order. As genes are sorted during this process, new allele combinations are created. These combinations are different from those of the parent. Successful combinations will continue because they will be passed to offspring. The combinations of traits that are not successful eventually die out, because individuals that carry them will not survive in numbers large enough to reproduce effectively.

Another way variation in traits occurs is mutation. Any change in the DNA sequence of an individual is called a **mutation**. Each cell of an organism contains hereditary material in a chemical known as the DNA code. When a cell divides, the DNA code is copied and passed to the new cells. Factors such as the exposure to radiation and chemicals of parents can cause mutations in offspring. Other mutations occur by chance. A mutation could result in a protein that does not work correctly. Offspring with the mutation might not survive. Sometimes, however, a mutation results in a useful variation. The mutation might give an organism the ability to see farther or run faster. An offspring with the beneficial mutation might survive better in its environment and pass the new trait on to its own offspring.
Natural Selection is the concept that organisms with traits best suited to their environment are the most likely to survive and reproduce. If offspring of individuals with these trait variations continue to survive and reproduce over many generations, a new species might evolve. This evolution might take hundreds, thousands, or millions of generations. An example of evolution can be seen in Figure 1, which shows how the traits of the camel have changed over time. Time is given in millions of years ago (mya).

There are three types of natural selection. One favors the average organisms in a population. Consider a population of spiders. It might be easy for predators in the area to see large spiders. This makes them easier to capture. However, it might be difficult for small spiders to find food. Therefore, in this environment, average-sized spiders are more likely to survive because they have the advantage.

Another type of natural selection occurs when one extreme trait is favored. For example, suppose an insect species invades the trees in an area. These insects live deep in tree tissues. Woodpeckers in the same area feed on the insects, but only the woodpeckers with long beaks can easily reach the insects. So, the long-beaked woodpeckers in the population have a better chance of survival over woodpeckers with short or average-sized beaks.

In yet another example, individuals are selected that have either extreme variation of a trait. For instance, marine organisms called limpets might have shell colors that range from white to tan to dark brown. As adults, limpets live attached to rocks. On light-colored rocks, limpets with white shells have an advantage. Bird predators cannot easily see them. On dark-colored rocks, dark-shelled limpets have the advantage. They are camouflaged. However, birds easily can see tan-colored limpets on either the light or dark rocks. In this case, natural selection tends to eliminate the organisms having the in-between color. It gives an advantage to the two extreme traits.

Within its lifetime, a species cannot develop a new phenotype—a look or way of behaving—in response to its environment. For example, a limpet with a tan-colored shell cannot change its shell color to one that is lighter or darker. Either of those traits must be passed from parent to offspring.

Figure 1 Several stages in the evolution of the modern camel are shown in the diagram.
1 About four million years ago, cheetahs were twice as heavy as cheetahs today. What traits associated with being lighter in weight might have helped these cheetahs to be selected naturally over heavier cheetahs?
   A. Lighter cheetahs probably had the ability to move faster, making it easier for them to capture food and avoid predators.
   B. Heavier cheetahs probably had the ability to hide better to avoid predators.
   C. Heavier cheetahs probably had the ability to move faster, making it easier for them to capture food.
   D. Heavier cheetahs probably had fewer predators.

2 Key deer are found only on approximately 30 islands in the lower keys of Florida. During the last ice age, Virginia white-tailed deer moved south ahead of an advancing ice sheet. When ice sheets melted worldwide about 4,000 to 10,000 years ago, ocean levels rose. Some deer were isolated on a chain of small islands and evolved into a new subspecies. The Key deer measure from 61 to 71 cm at the shoulder. Virginia white-tailed deer can be 91 to 107 cm tall at the shoulder. Which statement helps explain the change in deer over time?
   F. Larger deer probably had a higher survival rate because of the plentiful amount of food on the small islands.
   G. Smaller deer probably did not adapt to the environment in the north.
   H. Smaller deer probably adapted better to the limited amount of food on the small land areas.
   I. Larger deer probably had traits that helped them produce larger offspring on the islands.
The activities of humans can affect the systems on Earth in both positive and negative ways. Some activities improve the quality of life for humans but hurt the environment. These negative effects are not always known immediately. People are working to find ways to correct the problems, but it can take years to see the results because experimenting and testing possible solutions is a time-consuming process. Scientists must also ensure that the solutions do not cause new problems. An example of such a situation is air conditioning. Air conditioning makes the air in homes comfortable in summer and makes it possible for humans to live in desert climates. It also helps people who have breathing problems by filtering out allergens and other substances that can affect their health. However, over time, scientists discovered that the coolant used in air conditioning was thinning the atmosphere’s ozone layer, which protects living things from the Sun’s radiation. Since this discovery, humans have since found more ozone-friendly coolants for air conditioning that must replace the old coolants by 2010.

Interconnected Systems on Earth Many essential elements and compounds cycle through the environment. Water, for example, cycles from the atmosphere to the ground and bodies of water and back again to the atmosphere. Figure 1 illustrates this cycle and identifies the processes involved. The carbon cycle works in a similar way, as shown in Figure 2. Carbon is found in organisms. Nitrogen is an element also important to life. It is found in proteins and nucleic acids. The nitrogen cycle begins with the transfer of nitrogen from producers to consumers. It then moves back to the atmosphere or directly into producers.
Population Growth  The size of a population greatly affects ecosystems. Population sizes always are changing. The rate of change varies among populations. For example, in contrast to a mouse population, the number of pine trees in a forest changes slowly. However, a fire or disease could reduce these populations quickly.

All ecosystems have a limited amount of resources. These include food, water, living space, mates, and nesting sites. A limiting factor is any **biotic** (living) or **abiotic** (nonliving) **factor** that limits the number of individuals in a population. For example, a drought might reduce the number of seed-producing plants. This could affect a songbird population that feeds on the seeds of these plants. If the songbird population decreases, the animals that feed on the songbirds also will be affected.

Competition exists when organisms struggle to obtain the same resources that they need to survive and reproduce. As a population becomes more crowded, the struggle for the resources increases. At some point, resources become so scarce that some individuals are not able to survive or reproduce. When that happens, the environment has reached its **carrying capacity**. **Carrying capacity** is the largest number of individuals of a species that an environment can support and maintain for a long period of time.

*Figure 2  Earth's atmosphere contains about 0.03 percent carbon in the form of carbon dioxide (CO₂).*
Effects of Human Population Growth

While all living things affect the environments in which they live, humans can have a greater impact than other organisms. This is largely due to the growth of the human population, as shown in Figure 3. As the human population continues to grow, the demand for natural resources also will increase. The unwise use of resources can deplete them. Organisms in an ecosystem are interconnected through the food web, and they compete for limited resources. Human population growth in Florida has led to the loss of habitats of other organisms. For example, the Florida panther is the most endangered species in the world. The species originally lived in all parts of Florida, as far west as Louisiana and as far north as Tennessee. Human actions have led to the decline in the Florida panther population. Much of their habitat has been lost as cities have expanded to fill the land. Now only a small breeding population exists in national and state parks.

Using resources to meet the needs of people also can degrade, or lessen the quality of, the environment. For example, humans need energy to heat their homes and businesses and run their cars and machines. When fossil fuels are burned, certain chemicals are released into the atmosphere. These pollutants combine with water in the atmosphere and fall to Earth as acid precipitation. Acid precipitation can lower the pH (the measure of the amount of hydrogen ions in solution) of lakes, rivers, and streams, as well as soil. Some aquatic organisms cannot tolerate the lower pH and will die. Some organisms, such as frogs, might be able to tolerate the lower pH. However, if their source of food cannot survive the change in pH, they are affected as well. Acid precipitation also causes nutrients to seep out of soil. The loss of nutrients can lead to the death of trees. Acid precipitation also damages plant tissues and interferes with plant growth. Leaves can turn brown and fall off, and plant growth can be slowed. Organisms that depend on these plants as a food source will be affected.
Industrial pollutants, such as mercury (Hg), that are released into the air when fossil fuels are burned can harm aquatic life. Mercury reaches lakes and rivers through raindrops or in runoff from land. In water, mercury is changed to a toxic form by microorganisms. The toxin builds up in fish at levels that are harmful to the birds and mammals—including humans—that eat them. As the toxin moves through the food chain, predators of fish-eating animals also are affected.

Another example of human activity that affects the environment is the introduction of species that are not native to an ecosystem. These introduced species often are called exotic species. In Florida, Brazilian pepper was introduced in the 1800s as an ornamental tree. Brazilian pepper can grow so tall and dense that vegetation cannot survive under the thick branches. The plant takes over wetlands, pinelands, and pastures, killing native species. Kudzu was introduced in the 1920s and 1930s to help prevent soil erosion. Once planted, however, this vine with beautiful magenta flowers engulfed and smothered pine trees. Both species are fast-growing and have spread throughout Florida, especially in the south. Scientists are working to find a way to eliminate them safely. The main solution is to uproot them. Other people are trying to find uses for them. Some people make an herbal drink from kudzu, and some researchers think kudzu might have medicinal uses.

**Beneficial Actions** Because the ecosystems of the world are so susceptible to human influence, various scientific and conservationist groups have implemented action plans to protect the environment. One action is conserving resources such as trees. Trees from tree farms are used for lumber, and old growth forests are left intact. Helpful activities also involve reusing and recycling materials. This reduces the amount of waste. Sanitary landfills can help keep harmful waste products from entering the water and the air. In addition, major efforts have been made toward finding and using forms of fuel other than fossil fuels. The use of solar power, water power, and wind energy can decrease the amount of pollution released into the air.
Refer to Figures 1 and 2. Which illustrates how systems on Earth are connected?
A. Each cycle benefits only abiotic factors.
B. Each cycle benefits some biotic and some abiotic factors.
C. Precipitation and making carbohydrates are the same processes; both are important to all organisms.
D. Water and carbon both cycle from the atmosphere to the land environment and back to the atmosphere; both are important to all organisms.

Which statement illustrates how human activities can change the balance of an ecosystem?
F. A hurricane causes a stream to overflow its banks.
G. Increased winds increase water evaporation from a plant.
H. Water pollution from a factory decreases fish populations in a river.
I. The ozone shield helps prevent harmful radiation from reaching Earth’s surface.

The water hyacinth was introduced to the United States in the 1880s. It is a fast-growing plant that blocks sunlight from reaching water and slows the flow of water. In the Florida Everglades, the weed has smothered many plants and harmed other organisms. Scientists are searching for natural enemies of the water hyacinth, including a small fly that lays its eggs in the plant, which might weaken the plant. Introducing a natural enemy is an example of which of the following?
A. a biotic factor unrelated to direct human activity that can affect an ecosystem
B. an abiotic factor related to direct human activity that can affect an ecosystem
C. an abiotic factor unrelated to direct human activity that can affect an ecosystem
D. a biotic factor related to direct human activity that can affect an ecosystem
Key Questions:

1. What is involved in conducting scientific investigations?
2. How do scientists collect data from the universe?
3. Why are models and simulators used in scientific studies?

Science is both a body of knowledge and a way of understanding how the world works. Scientists practice science by observing and experimenting. They explore something new and try to duplicate experiments of other scientists. They also test how well a theory predicts future occurrences. A scientific **theory** is a way of explaining what has been learned from many observations and investigations.

**Scientific Methods** A set of procedures that are followed in conducting an investigation is called a **scientific method**. The steps, as shown in **Figure 1**, can vary. Some steps might be repeated. Other steps might be skipped. The first step usually involves identifying the problem or question the scientist wants to answer. The scientist then forms a hypothesis. A **hypothesis** is a possible explanation that can be tested. An example is “The heavier an object, the faster it will sink in water.” Often, a hypothesis is written as an “if-then” statement, such as “If you exercise for 10 min, then your heart rate will increase.” The results of the investigation either will or will not support the hypothesis.
An investigation examines how one thing affects another under controlled conditions. An investigation usually has at least two variables. A variable is a factor that can cause a change in the results of an investigation. A dependent variable is one that changes according to the changes in the other variables. The independent variable is changed to see how it affects the dependent variable. To keep an investigation accurate, all other factors must remain the same. Factors that do not change are called constants. A control is used to compare the results of the tests. A control is a set of conditions that is not changed. In the other sets of conditions of the investigation, the independent variable is changed to find its effect on the dependent variable.

**Figure 1**

An investigation examines how one thing affects another under controlled conditions. An investigation usually has at least two variables. A variable is a factor that can cause a change in the results of an investigation. A dependent variable is one that changes according to the changes in the other variables. The independent variable is changed to see how it affects the dependent variable. To keep an investigation accurate, all other factors must remain the same. Factors that do not change are called constants. A control is used to compare the results of the tests. A control is a set of conditions that is not changed. In the other sets of conditions of the investigation, the independent variable is changed to find its effect on the dependent variable.
During an investigation, scientists observe data and carefully record them. Tests should be repeated several times to determine whether the data are valid. Accurate records provide clues for determining why results have not been the same in each test. Graphs, tables, and charts commonly are used to display and analyze the data. Conclusions, or explanations, are drawn based on the analyzed data.

**Observational Studies**  
Sometimes a hypothesis cannot be tested by performing an experiment. In this case, scientists base their studies on observation. For example, ethical reasons keep scientists from testing humans to determine whether a particular chemical causes cancer. However, they can look at records that show how many people who have cancer were exposed to the chemical and compare it to the numbers of people who have cancer that were not exposed to the chemical. Then, they would compare the number of people without cancer who were and were not exposed to the chemical. In other cases, practical reasons like time, space, and money keep scientists from changing conditions in a complex system. They might observe animals in a wetlands habitat and track their numbers. Scientists look for patterns in data to help draw conclusions in observational studies.

**High-tech Data Collectors**  
Some places are not safe for scientists to study and some places are too far away, such as another planet or solar system. Scientists use instruments that record and send data over long distances. Such instruments often are launched from the Kennedy Space Center as part of Space Shuttle missions. For example, the X-ray telescopes aboard the Chandra X-ray Observatory provide a way to study black holes. Also, the *Cassini* space probe collects data about Saturn’s moon, Titan.

**Models**  
Scientists often use models to study distant or very small objects. A model represents an idea, event, or object to help people better understand it. A model can be a physical object that is smaller or larger than the object to be studied. A model also might be a computer program. Computer models often provide a way to solve difficult mathematical problems.

Another type of model is a simulator. A simulator imitates conditions as they are found in real life. For example, a pilot uses a flight simulator to practice flying a plane. The simulator reacts the same way a plane does when it flies, but it is safer for the pilot and the plane.

Scientists use special equipment to study properties and interactions of atoms and particles. A supercollider is a very large tool capable of accelerating subatomic particles to very high energies. Models and simulators help scientists gather information about the universe.
During a laboratory activity, a student combined two solutions. In the laboratory report, the student wrote “A yellow color appeared.” What does this statement represent?

A. a conclusion  
B. a hypothesis  
C. an observation  
D. a theory

The table below shows the speed at which different galaxies are moving. You want to determine how much faster one galaxy is moving than another. To which step in a scientific investigation does this operation apply?

F. analyzing the data  
G. communicating the results  
H. drawing a conclusion  
I. proposing a hypothesis

<table>
<thead>
<tr>
<th>Galaxy</th>
<th>Speed (km/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>210</td>
</tr>
<tr>
<td>B</td>
<td>450</td>
</tr>
<tr>
<td>C</td>
<td>972</td>
</tr>
<tr>
<td>D</td>
<td>1383</td>
</tr>
</tbody>
</table>

You are the head of the research division of a company that grows vegetables using hydroponic technology. Hydroponic technology involves growing plants in containers of growth solution in a greenhouse. No soil is used. The growth solution that the company uses contains water, nitrogen, and phosphorus. The company wants to know whether adding iron to this formula will improve the growth of lettuce. What is the hypothesis to be tested in this experiment?

A. If soil is used, the lettuce will grow at a faster rate.  
B. If the plants are moved outdoors, the lettuce will grow at a faster rate.  
C. If iron is added to the hydroponic solution, the lettuce will grow at a faster rate.  
D. If nitrogen is removed from the growth solution, the lettuce will grow at a faster rate.

When would a model or computer simulation be needed?

F. when studying the results of different cooling controls  
G. when testing the amount of radiation needed for cancer treatment  
H. when deciding whether a certain plant will survive with little water  
I. when testing the effects of a certain fertilizer on the growth of crops

When are instruments that collect data from afar needed?

A. when observing the Milky Way galaxy  
B. when studying different kinds of insects  
C. when finding the mass of different metals  
D. when finding the density of various liquids
New Ideas and Scientific Theories

**Standard SC.H.1.4.2:** The student knows that from time to time, major shifts occur in the scientific view of how the world works, but that more often the changes that take place in the body of scientific knowledge are small modifications of prior knowledge.

**Standard SC.H.1.4.3:** The student understands that no matter how well one theory fits observations, a new theory might fit them as well or better, or might fit a wider range of observations, because in science, the testing, revising, and occasional discarding of theories, new and old, never ends and leads to an increasingly better understanding of how things work in the world, but not to absolute truth.

**Standard SC.H.1.4.5:** The student understands that new ideas in science are limited by the context in which they are conceived, are often rejected by the scientific establishment, sometimes spring from unexpected findings, and usually grow slowly from many contributors.

**Standard SC.H.1.4.6:** The student understands that, in the short run, new ideas that do not mesh well with mainstream ideas in science often encounter vigorous criticism and that, in the long run, theories are judged by how they fit with other theories, the range of observations they explain, how well they explain observations, and how effective they are in predicting new findings.

**Key Questions:**

1. How are observations, new ideas, and theories connected?
2. Why is it important to be able to make accurate predictions?

A **scientific theory** is a way of explaining things or events based on what has been learned from many observations and investigations. Ideas about these observations and investigations lead to hypotheses. Hypotheses lead to theories. No matter how well one theory explains a set of observations, it is possible that another explanation will fit just as well or better. Theories should not be regarded as absolute truth. Rather, theories attempt to explain things and events in nature using what is known to date. New studies may change the theory. The new or revised theory should explain the new data and observations as well as the old data and observations.

A **scientific law** is a statement about what happens in nature that seems to be true all the time; it explains what will happen under certain conditions. Gravity is an example of a scientific law. The law of gravity states that any one mass will attract another mass. To date, no experiments have demonstrated otherwise. But this law does not explain why gravity works. Theories are used to explain how and why laws work.
New Ideas  New ideas form from making observations about the events around you. For example, based on many observations, it appears that redheads sunburn easily and seem to have a high risk of skin cancer. More than one million Americans develop skin cancer each year. Most people with light skin, eyes, and hair are at a higher risk. Sunburns pose a risk for everyone, especially if they occur during childhood, but some redheads who do not sunburn still develop skin cancer. Scientists have hypothesized that something other than sunburn puts redheads at high risk. One hypothesis proposes that the composition of melanin may be the risk factor. Melanin is the skin pigment that darkens with exposure to the Sun and produces either a tan or freckles. Redheads have different proportions of types of melanin than people with dark hair. Researchers have reported that they have found evidence that differences in melanin may cause the high risk of skin cancer. The photochemical reaction in the melanin can damage cells that, over time, can develop cancer. Redheads tend to have more pheomelanin, which may be linked to a higher incidence of skin cancer. Researchers think that eumelanin, the type of melanin found in higher proportions in people with dark hair, is helpful in protecting against UV rays. While more research is needed, scientists advise that sunscreen is a must, even if you do not sunburn often.

Discoveries from Discontinued Work  Sometimes a study is discontinued before any data is collected that supports the hypotheses. One example is the study of cloud seeding by the U.S. National Oceanic and Atmospheric Administration (NOAA). For more than 50 years, researchers have been working to modify weather by adding certain substances to clouds, through a process called cloud seeding. Project Stormfury was a project directed by the NOAA in Florida in the 1960s and 1970s. Researchers worked to find a way to reduce moisture in the air, thereby weakening the intensity of hurricanes. The power of a hurricane can be equal to that of a nuclear bomb. One method they tried was using aircraft to inject silver iodide (AgI), or dry ice, into the eye of a hurricane. The theory was that this would cause condensation inside the storm and speed up its life cycle while it was still over the ocean. This would weaken the storm. Other cloud seeding ideas included the use of a special liquid to prevent evaporation of seawater, because added moisture in the clouds fuels storms.

Some efforts seemed to lessen the intensity of hurricanes, but those effects could have been caused by natural events. The NOAA ended Project Stormfury in the early 1980s. To date, scientists have not been able to devise a way to weaken the strength of a coming hurricane. However, the efforts of NOAA researchers led to the development of methods and equipment related to predicting the path and intensity of hurricanes. Because of their research, people can be better prepared for hurricanes and know when to evacuate an area.
Refinement of Previous Work  The research of a Russian chemist named Dmitri Mendeleev provides an example of how science is a continual process of refining previous work. In the late 1800s, he searched for a way to organize knowledge of the elements. He arranged all the elements known at that time in a table and placed the elements in the order of increasing atomic masses. He discovered a pattern in the table. Chemical properties found in lighter elements repeated in heavier elements. Because the pattern repeated, it was considered periodic. He proposed a periodic law which said that the properties of the elements are a periodic function of their masses. From this pattern, Mendeleev was able to make predictions of elements not yet discovered. He left blank spaces in his table to keep the elements properly lined up according to their physical properties. He observed the properties and atomic masses of the elements around these blank spaces. From this information, he was able to predict the properties and mass numbers of the missing elements. When scientists later discovered these missing elements, they found the properties were very close to what Mendeleev had predicted. One prediction was for an element that he called ekasilicon. The predicted properties proved to match those of an element called germanium (Ge) that was discovered later.

Although the arrangement of the elements by Mendeleev was successful, it needed some changes. On his table, atomic mass gradually increased from left to right. However, several elements, such as cobalt (Co) and nickel (Ni), have atomic masses that decrease from left to right. In 1913, scientist Henry G.J. Moseley from Great Britain rearranged the elements according to increasing atomic numbers instead of atomic masses. This new arrangement seemed to correct the problems that had occurred in the old periodic table. The arrangement generated by Moseley is used in the current periodic table. The periodic table has several regions with specific names, as shown in Figure 1. The horizontal rows of elements on the table are called periods. The elements increase by one proton and one electron as you go from left to right in a period. The vertical columns are called groups. The elements in each group have consistent values for certain properties. Scientists around the world continue in their efforts to discover new elements that they predict will fit in this table.
Figure 1  The white squares are classified as metals. The medium gray squares are classified as nonmetals, such as oxygen (O) and carbon (C). The light gray squares are classified as metalloids, or semimetals. The dark gray squares indicate elements that have yet to be discovered or have yet to have experimental results repeated. The white squares at the bottom of the table are metals that fit between metals in the table, as shown by the dotted lines. They are placed at the bottom so the table is in a more usable format.

1. Which increases the reliability of a scientific explanation?
   A. notes taken after an investigation
   B. repeatable data
   C. several likely explanations
   D. vague statements

2. Which explains the status of the theory that cloud seeding can modify weather?
   F. The theory has been disproven.
   G. The theory has yet to be supported.
   H. The theory has been proven in Mexico.
   I. The theory has been shown to be definite.
Responsibilities of Scientists

Key Question:
What is involved in being a responsible scientist?

The work of scientists provides many current and potential benefits. For example, citrus canker is a major problem in Florida and elsewhere. While this disease does not harm humans, the bacteria cause citrus trees to stop producing fruit. The diseased and nearby trees have to be destroyed. Table 1 shows losses from citrus canker for selected varieties of citrus trees. Using biotechnology, scientists are developing strains of citrus trees that are resistant to the disease.

Table 1
Losses of Citrus Canker for Selected Varieties of Citrus Trees

<table>
<thead>
<tr>
<th>Variety</th>
<th>Estimated Acreage Loss (1,000 acres)</th>
<th>Trees Per Acre*</th>
<th>Equivalent Lost Trees (1,000 trees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early-midseason</td>
<td>30,664</td>
<td>127</td>
<td>3,881</td>
</tr>
<tr>
<td>Valencia</td>
<td>14,776</td>
<td>135</td>
<td>1,995</td>
</tr>
<tr>
<td>White seedless grapefruit</td>
<td>4.309</td>
<td>101</td>
<td>434</td>
</tr>
<tr>
<td>Navels</td>
<td>2.250</td>
<td>127</td>
<td>285</td>
</tr>
<tr>
<td>Tangelos</td>
<td>1.128</td>
<td>123</td>
<td>139</td>
</tr>
</tbody>
</table>

*Source: Citrus Summary 1999-00, FASS

Another area in which the work of scientists could provide many benefits is gene therapy. Gene therapy involves inserting copies of a specific gene into cells to restore a missing function or to give the cells a new function. For example, if a cell is unable to function normally because of a mutation in gene X, a normal copy of gene X could be inserted to cover for the defective gene. This type of therapy holds promise for the treatment of many diseases but will only be helpful if scientists present data accurately and truthfully.

Responsible Science Scientists work in many areas of life to meet human needs. Because this work can affect people and the environment in both positive and negative ways, scientists have a duty to work in an ethical manner. This includes conducting experiments methodically and responsibly. Scientists also should work to keep their experiments objective and report their results truthfully. In addition, work should be submitted for critical peer review.
Conducting Experiments  Scientists usually consider results from an experiment valid after they repeat the experiment several times and get similar results. Test results can come under question if they are based on data samples that are too small or taken from the wrong population. For example, a scientist wants to find the percent of adults who use the Internet. The scientist should sample people of all ages, locations, income levels, education, and level of internet use. The sample must be large enough to cut down the chance of errors. The size of the sample will not matter if the sample is taken from the wrong population. Suppose the scientist surveys people only through the Internet. If so, people who do not use the Internet will not be represented. Although many people might respond, the results will show that 100 percent of the people in the sample use the Internet. This does not answer the scientist’s original question.

Reducing Bias  Bias can occur when a scientist expects something to happen and lets the expectation influence an experiment. Bias might be based on a lack of knowledge or a poor understanding of scientific methods.

For example, suppose you are asked to conduct an experiment to determine how the amount of light a plant receives affects its growth. You already know that plants need light to carry out photosynthesis. You form a hypothesis that states that the more light a plant receives, the more it will grow. If you have not conducted background research, you might think that all plants need the same amount of light. You might select one type of plant to prove your hypothesis. If you chose a bean plant, you would find that the results support your hypothesis and conclude that the more light a plant receives over time, the larger it will grow. However, in this situation, you expected your hypothesis to be true based on your limited knowledge of plants and did not design the experiment to test different kinds of plants. If another scientist tested a plant such as ivy, the results probably would not support your hypothesis, because ivy does not need as much light as beans to grow.

Reporting Results  Scientists explain and share their work in reports. A scientific report describes the hypothesis and reviews previous studies. The report then details the methods used, describes the data, and states the conclusions drawn. The report should be free of bias. For example, a scientist might slant a report to show the advantages of a product being tested. If that product is promoted and the drawbacks are not listed, this could be considered fraud. Drawbacks should be presented so possible negative effects can be considered before the research is applied. Reporting methods and data clearly and accurately allows other scientists to recognize problems with the work. A truthful report also allows other scientists to repeat the investigation and match the results. If the results cannot be verified, the claims in the report could be called into question.
Refer to Table 1. Why is it important that these data be accurate?

A. so that growers know that they should grow only the tangelo variety
B. so that growers know that they should grow only the Valencia variety
C. so that growers know that they should grow only the early-midseason variety
D. so that growers and state planners know the extent of the problem in order to find a solution

A scientist wants to determine the percent of teenagers who like pizza. She interviews teenagers leaving a pizza restaurant. Out of 50 teenagers surveyed, 45 report that they like pizza. The scientist concludes that 90 percent of teenagers like to eat pizza. Which is a source of bias in this survey?

F. The scientist likes to eat pizza.
G. The survey cannot be repeated.
H. The size of the sample group was too small.
I. The sample group was drawn from the wrong population.

A scientist presents the results of an experiment in which she concludes that the drug she tested in the laboratory could stop a contagious disease from spreading. How should the scientific community respond to these results?

A. Begin testing the drug on the public.
B. Verify the results by using the methods the scientist used.
C. Ask a drug company to manufacture the drug for the public.
D. Encourage the scientist to experiment further to determine if the drug works on other diseases.
Standard SC.H.2.4.1: The student knows that scientists assume that the universe is a vast system in which basic rules exist that may range from very simple to extremely complex, but that scientists operate on the belief that the rules can be discovered by careful, systemic study.

Key Questions:
1. What is science?
2. What is the difference between a theory and a scientific law?

The word science comes from the Latin word scientia, which means “knowledge.” Science is a method for studying the natural world using observation and investigation, with the objective of gaining knowledge about events in nature. Scientists assume that nature follows a set of rules. These rules can be simple, such as the fact that Earth rotates about once every 24 h, or these rules can be complex, such as those concerning how the human body works.

As more is learned about the natural world, some earlier explanations might be found to be incomplete, or new technology might provide more accurate answers. A classic example of scientific study is that of Earth’s movement. Over 2300 years ago, Greek philosopher Aristotle proposed that the universe was composed of several spheres that revolved around Earth. The outermost sphere held the stars. A sphere within this sphere held the planets. Two more spheres held the Sun and the Moon. This idea of the universe was the most commonly accepted model for nearly 2000 years after it was proposed. In 1543, observations of objects in the night sky led a Polish astronomer named Nicolaus Copernicus to propose that the Sun, not Earth, was the center of the known universe. It wasn’t until the early twentieth century, however, that astronomers gathered enough evidence to know that neither Earth nor the Sun was at the center of the universe.

Although scientists do not always follow a rigid set of steps, investigations often follow a general pattern. An organized set of investigation procedures is called a scientific method. A scientist might add new steps, repeat some steps many times, or skip steps altogether when doing an investigation. Figure 1 diagrams one way to use scientific methods to solve a problem.

Notice that the procedure begins with a problem and leads to a hypothesis. When you form a hypothesis, you use what you know and observe to provide a possible explanation for a problem. Scientists gather and analyze data to decide whether or not a hypothesis is supported.

Figure 1  The series of procedures shown here is one way to use scientific methods to solve a problem.
The National Aeronautics and Space Administration (NASA) used a scientific method to develop the space shuttle. The space shuttle is designed to carry people to and from outer space. Entering Earth’s atmosphere requires a material for the outer covering of the space shuttle that can withstand the heat and forces of reentry into Earth’s atmosphere. NASA scientists knew a ceramic coating had been found which allows guided missiles to enter Earth’s atmosphere, and they hypothesized that a ceramic material might also work on the space shuttle. When lives are at stake, as in this case, scientists must be very sure of their results. For a hypothesis to be considered valid and widely accepted, an experiment must result in the same data every time it is repeated. If an experiment does not support the hypothesis, the hypothesis might be invalid.

A scientific **theory** is an explanation of things or events based on knowledge gained from many observations and investigations. It is not a guess. If scientists repeat an investigation, and the results always support the hypothesis, the hypothesis can be called a theory. As new information is collected, theories can be modified.

A **scientific law** is a statement about what happens in nature and seems to be true all the time. Laws describe what happens, but they do not explain why or how something happens. Gravity is an example of a scientific law. The law of gravity says that any one mass will attract another mass. No experiments have disproved the law of gravity.

1. An educated guess using what you know and observe is called a ______.
   A. theory  
   B. hypothesis  
   C. scientific law  
   D. scientific method

2. Which is a statement about something that happens in nature which seems to be true all the time?
   F. theory  
   G. conclusion  
   H. hypothesis  
   I. scientific law
Key Questions:

1. What are some different types of models?
2. What are some characteristics of a good model?

Studying objects and events directly is not always possible in science. Objects might be too big, such as a planet, or too small, such as atoms and molecules. An event might be too long, such as the lifetime of a star, or too dangerous, such as a volcano or hurricane. In cases like these, scientists construct models—objects that represent the object or event to be observed.

Scientists use many different kinds of models. A scientist might construct a scale model of a bridge to study its different aspects. The different parts of the scale model have the same proportions as the real bridge.

A model can never accurately reproduce every characteristic of the real object. When constructing a model, a scientist must decide which characteristics are most important to the current investigation and keep in mind the limitations of the model. For example, a scale model of a bridge might be helpful for determining how different parts would fit together. The model would not be as useful for studying forces on the bridge. Scientists can use a model to make predictions, but they must be willing to change a model if data show that predictions based on the model are incorrect.

A mathematical model is used to predict the behavior of real objects. Like all models, a mathematical model should be as simple as possible. It should have few variables in order to explain events clearly. An example of this is the equation for universal gravitation shown below. Though this equation is simple, it can be used to predict complex behavior, such as the orbits of the planets. Combining this equation with existing data helps scientists verify theories of the solar system.

\[
F_{\text{grav}} = \frac{Gm_1m_2}{r^2}
\]

Mathematical models also can be used to help formulate theories about phenomena that are not yet observed. For example, when trying to understand fundamental particles of nature, scientists first studied data from existing experiments and developed mathematical models that matched the data. Using these models, they were able to predict the existence of other fundamental particles. Experiments using this information were able to detect the predicted particles.
Another useful modeling technique used by scientists is a **computer simulation**. This is an extension of mathematical modeling because computers are used to perform mathematical calculations that are too difficult or time-consuming to be done by hand. Computer simulations can be used to predict how a system will respond in different scenarios. When applied to the structure of a bridge, a computer simulation can help predict situations that could result in damage to the bridge, and engineers can change their bridge design accordingly. Computer programs often are used to perform simulated tests on structural designs.

Sometimes a simulator involves much more than a computer on a desk. Pilots use airplane simulators to practice problem solving with various situations and conditions they might encounter in the air. It gives pilots a safe way to test different reactions and to practice certain procedures before they fly a plane.

Meteorology has changed greatly due to computer modeling. Using special computer programs, meteorologists now are able to more accurately predict disastrous weather and warn residents of an area to take precautions or evacuate the area. While meteorological computer modeling aids predictions, it does nothing to alter weather. Natural disasters will continue to destroy property and alter ecosystems, but we might be able to evacuate people from affected areas prior to disasters so that human lives can be saved. A computer graphic is a type of computer simulation that allows us to visualize complex situations like hurricanes, as illustrated in **Figure 1**.

Sometimes a concept is difficult to explain to others. In this case, scientists might use an **analogous system**, which is a model that explains a difficult concept by relating it to similar properties in a familiar concept. When explaining properties of electrical current, for example, scientists often use an analogy of water running through pipes. The pipes are like electrical wires. Sediment in the pipe, which slows the passage of water, is like an electrical resistor, and a break in the pipe is like an electrical short circuit.

![Figure 1](This hurricane image was generated through a computer program.)
1. A miniature bridge made by engineers is a(n) _______.
   A. analogous system.
   B. computer model.
   C. mathematical model.
   D. scale model.

2. Recent advancements in computer modeling of weather have enabled _______.
   F. scientists to change where storms move.
   G. scientists to discover what causes storms.
   H. people to stop storms by altering weather patterns.
   I. people to anticipate storms several days in advance.
Key Questions:
1. How do science and technology work hand-in-hand?
2. How do the attitudes and values of society affect technology?

The terms *science* and *technology* mean different things. Science is a process of exploration. Scientific processes are used to gain knowledge of and predict events in the natural world. Scientists often search for answers to human needs and problems. They also search for scientific knowledge for the sake of learning new information. When objects or methods are used to solve a human need or problem, the result is called technology.

**Science and Technology Work Together** Although science and technology are different, they are closely related. This is especially true when both are used to solve the same problem. For example, chemist Stephanie Kwolek was asked in 1964 to create a new type of fiber that was lightweight and tough. After a series of experiments, she created a lightweight fiber that was five times stronger than steel. This is an example of science. Using the material in such items as bulletproof vests, skis, and space vehicles is an example of technology. This fiber helps save lives and provides many other benefits.

**Which comes first?** Sometimes technology can lead to new discoveries. When the microscope was invented in the 1600s, it enabled scientists to view cells for the first time. Over the years, microscopes have been greatly improved. Scientists have learned more about the nature and structure of cells. Today, microscopes can magnify structures up to 500,000 times their original size.

**A Florida Case Study** An example of technology leading to science and circling back to technology involves the phosphate industry in Florida. Florida mines huge amounts of phosphate, providing 80 percent of the phosphate used in the United States. In addition, Florida provides 25 percent of that used in the rest of the world.

Phosphate is important because it helps cells use energy. It gives shape to DNA, the genetic material of all living things. Phosphate also is a source of phosphorus, a key ingredient in fertilizer. No one really knows who first discovered that phosphate makes good fertilizer. It has been used for centuries and was discovered in Florida in the 1880s. **Figure 1** shows the amount of phosphate mined in past years. Improved mining methods helped increase the output.
To make fertilizer, phosphate must be separated from the other materials in the mined mixture. After the phosphate is separated, it is sent to a chemical processing plant. There it goes through a chemical change to make ammonium phosphate—the basic fertilizer used in farming. The fertilizer dissolves in the water in the ground, where plant roots can access it. When fertilizer is applied to the soil, much of the phosphorus in it changes. It combines with other elements in the soil to form compounds that the plants cannot use. To get enough phosphorus to crops, farmers often use two to four times more fertilizer than they need.

Over time, the phosphorus builds up in the soil and runs off into bodies of water. By-products also result from the separation and chemical processes and enter the air and water. These activities cause environmental problems that concern both the industry and the public. Major efforts in both technology and science are underway to solve these problems.

**Technology and Values**  Technology changes over time, depending on what people value. For example, over the last 100 years, people have changed their attitudes toward cars. When they first were invented, many people thought cars were too noisy and too costly. Then technology was developed to mass-produce affordable cars. People also saw the convenience of getting to places faster than with a horse and buggy.

As more cars were sold, the demand for gas and oil increased. People started to buy smaller cars that use less gas. Then sport-utility vehicles and minivans became popular because of their multiple uses. Now gas prices are higher, and oil is becoming scarce. People are beginning to buy more fuel-efficient cars. The automobile industry is responding with new technology, such as hybrid cars that use both electricity and gasoline.

1. Which is an example of science leading to technology?
   A. separating phosphorus from the mined phosphate mixture  
   B. analyzing the fuel efficiency of hybrid car engines  
   C. inventing a microscope with higher magnification  
   D. setting up a mass-production process

2. Scientists often examine the genetic makeup of a person to help explain disease. They also can predict the risk of disease a person may have in the future. Many people are concerned that examining the genetic makeup of a person could lead to loss of health insurance or jobs. What does this concern illustrate?
   F. Future research in human genetics should be stopped.  
   G. Scientific inquiry involves collecting information from many sources.  
   H. Scientific explanations should not depend upon evidence from a single source.  
   I. Weighing values is important when making ethical decisions about the use of scientific knowledge and technology.
The Role of Scientists in Society

Key Question:

Why is it important for scientists to make the public aware of their findings?

Science and society are connected closely. Applying new knowledge gained by scientists can affect the ways people live. Likewise, concerns of society can lead to what scientists study. For example, scientists respond urgently when a contagious disease breaks out that spreads quickly and easily. Scientists work to find out what causes the disease and how it spreads. Then they recommend procedures people can follow to avoid the disease. Scientists also work to find treatments or cures for the disease.

Benefits and Negative Effects Scientists use analytical skills to solve problems. They look for solutions that do not cause harm. However, sometimes the solutions cause future negative effects that were not predicted. For example, at one time, the pesticide DDT was widely used. It killed insects that damaged crops, and crop damage caused by insects was greatly reduced. Years later, large birds, such as bald eagles, began to die out. Scientists found that a product that results from the breakdown of DDT was building up in the female adult eagles. This substance prevented the release of calcium needed to produce strong eggshells. This resulted in a drastic decline in the number of eaglets surviving each year. Scientists discovered that bald eagles had been exposed to the pesticide when they ate fish or other organisms that had the pesticide in their tissues.

The decline in the bald eagle population was due to many factors, but the discovery that the pesticide was one of these factors contributed to its ban in the United States. Since then, other pesticides have been developed to take its place. While scientists have a responsibility to cause no harm, the harmful effects cannot always be known, as in the case of the bald eagles.

Cause and Effect in Nature Scientists help people understand the possible causes and effects of many events, including those not caused by humans. For example, scientists at the Hurricane Research Division in Miami, Florida, record data about hurricanes. They use instruments in buoys in the ocean to record data about oceans, where hurricanes begin. Satellites take pictures of Earth’s atmosphere from space. During hurricanes, scientists fly over a hurricane and drop an instrument from the plane into the center of the storm to collect data.
The data from these sources are used to predict the strength and path of the storm. These predictions are important to people who live in areas where hurricanes are common. Four major hurricanes—Charley, Frances, Ivan, and Jeanne—hit Florida in 2004. More than 100 people lost their lives. Damage to property cost more than $40 billion.

Table 1 summarizes how scientists classify hurricanes. Warnings are given with each hurricane category so people can readily understand the possible danger. Then they can take proper steps to help save lives and property.

### Table 1

**Scientific Classification of Hurricanes**

<table>
<thead>
<tr>
<th>Hurricane Category</th>
<th>Wind Speed (km/hr)</th>
<th>Storm Surge (increase in sea level) (m)</th>
<th>Damage Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>119–153</td>
<td>1.2–1.5</td>
<td>Damage mainly to mobile homes not fastened down and shrubs and trees</td>
</tr>
<tr>
<td>2</td>
<td>178–177</td>
<td>1.8–2.4</td>
<td>Some damage to roofs, doors, and windows of buildings; considerable to mobile homes, signs, piers, and trees; coastal and low-lying escape routes flood 2–3 h before the arrival of the hurricane center</td>
</tr>
<tr>
<td>3</td>
<td>178–209</td>
<td>2.7–3.6</td>
<td>Some structural damage to small buildings; some trees blown down; mobile homes and some signs destroyed; low-lying escape routes flood 3–5 h before the arrival of the hurricane center</td>
</tr>
<tr>
<td>4</td>
<td>210–249</td>
<td>4.0–5.5</td>
<td>Some roofs blown off; trees and all signs blown down; extensive to doors and windows; complete destruction to mobile homes; low-lying escape routes may flood 3–5 h before the arrival of the hurricane center; major damage to lower floors near the shore; people in areas lower than 3 m above sea level might be required to leave their homes and businesses</td>
</tr>
<tr>
<td>5</td>
<td>Greater than 249</td>
<td>Greater than 5.5</td>
<td>Roofs collapse, and trees are blown down; some buildings collapse; mobile homes are destroyed; severe damage to windows and doors; low-lying escape routes flooded 3–5 h before the arrival of the center of the storm; people on low ground within 8–16 km of the shoreline might have to leave their homes and businesses</td>
</tr>
</tbody>
</table>

**Source:** NOAA/National Oceanic and Atmospheric Administration’s National Weather Service

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**When do scientists have a responsibility to share the findings from their research?**

A. when the results show positive effects only

B. always, but especially when people face a great risk

C. when people show an interest in the problem studied

D. only when a very large number of people will be affected

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**Mastering the FCAT, Grade 11**
Amanda is listening to the radio after her soccer practice. She turns it to a station emitting waves of 25,000 Hz. If the radio waves travel 400,000 km/s, and it takes 1.2 s to reach her car from the radio station, how many waves can hit her car in the allotted time?

The diagram below shows the position of two weather monitoring stations and the direction of local winds. At which station would you expect to see less precipitation? Explain your answer.

The chemical formula for nitroglycerin is shown below. Which describes nitroglycerin?

- A. atom
- B. compound
- C. element
- D. ion
4. The following is a chart of waves in the electromagnetic spectrum.

<table>
<thead>
<tr>
<th>Electromagnetic Waves</th>
<th>Frequency (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radio waves</td>
<td>$10^4$ to $10^8$</td>
</tr>
<tr>
<td>Microwaves</td>
<td>$10^8$ to $10^{12}$</td>
</tr>
<tr>
<td>Infrared</td>
<td>$10^{12}$ to $10^{14}$</td>
</tr>
<tr>
<td>Visible light</td>
<td>$10^{14}$ to $10^{15}$</td>
</tr>
<tr>
<td>Ultraviolet</td>
<td>$10^{17}$ to $10^{19}$</td>
</tr>
<tr>
<td>X rays</td>
<td>$10^{17}$ to $10^{19}$</td>
</tr>
</tbody>
</table>

If the speed of these waves is 300,000,000 m/s, what is true about the wavelengths of the waves reading from the top of the chart to the bottom?

F. The wavelength decreases by a factor of $10^5$.
G. The wavelength decreases by a factor of $10^{15}$.
H. The wavelength increases by a factor of $10^5$.
I. The wavelength increases by a factor of $10^{15}$.

5. Recently, scientists have found what they think might be evidence of water on Mars. Why is this finding significant to a biologist?
Natural disasters are unforeseen, fast, and deadly events that affect large groups of people. Scientists cannot precisely predict the location, duration, and damage of a disaster such as a hurricane. Using the example of a hurricane, explain how scientists might gather data, why the data might be limited, and how public warnings might not work well.

The majority of ionic compounds are found in what state of matter?

A. gas  
B. liquid  
C. plasma  
D. solid  

Down syndrome is much more common in children of older mothers. How many times more likely is it that a mother over the age of 45 will have a child with Down syndrome than will a mother under the age of 30?

<table>
<thead>
<tr>
<th>Age of Mother</th>
<th>Chance of Down Syndrome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 30 y</td>
<td>1 in 1,500 births</td>
</tr>
<tr>
<td>30-35 y</td>
<td>1 in 750 births</td>
</tr>
<tr>
<td>Over 45 y</td>
<td>1 in 16 births</td>
</tr>
</tbody>
</table>
Our nearest star, the Sun, is so hot that huge amounts of hydrogen undergo a constant star-wide nuclear reaction, like in a hydrogen bomb. Why can we see the Sun?

F. The huge reactions taking place in the Sun are constantly absorbing electromagnetic radiation from the universe. This pulls in light.

G. The huge reactions taking place in the Sun are constantly releasing electromagnetic radiation into the universe. This emits light.

H. The huge reactions taking place in the Sun are constantly absorbing gravitational energy. The reaction between the two energies emits light.

I. The huge reactions taking place in the Sun are constantly using fuel. This lack of fuel causes the Sun to absorb electromagnetic radiation from other stars. This pulls in light.

Locusts have an ability to avoid colliding with other locusts when traveling in huge swarms from location to location. Sensors in their brains detect when they are on a crash-course with another object. How could scientists use this knowledge for use in everyday life?

The law of the conservation of mass and energy states that the total amount of mass and energy in a closed system remains constant. However, no physical, chemical, or nuclear reaction is 100 percent efficient. What is this tendency of every closed system to lose energy?

A. enthalpy
B. entropy
C. exergonics
D. momentum
The food chain below shows the relationships between native organisms in an ecosystem. A non-native predator that feeds only on hawks is introduced to the ecosystem.

**Part A** Explain how the new predator will affect the ecosystem, with special regard to the hawk and snake populations.

**Part B** What would be a safe way to control the new predator in the ecosystem, and would you be able to determine if it were necessary to completely remove the predator?
About 100 years ago, the apple maggot fly started to become a serious pest to apple orchards in New England. It is now a threat throughout most of the northern United States. Originally, it fed only on hawthorn fruits, but now apples are a large part of its diet. How does the maggot’s adaptation to eating apples show natural selection at work?

It takes 0.38 J of energy to raise the temperature of 1 g of copper (Cu) 1° C. How much energy (in joules) would it take to raise the temperature of 100 g of copper 50° C?
The graph below shows the speed of a running cheetah. At what point is
the cheetah experiencing the most negative acceleration?

F. F  
G. G  
H. H  
I. I

For several years, scientists working in a forest tracked the number of organisms living there. Recently, logging has caused many trees to be removed. The table below shows the records made by the scientists. Describe the trend in the data, and explain how logging is affecting populations of birds and mice.

**Population Data for a Forest**

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Trees</th>
<th>Number of Birds</th>
<th>Number of Mice</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>198</td>
<td>58</td>
<td>99</td>
</tr>
<tr>
<td>1999</td>
<td>150</td>
<td>43</td>
<td>124</td>
</tr>
<tr>
<td>2000</td>
<td>126</td>
<td>33</td>
<td>138</td>
</tr>
<tr>
<td>2001</td>
<td>98</td>
<td>28</td>
<td>155</td>
</tr>
<tr>
<td>2002</td>
<td>77</td>
<td>19</td>
<td>171</td>
</tr>
</tbody>
</table>
Because the stars Castor and Pollux are in the constellation Gemini, they appear in the same region when seen from Earth, but they are not the same distance from Earth. Castor, a binary star, is 52 light-years from Earth, while Pollux is 34 light-years away.

If one of the stars in Castor’s system exploded as a supernova, how many years would it take for the explosion to be seen from a planet orbiting Pollux?

Some scientists believe that a hurricane’s intensity or path could be affected by human intervention in the beginning stages of the storm. How can scientists use this theory to predict which initial changes should be made?

A. simulate various initial storm conditions using a weather model
B. gather weather data throughout the cycle of a tropical storm
C. compare inland weather data to the initial storm conditions
D. use satellite images from the start of the storm to find weather conditions

Two groups of scientists in different fields are studying the effects of magnetism on the process of conductivity. The two groups present their findings in scientific journals and prove two completely different hypotheses. How is this possible?

F. The scientists fixed their data to support their hypotheses.
G. One group of scientists had access to better, more accurate data than the other group.
H. The scientists copied each other but altered the results to make them unique to their field of study.
I. The scientists had different specialties and interpreted their data so both could have different, but correct, results.
Describe the food web between the organisms listed below. Identify each one as a producer, decomposer, or consumer. Your food web description also should include the flow of energy from each organism.

**Food web organisms:**
- bacterium
- grass
- insect
- snake
- toad

What is the atomic number for an atom that has an electron configuration of 1s\(^2\)2s\(^2\)2p\(^6\)3s\(^2\)3p\(^6\)?

The table below represents different gravitational forces acting on Sue.

<table>
<thead>
<tr>
<th>Position</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force (N)</td>
<td>500.0</td>
<td>125.0</td>
<td>31.25</td>
<td>7.813</td>
</tr>
</tbody>
</table>

Which explains what is happening to Sue at each position?

A. She doubles her mass.
B. She cuts her mass in half.
C. She doubles her distance from Earth.
D. She cuts her distance from Earth in half.
One of the roles of proteins is to act as catalysts. There are numerous kinds of protein catalysts in one organism. Why are there so many kinds of protein catalysts? Give an example of a protein and its function.

According to geologists, the Atlantic Ocean covered much less land 18,000 y ago. As a result, the East Coast of the United States extended well into the Atlantic Ocean. Which of the following explains how this was possible?

F. Earth’s average temperature was colder, freezing 30 percent of Earth’s water.
G. Continental shifts caused an increase in sea level for most of the East Coast.
H. The Moon was much closer to Earth 18,000 y ago, so the tides were greater.
I. Earth’s temperature was warmer, causing a high rate of evaporation that lowered ocean levels.
25 Fossil fuels contain hydrocarbons. The hydrogen and carbon in the hydrocarbon combine with oxygen in the air to produce carbon dioxide, water, and thermal energy. What is that process called?
   A. combustion  C. oxidation
   B. corrosion  D. refining

26 A lab sequenced the DNA for a gene in a flowering plant as well as the mRNA produced in the flowers. The resulting sequences are represented in the diagram. What accounts for these results?

   DNA
   mRNA

   F. sequencing errors  H. transcriptional errors
   G. removal of introns  I. post-translational modifications

27 What is the term used to describe the body’s regulation of its internal environment?
   A. glucose stasis  B. homeostasis
   C. negative feedback  D. physiological control

28 Ionization energy refers to the energy necessary to remove the outermost highest-energy electron from a neutral atom. According to the graph below, what is the periodic trend shown between the atomic number and the ionization energy?

   F. The atomic number is equal to the ionization energy.
   G. As the atomic number increases, the ionization energy decreases.
   H. As the atomic number increases, the ionization energy increases.
   I. There is no effect on ionization energy as the atomic number increases.
Scientists are studying frogs in the cloud forests of Costa Rica. They report that only 20 of the 50 species originally identified in the site now can be found. These disappearances coincide with moisture level reductions of the cloud forests from oceanic and atmospheric warming. What does this study indicate about climate change and its effect on the biosphere?

A. The frogs went to an area with higher moisture levels.
B. Costa Rica is not doing enough to protect this species of frog.
C. If moisture levels rise, the species will return to their original numbers.
D. Climate change already is having a dramatic effect on biological systems.

Scientists studying a virus that is lethal to humans have discovered a possible vaccine. What is the next step that should be taken with the results of these studies?

F. The scientists should establish a public health initiative with these studies.
G. The scientists should patent the vaccine to prevent others from duplicating the study.
H. The scientists should publish their studies so other scientists can replicate the experiments.
I. The scientists should not report their findings until they are certain that the vaccine will prevent the disease.

Rocket propulsion can push a car faster than a conventional engine. The picture shows a car using rocket propulsion. The car is moving in the direction of the arrow. Which explains the movement of the car?

A. The car is moving in the opposite direction of the gravitational force.
B. The car is moving in the same direction as the force applied by wind.
C. The car is moving in the same direction as the force applied by friction.
D. The car is moving in the same direction of the force applied by the rocket propulsion.
The force exerted by the Moon on Earth’s water causes a fluctuation in ocean waves that creates high tides and low tides. What is the force that the Moon exerts on the tides?

F. gravitational force  
G. lunar force  
H. strong force  
I. wave force

The National Weather Service (NWS) issues hurricane watches and warnings and projects the paths of hurricanes like the one shown below. NWS bases its projections on satellite data and computer models from past storm data. What is the effect of hurricane research?

A. Technology has helped scientists control weather patterns.  
B. Research helps meteorologists know where all storms start.  
C. Scientists are able to help people escape dangerous situations.  
D. Satellites and other techniques help scientists avoid the formation of storms.

A central theory of biology is that genetic information follows the pattern: DNA → RNA → Protein. Some genetic information does not follow this pattern. Why has the theory not been rejected?

F. Data that do not fit popular theories are ignored.  
G. Scientists do not like facts that they cannot understand.  
H. The theory has become scientific law and therefore cannot be rejected.  
I. The scientific community is slow to accept observations that appear to violate major ways of explaining things.
The table shows the number of hatching turtles after eggs were kept at a range of temperatures. What conclusion is supported by the data?

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>22</th>
<th>24</th>
<th>26</th>
<th>28</th>
<th>30</th>
<th>32</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Eggs Started</td>
<td>40</td>
<td>27</td>
<td>38</td>
<td>34</td>
<td>38</td>
<td>22</td>
</tr>
<tr>
<td>Number of Males Hatching</td>
<td>40</td>
<td>26</td>
<td>35</td>
<td>5</td>
<td>0</td>
<td>22</td>
</tr>
<tr>
<td>Number of Females Hatching</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>28</td>
<td>36</td>
<td>19</td>
</tr>
</tbody>
</table>

A. Few eggs actually survived the experiment.
B. Turtles lay eggs that are mostly one sex or another.
C. Certain temperatures kill eggs of one sex or another.
D. The temperature affects the sex of the hatching turtle.

According to the periodic table, how many protons does argon (Ar) have in its nucleus?

F. 2
G. 6
H. 12
I. 18

A heating curve shows the change in a substance as thermal energy is added. The following graph shows the changes in water as thermal energy is added. What is happening at points A and C on the graph?

A. The water has used up the added energy.
B. The water molecules have no kinetic energy.
C. The water molecules’ kinetic energy is increasing.
D. The water molecules’ kinetic energy is decreasing.
38 In one type of radioactive decay, a neutron decays into a proton, and the atom emits an electron. What is the electron emitted from the atom?

F. an alpha particle
G. a beta particle
H. gamma radiation
I. a negatron

39 Phosphorus is essential to living organisms. The image below shows that the phosphorus cycle is similar to the oxygen and nitrogen cycles. Which is an important difference between the phosphorus cycle and the other biogeochemical cycles?

A. Phosphorus can convert from solar energy.
B. Organisms can create their own phosphorus.
C. Phosphorus never enters the atmosphere.
D. Organisms can use elements besides phosphorus.

40 The electrical force between two charged particles is directly proportional to the charge of each particle and inversely proportional to the square of the distance between the charges. How would the electrical force between two particles change if they were moved apart half the original distance?

F. The force would be cut in half.
G. The force would stay the same.
H. The force would be two times greater.
I. The force would be four times greater.
The Florida panther is one of the most endangered species on Earth. The small population of remaining panthers must breed within itself. How does this affect the survival of the panthers?

A. It results in offspring that lack genetic diversity.
B. It makes the panthers safe from attacks by other species.
C. It protects the panthers by preventing them from traveling to mate.
D. It ensures that the best genes will be passed from one generation to the next.

The Kuiper Belt is a region in our solar system that contains small bodies mostly made of ice. Some objects in the Kuiper Belt that have been discovered are about half the size of Pluto. What might happen if an object larger than Pluto is discovered in the Kuiper Belt?

F. It will prove that Pluto and Neptune are closer to the Sun than previously thought.
G. All objects found in the Kuiper Belt will be classified as planets in our solar system.
H. If it revolves around the Sun, the number of planets in our solar system will increase.
I. Pluto will be classified as the eighth planet in our solar system, and Neptune will be the ninth.

Our understanding of the universe has changed greatly over time. Which explains why this has occurred?

A. New scientific discoveries lead to new theories.
B. Theories are redesigned every 10 years as a necessity.
C. The constantly evolving universe requires new theories to describe it.
D. Larger numbers of scientists have opinions that must be incorporated.
Posttest

44 Tsunamis are large waves that travel through the ocean at great speeds and can cause severe damage as they rise and crash into shorelines. How are tsunamis formed?

45 The Moon, which receives almost an equal amount of solar energy per square meter of surface, is about –20ºC in direct sunlight. Why is there such a temperature difference between Earth and the Moon?

F. Earth generates heat from its core to maintain a higher temperature.
G. The greenhouse gases in Earth’s atmosphere trap the needed energy.
H. The Moon is smaller and doesn’t radiate as much geothermal energy.
I. Earth blocks the Moon from the Sun, causing decreasing temperatures.

46 Scientists retrieve a sample of rock from Mars and test its chemical makeup. One test determined the melting point of the chemicals. How does a physical property help scientists determine chemical identity?

A. Melting point can change over time, so the melting point can show the age of the chemical.
B. Melting point is a constant for chemicals and enables scientists to determine the chemical’s identity.
C. Melting point can vary for chemicals in different mixtures and can show properties of other present chemicals.
D. Melting point is an indicator of reactivity and needs to be known so the scientists know which chemical tests to run.
Kendal did an experiment to see what affects the rate of reaction between an antacid tablet and vinegar. Which did not affect the rate of reaction?

- F. Kendal heated the vinegar.
- G. Kendal crushed the antacid tablet.
- H. Kendal poured more vinegar into the beaker.
- I. Kendal placed the reaction in a closed container.

Shannon can paddle a boat at a maximum of 16 km/h in still water. If the boat is in a stream that flows 6 km/h to the south, and Shannon begins to paddle her fastest to the north, what is the maximum speed, in kilometers per hour, the boat will travel relative to the water’s shoreline?

Explain, in terms of energy, why plant life is necessary in a forest food chain.
An encased wire carrying current runs down vertically through a plate. When iron filings are sprinkled onto the plate, they line up in increasingly larger circles around the wire. What explains this situation?

A. Copper is a magnetic material.
B. A current creates a magnetic field.
C. The metal filings become electrified.
D. Electricity changes the air flow around the wire.
**Glossary**

**A**

**abiotic factor**  a nonliving factor that limits the number of individuals in a population

**acceleration**  the rate of change in velocity

**accuracy**  the extent to which a measurement is in proximity to the standard or expected value

**acid**  a substance that increases the H+ concentration when added to a water solution

**activation energy**  the least amount of energy required to start a particular chemical reaction

**adaptation**  a particular development, behavior, or physiological change in a population of organisms in response to changes in the populations

**allele**  alternative form of a gene for each trait of an organism

**amino acid**  an organic molecule containing an amino (-NH2) and a carboxyl (-COOH) group from which proteins are synthesized

**analogous structures**  the body parts of organisms that do not have a common evolutionary origin but are similar in function

**analogous system**  a model that explains a difficult concept by relating it to similar properties in a familiar concept

**aqueous solution**  a solution containing water

**asteroid**  a piece of rock or metal made up of material similar to that which formed the planets

**astronomical unit**  a distance within the solar system (AU)

**atmosphere**  the gases surrounding Earth

**atom**  the smallest particle of an element that still retains the properties of the element

**atomic mass**  the weighted-average mass of a mixture of an element’s isotopes

**atomic number**  the number of protons in the nucleus of each atom

**autotroph**  an organism that uses light energy or energy stored in chemical compounds to make other energy-rich compounds; a producer; grass, trees, and other plants

**base**  a substance that increases the OH− concentration of a solution; a proton acceptor

**biodiversity**  the variety of life in an ecosystem

**biome**  a large region that has similar climates and similar ecosystems

**biotic factor**  a living factor that limits the number of individuals in a population

**black hole**  a region from a collapsed supernova where the gravity is so strong that nothing can escape from it, not even light

**carbohydrates**  a class of organic molecules formed from the Sun’s energy; are broken down in the process of cellular respiration to harness energy for living cells

**carrying capacity**  the largest number of individuals of a species that an environment can support and maintain for a long period of time

**catalyst**  a substance that speeds up or slows down the rate of a reaction without being consumed or altered

**cellular respiration**  the process of converting glucose into the energy molecule adenosine triphosphate (ATP)

**centrifugal**  a force that causes motion away from the center of a circle

**centripetal force**  a force that causes an object to move in a circular path

**charge by conduction**  a process that occurs when electrons convert an overall negative charge to an overall positive charge

**charge by induction**  a process that occurs when a charged object is brought near an uncharged object and electrons move toward the charged object or away from it, causing a separation of charge

**climate**  average weather pattern in an area over a long period of time

**climax community**  a community in which primary succession has slowed and the system has stabilized

210  *Glossary*
**coal**  a solid fossil fuel formed from the remains of numerous generations of tropical swamp plants

**comet**  an object made of dust and rock mixed with ice, methane, and ammonia; can range from 1 to 10 km in diameter; exists in or near the solar system but farther from the Sun than an asteroid

**commensalism**  a relationship in which only one species benefits and the other species is not harmed or helped

**compound**  a substance in which the atoms of two or more elements are combined in a fixed proportion

**computer simulation**  an extension of mathematical modeling; computers are used to perform mathematical calculations that are too difficult or time-consuming to be done by hand

**decomposer**  an organism that breaks down the complex compounds of dead and decaying plants and animals; many bacteria and most fungi

**dependent variable**  a variable that changes according to the changes in the other variables

**diffraction**  the bending of a wave around an obstruction

**directional selection**  occurs when natural selection favors one of the extreme variations of a trait

**displacement**  a measure of the difference between an object’s final position and its initial position

**disruptive selection**  occurs when individuals with either extreme of a trait’s variations are selected for survival

**distance**  how far an object is from the origin of your frame of reference

**divergent boundary**  a boundary between two plates that are moving apart

**DNA**  a nucleic acid that carries genetic material; present in all cellular organisms

**electromagnetic force**  the force that acts between charged particles in a manner which is either attractive or repellent

**electromagnetic wave**  a wave produced when electric charges vibrate periodically, or oscillate

**element**  a substance that cannot be broken down into simpler substances by physical or chemical means

**energy**  the ability of an object to produce change in itself or in its surroundings

**energy pyramid**  a model that shows the amount of energy available at each feeding level in an ecosystem

**entropy**  a measure of the disorder in a physical system; refers to the amount of energy that cannot be used to do work
fault  a rock fracture along which movement or displacement of Earth’s crust has taken place
first law of thermodynamics  a law that states that the increase in thermal energy of a system equals the work done on the system plus the heat transferred to the system

food web  a model that shows all possible feeding relationships at each trophic level in a community
fossil  the remains, imprint, or trace of a prehistoric organism
frame of reference  a coordinate system in which the positions of objects are measured

gametes  the female and male sex cells of the egg and sperm
gas giant  a planet that is larger, less dense, and more gaseous than the terrestrial planets
genotype  the genetic characteristics of a sexually produced organism
gravitational force  a force that is always attractive and present between any two objects in the universe; the weakest of the four fundamental forces

greenhouse effect  a natural heating process that occurs when gases trap heat from Earth
groups, or families  the vertical columns of the periodic table
Gulf Stream  a warm-water current that originates near the equator and affects the climate of Florida

half-life  the amount of time required for half of an original sample of radioactive material to decay or undergo radioactive transformation
heat  the transfer of thermal energy between two objects in contact with one another
heat of fusion  the amount of energy required to change 1 kg of a substance from a solid to a liquid at its melting point
heat of vaporization  the amount of energy required for 1 kg of a liquid at its boiling point to become a gas
heterotroph  an organism that must eat other organisms to obtain its food and energy; a consumer; animals

heterozygous  an organism that has two different alleles for a trait
homologous chromosomes  paired chromosomes with genes for the same traits arranged in the same order
homologous structures  structural features with a common evolutionary origin
homozygous  an organism that has two of the same alleles for a trait
hypothesis  a possible explanation that can be tested

indicator  a chemical compound that changes color depending on the pH of the solution or other chemical change
interneuron  a neuron in the spinal cord or brain that processes incoming impulses and passes on response impulses to motor neurons
ion  a charged particle that has either more or fewer electrons than protons
**Glossary**

**Ionic bond** the electrostatic force that holds oppositely charged particles together in an ionic compound

**Isotope** the form of an element with the same number of protons but a different number of neutrons

**Kelvin** fundamental SI unit of temperature where 0 K is equal to absolute zero; 1 K equals 1°C

**Kinetic energy** energy of an object that depends on the mass and speed of the object; also called energy of motion

**Law of conservation of energy** a principle that states that energy cannot be created or destroyed

**Light-year** the distance light travels in one year, which is equal to about 9.5 trillion km

**Limiting factor** anything that limits the ability of an organism to live in a certain place

**Magnetic field** an area that surrounds a magnet and exerts a force on other magnets and objects made of magnetic materials

**Mass number** the total number of protons and neutrons in a nucleus

**Mathematical model** a model used to predict the behavior of real objects

**Mature star** a stable star that continues to use its hydrogen fuel and change slowly for billions of years

**Meiosis** sexual reproduction in which cell division produces gametes containing half the number of chromosomes as a parent’s body cell

**Membrane** a thin layer of tissue that surrounds or lines a cell, a group of cells, or a cavity; any barrier separating two fluids

**Metallic** elements that are good conductors of heat and electricity, solids at room temperature, malleable, and ductile

**Metalloid** an element that has chemical and physical properties of both metals and nonmetals

**Meteoroid** a rocky object orbiting throughout the solar system

**Mid-ocean ridge** a continuous, seismic mountain range extending across the floor of a major ocean; area where two oceanic plates are moving away from each other; area where new crustal material can be released

**Mitosis** reproduction that produces new cells asexually; the orderly process of nuclear division in which two new daughter cells each receive a complete set of chromosomes

**Mixture** matter that is made by combining two or more different elements or compounds in any proportion by physical means

**Model** an object that represents an idea, event, or the object to be observed

**Molecule** a neutral particle that forms as a result of electron sharing, or covalent bonding

**Momentum** a vector quantity that is the product of an object’s mass and velocity; the general effect of ongoing motion

**Moon phases** differences in appearances of the Moon which result from the changing positions of the Moon relative to Earth and the Sun

**Motor neuron** a neuron that carries a response impulse away from the brain and spinal cord to a muscle or gland
Glossary

**mutation**  the process by which a gene undergoes a change in DNA sequence or a change in structure

**natural gas**  a vaporous fossil fuel

**natural selection**  the concept that organisms with traits best suited to their environment are the most likely to survive and reproduce with certain natural variations adapted to their specific environments

**nebula**  a cloud of interstellar gas and dust

**neutral**  an atom with the same number of protons and electrons

**neutron star**  a star approximately 20 km in diameter with a dense core where only neutrons exist

**new star**  a star that forms when a cloud of interstellar gas and dust collapses on itself as a result of gravity

**niche**  the unique position occupied by a particular species in terms of the area it inhabits and the function it performs within the community

**octet**  the eight electrons which fill the orbital of an atom's valence shell

**old star**  a star that evolves to the point of becoming unstable and leaves the main sequence

**parasitism**  a relationship in which a member of one species benefits at the expense of another species

**particle**  a very small portion of matter

**period**  a horizontal row in the periodic table

**permeability**  the capability of a porous substance or membrane to allow a fluid or gas to enter it

**petroleum**  a liquid fossil fuel formed by pressure from the overlying sediment converting the remains of ancient marine organisms

**pH**  a measure of the acidity or alkalinity of a solution

**phenotype**  the way an organism looks and behaves in response to its environment

**photon**  an electromagnetic wave that behaves like a particle

**photosynthesis**  the process of storing energy from the Sun in the form of glucose

**plate boundary**  an area where plates interact; the three types of plate boundaries are divergent, convergent, and transform

**polar**  opposite poles: negative at one end and positive at the other end

**potential energy**  the energy stored in the position, composition, or structure of an object

**precision**  the degree of accuracy or exactness of a measurement or tool

**pressure**  the amount of force exerted per unit area

**mutualism**  a relationship in which both species benefit

**noble gas**  an element that is unreactive and is sometimes called an inert gas; found in Group 18 of the periodic table

**nonmetallic**  elements that are either gases at room temperature or dull, brittle solids that are poor conductors of heat and electricity

**normal force**  an upward force

**nuclear fission**  the process by which an atomic nucleus splits into two or more large fragments of comparable mass, simultaneously producing additional neutrons and vast amounts of energy

**nuclear fusion**  the process by which two lighter atomic nuclei combine at extremely high temperatures to form a heavier nucleus and release vast amounts of energy

**nuclear radiation**  particles and energy emitted by radioactive decay

**nucleotide**  a complex biomolecule that stores cellular information in the form of a code; a subunit of nucleic acid
prevailing wind  a wind that generally blows in the same direction over time
primary succession  succession that begins on land that does not have any living organisms
product  a substance or compound resulting from a chemical reaction

protein  a biological macromolecule composed of one or more chains of amino acids
protostar  a hot, condensed object at the center of the disk in a nebula cloud

radioactive decay  the process of decay in an unstable nucleus
radiometric dating  a method of measuring the rate of decay, or breakdown, of radio isotopes within rocks
rate of reaction  the speed at which reactants are consumed and products are produced in a given reaction
reactant  any substance or molecule that participates in a chemical reaction
red giant  an extremely large star with low surface gravity, which causes the star to lose gases from its outer layers

reflex  an automatic response to a stimulus
relative dating  a method of determining the age of fossils based on the theory that rocks form in layers, with new layers added on top of old layers; fossils in lower levels are thought to be older than fossils in higher layers
response  a reaction to a stimulus
rift valley  a long, narrow valley in Earth’s crust bounded by faults
RNA  a single-stranded nucleic acid consisting of a phosphate group and one of four nitrogenous bases that encodes information needed to synthesize proteins

scale mode  a model built with the same proportions as the object or event to be observed
scientific law  a statement about what happens in nature that seems to be true all the time; it explains what will happen under certain conditions
scientific method  a set of procedures that are followed in conducting an investigation
scientific theory  a way of explaining things or events based on what has been learned from many observations and investigations
second law of thermodynamics  a law that states that heat always flows spontaneously from warmer areas to cooler areas
secondary succession  succession that occurs in areas that previously contained life and still contain soil
Sedna  an object in the solar system that is smaller than Pluto but larger than asteroids and comets; has puzzled scientists for some time; labeled a planetoid
sensory neuron  a neuron that carries impulses from the body to the spinal cord and brain

solar eclipse  an event experienced on Earth when the Moon passes between the Sun and Earth and casts a shadow on Earth
solar mass  the quantity equal to the mass of the Sun
solar system  an area extending billions of kilometers in all directions from the Sun
solubility  the ability or tendency of one substance to dissolve in another at a given temperature and pressure
species  a group of organisms of common ancestry able to reproduce only among themselves; usually geographically distinct
stabilizing selection  natural selection that favors average individuals in a population
standard model  a theory that describes four forces which explain the behavior of all matter and energy
static discharge  the transfer of electrical charges when collisions between particles occur
static electricity  electrical charges caused by friction or induction
stimulus  a condition that produces a response from an organism
strong nuclear force  the attractive force that holds the nuclei of atoms together; the strongest of the four fundamental forces; also called the strong force

subduction  occurs when one plate sinks underneat another plate

succession  the normal, gradual changes that occur in the types of species that live in an area

surface area  the total area of the outside of a three-dimensional shape

supernova  a burst of energy caused by an explosion in the core of a supergiant

supercluster  a cluster of galaxies organized into a large group

supergiant  a star with a mass of about five solar masses

symbiosis  a close relationship between two or more different species

tectonics  plate movement and resulting features

temperature  a measure of the average kinetic energy of the particles in a substance

terrestrial planet  a small planetary body with a solid surface

topography  the changing elevation of a place; describes the surface of Earth

thermal energy  the total kinetic energy and potential energy of all the particles in a sample of matter

thermal equilibrium  a condition that exists when there is no longer a net transfer of thermal energy

tide  a huge wave produced by the gravitational pull among Earth, the Moon, and the Sun

topography  the changing elevation of a place; describes the surface of Earth

transform boundary  boundary where two plates slide past one another

valence electron  an electron in an atom’s outermost orbital; determines the chemical properties of an element

valence shell  the outermost electron level of an atom

vaporization  the process in which a liquid changes to a gas

variable  a factor that can cause a change in the results of an investigation

vector  a physical quantity with both a magnitude and direction

velocity  the speed of an object and the direction of its motion

volcano  an opening in the surface of Earth where molten lava, ash, and sulfurous gases escape

wave  a repeating disturbance or movement that transfers energy

weak nuclear force  a repulsive force with weak and limited range that acts on particles in the atomic nuclei

white dwarf  a small, hot object about the size of Earth that evolved when a red giant lost its energy