Exploring The Building Blocks of Science

Featuring Chapters from:
- Student Textbook
- Laboratory Notebook
- Teacher’s Manual
- Lesson Plan
- Study Notebook
- Quiz questions
- Graphics Package

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3.1 Introduction

Organic chemistry is a special branch of chemistry that singles out just one element for special consideration—carbon. The chemistry of carbon is especially important because carbon is the most useful and versatile of all the elements in the periodic table. Carbon can be used to form more kinds of molecules than any other element. Carbon also forms some of the strongest chemical bonds known, and it is the only element that can form very large, complex molecules. For these reasons carbon is essential to all of life as we know it, and understanding the chemistry of carbon will be important if we are to understand the molecules that fuel not only our bodies but our cars, boats, and airplanes as well.

If we were to make a list of all known molecules (a very, very long list), we would find that the vast majority are based on carbon atoms. Because the chemistry of carbon is so important, the science of chemistry is divided into two main branches: organic chemistry, which deals with carbon-containing molecules, and inorganic chemistry, which deals with everything else. With a few exceptions, all molecules that contain carbon are considered to be organic molecules. Table 3.1 shows some common examples of organic molecules.

There is no limit to the size and complexity of organic molecules. Those shown in Table 3.1 are often called “small molecules” by organic chemists. There are larger organic molecules, such as proteins and DNA found inside living things, that have thousands or even millions of atoms each. Organic chemistry is a huge subject. At the college level, it is usually taught as a yearlong course all by itself. In this chapter, we will only introduce the main ideas and classes of organic molecules. These important ideas include the following concepts:

1. **Isomers**—two molecules that have the same atoms but different structures;
2. **Functional groups**—special sites on larger molecules at which chemical reactions can take place and that can be used by organic chemists to build new molecules;
3. **Parent molecules**—simple molecules from which other, more complex molecules are built.

---

1 Carbon dioxide (CO₂), hydrogen cyanide (HCN), graphite, and diamond are not considered by most scientists to be organic substances even though they contain carbon.
### Table 3.1 Common Organic Molecules

<table>
<thead>
<tr>
<th>Name of Molecule</th>
<th>Chemical Formula</th>
<th>Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>methane</td>
<td>CH$_4$</td>
<td><img src="image1" alt="Structure" /></td>
</tr>
<tr>
<td>acetylene</td>
<td>C$_2$H$_2$</td>
<td><img src="image2" alt="Structure" /></td>
</tr>
<tr>
<td>ethanol</td>
<td>CH$_3$CH$_2$OH</td>
<td><img src="image3" alt="Structure" /></td>
</tr>
<tr>
<td>chloroform</td>
<td>CHCl$_3$</td>
<td><img src="image4" alt="Structure" /></td>
</tr>
<tr>
<td>acetic acid</td>
<td>CH$_3$COOH</td>
<td><img src="image5" alt="Structure" /></td>
</tr>
<tr>
<td>formaldehyde</td>
<td>H$_2$CO</td>
<td><img src="image6" alt="Structure" /></td>
</tr>
<tr>
<td>glycine</td>
<td>H$_2$NCH$_2$COOH</td>
<td><img src="image7" alt="Structure" /></td>
</tr>
<tr>
<td>benzene</td>
<td>C$_6$H$_6$</td>
<td><img src="image8" alt="Structure" /></td>
</tr>
<tr>
<td>octane</td>
<td>C$<em>8$H$</em>{18}$</td>
<td><img src="image9" alt="Structure" /></td>
</tr>
</tbody>
</table>
Isomers, Functional Groups, and Parent Molecules

Whenever two molecules have the same atoms but different structures they are called isomers of each other. In the following Table 3.4 notice the two different molecules called n-butane and isobutane, both of which have four carbon atoms. Looking more closely, you can see that both molecules also have 10 hydrogen atoms each. In fact, both are made up of exactly the same number and type of atoms. The difference between them is in their structure—that is, the way in which the atoms are connected to each other. You could take n-butane apart and use the very same atoms to build isobutane with no extra atoms needed and none left over. Isobutane is an isomer of n-butane. That’s why it’s called isobutane. Iso- comes from the Greek word isos meaning “equal to, identical” and -mer comes from the Greek meros meaning “part.” Isomers of each other have identical parts.

Isomers are very common in organic chemistry. Because they differ in structure, isomers also differ from each other in their physical and chemical properties, even though they are made up of the same atoms. For example, ethanol, CH₃CH₂OH, and dimethyl ether, CH₃OCH₃, both have two carbons, six hydrogens, and one oxygen, and so are isomers of each other. But ethanol is a liquid at room temperature (it boils at 78°C), and dimethyl ether is a gas (it boils at -23°C). Ethanol is completely soluble without limit in water, but dimethyl ether has only limited solubility in water. Finally, ethanol takes part in very different kinds of chemical reactions than does dimethyl ether.

In organic chemistry it is always necessary to know the structure of the molecule. Just knowing the number of atoms is not enough. Chemists have worked out two ways to
describe the structures of complex molecules. One method is a very complicated system for naming organic molecules. The name of the molecule alone can be used to tell how the molecule is built. Sometimes the names become VERY long: The name for the molecule in Figure 3.2 is a rather short one: 4-ethyl-3-methylheptane. Though naming is often useful, we will not use it in this book. The other method is just to draw the molecule, as in the preceding figures and table. This is much simpler, more straightforward, and is probably more widely used by everyone except the most experienced organic chemists.

A functional group is a special site on an organic molecule at which chemical reactions occur. Functional groups are used by organic chemists to alter molecules and to build new ones. The molecule 4-ethyl-3-methylheptane has two functional groups—a methyl group and an ethyl group. (See Figure 3.2.) Organic molecules are classified according to their functional groups because the functional groups control both their chemistry and reactions. The double bond in an alkene, the triple bond in an alkyne, the -OH group on an alcohol, the -NH₂ group on an amine, the C=O group of a ketone, the -C=OH group in an aldehyde, and the COOH group of an acid are all functional groups. We will learn more about these molecules later in the chapter.

A related idea is the concept of a parent molecule. A parent molecule is a simple molecule from which more complex molecules are built. The parent molecule in Figure 3.2 is the 7–carbon chain called heptane. Another example is the alcohol molecule ethanol, CH₃CH₂OH. (See Figure 3.3.) Ethanol is thought of as a simple alkane, ethane, CH₃CH₃, with an -OH group replacing an H atom at one end. Ethane is thought of as the

<table>
<thead>
<tr>
<th>Table 3.2 Common Functional Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group</strong></td>
</tr>
<tr>
<td>-OH</td>
</tr>
<tr>
<td>-NH₂</td>
</tr>
<tr>
<td>C=O</td>
</tr>
<tr>
<td>O</td>
</tr>
<tr>
<td>O</td>
</tr>
<tr>
<td>O</td>
</tr>
<tr>
<td>X</td>
</tr>
<tr>
<td>O</td>
</tr>
<tr>
<td>C-C</td>
</tr>
<tr>
<td>C=O</td>
</tr>
<tr>
<td>C≡C-</td>
</tr>
</tbody>
</table>
parent molecule from which ethanol is made. Likewise, the alkene molecule ethene, \( \text{CH}_2=\text{CH}_2 \), is thought of as coming from ethane, \( \text{CH}_3\text{CH}_3 \), by removing two H atoms (one from each carbon) and creating a double bond between the two carbons. Once again, ethane is thought of as the parent molecule from which ethene is made. In reality, both ethanol and ethene may come from many sources and are rarely made from ethane. (Ethanol usually comes from anaerobic fermentation in yeast, for example). So the concept of a parent molecule is a useful way to describe a more complex molecule, although it is usually not the real source of the molecule.

Classes of Organic Molecules

Because there are so many different kinds of organic molecules, it is useful to classify them into groups, or classes, and learn about the groups one at a time. The most common groups
of organic molecules are alkanes, alkenes, alkynes, aromatics, alcohols, amines, aldehydes, acids, ketones, esters, and amides. Table 3.3 shows examples of each of these kinds of organic molecules. There are also many other types, but these are sufficient to understand the basics of organic chemistry and most of the chemistry of biology.

It is possible for one molecule to be in more than one group. For example, the molecule \( \text{H}_2\text{N}-\text{CH}_2\text{-CH}_2\text{-OH} \) (called ethanolamine) has both a -OH attached to C, and a -NH\(_2\) attached to C, so it is both an alcohol and an amine.

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Structure</th>
</tr>
</thead>
</table>
| alkanes   | Molecules that contain only carbon and hydrogen and only single bonds between carbon atoms | \[
\begin{align*}
\text{H}_2\text{C-H} \\
\text{H}
\end{align*}
\]
|           |                                                                             | methane            |
| alkenes   | Molecules with one or more double bonds between two carbon atoms             | \[
\begin{align*}
\text{H} & \cdots \text{C-} \\
\text{C} & \cdots \text{H}
\end{align*}
\]
|           |                                                                             | ethene             |
| alkynes   | Molecules with one or more triple bonds between two carbon atoms             | \[
\begin{align*}
\text{H} & \cdots \text{C} \\
\text{C} & \cdots \text{H}
\end{align*}
\]
|           |                                                                             | ethyne             |
| aromatics | Molecules containing a benzene ring                                         | \[
\begin{align*}
\text{Br} & \cdots \text{C} \\
\text{C} & \cdots \text{H}
\end{align*}
\]
|           |                                                                             | bromobenzene       |
| alcohols  | Molecules with an -OH attached to a carbon atom                              | \[
\begin{align*}
\text{H} & \cdots \text{C} \\
\text{C} & \cdots \text{H} & \cdots \text{OH}
\end{align*}
\]
|           |                                                                             | methanol (methyl alcohol) |
| amines    | Molecules with a -NH\(_2\) attached to a carbon atom                         | \[
\begin{align*}
\text{CH}_3 & \cdots \text{C} \\
\text{C} & \cdots \text{NH}_2 \\
\text{CH}_3
\end{align*}
\]
|           |                                                                             | butylamine          |
| aldehydes | Molecules with \( \text{O} \cdots \text{C} \cdots \text{H} \)             | \[
\begin{align*}
\text{CH}_3 & \cdots \text{C} \\
\text{C} & \cdots \text{H}
\end{align*}
\]
|           |                                                                             | ethanal (acetaldehyde) |
3.2 Hydrocarbons: Alkanes, Alkenes, Alkynes, and Aromatics

The first four kinds of organic molecules (alkanes, alkenes, alkynes, and aromatics) are all hydrocarbons—that is, they contain only hydrogen and carbon. They are all very nonpolar, flammable, and similar in both appearance and touch (for the solids and liquids).

Alkanes

The simplest organic molecules are the alkanes which have only single bonds, and only carbon and hydrogen. Table 3.4 shows some common examples of alkanes. An alkane can be as long as you like. The shortest is methane, CH₄, with only one carbon atom. Ethane has two carbons, propane has three carbons, and so on up to eicosane with 20 carbons, and polyethylene, which may have hundreds or even thousands of carbons.

The small alkanes are gases, the medium ones (from pentane on) are liquids, and the larger ones are solids. All the alkanes are very nonpolar: the liquids are gasoline-like or oily and act as solvents for nonpolar substances. The solids are waxes (like paraffin) or plastics, with a waxy, greasy feeling to the touch. (This is the way all nonpolar substances feel.) They all burn in air and are often used as fuels (natural gas, LP gas, butane lighters, gasoline, candles, etc.).
Table 3.4 Alkanes

<table>
<thead>
<tr>
<th>Name</th>
<th>Structure</th>
<th>Properties</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>methane</td>
<td>CH₄</td>
<td>colorless odorless gas</td>
<td>main component of natural gas</td>
</tr>
<tr>
<td>ethane</td>
<td>CH₃CH₃</td>
<td>colorless odorless gas</td>
<td>a component of natural gas</td>
</tr>
<tr>
<td>propane</td>
<td>CH₃CH₂CH₃</td>
<td>gas</td>
<td>can be liquefied at high pressure (LP gas used for camp stoves and gas grills)</td>
</tr>
<tr>
<td>n-butane</td>
<td>CH₃CH₂CH₂CH₃</td>
<td>gas</td>
<td>can be liquefied at low pressure (used in butane lighters)</td>
</tr>
<tr>
<td>isobutane</td>
<td>CH₃CH(CH₃)CH₃</td>
<td>gas</td>
<td>can be liquefied at low pressure</td>
</tr>
<tr>
<td>n-pentane</td>
<td>CH₃CH₂CH₂CH₂CH₃</td>
<td>liquid</td>
<td>gasoline-like fuel</td>
</tr>
<tr>
<td>n-decane</td>
<td>CH₃(CH₂)₈CH₃</td>
<td>liquid</td>
<td>a bit oily</td>
</tr>
<tr>
<td>n-eicosane</td>
<td>CH₃(CH₂)₁₈CH₃</td>
<td>waxy solid</td>
<td>found in paraffin waxes in candles</td>
</tr>
<tr>
<td>polyethylene</td>
<td>CH₃(CH2)ₙCH₃</td>
<td>common plastic</td>
<td>(milk bottles, etc.)</td>
</tr>
</tbody>
</table>

**Alkenes and Alkynes**

An alkene is any organic molecule with a carbon-to-carbon double bond, and an alkyne is any molecule with a carbon-to-carbon triple bond. Tables 3.5A and 3.5B show a few common examples (ethene, butene, ethyne, etc.). Like the alkanes, the smaller alkenes and alkynes are gases, the medium ones are nonpolar liquids, and the larger ones are waxy solids or plastics. Also like the alkanes, the alkenes and alkynes burn in air. Gasoline is a mixture of many organic molecules, including large amounts of both alkanes and alkenes. Acetylene, the smallest alkyne, burns so hot it is used in welding and cutting torches.
### Table 3.5A  Alkenes

<table>
<thead>
<tr>
<th>Name</th>
<th>Structure</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>ethene (ethylene)</td>
<td><img src="image" alt="Structure" /></td>
<td>plant hormone that causes ripening of fruit</td>
</tr>
<tr>
<td>propene (propylene)</td>
<td><img src="image" alt="Structure" /></td>
<td>monomer used to make polypropylene, a common polymer</td>
</tr>
<tr>
<td>1-butene (butylene)</td>
<td><img src="image" alt="Structure" /></td>
<td>monomer used to make polybutylene, a common polymer</td>
</tr>
<tr>
<td>2-butene</td>
<td><img src="image" alt="Structure" /></td>
<td>used in the production of gasoline</td>
</tr>
</tbody>
</table>

### Table 3.5B  Alkynes

<table>
<thead>
<tr>
<th>Name</th>
<th>Structure</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>ethyne (acetylene)</td>
<td><img src="image" alt="Structure" /></td>
<td>used in welding and cutting torches</td>
</tr>
<tr>
<td>propyne</td>
<td><img src="image" alt="Structure" /></td>
<td>used in welding torches</td>
</tr>
<tr>
<td>1-butyne</td>
<td><img src="image" alt="Structure" /></td>
<td>used in the synthesis of organic compounds</td>
</tr>
<tr>
<td>2-butyne</td>
<td><img src="image" alt="Structure" /></td>
<td>used in the synthesis of organic compounds</td>
</tr>
</tbody>
</table>
Aromatics

The last and most complex of the hydrocarbons are the aromatic molecules. (They usually smell good!) There are many different kinds of aromatic molecules, but we will focus on the simplest one, benzene.

As you can see in Figure 3.4, benzene is a ring of six carbon atoms and six hydrogens in the shape of a hexagon. There are three double bonds alternating with three single bonds around the ring.

3.3 Alcohols, Amines, Aldehydes, Acids, Ketones, Esters, and Amides

Alcohols and Amines

The simplest organic molecules beyond the hydrocarbons are the alcohols and amines as shown in Table 3.6. An alcohol is any molecule with a -OH group attached to a carbon atom, and an amine is any molecule with a -NH₂ group attached to a carbon atom. Both the -OH group and the -NH₂ group are very polar, so alcohols and amines are usually polar as well. They tend to dissolve well in water, and the liquid alcohols, especially, can act as solvents for other polar molecules.

Both alcohols and amines are very important for living things. All the carbohydrates including sugars, starches, and cellulose are large alcohols with many -OH (alcohol) groups each. The amino acids from which all proteins are built are amines and acids.
### Some Simple Alcohols and Amines

<table>
<thead>
<tr>
<th>Name</th>
<th>Structure</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>methanol</td>
<td>CH₃OH</td>
<td>methyl alcohol—wood alcohol</td>
</tr>
<tr>
<td>ethanol</td>
<td>CH₃CH₂OH</td>
<td>ethyl alcohol—“alcohol” in wine, beer, etc.</td>
</tr>
<tr>
<td>1-propanol</td>
<td>CH₃CH₂CH₂OH</td>
<td>used as a solvent</td>
</tr>
<tr>
<td>2-propanol</td>
<td>OH</td>
<td>isopropyl alcohol—“rubbing alcohol”</td>
</tr>
<tr>
<td></td>
<td>CH₃CH₂CH₃</td>
<td></td>
</tr>
<tr>
<td>1-butanol</td>
<td>CH₃CH₂CH₂CH₂OH</td>
<td>a solvent</td>
</tr>
<tr>
<td>ethylene glycol</td>
<td>HOCH₂CH₂OH</td>
<td>antifreeze</td>
</tr>
<tr>
<td>glycerol</td>
<td>HOCH₂CH₃OH</td>
<td>glycerine</td>
</tr>
<tr>
<td>methylamine</td>
<td>CH₃NH₂</td>
<td>used in producing agricultural chemicals</td>
</tr>
<tr>
<td>ethylamine</td>
<td>CH₃CH₂NH₂</td>
<td>used in synthesizing organic molecules</td>
</tr>
<tr>
<td>1-propylamine</td>
<td>CH₃CH₂CH₂NH₂</td>
<td>used in chemical analysis and synthesis</td>
</tr>
</tbody>
</table>

### Aldehydes, Acids, and Ketones

In our next group, all the molecules have a characteristic feature called a **carbonyl**, which is a carbon atom that is double bonded to an oxygen [-C=O]. Like alcohols and amines, the carbonyl is polar, so all the molecules in this section are also polar, though not as much so as the alcohols and amines. Depending on what is next to the carbonyl group, the molecule may be an aldehyde, an acid, or a ketone:

- **An aldehyde** is any molecule with: \[\overset{\text{O}}{-\overset{-\text{H}}{\text{C}}-}\] It has only an H atom on one side of the carbonyl;
- **An acid** is any molecule with: \[\overset{\text{O}}{-\overset{-\text{OH}}{\text{C}}-}\] It has an -OH group next to the carbonyl;
- **A ketone** is a molecule with carbon atoms on both sides. \[\overset{\text{O}}{\overset{\text{C}-\text{C}-}{\text{C}}-}\]
Table 3.7 shows simple examples of all three types.

Aldehydes and ketones often smell nice and are frequently found in fruit oils and scents. The organic acid group \([-\text{COOH}\] is acidic, of course. When an organic acid is added to water, it releases $H^+$ ions which lowers the pH and raises the acidity of the water. For example, the reaction for benzoic acid is as follows:

![Reaction for benzoic acid]

Organic acids are often used inside living cells to control pH. Between the amines and the acids, organic molecules include both bases and acids, so they can be used to control pH over a wide range and in either direction (higher or lower).

<table>
<thead>
<tr>
<th>Name</th>
<th>Structure</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>methanal</td>
<td>$\text{O}$</td>
<td>formaldehyde, preservative</td>
</tr>
<tr>
<td>ethanal</td>
<td>$\text{O}$</td>
<td>used in making perfumes and food flavors</td>
</tr>
<tr>
<td>octanal</td>
<td>$\text{CH}_3\text{-CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{H-C-OH}$</td>
<td>citrus aroma found in citrus oils</td>
</tr>
<tr>
<td>formic acid</td>
<td>$\text{O}$</td>
<td>both an acid and an aldehyde; used in food preservatives</td>
</tr>
<tr>
<td>ethanoic acid (acetic acid)</td>
<td>$\text{O}$</td>
<td>vinegar</td>
</tr>
<tr>
<td>glycine</td>
<td>$\text{NH}_2\text{-CH}_2\text{-C-OH}$</td>
<td>the simplest amino acid (both an acid and an amine); used to make proteins</td>
</tr>
</tbody>
</table>
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| Alanine | \[
\begin{array}{c}
\text{O} \\
\text{NH}_2 \cdot \text{CH} \cdot \text{C} \cdot \text{OH} \\
\text{CH}_3
\end{array}
\] | the next simplest amino acid used to make proteins |
|---------|----------------------------------|--------------------------------------------------|
| Benzoic Acid | \[
\begin{array}{c}
\text{C} \cdot \text{OH}
\end{array}
\] | both an aromatic and an acid often used as a preservative in sodas (under the name sodium benzoate—look on the label on a soda) |
| Propanone (acetone) | \[
\begin{array}{c}
\text{Cl}_{3} \cdot \text{C} \cdot \text{CH} \cdot \text{CH}_3
\end{array}
\] | a solvent |
| Butanone | \[
\begin{array}{c}
\text{Cl}_{2} \cdot \text{CH} \cdot \text{C} \cdot \text{CH}_3
\end{array}
\] | methyl ethyl ketone or MEK, a common solvent |
| 2-Pentanone | \[
\begin{array}{c}
\text{Cl}_{2} \cdot \text{CH}_2 \cdot \text{CH} \cdot \text{CH} \cdot \text{CH}_3
\end{array}
\] | food flavoring and perfumes |

**Esters and Amides**

The esters and amides are a bit more complicated than the earlier classes, but are very important for biology, so we include them here. An ester has a carbonyl, an oxygen next to the carbonyl, and a carbon atom attached to the oxygen. It's like an acid, except instead of a -OH next to the carbonyl, there is a -OR, where R is something organic.

One of the main reasons esters are important is that they provide an easy way to hook two big molecules together.

An ester can be made by reacting an *acid* with an *alcohol*. For example, acetic acid will react with ethanol to make an ester called ethyl acetate.

\[
\begin{array}{c}
\text{O}
\end{array}
\begin{array}{c}
\text{CH}_3 \cdot \text{C} \cdot \text{OH}
\end{array} + \begin{array}{c}
\text{CH}_3 \cdot \text{CH}_2 \cdot \text{OH}
\end{array} \rightarrow \begin{array}{c}
\text{O}
\end{array} \begin{array}{c}
\text{CH}_3 \cdot \text{C} \cdot \text{O} \cdot \text{CH}_2 \cdot \text{CH}_3
\end{array} + \begin{array}{c}
\text{H}_2 \text{O}
\end{array}
\]

*acetic acid* | *ethanol* | *ethyl acetate* (an ester)
3.4 Carbohydrates, Lipids, Fats, and Steroids

Carbohydrates

Recall from *Book 6* that carbohydrates are molecules that are essential for living things and are made inside living things through two main biochemical processes: gluconeogenesis and photosynthesis. Carbohydrates are found as small simple sugars and large complex polymers. Small simple sugars are called monosaccharides.

The smallest monosaccharides have three carbon atoms. These are called trioses. Larger simple sugars with four, five, six, and seven carbons are called tetrose, pentose, hexose, and heptose, respectively. Glucose is a hexose and has six carbon atoms. Ribose is a pentose and has five carbons. Erythrose is a tetrose with four carbon atoms, and glyceraldehyde, the simplest sugar, is a triose with only three carbons.

A sugar molecule has two kinds of reactive groups: a carboxyl group on one end and several hydroxyl groups on the other carbons. The carboxyl group can react with any of the hydroxyl groups, creating a circular molecule. For glucose, it turns out that the carboxyl oxygen reacts best with the second-to-last hydroxyl group on the linear molecule. This creates a six-membered ring called a pyranose. The official name for a circular glucose molecule is glucopyranose.
Glucopyranose can assume different conformations, or shapes, but is typically found in what is known as a chair conformation in which the ends of the ring buckle and fold in opposite directions.

When single sugars are added one to another, larger and more complex carbohydrates are formed. When two monosaccharides are connected, the molecule becomes a disaccharide (di- means “two”). Sucrose, or table sugar, is a disaccharide of a single glucose and a single fructose.

Lactose, the sugar found in milk, is made of a glucose and a galactose.

Fig. 3.7  **Glucopyranose**  
can adopt different conformations

Fig. 3.8  **Sucrose** (table sugar)  
a disaccharide of glucose and fructose

Fig. 3.9  **Lactose** (milk sugar)  
a disaccharide of glucose and galactose
The bond formed between the two monosaccharides in lactose is called a glycosidic bond. There are two ways a glycosidic bond can form, both of which depend on the orientation of the bonding oxygen. If the oxygen is pointing downward, the bond is called an α-glycosidic bond (alpha-glycosidic bond). If the oxygen is pointing upward, the bond is called a β-glycosidic bond (beta-glycosidic bond).

When a few (more than two) saccharides are added together, the molecule is called an oligosaccharide (oligo- means “few”), and when many saccharides are added together in a long chain, the molecule is called a polysaccharide [poly- means “many”].

There are two major types of polysaccharides: structural polysaccharides and storage polysaccharides. As the name implies, structural polysaccharides are carbohydrates that are primarily involved in plant cell walls and insect exoskeletons. Storage polysaccharides, on the other hand, are used for storing food energy. Cellulose and chitin are two structural polysaccharides. Cellulose is the primary structural polysaccharide for cell walls in plants. Cellulose is a linear polymer composed of several hundred glucose molecules linked together by a β-glycosidic bond. The long-chain glucose polymers stack on top of each other forming layered plates.
Chitin is the main structural polysaccharide found in the exoskeletons of insects, spiders, and crustaceans, and it forms similar stacked layers. Although chitin and cellulose have similar structures, chitin has a different functional group on one of the carbon atoms in its monomer.

Starch and glycogen are the primary storage polysaccharides found in plants and animals. Starches are found only in plants, and glycogen is the storage polysaccharide found in animals.

Starch is composed of two different polysaccharides: amylose and amylopectin. Amylose is a linear polymer of glucose monomers linked together by an \(\alpha\)-glycosidic bond.

Amylose forms a spiral coil, or helix which looks similar to a Slinky\textsuperscript{®}. It is this unique structure that binds iodine molecules, creating a deep purple color in iodine-stained foods.
Amylopectin is also a polymer of linked glucose monomers hooked together by \( \alpha \)-glycosidic bonds. But unlike amylose, amylopectin is branched instead of linear and does not form a helical coil.

Glycogen is composed of glucose molecules linked by \( \alpha \)-glycosidic bonds, similar to amylopectin but with many more branches. Glycogen is present in nearly all cells, but in humans it is found primarily in liver and skeletal-muscle cells.

**Lipids: Fats and Steroids**

Another important group of nutrients required for the healthy maintenance and function of our bodies are the lipids. Lipids include fats, sterols, waxes, fat-soluble vitamins, and other molecules. Fats allow the body to absorb fat-soluble vitamins, provide energy, and are an essential component of cellular membranes.

The most common fats in living things are made from glycerol. Glycerol is a small three-carbon carbohydrate. Fats are made of a derivative of glycerol, called a triglyceride. In a triglyceride, the hydroxyl hydrogen has been replaced with a carbon, an oxygen, and an “R” group. The “R” group is any long chain of hydrocarbons.

Have you ever wondered why animal fat is solid at room temperature, but vegetable oil is liquid at room temperature? Both animal fat and vegetable oil are fats made of a triglyceride and three long chains of hydrocarbons, but an animal fat has no double bonds in its hydrocarbon “R” groups, whereas a vegetable oil does. If there are no double bonds, the
fat is called saturated. If the fat does contain double bonds, it is called unsaturated. Saturated fats have a higher melting temperature than unsaturated fats. Because animal fats are typically saturated and have no double bonds, they are solids at room temperature. Vegetable fats are unsaturated, do have double bonds, and have a lower melting temperature than animal fats, making them liquid at room temperature.

Finally, another set of important nutrients is called steroids. Steroids are found in both plants and animals and are among the most important natural products. Steroids are involved in sex hormones, bile acids, and the formation of animal membranes.

Cholesterol is the most common steroid found in animals. Cholesterol is a type of lipid found in the brain and spinal column tissues of humans and is the major component in the plasma membranes of animal cells (see Book 5, Chapters 7 and 8).

Cholesterol is the primary starting material of steroid hormones. Although there has been significant dietary controversy over cholesterol, it is an important biochemical molecule and a vital nutrient for the proper health and maintenance of our bodies. (See Fig. 3.17)
3.5 Summary

- **Organic chemistry** deals with carbon-containing compounds.

- **Isomers** are two molecules that have the same number and kind of atoms but have different structures.

- A **functional group** is a subset of atoms on a molecule that together form a reactive unit.

- A **parent molecule** is a molecule from which other molecules are built.

- **Alkenes, alkynes, alkanes, and aromatics** are groups of organic molecules that contain only hydrogen and carbon.

- **Carbohydrates** are made of simple sugars or chains of simple sugars, and provide energy for living things.

- Sugars are linked to each other through **glycosidic bonds**, which can be “up” (β-glycosidic bond) or “down” (α-glycosidic bond).

- **Cellulose and chitin** are structural polysaccharides. **Cellulose** is found in plants, and **chitin** is found in the exoskeletons of insects and crustaceans. **Starch** and **glycogen** are storage polysaccharides found in both plants and animals.

- An **unsaturated** fat has double bonds, and a **saturated** fat has no double bonds.
Chapter 7  Photosynthesis

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7.1 Introduction

Plants have the remarkable ability to make food out of sunlight, carbon dioxide, and water. The entire animal kingdom relies upon plants for food—without plants animal life on Earth would cease to exist.

Plants are called autotrophs because they make their own food by a process called photosynthesis. Photo comes from the Greek word photos, which means “light” and synthesis, which means “to make.” Photosynthesis means “to make with light.”

The process of photosynthesis occurs in plastids called chloroplasts. Recall from Chapter 6 that plastids are specialized organelles found in plants and some other organisms. Chloroplasts are bound by both an inner and an outer membrane that allow all the necessary chemical reactions to be carried out in a confined container. Inside the chloroplast are membrane-bound structures called thylakoids that are arranged in stacks called grana (singular, granum). Within the thylakoid membrane are chlorophyll molecules that give plants their green color. Chlorophyll molecules are carefully arranged in the thylakoid so that when sunlight interacts with one chlorophyll molecule, it starts a cascade of interconnected chemical reactions. Surrounding the...
thylakoids is the stroma, a colorless liquid that contains supportive fibers that hold the chloroplast together.

Chloroplasts are found in all the green parts of a plant including the leaves, stems, and unripened fruit. However, green leaves are the major site of photosynthesis in most plants. Because of their shape and location on the plant, leaves can collect much more sunlight than any other part of the plant. For example, the leaves of flowering plants are broad with a flat shape. This shape enables the leaves to collect as much sunlight as possible. On trees, the leaves are fixed to the branches at many different angles. This enables the leaves to collect sunlight from all directions during the day as the Sun moves across the sky.

Photosynthesis occurs year-round in some plants, for example, conifer trees. Instead of broad, flat leaves, many conifers have needles, very narrow leaves covered by a cuticle—a waxy, waterproof outer coating. (We will learn more about the cuticle in Chapter 8.) Trees that have needles are uniquely designed to live in places where it is drier and where broad, flat leaves would tend to dry out. Because they keep their needles year-round, conifers can carry out photosynthesis during the winter, and the shape and arrangement of needles help the trees shed snow so the branches don't break from the weight.
Some organisms that are not classified as plants also use the Sun’s energy to make food. For example, many types of algae are photosynthetic. Algae are in the kingdom Protista and can be microscopic or macroscopic (large enough to see with the unaided eye). Seaweeds found in the ocean are classified as algae rather than true plants. Although seaweeds have structures that look like those of plants, they are not classified as plants because they lack true roots, stems, and leaves. Seaweeds don’t have vascular tissues, and they absorb nutrients directly from the water they are submerged in. Not all seaweeds are green. Some are red or brown. However, all seaweeds do use photosynthesis to make their own food just like land plants do. Microscopic algae make most of the food for the animals in the ocean.

Another class of organisms that use the Sun’s energy to make food are the cyanobacteria. Cyanobacteria were once called blue-green algae, but because the cells don’t have a nucleus (they are prokaryotes), they are not like other algae. They are now grouped in the kingdom Bacteria.
7.2 Photosynthesis

Although the exact series of chemical reactions for photosynthesis is complex, the overall photosynthetic reaction has been known since the early 1800s. In summary, light energy, water, and carbon dioxide produce glucose (a simple sugar) and oxygen.

The overall chemical reaction can be written as:

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

(6 molecules of carbon dioxide + 12 molecules of water + light energy = one molecule of glucose + 6 molecules of oxygen + 6 molecules of water)

The investigation of photosynthesis grew out of a simple question: “When a seedling starts to grow, where does the increase in mass come from?” Does it come from the water? Does it come from the soil? Does it come from the air?

Beginning in the mid 1600s scientists began exploring the chemistry behind how plants grow to determine where in the process plants create the additional tissue needed to grow into tall trees, long grasses, and bountiful vegetables. In 1845 Julius Robert von Mayer (1814-1878) proposed that plants convert light energy into chemical energy, and by the mid 1900s several scientists showed that atmospheric carbon dioxide is turned into simple sugars while releasing oxygen.

The simple photosynthetic equation above is actually a series of two distinct stages of multiple reactions known as the light-dependent reactions and the light-independent reactions, or Calvin Cycle. The light-dependent reactions are the chemical reactions that occur when a chloroplast captures light energy from the Sun, and the Calvin Cycle (historically called the dark reactions) refers to the chemical reactions that produce sugar. One way to look at these two sets of reactions is that the light-dependent reactions are the photo part of photosynthesis and the Calvin Cycle is the synthesis part of photosynthesis. We’ll take a look at the light-dependent reactions and the Calvin Cycle in more detail later in this chapter.
How does the process of photosynthesis work? How does a plant use sunlight to make food? Recall that light is composed of both electric and magnetic energy that combine to make an electromagnetic wave. Electromagnetic waves have different frequencies and wavelengths. For example, radio waves have low frequencies and long wavelengths, and gamma rays have high frequencies and short wavelengths. The visible light part of the electromagnetic spectrum is a narrow range of wavelengths that are visible to the eye. Visible light wavelengths are between the longer infrared and the shorter ultraviolet wavelengths, both of which require instruments to be observed.

Recall that light can be reflected, absorbed, or transmitted. When a light wave is reflected, it bounces back away from the material. When a light wave is absorbed, energy from the light is transferred to the material that is absorbing it, and when a light wave is transmitted, it passes through the material. The color the material appears to us is the wavelength of visible light that is reflected the most. Plant leaves look green because green light is reflected. This means that violet, blue, red, orange, and yellow light wavelengths are absorbed.

When sunlight hits a plant cell that contains a chloroplast, light is absorbed by special molecules known as pigments. Different pigments absorb and reflect light at different
wavelengths depending on the chemical structure of the pigment molecules. Pigments are large molecules with several rings and alternating double bonds. Because they have rings and double bonds, pigments can absorb light of different wavelengths by converting light energy into chemical potential energy inside these rings and double bonds. We’ll take a closer look at pigment molecules later, but first let’s explore how they can absorb and release light energy. How does this happen?

Recall that light energy is made of photons which are packets of energy that travel through space like a wave. In a nutshell, the way a pigment molecule converts light energy into chemical energy is to take energy from a photon and use this energy to bump one or more of its electrons into a higher energy state. Most atoms and molecules exist in what is called the ground state. The ground state is the lowest energy state possible for any given atom or molecule. However, when a photon strikes a molecule that has lots of double bonds and rings, there are high energy states that an electron can occupy. In other words, the molecule can absorb the energy of the photon and use it to move an electron from a low energy state to a high energy state. This electron can stay in the high energy state only briefly, and as it drops back down to the ground state, the energy released can be used to drive chemical reactions.
The key light absorbing pigment in most plants is called chlorophyll $a$. Chlorophyll $a$ has a connected set of carbon-nitrogen rings attached to a long hydrocarbon tail. An accessory pigment called chlorophyll $b$ also absorbs light but at slightly different wavelengths. The only difference in structure between these two molecules is a side-group on one of the carbon-nitrogen rings. Chlorophyll $a$ has a methyl group in this position and chlorophyll $b$ has a carboxyl group.

Chlorophyll $a$ absorbs light in the purple to blue range and in the yellow to red range of the visible spectrum, and chlorophyll $b$ absorbs at slightly longer wavelengths in the blue region of the visible spectrum and slightly shorter wavelengths in the red to yellow region. As a result the wavelengths that are reflected make chlorophyll $a$ appear blue-green and chlorophyll $b$ appear yellow-green in the visible light spectrum.
7.3 The Photosystem

How chlorophyll molecules capture and release energy and drive the chemical reactions needed to make sugar involves a complex group of proteins and other molecules working together in a photosystem. There are two photosystems that work together during photosynthesis—photosystem I and photosystem II. Photosystem II functions first in the light-dependent reactions for photosynthesis and is followed by photosystem I.

When light strikes a plant cell, the light is absorbed by a chlorophyll molecule, and this event begins the first series of chemical reactions in photosystem II. Energy from the light is absorbed by the electrons of a chlorophyll molecule and then transferred to other electrons on other chlorophyll molecules. The electrons bounce from molecule to molecule until they reach a specific section of the photosystem called the reaction center complex. Inside the reaction center complex is a special molecule called the primary electron acceptor that takes the electrons, and using the energy released from breaking apart a water molecule, excites them once more to a high energy state. The excited electrons then travel through an elaborate set of proteins called the electron transport chain where they are transferred to photosystem I, and ATP is made. ATP stands for adenosine triphosphate which is a molecule that is essential for providing energy to many chemical reactions inside cells.
A set of chemical reactions similar to photosystem II begins in photosystem I with electrons being absorbed by chlorophyll molecules and eventually transferred to another primary electron acceptor. At this point, when the high energy electrons are transferred to the primary electron acceptor in photosystem I, \textit{NADPH} is made which is transferred to the Calvin cycle for making sugar. NADPH stands for \textit{nicotinamide adenine dinucleotide phosphate} and, like ATP, it is also a molecule that provides energy for chemical reactions inside cells.

### 7.4 The Calvin Cycle

The basic job of photosystem II and photosystem I is to convert the Sun's energy, which arrives in the form of photons, into high energy electrons. The reason the plant cell needs high energy electrons is to make the two very important molecules called ATP and NADPH mentioned above. Both ATP and NADPH are needed in the \textbf{Calvin Cycle} where carbon dioxide is made into sugar.

The Calvin Cycle is a cycle of chemical reactions that can be divided into three separate phases. In phase 1, carbon dioxide enters the cycle and gets converted into \textit{3-phosphoglycerate}. In phase 2, ATP enters the cycle, changing \textit{3-phosphoglycerate} into \textit{1,3-bisphosphoglycerate}. In phase 3, \textit{NADPH} enters the cycle, and glyceraldehyde 3-phosphate leaves the cycle and is used to make glucose (sugar).
into 1,3-bisphosphoglycerate which then gets converted to glyceraldehyde 3-phosphate by NADPH. One of the glyceraldehyde 3-phosphate molecules exits the cycle to make glucose, and the remaining glyceraldehyde 3-phosphate molecules continue through the cycle. In phase 3 ATP enters the cycle to convert glyceraldehyde 3-phosphate into ribulose 1,5-bisphosphate that is used to convert more carbon dioxide into more 3-phosphoglycerate molecules and the process repeats.

In summary, the light-dependent reactions consist of the two photosystems whose job is to convert sunlight into high energy electrons that can be used to make ATP and NADPH. These two molecules are used in the Calvin Cycle which converts carbon dioxide into sugar used by the plant for food.
7.5 Summary

• Plants make their own food by a process called photosynthesis during which light energy, water, and carbon dioxide are used to produce glucose (a simple sugar) and oxygen.

• The process of photosynthesis occurs in plastids called chloroplasts.

• Chlorophyll is the pigment molecule that gives plants their green color by reflecting green light wavelengths.

• Photosynthesis is a series of two distinct stages of multiple chemical reactions known as the light-dependent reactions and the Calvin Cycle. The light-dependent reactions are the chemical reactions that occur when a chloroplast captures light energy from the Sun, and the Calvin Cycle refers to the chemical reactions that produce sugar.

• How chlorophyll molecules capture and release energy and drive the chemical reactions needed to make sugar involves a complex series of proteins and other molecules working together in a photosystem.

• In the Calvin Cycle carbon dioxide is converted into sugar that is used by the plant for food.
Chapter 19  Our Galaxy—
The Milky Way

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Recall that a galaxy is a large collection of stars, gas, dust, planets, and other objects held together by its own gravity, and the Milky Way Galaxy is the galaxy that our Earth, Sun, and entire solar system reside in.

We cannot observe the entire Milky Way Galaxy because Earth is one very tiny speck in the midst of its vast area. We live inside the galaxy, and the distance is too great for us to be able to travel outside the Milky Way to view it as a whole. This makes it very challenging to study. We might compare the effort to map our own galaxy to a scuba diver trying to map the entire Earth from
within one small part of the ocean. Studying other galaxies that are outside the Milky Way helps us understand more about our own galaxy. It is easier to gather significant details about these other galaxies because we can observe the whole structure of the galaxy.

19.2 Shape and Structure

Early astronomers had very different ideas about the size, shape, and nature of the Milky Way than we do today. In 1785 the English astronomer William Herschel (1738-1822) presented a paper with his conclusions about the size and shape of our galaxy. With the aid of a telescope and assisted by his sister Caroline Herschel (1750-1848), William counted and mapped as many stars as could be seen in every direction. By estimating the distance to the several hundred stars that could be observed at that time and recording their location, a map was drawn that was thought to represent our galaxy’s shape and size. Herschel’s map showed the Milky Way as a flat, disk-shaped collection of stars with our Sun at or near the center. We now know that the Milky Way is not entirely flat nor is the Sun at its center, but Herschel was correct in predicting that it has a flattened disk shape.

Astronomers estimate that there are billions or trillions of galaxies outside the Milky Way, and with the help of ground-based and space-based telescopes they have found galaxies of many shapes and sizes. Recall that astronomers group the many variations they see into several basic types of galaxies: spirals, barred spirals, ellipticals, and irregulars. We will learn more about other galaxies in Chapter 20.
By using various mapping methods and different instruments, astronomers have concluded that the Milky Way Galaxy contains hundreds of billions of stars, enough gas and dust to form billions more stars, and probably billions of planets. The Milky Way is most likely a **barred spiral galaxy**. If we could leave our galaxy in a spaceship and look at the Milky Way from above, we would expect to see **spiral arms** similar to a pinwheel, with these spiral arms extending from the ends of an elongated bar-shaped structure made of bright stars at the galactic center. Most new star formation occurs within the spiral arms.

Astronomers have concluded that the Milky Way has two major spiral arms, **Scutum-Centaurus** and **Perseus**, that are packed with stars, gas, and dust. The two minor arms, the **Norma Arm** and the **Sagittarius Arm**, have as much gas and dust but fewer stars. Our solar system resides on a small, partial spiral arm called the **Orion Spur** located between the Sagittarius Arm and the Perseus Arm.
The Milky Way Galaxy can be divided into four main regions. The **galactic bulge** (also called the **central bulge**), the **thin disk**, the **thick disk**, and the **galactic halo**.

The Milky Way’s **galactic bulge** is a thick, elongated bar-shaped area of stars, dust, and gas orbiting the galactic center. Because there is so much dust and gas in the galactic bulge, visible light from inside the galactic bulge is blocked from our view. However, instruments that detect infrared, radio waves, and X-rays can be
used to explore the bulge. It is thought that from an edge-on view the galactic bulge would appear to have a shape similar to a peanut in the shell. It is extremely dense with old stars that have a reddish appearance in images and some younger stars that appear blue. Star formation may be taking place in the inner region of the bulge.

Several very dense globular clusters of stars have been found in the galactic bulge. The Arches Cluster is the densest of these and also the closest to the galactic center at only one light year away. In an area within the Arches Cluster equal to the distance from the Sun to our nearest star, we would see over 100,000 stars. The Arches Cluster contains over 150 stars that are the brightest and most massive in the Milky Way Galaxy.

The supermassive black hole Sagittarius A* lies at the center of the galactic bulge. At 4 million times the mass of the Sun, Sgr A* is a rather small black hole and generally not very active. However, it does have some outbursts of flares that can be picked up with instruments that detect X-rays. It is thought that these flares are extra energy burped out by the black hole as it consumes fuel such as gas or possibly asteroids. A cloud of very hot gas with temperatures of up to about 1000° C has been detected spiralling around Sgr A* and may be feeding it.
When we see the Milky Way as a faint band of light in the night sky, we are viewing the thin disk edge-on from Earth’s position within it. The thin disk orbits the galactic bulge, contains the spiral arms and the majority of the stars in the galaxy, and would look almost circular when viewed from above. Our Sun and the Earth are located in the thin disk. Stars of all ages are found here and clouds of gas and dust create beautiful nebulae and star forming areas. Most of the youngest stars are found here. The thick disk surrounds the thin disk and contains mostly older stars. The thin and thick disks together are called the stellar disk or the galactic disk.

Surrounding the entire galaxy is the galactic halo, a spherical grouping of gas, individual old stars, and globular clusters. Over 150 globular clusters of stars that are over 10 billion years old have been discovered in the Milky Way with most being found in the halo and fewer in the thick disk. The gaseous part of the halo is enormous and is estimated to be at least 600,000 light years in diameter. It is made up of warm and very hot gases with temperatures estimated at between 100,000 and 2.5 million degrees C. There is little or no dust in the halo. The Large Magellanic Cloud and Small Magellanic Cloud galaxies are within the Milky Way’s halo.
The halo is made up of more than gas and stars. Astronomers theorize that most of the halo is made of the very mysterious dark matter. The dark matter part of the halo is called the dark halo. Although most of the Milky Way, and in fact most of the universe, is thought to be made of dark matter, it is not yet known what it is! It was named “dark” matter because it doesn’t interact with electromagnetic force and therefore can’t be detected directly. Light isn’t emitted from dark matter, light isn’t absorbed by it, and light doesn’t bounce off it. So we can’t see it.

However, the effects of the gravitational force of dark matter can be detected. The galaxy is rotating so fast around the Galactic Center that the gravity created by the amount of matter that can be detected (visible matter) is not great enough to hold the galaxy together. Without enough gravitational force to hold them in orbit, the stars would go flying out of the galaxy. It is thought that dark matter gives the galaxy—and the universe—the extra mass needed to have enough gravity to hold everything together. Because dark matter appears to be a source of gravitational force, it is believed that dark matter is made of an as yet unidentified particle that has mass and thus has gravitational force.

In addition to looking at gravitational force, astronomers look at the total mass of the galaxy, a number arrived at through mathematical calculations. They have found that the mass of all the visible objects in the Milky Way Galaxy combined isn’t enough to add up to the total mass. Dark matter is thought to make up the difference. It is theorized that there may be 5 times as much dark matter as visible matter in the Milky Way.

To make understanding the galaxy even more difficult, there’s another big mystery in astronomy—dark energy. While dark matter is thought to have mass and the attractive force of gravity, dark energy is thought to have a repelling force, pushing objects farther apart and causing the
universe to expand. But, like dark matter, dark energy cannot be detected directly, and its existence is only theorized from observations of how objects in space behave. It appears that empty space is not empty at all; we just don’t know what’s there. It's estimated that 22% of the universe is made of dark matter, 74% dark energy, and only 4% is visible matter that we can detect! This leaves a staggering amount yet to be discovered about the universe and how it works.

19.3 Size

How big is the Milky Way Galaxy? Since we are on a small planet circling a relatively small sun off to one side of a huge galaxy, it’s tough to measure its size. Because we can’t take a spaceship and a tape measure to the end of the galaxy, astronomers estimate distances by using other techniques. Early astronomers assumed that all stars are equally bright and used this assumption to estimate distances to faraway stars. With more advanced technology, astronomers are able to get a more accurate picture of objects and distances in the galaxy.

In the early 20th century an American astronomer named Harlow Shapley (1885-1972) studied globular clusters within the Milky Way. Shapley was able to calculate the distances to the different globular clusters by using the period-luminosity relationship of Cepheid stars and RR Lyrae stars. Like Cepheid stars, RR Lyrae stars are variable stars, but they have a short period of somewhere between four hours and one day, and they are more numerous in the galaxy than Cepheids. Shapley found that globular clusters in the halo are arranged in a spherical grouping, and he concluded that the center of the galaxy would be at the center of the spherical group. By finding the center of the galaxy and using RR Lyrae stars to measure distances, Shapley was able to observe that the Sun is not at the center of the Milky Way. His estimate of the Sun being 50,000 light years away from the galactic center was not accurate, but his discovery that the Sun is far from the galactic center was a major change in how the universe was viewed at that time.

The brightness of an RR Lyrae star varies on a regular schedule (the period-luminosity relationship). This graph shows the regular change in brightness of an unidentified RR Lyrae star that has a period of less than one day.

Derived from a NASA illustration
Finding Cepheid stars

Above: The Trifid Nebula seen in visible light

Upper right: To the right of center in this infrared image, the Trifid Nebula appears as a faint blue area. We can see that by imaging this area of the galaxy in infrared, astronomers are able to see through dust and gas to find out what’s behind them. In this way two previously unseen Cepheid stars were found. These stars are located farther away than the nebula.

Bottom right: The location of the Cepheid stars is indicated. The Cepheids are circled in the inset.

Credits: Visible light image courtesy of ESO; Infrared images courtesy of ESO/VVV consortium/D. Minniti
A full description of how astronomers measure distances using variable stars is beyond the scope of this text, but basically astronomers calculate distances by use of a mathematical relationship between the absolute magnitude of the star and the star’s apparent magnitude.

**Astronomical Math!**

### Measuring Distance to Stars

**Basic Formula**

$$\text{distance}^2 = \frac{\text{absolute magnitude (luminosity)}}{\text{apparent magnitude}}$$

The *absolute magnitude* of Cepheid and RR Lyrae stars can be calculated using the period-luminosity relationship, and the *apparent magnitude* is measured from Earth. These values can then be plugged into the equation to find distance. From this formula it can be seen that the farther away a star is, the dimmer it will appear when viewed from Earth.

Astronomers use different units of measure to express distances in space. Recall that a *light year (ly)* is the distance that light travels in one year, and one light year is $9.4607 \times 10^{12}$ km (9.46 trillion kilometers). Another unit of measure for astronomical distances is the *parsec (pc)*. A parsec is $3.086 \times 10^{13}$ km (almost 31 trillion km), or 3.2 light years—a very big number! Astronomers also use a unit of measure called the *kiloparsec (kpc)* which is equal to 1,000 parsecs. For some time astronomers have estimated the diameter of our galaxy to be about 100,000 light years in diameter. This diameter can be expressed as 100,000 light years, 30,000 parsecs, or 30 kiloparsecs—these all mean the same distance. Whichever measurement system is used, you can see that the Milky Way Galaxy is unimaginably huge!

A new theory proposes that the Milky Way Galaxy may be much larger. The theory grew out of the discovery of a bulging ring of stars named the *Monoceros Ring* that was observed to be encircling the outside of the Milky Way Galaxy with a space between this ring and the end of the galactic disk. The Monoceros Ring of stars was thought to be outside the Milky Way Galaxy and perhaps merging with it.

From further study of the data collected, it is now theorized that rather than being a separate ring of stars, the Monoceros Ring is actually an extended part of the galactic disk.
and that the part of the galaxy from the Sun outward isn’t a flat plane. Rather, the disk has a “corrugated” structure of waves that ripple outward from the location of the Sun toward the outer edge of the galaxy in a way that is similar to how ripples form and move outward when a stone is dropped in water. Recall from physics that as a wave of energy travels through matter, atoms and molecules are displaced but they don’t move horizontally along with the wave. We can imagine that as a wave of energy passes through them the stars in the outer part of the galaxy move up and down, or oscillate, as a group and form peaks and valleys.

In early studies of the data the Monoceros Ring appeared to be a separate ring of stars because what was being observed was the peak of a wave. The stars in the valley of the wave between the Monoceros Ring and the Sun were lower and went unnoticed. This made it appear that the galactic disk dropped off and ended before it got to the Monoceros Ring, making the Monoceros Ring separate from the galaxy. But now that the valley of stars, called the South Middle Structure, has been discovered, it is thought that the Monoceros Ring is part of the galactic disk. In the illustration we can see that there may be several ripples in the galactic disk between the Sun and the outer reaches of the galaxy.
It is suspected that the entire galactic disk from the galactic bulge outward is corrugated, but data is not yet available to support this idea.

It isn’t known what causes the ripples in the galactic structure to form. One possibility is that a dwarf galaxy or other clump of matter passed through the outer part of the spiral arms, providing the energy to create waves. Another possibility is that gravitational force from dwarf galaxies or other objects orbiting the Milky Way creates the waves.

Because we are limited by what we can observe about the galaxy from inside it and by what our current instrumentation can detect, it is difficult for astronomers to determine how big the Milky Way actually is or to know all the details of its structure. With the addition of the Monoceros Ring and the TriAndromeda Ring beyond it, the diameter of the known galaxy (excluding the halo) is estimated at about 150,000 or more light years. Since there is much yet to be discovered about our galaxy, in the future the corrugated galaxy theory may prove to be true, or it may be amended or replaced by a different theory.

19.4 Viewing the Milky Way Galaxy

When we talk about observing objects in space, we often think about using our eyes aided by telescopes. Recall that what we see with our eyes is the part of the electromagnetic spectrum that is referred to as visible light, or the visible spectrum.

Visible light is only a very small part of the electromagnetic spectrum. By using different types of instruments, scientists can collect data from parts of the electromagnetic spectrum that we cannot see with our eyes. For example, if you look at your hand, you can see the skin and fingernails that are on the surface. If you have an X-ray taken, you will be able to
see the bones underlying the skin. These are two different ways of seeing the same object (your hand), one using visible light that is detected by the eyes and the other using X-rays that are detected mechanically.

Looking at the diagram of the electromagnetic spectrum, you can see that the peaks of the longer radio waves are farther apart, or occur less frequently, than the peaks of the shorter gamma ray waves which are closer together and occur with greater frequency. Since the length of the wave determines the frequency at which it occurs, wavelength and frequency are often used interchangeably. If you hear that gamma rays are short wavelength or that gamma rays are high frequency, these mean the same thing. For more about the electromagnetic spectrum, see *Exploring the Building Blocks of Science Book 4*.

Celestial bodies emit, or radiate, waves of different wavelengths. These emitted waves are referred to as electromagnetic radiation. Different types of instruments are used to detect different wavelengths of the electromagnetic spectrum, and a group of wavelengths is called a spectral band. For example, our eyes detect wavelengths that are in the visible spectral band (or visible spectrum).

The wavelength data collected is transformed by computers into images that scientists can study. Images made from wavelengths outside the visible light spectral band are called false-color images because colors are assigned by artists and computers according to the data being processed.

Saturn viewed at three different spectral bands
These three views of Saturn reveal information about its atmosphere. Because the same types of particles in Saturn’s atmosphere reflect different wavelengths in predictable ways, astronomers can use instruments to make images of Saturn as it is seen in different wavelengths. The data collected can then be interpreted to find out details about Saturn’s clouds and haze.

Courtesy of NASA and E. Karkoschka (University of Arizona/STScI)
The Milky Way Galaxy Visualized at Different Wavelengths

In the following illustration, each band shows approximately the same area of the Milky Way Galaxy, but each represents different spectral bands of the electromagnetic spectrum, and each provides scientists with different information about the Milky Way. The descriptions below refer to the following illustration.

1. **Radio waves** (radio telescope). Radio waves have the longest wavelengths (low frequency waves). This image puts together data from ground-based radio telescopes and shows high-energy electrons scattered from hot, ionized gases. Atoms and molecules are ionized when they have gained or lost electrons and thus become electrically charged. On the left side of the image a supernova is visible as a yellow blob.

2. **Radio waves** (radio telescope). Radio waves are used to detect atomic hydrogen, showing warm interstellar gases. (Interstellar means located between stars.) Clouds of gases and dust can be up to hundreds of light years in size.

3. **Radio waves** (radio telescopes). Shorter wavelengths than in Number 1 show galactic objects in more detail. Hot, ionized gases and high-energy electrons are made visible.

4. **Radio waves** (radio telescope). Shorter wavelengths. Radio waves are used to detect molecular hydrogen—cold, dense gas which is found in “molecular clouds” concentrated in the spiral arms of the Milky Way. These areas are often the sites of star formation.

5. **Infrared wavelengths** (satellite). Here heat is detected, mostly coming from interstellar dust warmed by starlight.

6. **Mid-infrared** (waves from the middle of the infrared spectral band) (satellite). Most of the hazy-looking area in this image is thought to come from hydrocarbon molecules commonly found in interstellar gas clouds and also in coal on Earth. The many bright spots are red giant stars, planetary nebulae, and massive young stars.

7. **Near infrared** (shorter infrared wavelengths that are nearer to the visible light spectral band) (satellite). Cool, low mass stars are revealed.

8. **Optical, or visible light** (photographs from Earth) Interstellar dust hides stars that are farther away from Earth than a few thousand light years (recall that the Milky Way is at least 100,000 light years in diameter).
9. **X-ray** (satellite). Thin, hot gases emit the X-rays detected here. The shadowy areas are cold interstellar gases that absorb X-rays. Variations in color are due to differences in the amount of absorption of the X-rays by gases and differences in temperatures of the emissions. The white areas are supernova remnants.

10. **Gamma ray** (satellite). Gamma rays have the shortest wavelengths (highest frequency) and the most energy. Extreme high-energy photon emissions are shown, including several gamma ray pulsars on the right side of the image. A pulsar is a type of rotating neutron star that emits pulses of radio waves, X-rays, and gamma rays. A neutron star is the remaining core of a star that has exploded in a supernova. Electrons and protons are squeezed together to form neutrons which make up most of the extremely dense and hot neutron star.

![The Milky Way Galaxy visualized at different wavelengths](http://mwmw.gsfc.nasa.gov/)
The Milky Way Galaxy seen in different wavelengths of the microwave spectral band of the electromagnetic spectrum.

The large image at the top combines the other four images to make a composite view of the Milky Way. The smaller images below it are the individual parts of the composite. All images are false-color.

Upper left: Dust glow. The red colors show the heat of dust in the galaxy although it is only -253°C.

Upper right: Carbon monoxide gas appears as yellow in the densest clouds of gas and dust where stars are formed.

Lower left: The electrons and protons of hot, ionized gas near massive stars are colored green.

Lower right: The blue shows fast-moving electrons captured in the Milky Way’s magnetic field.

Courtesy of ESA/NASA/JPL-Caltech
Milky Way Galactic Center

The false-color image at the top is a composite of the images below. By detecting infrared and X-ray wavelengths, we are able to see through the dust of the galaxy to observe the galactic center. The bright spot to the right of center is the galactic core where supermassive black hole Sgr A* resides.

Red - infrared wavelengths detected by the Spitzer Space Telescope. Here we can see hundreds of thousands of stars that heat the surrounding gas and dust making it glow when viewed in infrared. The gas and dust have been formed into blobs, clouds, and stringy structures by radiation and winds from stars.

Yellow - near-infrared wavelengths observed by the Hubble Space Telescope reveal energetic regions of star formation areas of warm gas and hundreds of thousands of stars. Radiation and winds from stars have formed the arcs and other structures seen here.

Blue and violet - X-rays seen by the Chandra X-Ray Observatory. Lower energy X-rays show as pink areas with higher energy X-rays appearing as blue. This view shows gas that has been heated to millions of degrees by stellar explosions, emissions from SgrA*, and winds from massive stars.

Courtesy of NASA, ESA, SSC, CXC, and STScI
As you can see from the previous examples, astronomers have many different ways of observing features of the universe that we cannot see directly with our eyes.

**19.5 Summary**

- The galaxy Earth resides in is the **Milky Way Galaxy**.
- The **Milky Way Galaxy** is a **barred spiral galaxy** with a **galactic bulge** at the center of a stellar disk.
- Earth resides between the **Sagittarius Arm** and the **Perseus Arm** on a small, partial spiral arm called the **Orion Arm**.
- The size of the **Milky Way Galaxy** is estimated to be at least 100,000 light years (ly), 30,000 parsecs (pc), or 30 kiloparsecs (kpc) in diameter. These are different ways of stating the same distance in space.
- Astronomers use different instruments to detect **electromagnetic radiation** that lies outside the visible part of the spectrum, thus allowing them to visualize features of the **Milky Way Galaxy** that cannot be seen with the eyes.
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- Experiment 3: Show Me the Starch!
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## BIOLOGY
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- Experiment 7: Take Away the Light
- Experiment 8: Seeing Inside Plants
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Experiment 3

Show Me the Starch!
Introduction

Which food items do you think contain starch? Can you find out?

I. Think About It

1. Do you think potatoes contain starch? Why or why not?

2. What type of food would you eat if you wanted lots of energy to climb a mountain or run a marathon? Why?

3. Do you think there is a way to test for starch? Why or why not?
What do you think happens when a banana or other fruit ripens?

Do you think you could detect the changes in carbohydrates that a banana undergoes as it ripens? Why or why not?

What do you think is different about the structure of starch and the structure of sugars?
II. Experiment 3: Show Me the Starch!  

Date __________

Objective  

Hypothesis  

Materials

tincture of iodine [Iodine is VERY poisonous — DO NOT EAT any food items with iodine on them.]
a variety of raw foods, including:
  pasta
  bread
  celery, sliced
  potato, sliced
  banana and other fruits
liquid laundry starch (or a borax and corn starch mixture)
absorbent white paper
eyedropper
cookie sheet
marking pen

EXPERIMENT

1. Take several food items and a piece of absorbent paper and place them on a cookie sheet.

2. Label the piece of absorbent paper Control. Using the eyedropper, put a small amount of liquid starch (or a borax and corn starch mixture) on the paper. Let it dry.

3. Add a drop of iodine to the control starch on the absorbent paper. In the chart in the Results section, record the color.

4. Add iodine to each of the food items and record the color for each.

5. Compare the color of the “control” to the color of each food item.
## Results

<table>
<thead>
<tr>
<th>Food Item</th>
<th>Color</th>
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<tbody>
<tr>
<td>Control</td>
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</table>
III. Conclusions

What conclusions can you draw from your observations?
IV. Why?

Natural starches are a mixture of 10-20% amylose and 80-90% amylopectin. Both amylose and amylopectin contain chains of linked glucose monomers. Amylopectin forms a branched structure and amylose forms a helical coil.

The amylose in starchy foods is responsible for the formation of the deep blue color in the presence of iodine. The iodine molecule inserts itself inside the amylose coil, forming an iodine-amylose complex. A complex is a compound, or joint, molecule made of more than one molecule that are not chemically bonded.

In this experiment you used the iodine-starch test to detect the presence of complex carbohydrates. Complex carbohydrate molecules have chains of a few to thousands of monosaccharide units. Specifically, you tested for the presence of amylose. When iodine is added to amylopectin, cellulose, or small sugars, iodine will keep its orange or yellow color, but when amylose is present, a blue-black color change occurs. The complex creates the blue color by bending light waves in a way that causes wavelengths that create a deep blue to be reflected. Alone, iodine or amylose do not bend light in this way, but when combined in a complex, they do.
V. Just For Fun

A Banana Ripens!

Test what happens when a banana ripens.

1. Cut a slice off a green banana and test for starch using the iodine-starch test from the first experiment. Leave the banana at room temperature for the entire experiment.

2. In the following chart, record your observations.

3. Test a new slice of banana each day for several days as the banana ripens. Record your observations each time.

<table>
<thead>
<tr>
<th>Day 0</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
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4. Review your data. What conclusions can you draw as a result of your experiment?

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Experiment 7

Take Away the Light
Introduction

Explore photosynthesis!

I. Think About It

1. Where do you think plants get their food and nutrients? How do they get them?

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2. Do you think some types of plants need more sunlight than other types of plants? Why or why not?

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3. Why do you think different types of plants have different kinds of leaves?

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4. What do you think Earth would be like if there were no plants? Why?

5. What do you think would happen to a plant if it didn’t get water for a long time? Why?

6. What do you think would happen to a plant if bugs ate all its leaves? Why?
II. Experiment 7: Take Away the Light

Objective

Hypothesis

Materials
- plant with at least 6 flat, green leaves
- lightweight cardboard or construction paper
- scissors
- tape
- 2 small jars
- marking pen

EXPERIMENT

1. Take some cardboard or construction paper and cut it into pieces large enough to completely cover a leaf. Make enough pieces to cover the front and back of 3 leaves.

2. Six different leaves will be tested. Two of the leaves will be left on the plant (attached) and four leaves will be removed from the plant (unattached).

3. Using the cut out cardboard pieces from Step 1, tape two pieces so they cover the front and back of one of the leaves attached to the plant. Another leaf will stay attached to the plant and remain uncovered.

4. Remove four leaves from the plant. Cover two of them with cardboard. These unattached leaves will be either: covered with cardboard and the stem placed in water, covered out of water, uncovered with the stem in water, or uncovered out of water.
With the marking pen, label the leaves in the following manner:

Leaf 1: **UA** — uncovered, attached

Leaf 2: **CA** — covered, attached

Leaf 3: **UUW** — uncovered, unattached, in water

Leaf 4: **CUW** — covered, unattached, in water

Leaf 5: **UU** — uncovered, unattached (no water)

Leaf 6: **CU** — covered, unattached (no water)

Take two small jars and fill them with water. Take the two leaves that will be placed in water and prop one in each jar, keeping the stem submerged and the leaf out of the water. Check the water level every day over the course of the experiment to make sure there is enough water in the jars for the stems to be submerged.

Wait several days, and then every day observe the changes to the leaves. Carefully remove the cardboard from the covered leaves to make your observations, and then re-tape the cardboard. Record your observations in the chart in the *Results* section.
<table>
<thead>
<tr>
<th>Results</th>
<th>UA</th>
<th>CA</th>
<th>UUW</th>
<th>CUW</th>
<th>UU</th>
<th>CU</th>
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</table>
III. Conclusions

What conclusions can you draw from your observations?

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IV. Why?

Because plants don’t have teeth, a mouth, a stomach, or saliva, they can’t eat food the way animals do. Instead, plants are photosynthetic and use the Sun’s energy to make their own food. However, there are a few carnivorous and parasitic plants that obtain additional nutrients by non-photosynthetic means.

Photosynthesis occurs in specialized organelles called chloroplasts that contain chlorophyll molecules found in the thylakoid, a membrane-bound compartment in the chloroplast. The chlorophyll molecules “pick up” the light energy and transfer this energy to other molecules in a series of reactions that ultimately produce sugar molecules. This is an example of “light energy” being converted into “chemical energy.”

It is hard to overemphasize the importance of photosynthesis to all living things. All creatures need a source of energy or they will die. Plants use photosynthesis to make their food from energy from the Sun. We, and all other animals, get our energy by eating plants or by eating other animals that eat plants. The Sun’s energy is ultimately the source of energy for all living things. Plants put this energy into a form usable by animals, including ourselves.

In this experiment you explored how plants need light to grow and stay healthy. Leaves are the main organ for carrying out photosynthesis in plants. Two of the leaves you used in this experiment are “controls.” The leaf that is attached and uncovered is a positive control (Leaf 1). This leaf should remain healthy throughout the course of the experiment unless something happens to the plant. The leaf that is covered and unattached and without water is a negative control (Leaf 6). This leaf should die first.

Positive controls help the investigator determine if the experimental setup is working. Negative controls tell the investigator when the desired effects of the experiment have indeed occurred. Both types of controls are useful for making sure the experimental results are valid. In other words, if the positive control did not work (the leaf died on the plant), then when the other leaves die, it could not be concluded that the leaves died because of the changes made during the experiment. Likewise, the negative control should be a negative result (the leaf should die without water or sunlight) to prove that the other samples survive or die accordingly. If the negative control survives, it is an indication that something else is happening. For example, the leaves are especially tough, the experiment needs more time, a plastic plant was used instead of a real one and so the leaves cannot die (anything is possible). Positive and negative controls give the experimenter boundaries for the experiment and allow valid conclusions to be made about the samples in between.
V. Just For Fun

1. Get 4 or more plant pots and fill them with potting soil. In each pot, plant 3-4 bean seeds and add enough water to thoroughly moisten the soil.

2. Label each pot for reference when recording your observations.

3. Put the pots in a warm, sunny location and keep the soil moist until the beans begin to grow into seedlings.

4. Place the pots with the seedlings in different locations with varying amounts of sunlight—from no sunlight to full sun. The pots can all be placed inside or all outside. Water them regularly.

5. Think about what information you will need to record during the experiment. In the following space or in your field notebook or on separate paper, make up your own chart for recording your observations. Include the plant identifier (number) and how much sunlight the plant will get in its particular location.

Observe the plants for several weeks and compare their growth and health. Record observations for all the plants every few days.

Observations of Photosynthesis
Observations of Photosynthesis
Observations of Photosynthesis
Conclusions

What conclusions can you draw from your observations?
Experiment 19

The Center of the Milky Way
Introduction

Locate the center of the Milky Way galaxy using globular cluster data.

I. Think About It

1. How easy or difficult do you think it would be to find the center of the Milky Way Galaxy?

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2. How would you describe a globular cluster?

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________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

3. How do you think knowing about globular clusters could be helpful in finding the center of the Milky Way Galaxy?

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4. How many stars do you think a globular cluster contains? Why?

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5. What objects do you think are located in the galactic center of the Milky Way? How would you describe them?

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6. Do you think the galactic center can be observed from Earth? Why or why not?

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__________________________________________________________________________
II. Experiment 19: The Center of the Milky Way

Date ______

Objective

Hypothesis

Materials

computer
internet access

EXPERIMENT

1. Set up the online resource you chose in Experiment 18.

2. The Appendix at the back of this book gives data for globular clusters observed in our Milky Way Galaxy. The data table shows 158 globular clusters compiled as of June 30, 2010. From left to right the table lists the ID, name, and cross-reference for the cluster followed by the constellation where the cluster is located and various astronomical parameters associated with the cluster.

   Look at the data table in the Appendix, and locate the three constellations that have the highest number of globular clusters. [Note: The number of globular clusters observed in a constellation is found in parentheses next to the constellation name. Constellations with fewer than two globular clusters are not listed.]

3. In the chart below, record the three constellations that have the most globular clusters.

<table>
<thead>
<tr>
<th>Constellation Name</th>
<th># of Globular Clusters</th>
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</table>
Results

Open the resource you have chosen for finding the galactic center of the Milky Way Galaxy. Search for the three constellations listed in Step 3 of the experiment. If your resource shows their locations, record this information. Since globular clusters are most numerous in the galactic center, these three constellations will lead you to the center of the Milky Way. Do a search for the location of the galactic center to check your results. In the space below, record your observations.
III. Conclusion

What conclusions can you draw from your research? Based on your observations, where is the galactic center of the Milky Way? How easy or difficult do you think it is to find the center of a galaxy?
IV. Why?

In this experiment you used and evaluated data on globular clusters to determine the center of the Milky Way galaxy. The appendix at the end of this workbook lists a number of different constellations together with the identification numbers, distance from the Sun or galactic center, apparent magnitude, and apparent dimension. The number of globular clusters in a constellation is found in parentheses next to the constellation name. Using this information you should have discovered that the globular clusters that contain the highest number of stars are Sagittarius with 34 globular clusters, Ophiuchus with 25 globular clusters, and Scorpio with 20 globular clusters. Because we know that the densest group of stars is at the center of the Milky Way Galaxy, we can use these three constellations with the largest number of globular clusters to find the galactic center.

Learning how to read and sort through scientific data is an important skill. Scientists often have to work with large amounts of data, sorting through numbers, names, and symbols. It takes time to learn how to study and evaluate scientific data. In this experiment the data was presented in a chart with the globular cluster count already identified. It might have taken longer or been more difficult if this information was not presented on a chart. You also may have noticed that some of the information listed on the chart was not used to determine the galactic center.

Depending on the software you selected, you should have been able to verify your results. You should have been directed to the identical location searching on the words “galactic center” as you found by typing in the three constellations, Sagittarius, Ophiuchus, and Scorpio. Being able to verify a result is an important step for any scientific research. If you were not able to verify the galactic center, you can redo the experiment or use a different software program. If the programs you are using are reliable, you should be able to verify your results.

The globular cluster chart includes information about right ascension, declination, and dimensions in arc minutes. With a little further research you can learn the meaning of these terms and how they are used in astronomy.
V. Just For Fun

Finding galaxies!

1. Observe more galaxies with your astronomy software. Find the following galaxies, and in the spaces provided, draw what you observe.

   - Whirlpool Galaxy
   - NGC 1427A
   - M 101
   - M 82
   - Bode’s Galaxy
   - M 87
   - Sombrero Galaxy
   - Sunflower Galaxy
   - Hoag’s Object
   - Cartwheel Galaxy
   - NGC 3314

2. Look for other galaxies. Find the ones that you think are the most interesting, beautiful, intricate, or weird and record what you see.
More Galaxies!
A Note From the Author

This curriculum is designed for middle school level students and provides an introduction to the scientific disciplines of chemistry, biology, physics, geology, and astronomy. *Exploring the Building Blocks of Science Book 7 Laboratory Notebook* accompanies the *Building Blocks of Science Book 7 Student Textbook*. Together, both provide students with basic science concepts needed for developing a solid framework for real science investigation. The *Laboratory Notebook* contains 44 experiments—two experiments for each chapter of the Student Textbook. These experiments allow students to further explore concepts presented in the *Student Textbook*. This teacher’s manual will help you guide students through laboratory experiments designed to help them develop the skills needed to use the scientific method.

There are several sections in each chapter of the *Laboratory Notebook*. The section called *Think About It* provides questions to help students develop critical thinking skills and spark their imagination. The *Experiment* section provides students with a framework to explore concepts presented in the *Student Textbook*. In the *Conclusions* section students draw conclusions from the observations they have made during the experiment. A section called *Why?* provides a short explanation of what students may or may not have observed. And finally, in each chapter an additional experiment is presented in *Just For Fun*.

Most of the experiments take up to 1 hour. The materials needed for each experiment are listed on the following pages and also at the beginning of each experiment.

Enjoy!

*Rebecca W. Keller, PhD*
# Materials at a Glance

<table>
<thead>
<tr>
<th>Experiment 1</th>
<th>Experiment 2</th>
<th>Experiment 3</th>
<th>Experiment 4</th>
<th>Experiment 5</th>
<th>Experiment 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>internet or library notebook or blank paper imagination</td>
<td><strong>See page viii for information about choosing a microscope.</strong></td>
<td>tincture of iodine [Iodine is VERY poisonous — DO NOT LET STUDENTS EAT any food items with iodine on them.] raw foods, including: pasta bread celery, slice potato, slice banana and other fruits, sliced liquid laundry starch (or borax and corn starch mixture) absorbent white paper eyedropper cookie sheet marking pen 1 green banana knife</td>
<td>tincture of iodine [VERY POISONOUS—DO NOT LET STUDENTS EAT] bread (1-2 slices) timer wax paper marking pen cup one raw egg one raw onion table salt clear liquid dish washing detergent rubbing alcohol (isopropanol, 70-90%) wooden stir stick or Q-tip coffee filter (any color) sieve 2 glass jars or large test tubes measuring cup and measuring spoons blender</td>
<td>colored pencils handheld magnifying glass field notebook (an existing one or a new one with blank or faintly lined pages) backpack with water and snacks 2 plant pots potting soil corn seeds, 8 or more, with packet bean seeds, 8 or more, with packet water warm, sunny location <strong>Optional</strong> field guide to the plants book iPad, camera, or smartphone with camera plant identification app of your choice</td>
<td></td>
</tr>
<tr>
<td><strong>Experiment 2</strong></td>
<td>about 120 ml (1/2 c.) ea.: water ammonia vegetable oil rubbing alcohol melted butter vinegar small jars (7 or more) food coloring (6 colors) dish soap, 30 ml (2 tsp) eyedropper measuring cup &amp; spoons marking pen spoon ballpoint ink pens (see Experiment 2) rubbing alcohol coffee filters (white) shoebox (or similar box) tape, scissors, ruler</td>
<td>bean seeds (12 or more) potting soil 4 or more plant pots marking pen scissors lightweight cardboard or construction paper—enough to cut out 6 pieces that are bigger than a leaf scissors tape 2 small jars marking pen 4 or more plant pots potting soil bean seeds (12 or more)</td>
<td>fresh vegetable scraps (see Exper. 9) knife toothpicks several small glass jars or small drinking glasses colored pencils or pens several plant pots potting soil water</td>
<td>Optional existing or new field notebook garden trowel or spoon</td>
<td></td>
</tr>
<tr>
<td><strong>Experiment 7</strong></td>
<td><strong>Experiment 8</strong></td>
<td><strong>Experiment 9</strong></td>
<td><strong>Experiment 10</strong></td>
<td><strong>Experiment 11</strong></td>
<td></td>
</tr>
<tr>
<td>plant with at least 6 flat, green leaves (a tree may be used) lightweight cardboard or construction paper—enough to cut out 6 pieces that are bigger than a leaf scissors tape 2 small jars marking pen 4 or more plant pots potting soil bean seeds (12 or more)</td>
<td>microscope with 4X, 10X, and 40X objective lenses; 100X recommended** glass microscope slides (plain) glass microscope coverslips immersion oil for 100X lens water eyedropper sharp knife toothpick colored pencils raw celery stalk with leaves (1) raw carrot (1) large leaf (1) other plant parts of students’ choice 3 or more small jars several fresh white carnation flowers food coloring</td>
<td>fresh vegetable scraps (see Exper. 9) knife toothpicks several small glass jars or small drinking glasses colored pencils or pens several plant pots potting soil water</td>
<td>10-20 copper pennies (pennies made before 1982 work best) aluminum foil paper towels salt water: 30-45 ml (2-3 Tbsp.) salt per 240 ml (1 cup) water voltmeter (see Exper. 10) 2 plastic-coated copper wires, each 10-15 cm (4”-6”) long duct tape (or other strong tape) scissors wire cutters fine steel wool, plain (no soap), 1 pad 9 volt battery ovenproof pan or dish heatproof pad or surface</td>
<td>jar, small glass with lid aluminum foil paperclip tape, duct (or other strong tape) rod, plastic or rubber rod (or balloon) silk fabric (or hair) scissors ruler awl or other tool to make a hole straws, thin, bendable plastic, several paper tissues (Kleenex) or cloth made of silk or wool paper, small piece aluminum foil, small piece book(s), with thin pages combs, plastic, 1-2 cup, plastic bowl, shallow or a plate</td>
<td></td>
</tr>
</tbody>
</table>


** See page viii for information about choosing a microscope.
<table>
<thead>
<tr>
<th>Experiment 12</th>
<th>Experiment 13</th>
<th>Experiment 14</th>
<th>Experiment 15</th>
<th>Experiment 16</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2) D cell batteries and battery holder</td>
<td>metal rod, 16d nail, or unmagnetized screwdriver</td>
<td>about 1-2 liters (1-2 qts): gravel, sand, dirt (soil) and pottery clay water</td>
<td>field notebook, 1-2 (new or existing) pencil and colored pencils</td>
<td>steel needle bar magnet piece of cork tape medium size bowl water compass small object of student's choice to use for treasure</td>
</tr>
<tr>
<td>(2) 3.7 volt light bulbs and sockets</td>
<td>electrical wire, 3-6 meter (1'-2') 10-20 paperclips</td>
<td>6v or larger battery (use a 12v battery if a screwdriver is used) electrical tape or 2 alligator clips</td>
<td>small backpack water bottle snacks</td>
<td></td>
</tr>
<tr>
<td>(1) switch</td>
<td>scissors</td>
<td>pencil marking pen</td>
<td>binoculars (inexpensive ones are fine; small, lightweight ones are easier to carry)</td>
<td></td>
</tr>
<tr>
<td>(4) alligator clip connectors</td>
<td>wire cutters</td>
<td>measuring cups</td>
<td>field guide to the birds book (for example, <em>The Young Birder’s Guide to Birds of North America</em>)</td>
<td></td>
</tr>
<tr>
<td>(2) 5 ohm, 1/4 watt resistors</td>
<td>bar magnet</td>
<td>clear plastic container with lid [about 5 cm x 8 cm x 1.5 cm (2” x 3” x 1/2”)]</td>
<td>Optional: clock w/ second hand screen or cloth</td>
<td></td>
</tr>
<tr>
<td>(1) DC motor with propeller</td>
<td>small plastic baggie</td>
<td>clear Karo syrup spoon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials are available as a kit from Home Science Tools (as of this writing): Product #: EL-KITBASC.</td>
<td>clear plastic container with lid</td>
<td>2 pencils or other props</td>
<td>Optional: clock w/ second hand screen or cloth</td>
<td></td>
</tr>
<tr>
<td><a href="http://www.hometrainingtools.com/">http://www.hometrainingtools.com/</a></td>
<td></td>
<td>Optional</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Experiment 17</th>
<th>Experiment 18</th>
<th>Experiment 19</th>
<th>Experiment 20</th>
<th>Experiment 21</th>
<th>Experiment 22</th>
</tr>
</thead>
<tbody>
<tr>
<td>pencil, pen imagination</td>
<td>computer internet connection</td>
<td>computer internet connection</td>
<td>computer internet connection</td>
<td>computer internet connection</td>
<td>computer internet connection</td>
</tr>
<tr>
<td>Optional notebook</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

*Iron filings can be ordered from Home Science Tools, CH-IRON, http://www.hometrainingtools.com/*
## Materials

### Quantities Needed for All Experiments

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Equipment (continued)</th>
<th>Foods</th>
</tr>
</thead>
<tbody>
<tr>
<td>alligator clip connectors, 4**</td>
<td>knife</td>
<td>banana and other fruits, sliced, raw</td>
</tr>
<tr>
<td>apron</td>
<td>knife, sharp</td>
<td>banana, green, 1</td>
</tr>
<tr>
<td>awl or other tool to make a hole</td>
<td>knife, utility or X-Acto</td>
<td>bread (1-2 slices)</td>
</tr>
<tr>
<td>backpack, small, with water and snacks</td>
<td>light bulb, 3.7 volts and sockets, 2**</td>
<td>bread, raw</td>
</tr>
<tr>
<td>battery, 6v or larger (use a 12v battery if a screwdriver is used) Exper. 13</td>
<td>magnet, bar, 1</td>
<td>butter, melted [about 120 ml (1/2 c.)]</td>
</tr>
<tr>
<td>battery, 9 volt</td>
<td>magnifying glass, handheld</td>
<td>carrot, raw 1</td>
</tr>
<tr>
<td>beaker or glass jar</td>
<td>measuring cups and measuring spoons</td>
<td>celery stalk with leaves, raw, 1</td>
</tr>
<tr>
<td>binoculars (inexpensive ones are fine; small, lightweight ones are easier to carry)</td>
<td>microscope with 4X, 10X, and 40X objective lenses; 100X recommended***</td>
<td>celery, slice, raw</td>
</tr>
<tr>
<td>blender</td>
<td>microscope coverslips, glass</td>
<td>egg, raw, 1</td>
</tr>
<tr>
<td>book(s), with thin pages</td>
<td>microscope slides, glass (plain)</td>
<td>food coloring (6 colors)</td>
</tr>
<tr>
<td>bowl, large</td>
<td>motor, DC with propeller, 1**</td>
<td>Karo syrup, clear</td>
</tr>
<tr>
<td>bowl, medium size</td>
<td>Nylon Synthesis and Rope Trick Kit from Home Science Tools*</td>
<td>onion, raw, 1</td>
</tr>
<tr>
<td>bowl, shallow or a plate</td>
<td>object, small, of student's choice to use for treasure</td>
<td>pasta, raw</td>
</tr>
<tr>
<td>bucket and/or outdoor area</td>
<td>pan or dish, ovenproof</td>
<td>potato, slice, raw</td>
</tr>
<tr>
<td>combs, plastic, 1-2</td>
<td>plant pots, several</td>
<td>snacks</td>
</tr>
<tr>
<td>compass</td>
<td>resistors, 5 ohm, 1/4 watt 2**</td>
<td>table salt</td>
</tr>
<tr>
<td>computer</td>
<td>rod (metal), 16d nail, or unmagnetized screwdriver</td>
<td>vegetable oil [about 120 ml (1/2 c.)]</td>
</tr>
<tr>
<td>container with lid, small flat-bottomed clear plastic [about 5 cm x 8 cm x 1.5 cm (2” x 3” x 1/2”)]</td>
<td>rod, glass stirring</td>
<td>vegetable scraps, fresh (see Exper. 9)</td>
</tr>
<tr>
<td>cookie sheet</td>
<td>rod, plastic or rubber rod (or balloon)</td>
<td>vinegar [about 120 ml (1/2 c.)]</td>
</tr>
<tr>
<td>copper pennies, 10-20 (pennies made before 1982 work best)</td>
<td>rubber gloves</td>
<td>water</td>
</tr>
<tr>
<td>cup</td>
<td>ruler</td>
<td></td>
</tr>
<tr>
<td>cup, plastic</td>
<td>safety goggles</td>
<td></td>
</tr>
<tr>
<td>cups, 16 oz. clear plastic cups, drinking glasses, or other clear containers, 4 cups, Styrofoam, about 355 ml (12 ounce)</td>
<td>scissors</td>
<td></td>
</tr>
<tr>
<td>size, 4</td>
<td>sieve</td>
<td></td>
</tr>
<tr>
<td>D cell batteries, 2, and battery holder**</td>
<td>silk fabric (or hair)</td>
<td></td>
</tr>
<tr>
<td>eyedropper</td>
<td>spoon</td>
<td></td>
</tr>
<tr>
<td>field guide to the birds book (for example, The Young Birder's Guide to Birds of North America)</td>
<td>switch for electric circuit, 1**</td>
<td></td>
</tr>
<tr>
<td>graduated cylinder, 10 ml</td>
<td>timer</td>
<td></td>
</tr>
<tr>
<td>graduated cylinder, 100 ml</td>
<td>voltmeter (see Exper. 10)</td>
<td></td>
</tr>
<tr>
<td>heatproof pad or surface</td>
<td>water bottle</td>
<td></td>
</tr>
<tr>
<td>jar, small glass with lid</td>
<td>wire cutters</td>
<td></td>
</tr>
<tr>
<td>jars, small glass (7 or more)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>jars, glass 2, or large test tubes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>jars, several small glass, or small drinking glasses</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** Materials are available as a kit from Home Science Tools (as of this writing): Product #: EL-KITBASC, http://www.hometrainingtools.com/  
*** See page viii for information about choosing a microscope.
## Materials

### Quantities Needed for All Experiments

<table>
<thead>
<tr>
<th>Materials</th>
<th>Materials (continued)</th>
<th>Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>aluminum foil</td>
<td>plastic wrap or plastic bags</td>
<td>carnation flowers with stems, white, several fresh</td>
</tr>
<tr>
<td>ammonia [about 120 ml (1/2 c.)]</td>
<td>Popsicle sticks, several potting soil</td>
<td>leaf, large, 1</td>
</tr>
<tr>
<td>baggie, small plastic, 1</td>
<td>rubbing alcohol (isopropanol, 70-90%)</td>
<td>plant parts of students’ choice</td>
</tr>
<tr>
<td>cardboard</td>
<td>rubbing alcohol [about 120 ml (1/2 c.)]</td>
<td>plant with at least 6 flat, green leaves</td>
</tr>
<tr>
<td>cardboard, lightweight, or construction paper—enough to cut out 6 pieces that are bigger than a leaf</td>
<td>salt water: 30-45 ml (2-3 Tbsp.) salt per 240 ml (1 cup) water</td>
<td>(a tree may be used)</td>
</tr>
<tr>
<td>clay, pottery, about 1-2 liters (1-2 qts)</td>
<td>sand, about 1-2 liters (1-2 qts)</td>
<td>seeds, bean (12 or more)</td>
</tr>
<tr>
<td>coffee filter (any color)</td>
<td>shoebox (or similar box)</td>
<td>seeds, bean, 8 or more, with packet</td>
</tr>
<tr>
<td>coffee filters (white), several</td>
<td>steel wool, fine, plain (no soap), 1 pad</td>
<td>seeds, corn, 8 or more, with packet</td>
</tr>
<tr>
<td>copper wires, 2 plastic-coated, each 10-15 cm (4”-6”) long</td>
<td>taper, thin, bendable plastic, several tape</td>
<td>Other</td>
</tr>
<tr>
<td>cork, piece</td>
<td>tape, duct (or other strong tape)</td>
<td>imagination</td>
</tr>
<tr>
<td>dirt (soil), about 1-2 liters (1-2 qts)</td>
<td>tape, electrical or 2 alligator clips</td>
<td>internet connection</td>
</tr>
<tr>
<td>dish soap, 30 ml (2 tbsp)</td>
<td>toothpicks</td>
<td>internet or library</td>
</tr>
<tr>
<td>dish washing detergent, clear liquid</td>
<td>wax paper</td>
<td>warm, sunny location for plants</td>
</tr>
<tr>
<td>field notebook (existing or new with blank or faintly lined pages), 1-2 glue, Elmer’s blue, or other glue different from white, 60 ml (1/4 cup)</td>
<td>wire, electrical, .3-.6 meter (1’-2’)</td>
<td>Optional</td>
</tr>
<tr>
<td>glue, Elmer’s white, 60 ml (1/4 cup)</td>
<td>wooden stir stick or Q-tip</td>
<td>bird identification app (such as free app from Audubon Society, <a href="http://www.audubon.org/apps">http://www.audubon.org/apps</a>)</td>
</tr>
<tr>
<td>gravel, about 1-2 liters (1-2 qts)</td>
<td></td>
<td>plant identification app of your choice</td>
</tr>
<tr>
<td>immersion oil for 100X lens</td>
<td></td>
<td></td>
</tr>
<tr>
<td>iron filings*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>iodine, tincture of [Iodine is VERY poisonous — DO NOT LET STUDENTS EAT any food items with iodine on them.,], small amount</td>
<td></td>
<td></td>
</tr>
<tr>
<td>laundry starch, liquid,120 ml (1/2 cup) — or 10 ml (2 tbsp.) borax + 10 ml (2 tbsp.) cornstarch + 320 ml (1 1/3 cup) water [you will need a little more than this amount]</td>
<td></td>
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</tr>
<tr>
<td>needle, steel</td>
<td></td>
<td></td>
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<tr>
<td>notebook or blank paper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>paper, blank</td>
<td></td>
<td></td>
</tr>
<tr>
<td>paper tissues (Kleenex) or cloth made of silk or wool</td>
<td></td>
<td></td>
</tr>
<tr>
<td>paper towels</td>
<td></td>
<td></td>
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<tr>
<td>paper, absorbent white</td>
<td></td>
<td></td>
</tr>
<tr>
<td>paperclips, 10-20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pen, marking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pen, marking (that will write on glass)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pencil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pencils, colored</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pens, ballpoint ink (see Experiment 2)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Iron filings can be ordered from Home Science Tools, CH-IRON, http://www.hometrainingtools.com/*
How to Buy a Microscope

What to Look For

- A metal mechanical stage.
- A metal body painted with a resistant finish.
- DIN Achromatic Glass objective lenses at 4X, 10X, 40X (a 100X lens is optional but recommended).
- A focusable condenser (lens that focuses the light on the sample).
- Metal gears and screws with ball bearings for movable parts.
- Monocular (single tube) “wide field” ocular lens.
- Fluorescent lighting with an iris diaphragm.

Price Range

$50-$150: Not recommended: These microscopes do not have the best construction or parts and are often made of plastic. These microscopes will cause frustration, discouraging students.

$150-$350: A good quality standard student microscope can be found in this price range. We recommend Great Scopes for a solid student microscope with the best parts and optics in this price range. http://www.greatscopes.com

Above $350: There are many higher end microscopes that can be purchased, but for most students these are too much microscope for their needs. However, if you have a child who is really interested in microscopy, wants to enter the medical or scientific profession, or may become a serious hobbyist, a higher end microscope would be a valuable asset.

Objective lenses: Magnification/Resolution/Field of View/Focal Length

The objective lenses are the most important parts of the microscope. An objective lens not only magnifies the sample, but also determines the resolution. However, higher powered objective lenses with better resolution have a smaller field of view and a shorter focal length.

The resolution and working distance (focal length) of a lens is determined by its numerical aperture (NA). Following is a list of magnifications, numerical aperture, and working distance for some common achromatic objective lenses.
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Experiment 3

Show Me the Starch!

Materials Needed

- tincture of iodine [Iodine is VERY poisonous—DO NOT LET STUDENTS EAT any food items with iodine on them.]
- a variety of raw foods, including:
  - pasta
  - bread
  - celery, slice
  - potato, slice
  - slices of banana and other fruits
- liquid laundry starch (or a borax and corn starch mixture)
- absorbent white paper
- eyedropper
- cookie sheet
- marking pen
- 1 green banana
- knife
Objectives

In this experiment students will use iodine as an indicator (yes?) and will use a control.

The objectives of this lesson are for students to:

- Practice using a control in an experiment.
- Explore how simple tests can be used in scientific discovery.

Experiment

I. Think About It

Read this section of the Laboratory Notebook with your students.

Ask questions such as the following to guide open inquiry.

- Do you think it could be helpful to know what type of molecules are in different foods that you eat? Why or why not?
- Do you think simple sugars and carbohydrates are the same thing? Why or why not?
- Do you think simple sugars have something to do with carbohydrates? Why or why not?
- Do you think starches are important? Why or why not?
- What have you noticed about fruit as it ripens? Why do you think this happens?
- Do you think an experiment has to be complicated to be useful? Why or why not?
- When do you think you would use a control in an experiment? Why?

II. Experiment 3: Show Me the Starch!

Have the students read the entire experiment before writing an objective and a hypothesis.

Objective: Have the students write an objective (What will they be learning?). Some examples:

- To find out which foods contain starch.
- We will see if iodine can be used to test for starch.
**Hypothesis:** Have the students write a hypothesis. Some examples:

- *Iodine will show whether a food contains starch.*
- *Not all foods contain starch.*

**EXPERIMENT**

Have the students collect food items to test. The materials list contains foods that do and do not contain starch. Substitutions can be made but make sure there are some of each type of food. Students can also test additional foods that are not listed.

[Iodine is VERY poisonous — DO NOT LET STUDENTS EAT any food items that have iodine on them.]

1. Have the students place the food items and the piece of absorbent paper on a cookie sheet.
2. Have the students label the paper “Control” and then use an eyedropper to put a small amount of liquid starch (or a borax and corn starch mixture) on the paper and let it dry.
3. Once the control paper is dry, students will add a drop of iodine to the starch. Have them record the resulting color. A chart is provided in the *Results* section.
4. Have the students add a drop of iodine to each food item and record the resulting color.
5. Once all the food items have been tested, have the students review their results, comparing the test color of each food item to the control sample.

**Results**

At the end of the experiment students will have a chart of all their results.

**III. Conclusions**

Have the students review the results they recorded for the experiment. Have them draw conclusions based on the data they collected.

**IV. Why?**

Read this section of the *Laboratory Notebook* with your students. Discuss any questions that might come up.
V. Just For Fun

A Banana Ripens!

Students will test what happens when a banana ripens.

1. Have the students cut a slice off a green banana and test for starch using the iodine-starch test from the first experiment. They should keep the banana at room temperature for the entire experiment so it can ripen.

2. Have them record their observations in the chart provided.

3. Students will test a fresh slice of banana each day for several days as the banana ripens. Have them record their observations each time.

4. Have the students review their results and write their conclusions in the space provided.
Experiment 7

Take Away the Light

Materials Needed

- plant with at least 6 flat, green leaves (a tree may be used)
- lightweight cardboard or construction paper—enough to cut out 6 pieces that are bigger than a leaf
- scissors
- tape
- 2 small jars
- marking pen
- 4 or more plant pots
- potting soil
- bean seeds (12 or more)
Objectives

In this experiment students will be introduced to photosynthesis.

The objectives of this lesson are for students to:

- Observe some conditions that plants require to grow and be healthy.
- Explore conditions needed for photosynthesis to occur.

Experiment

I. Think About It

Read this section of the Laboratory Notebook with your students.

Ask questions such as the following to guide open inquiry.

- What conditions do you think a plant requires to grow and be healthy?
- How do you think a plant gets food and nutrients?
- What do you think a plant does with sunlight that falls on its leaves?
- Do you think a plant that has leaves could live in your closet? In the garage? In the living room? Outside? Why?
- Do you think photosynthesis is important to all life on the planet or just to plants? Why?

II. Experiment 7: Take Away the Light

In this experiment students will examine the effects of removing light from the leaves of a photosynthetic plant. The results for this experiment may vary depending on the type of plant that is used. A tree with leaves can also be used.

Have the students first read the experiment through to determine what is being investigated. Then have them write the objective.

Objective: (What will they be learning?) For example:

- We will place plant leaves under different conditions and after several days observe whether light and water are sufficient to keep a leaf alive whether or not it is attached to the plant.
Next, discuss the possible outcomes for each of the leaves. Ask the students questions such as the following before they write the hypothesis.

- **What do you think will happen to Leaf 1?** It is uncovered and attached to the plant. It can get sunlight and also can get water and other nutrients from the rest of the plant.

- **What do you think will happen to Leaf 2?** It is covered and attached to the plant. This means it cannot get any sunlight, but it does get water and other nutrients from the rest of the plant.

- **What will happen to Leaf 3?** It is uncovered (will get sunlight) and not attached to the plant (no additional nutrients), but it is placed in water, so it will receive water.

- **What will happen to Leaf 4?** It is covered (will not get sunlight), is unattached (will not get additional nutrients), but it will get water.

- **What will happen to Leaf 5?** It is uncovered (will get sunlight) but is unattached and will get no water or nutrients.

- **What will happen to Leaf 6?** It is covered (will get no sunlight), and it will not get any water or additional nutrients.

Have the students guess which leaf will die first, which will not die, and which may survive a short time. Have them write a suitable hypothesis based on this discussion.

**Hypothesis:** Some examples:

- **All of the leaves not in water will die.**
- **Only the leaves without sunlight will die.**
- **Only Leaf 6 will die.**
- **Only Leaf 1 will stay healthy.**

**EXPERIMENT**

1. Have the students cut out 6 pieces of cardboard or construction paper that are large enough to completely cover a leaf. These will be used to cover the front and back of 3 leaves.

2. Six different leaves will be tested. Two of the leaves will be left on the plant (attached) and four leaves will be removed from the plant (unattached).
Have the students tape two of the cut out pieces so they cover the front and back of one of the leaves that is attached to the plant. At least one other leaf will stay attached to the plant and remain uncovered.

Have the students remove four leaves from the plant and cover two of them with cardboard. The four unattached leaves will be either: covered with cardboard and the stem placed in water, covered out of water, uncovered with the stem in water, or uncovered out of water.

Have the students use a marking pen to label the leaves in the following manner:

Leaf 1: **UA** — uncovered, attached

Leaf 2: **CA** — covered, attached

Leaf 3: **UUW** — uncovered, unattached, in water

Leaf 4: **CUW** — covered, unattached, in water

Leaf 5: **UU** — uncovered, unattached (no water)

Leaf 6: **CU** — covered, unattached (no water)

Have the students fill two small jars with water and place one covered unattached leaf in one jar and one uncovered unattached leaf in the second jar so that the stems stay submerged and the leaves are out of the water. Have the students check the water level every day over the course of the experiment to make sure there is enough water in the jars.

After several days have the students make daily observations of the changes to the leaves. They will need to carefully remove the cardboard from the covered leaves to make their observations, and then re-tape it. Have them record their observations in the **Results** section.

**Results**

A chart is provided for recording observations. Short one or two word descriptions like, “green,” “green with some brown,” “mostly brown,” “wrinkled,” are fine.

**III. Conclusions**

Have the students review the results they recorded for the experiment. Have them write valid conclusions based on the data they collected.

For example:

- **Leaf 1 survived for one week.**
- **Leaf 2 did not survive past two days.**
- **Leaf 3 survived for one week. Leaf 3 needs only sunlight and water to live one week unattached from the plant.**
• All of the leaves without sunlight turned yellow-brown, but did not die.

(Answers will vary.)

Have the students discuss what they learned. Is it true that water and sunlight alone are sufficient for the survival of a detached leaf? How about for a leaf that remains attached, but lacks sunlight—is sunlight required for this leaf to survive?

IV. Why?

Read this section of the Laboratory Notebook with your students. Discuss any questions that might come up.

V. Just For Fun

In this experiment students will grow bean plants to observe what happens when they are placed in locations with differing amounts of sunlight.

1. Have the students decide how many plants they would like to grow for this experiment. Growing at least 4 plants will work best. They will be placing them in locations that get different amounts of sunlight. Have the students put potting soil in the pots, plant 3-4 bean seeds in each, and water them thoroughly.

2. Have the students label each plant pot with a number or some other identifier they can reference when recording their observations.

3. The pots should be placed in a warm, sunny location and the soil kept moist until the seeds sprout and begin to grow into seedlings. Depending on the variety of bean chosen, it should take about 7-14 days for the sprouts to show above the soil.

4. Help the students find locations with varying amounts of sunlight. One plant should be placed in full sun and one where there is no sun, for example, in a closet. The other plants should be put in locations that have varying amounts of sunlight. The plants should be placed either all indoors or all outdoors and need to be watered regularly.

5. Over the course of several weeks the students will observe the plants and record observations of their growth and health. Help the students think about what data they will need to record and then have them create a chart. Space is provided for recording their observations or they can use their field notebook or separate paper. Each plant should be listed by its identifier along with the amount of sunlight the plant will get during the day. Space should be provided for periodic notes made about the condition of the plant. Students might want to have a page for each plant, and they may want to draw as well as write.

At the end of the experiment, have the students draw conclusions based on their observations, then write them in the space provided. What did they learn about photosynthesis and sunlight?
Experiment 19

The Center of the Milky Way

Materials Needed
- computer
- internet connection
Objectives

In this experiment students will use an astronomy data chart to find the center of the Milky Way Galaxy.

The objectives of this lesson are to have students:

- Learn to read and use a scientific data chart.
- Verify a result.

Experiment

I. Think About It

Read this section of the Laboratory Notebook with your students.
Ask questions such as the following to guide open inquiry.

- How easy or difficult do you think it is to map an area you cannot directly investigate?
- What types of sites and programs have you used to learn about science?
- Do you think astronomers’ current ideas about the size and shape of the Milky Way Galaxy are accurate? Why or why not?
- If Earth were located in the center of the Milky Way Galaxy, would it be easier to measure the size of the Milky Way Galaxy? Why or why not?
- Do you think galaxies would exist if planets and stars had no gravity? Why or why not?

II. Experiment 19: The Center of the Milky Way

Have the students read the entire experiment before writing an objective and a hypothesis.

Objective: Have the students write an objective. Some examples:

- I can find the center of the Milky Way Galaxy using data tables containing information about globular clusters.
- I can learn to read and use a data table to find the center of the Milky Way Galaxy.
Hypothesis: Have the students write a hypothesis. Some examples:

- The center of the Milky Way Galaxy will be found near the constellations with the greatest number of globular clusters.
- The data table I have will allow me to calculate the center of the Milky Way Galaxy and I can verify the location.

EXPERIMENT

1. Help the students set up the online resource from Experiment 18. If no suitable online resource was found, have the students use Google Sky, www.googlesky.com

2. Have the students review the Appendix at the end of this book and familiarize themselves with the data shown in the table. They will find globular cluster data grouped in parentheses beside a constellation name.

3. In the chart provided, have the students list the three constellations that have the highest number of globular clusters. They should get the following results.

<table>
<thead>
<tr>
<th>Constellation Name</th>
<th># of Globular Clusters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sagittarius</td>
<td>34</td>
</tr>
<tr>
<td>Ophiuchus</td>
<td>25</td>
</tr>
<tr>
<td>Scorpio</td>
<td>20</td>
</tr>
</tbody>
</table>

Results

Using their online resource, have the students do a search for each of the three constellations they listed in Step 3 of the experiment. Have them observe the image of the constellation and, if it is shown, record the location. If using Google Sky, they can observe coordinates at the bottom of the screen as they move the cursor. Have them place the cursor in the middle of the object and write down the coordinates. Because globular clusters are most numerous at the galactic center, by finding the locations of the constellations with the largest number of globular clusters, students will also be locating the center of the Milky Way Galaxy. In the space provided, have them record their observations.

III. Conclusions

Have the students review the results they recorded for the experiment. Have them draw conclusions based on the data they collected.
IV. Why?

Read this section of the Laboratory Notebook with your students. Discuss any questions that might come up.

V. Just For Fun

1. Have the students use their online resource to explore the galaxies that are listed. Have them draw the galaxies in the space provided.

2. Students are asked to find additional galaxies that they find visually interesting and draw what they see.
LESSON PLAN INSTRUCTIONS

This Lesson Plan is designed to accompany Exploring the Building Blocks of Science Book 5 Student Textbook, Laboratory Notebook, and Teacher’s Manual. It is designed to be flexible to accommodate a varying schedule as you go through the year’s study. And it makes it easy to chart weekly study sessions and create a portfolio of your student’s yearlong performance. The PDF format allows you to print pages as you need them.

This Lesson Plan file includes:

• Weekly Sheets
• Self-Review Sheet
• Self-Test Sheet
• Sticker Templates

Materials recommended but not included:

• 3-ring binder
• Indexing dividers (3)
• Labels—24 per sheet, 1.5” x 1.5” (Avery 22805)

Use the Weekly Sheets to map out daily activities and keep track of student progress. For each week you decide when to read the text, do the experiment, explore the optional connections, review the text, and administer tests. For those families and schools needing to provide records of student performance and show compliance to standards, there is a section on the Weekly Sheets that shows how the content aligns to the National Science Standards.

To use this Lesson Plan:

• Print the Weekly Sheets
• Print Self-Review Sheets
• Print Self-Test Sheets
• Print the stickers on 1.5” x 1.5” labels
• Place all the printed sheets in a three-ring binder separated by index dividers

At the beginning of each week, use the squares under each weekday to plan your daily activities. You can attach printed stickers to the appropriate boxes or write in the daily activities. At the end of the week, use the Notes section to record student progress and performance for that week.
Here is a sample of a normal week.

The recommended sequence is:
1. Read the student textbook on the first day.
2. Do the laboratory experiment on the second day.
3. Pick one or more connections to explore on the third day.
4. Do the self-review sheet on the fourth day.
5. Administer the self-test or another exam on the fifth day.

Here is a sample of a week with other activities:

1. Find at least one day to READ the text.
2. Find a day to perform the EXPERIMENT.
3. Find a day to do the REVIEW or TEST.

Any activity that is missed can be rescheduled for the following week. However, keep to the main sequence of reading the text, doing the experiment, and reviewing what has been covered. If an activity needs to be missed, choose the CONNECTIONS or SELF-TEST.
CHAPTER 3: ORGANIC CHEMISTRY—THE CHEMISTRY OF CARBON

<table>
<thead>
<tr>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
</tr>
</thead>
</table>

**Objectives**
- To give students an overview of organic chemistry.

**Educational Standard**
- Disciplinary Core Idea (MS-PS-1.A): Substances are made from different types of atoms which combine with one another in various ways.

*From the Next Generation Science Standards (2013), National Academies Press.

**Activity**
- ☐ Laboratory Experiment 3
- ☐ Other _______________________

**Connections**
- ☐ History  Look up the history of benzene and write a short summary of what you discover.
- ☐ Philosophy Discuss the ethics of industrial chemical production for organic molecules and why governments need to regulate waste product disposal.
- ☐ Art, Music, Math Look up the chemical composition of oil paints and write a brief summary of what they are made of.
- ☐ Technology Look up "synthetic organic chemistry" online or in the library and discuss how this field of research has contributed to technology.
- ☐ Language Look up the word alkene in a dictionary, encyclopedia, or online resource and discuss the meaning.

**Assessment**
- ☐ Self-review
- ☐ Self-test
- ☐ Other _______________________

**Notes**
**LESSON PLAN — Exploring the BUILDING BLOCKS of SCIENCE BOOK 7**

**CHAPTER 7: PHOTOSYNTHESIS**

<table>
<thead>
<tr>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
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<tbody>
<tr>
<td></td>
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</tbody>
</table>

**Objectives**
- To give students an overview of photosynthesis.

**Educational Standard**
- Disciplinary Core Idea (MS-LS1-C): Plants use energy from light to make sugars from carbon dioxide through photosynthesis.

*From the Next Generation Science Standards (2013), National Academies Press.*

**Activity**
- [ ] Laboratory Experiment 7
- [ ] Other _____________________

**Connections**
- [ ] History
  - Research Julius Robert von Mayer and write a short summary of his contribution to our understanding of photosynthesis.

- [ ] Philosophy
  - Find a copy of *ARISTOTLE, On Plants* by Loeb Classics and read the first few chapters. Discuss Aristotle’s views on plants and how they differ from animals.

- [ ] Art, Music, Math
  - Discuss how graphic artists make it possible to represent complex biochemical processes in a way that helps students better understand how they work.

- [ ] Technology
  - Research the spectrophotometer and discuss how it works.

- [ ] Language
  - Look up the word chlorophyll in a dictionary, encyclopedia, or online resource and discuss the meaning.

**Assessment**
- [ ] Self-review
- [ ] Self-test
- [ ] Other _____________________

**Notes**
## Lesson Plan — Exploring the Building Blocks of Science Book 7
### Chapter 19: Our Galaxy - The Milky Way

<table>
<thead>
<tr>
<th>Week ___________</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
</tr>
</thead>
<tbody>
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<td></td>
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</tbody>
</table>

### Objectives
- To give students an overview of the Milky Way galaxy.

### Educational Standard*
- Disciplinary Core Idea (MS-ESS1-2): Earth and its solar system are part of the Milky Way galaxy, one of many galaxies in the universe.

*From the Next Generation Science Standards (2013), National Academies Press.

### Activity
- [ ] Laboratory Experiment 19
- [ ] Other _____________________

### Connections
- [ ] History
  - Research William and Caroline Herschel and write a brief summary of their contribution to our understanding of the Milky Way galaxy.
- [ ] Philosophy
  - Research dark matter and discuss how philosophical ideas about matter shape this concept.
- [ ] Art, Music, Math
  - Discuss how images of galaxies inspire artists.
- [ ] Technology
  - Research how the Spitzer Space Telescope works.
- [ ] Language
  - Look up the word kiloparsec in a dictionary, encyclopedia, or online resource and discuss the meaning.

### Assessment
- [ ] Self-review
- [ ] Self-test
- [ ] Other _____________________

### Notes

---

**LESSON PLAN — Exploring the BUILDING BLOCKS of SCIENCE BOOK 7**

**CHAPTER 19: OUR GALAXY — THE MILKY WAY**

**Objectives**
- To give students an overview of the Milky Way galaxy.

**Educational Standard**
- Disciplinary Core Idea (MS-ESS1-2): Earth and its solar system are part of the Milky Way galaxy, one of many galaxies in the universe.

*From the Next Generation Science Standards (2013), National Academies Press.*
SELF-REVIEW

Think about all of the ideas, concepts, and facts you read about in this chapter. In the space below, write down everything you’ve learned.

Date _______________  Chapter ____________________________________

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SELF-TEST

Imagine you are the teacher and you are giving your students an exam. In the space below, write 5 questions you would ask a student based on the information you learned in this chapter.

Date _______________  Chapter ____________________________

________________________________________________________________________
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________________________________________________________________________
Exploring The Building Blocks of Science
Book 7
Study Notebook

Rebecca W. Keller, PhD
Welcome to your study notebook

This notebook is your place to record anything you want as you learn about atoms, forces, rivers, stars, plants, molecules, viruses, volcanoes and all the other amazing facts and concepts we call science.

There are questions and suggestions. Some are serious and some are whimsical. If you don’t like them, cross them out and create your own.

Just explore what you think about all the topics you are learning and try not to get too worried about writing down the “right” answers. This is an opportunity for you to explore what YOU like.

There are places in this notebook that are unscripted and have little instruction. There are also questions that just dangle on the edges of the page. That’s OK. Just record, draw, or paste images that you think apply. Add extra pages as you like. Answer the questions and suggestions in a way that makes the most sense to you. Most of real science is unscripted and making discoveries has no set of instructions. Just play with it. You’ll be fine and you might find out something unexpected and amazing.

This notebook is not meant to be graded. So parents and teachers, just let it go. Don’t grade this notebook or make your student “turn it in.” If your student wants to share all they are learning great! If not, let that be OK too.
CHAPTER III

Draw your favorite, most beautiful molecules and label their parts.
Try drawing an aromatic molecule. What are the characteristics of this type of molecule and how would you describe one visually?

Compare fats:

(What are fats, anyway?)

Saturated:  Unsaturated:
Choose 5 groups of molecular structures and identify the **functional group** in each.

1. Draw them!

2.
CHAPTER VII

Photosynthesis: “To make with light”

If all you knew about the word ‘photosynthesis’ was this definition, what would you imagine photosynthesis to be? In other words, what does its meaning make you think of?

What’s the big deal about photosynthesis???
Write about different ways a plant is **structured** to collect sunlight. How much of this structure seems random when you first look at a plant? How do you think a plant would **look** if it didn’t need sunlight?

Could a plant have colors without the sun?
Describe the way chlorophyll and other pigment molecules show us ‘colors.’

Do you think colors are beautiful? How do you think molecules affect our conception of beauty?
CHAPTER XIX

What limits humans in their observations of the universe?

How will the James Webb Telescope expand our knowledge?

What new inventions would advance our explorations?
Make a drawing of the Milky Way with the location of our Sun.

What are the different kinds of waves in the universe? Make a diagram and explain how scientists use them.

Look up different land based telescopes and images they have taken of objects in the Milky Way Galaxy. What different types of celestial objects can you observe? What is your favorite image?
Because dark matter and dark energy cannot be observed by light or electromagnetic forces, does that make them effectively **nothing**? How do we know that they are **something**? Do you think dark matter and dark energy are made up to explain what isn’t yet known?
Building Blocks of Science Book 7
Midterm I Chapters 1-11, 30 questions, 10 points each
Sample questions Chapters 3 & 7

4. Match the term with its definition. (10 points)

_____ organic chemistry
a. a polysaccharide that provides structural support for plants

_____ isomers
d. molecules made of long chains of sugars; provide energy for living things

_____ functional group
e. a subset of atoms on a molecule that together form a reactive unit

_____ parent molecule
f. two molecules that have the same number and kind of atoms but have different structures

_____ carbohydrates

_____ cellulose

5. A functional group is (10 points)

- a set of molecules that provide energy to living things.
- a subset of atoms on a molecule that together form a reactive unit where chemical reactions can occur.
- two molecules with the same atoms but different structures.
- a group of chemists working together on a project.

6. Because isomers are made of the same atoms, they have the same physical and chemical properties even though they have different structures. (10 points)

- True
- False

16. Match the biological term with its definition. (10 points)

_____ chlorophyll
a. an organism that makes its own food

_____ autotroph
d. organisms that are in the kingdom Protista

_____ cloroplast
e. chemical reactions that occur when a chloroplast captures energy from the Sun

_____ algae
f. light-absorbing pigment in plants that gives them color

_____ light reactions

_____ Calvin Cycle
17. In a plant, photosystem II and photosystem I work together to capture and release energy and drive the chemical reactions needed to make sugar. (10 points)
   - True
   - False

18. Photosynthesis produces (Check all that apply.) (10 points)
   - photosystems.
   - carbon dioxide.
   - oxygen.
   - chlorophyll.
   - glucose.
Building Blocks of Science Book 7
Midterm II Chapters 12-22, 30 questions, 10 points each
Sample questions Chapter 19

22. The Milky Way Galaxy is most likely a barred spiral galaxy. (10 points)
   - True
   - False

23. A kiloparsec is equal to 1000 parsecs. (10 points)
   - True
   - False

24. The arms of the Milky Way are named (Check all that apply.) (10 points)
   - Perseus.
   - Juliet.
   - Sagittarius.
   - Scutum-Centarus.
   - Norma.

Answer Sheet

Building Blocks of Science Book 7
Midterm II Chapters 12-22, 30 questions, 10 points each
Sample questions Chapter 19

22. True
23. True
4. The arms of the Milky Way are named (Check all that apply.) (10 points)
   - Perseus.
   - Norma.
   - Scutum-Centaurus.
   - Juliet.
   - Sagittarius.

5. A kiloparsec is equal to 1000 parsecs. (10 points)
   - True
   - False

6. The Milky Way Galaxy is most likely a barred spiral galaxy. (10 points)
   - True
   - False

29. In a plant, photosystem II and photosystem I work together to capture and release energy
    and drive the chemical reactions needed to make sugar. (10 points)
   - True
   - False

30. Match the biological term with its definition. (10 points)

   _____ chlorophyll  a. an organism that makes its own food
   _____ autotroph  b. light-absorbing pigment in plants that gives them color
   _____ chloroplast  c. chemical reactions that occur when a chloroplast captures
                    energy from the Sun
   _____ algae  d. organisms that are in the kingdom Protista
   _____ light reactions  e. the chemical reactions that produce sugar in a plant
   _____ Calvin Cycle  f. an organelle in which photosynthesis occurs
36. Because isomers are made of the same atoms, they have the same physical and chemical 
properties even though they have different structures. (10 points)
- True
- False

37. A functional group is (10 points)
- a subset of atoms on a molecule that together form a reactive unit where chemical 
  reactions can occur.
- a set of molecules that provide energy to living things.
- a group of chemists working together on a project.
- two molecules with the same atoms but different structures.

38. Match the term with its definition. (10 points)

- _____ organic chemistry
  a. a polysaccharide that provides structural support for plants
- _____ isomers
  b. the chemistry of carbon-containing compounds
- _____ functional group
  c. a subset of atoms on a molecule that together form a reactive unit
- _____ parent molecule
  d. molecules made of long chains of sugars; provide energy for living things
- _____ carbohydrates
  e. a molecule from which other molecules are built
- _____ cellulose
  f. two molecules that have the same number and kind of atoms but have different structures

Answer Sheet

Building Blocks of Science Book 7
Final Chapters 1-22, 40 questions, 10 points each
Sample questions Chapters 3, 7, 19

5. True
6. True
29. True
30. b, a, f, d, c, e
36. False
37. a subset of atoms on a molecule that together form a reactive unit where chemical 
  reactions can occur.
38. b, f, c, e, d, a
Illustrations: Janet Moneymaker

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Exploring the Building Blocks of Science Book 7 Graphics Package

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www.gravitaspublications.com
<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>alkanes</td>
<td>Molecules that contain only carbon and hydrogen and only single bonds</td>
<td>H–C–H</td>
</tr>
<tr>
<td></td>
<td>between carbon atoms</td>
<td>methane</td>
</tr>
<tr>
<td>alkenes</td>
<td>Molecules with one or more double bonds between two carbon atoms</td>
<td>H–C–C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ethene</td>
</tr>
<tr>
<td>alkynes</td>
<td>Molecules with one or more triple bonds between two carbon atoms</td>
<td>H–C–C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ethyne</td>
</tr>
<tr>
<td>aromatics</td>
<td>Molecules containing a benzene ring</td>
<td>Br–C–C–C–C–C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>bromobenzene</td>
</tr>
<tr>
<td>alcohols</td>
<td>Molecules with an -OH attached to a carbon atom</td>
<td>H–C–OH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>methanol (methyl alcohol)</td>
</tr>
<tr>
<td>amines</td>
<td>Molecules with a -NH₂ attached to a carbon atom</td>
<td>CH₃–C–NH₂</td>
</tr>
<tr>
<td></td>
<td></td>
<td>butylamine</td>
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<td>aldehydes</td>
<td>Molecules with −C=H</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>ethanal (acetaldehyde)</td>
</tr>
<tr>
<td>acids</td>
<td>Molecules with −COH</td>
<td>CH₃–C=OH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ethanoic acid (acetic acid)</td>
</tr>
<tr>
<td>ketones</td>
<td>Molecules with −C=C−C</td>
<td>CH₃–C=CH₃</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2-propanone (acetone)</td>
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<tr>
<td>esters</td>
<td>Molecules with −C=O</td>
<td>CH₃–C=O−CH₂CH₃</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ethyl acetate</td>
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<tr>
<td>amides</td>
<td>Molecules with −C−NH₂</td>
<td>CH₃–C−NH₂</td>
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<tr>
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<td>ethanamide</td>
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*Exploring the Building Blocks of Science: Book 7*
The light-dependent reactions and the Calvin cycle in a chloroplast
Saturn viewed at three different spectral bands

These three views of Saturn reveal information about its atmosphere. Because the same types of particles in Saturn’s atmosphere reflect different wavelengths in predictable ways, astronomers can use instruments to make images of Saturn as it is seen in different wavelengths. The data collected can then be interpreted to find out details about Saturn’s clouds and haze.

Courtesy of NASA and E. Karkoschka (University of Arizona/STScI)