Exploring The Building Blocks of Science
Book 6
Student Textbook

Rebecca W. Keller, PhD
Contents

Introduction

CHAPTER 1 Technology in Science 1
  1.1 Introduction 2
  1.2 Archimedes: A Great Inventor 3
  1.3 How Science Shapes Technology 5
  1.4 How Technology Shapes Science 6
  1.5 Tools in Science 8
  1.6 Summary 9

Chemistry

CHAPTER 2 Technology in Chemistry 10
  2.1 Introduction 11
  2.2 The Typical Chemistry Laboratory 11
  2.3 Types of Glassware and Plasticware 13
  2.4 Types of Balances and Scales 16
  2.5 Types of Instruments 18
  2.6 Summary 20

CHAPTER 3 Acids, Bases, and pH 21
  3.1 Introduction 22
  3.2 Properties of Acids and Bases 23
  3.3 Acid-Base Theory 23
  3.4 Distinguishing Acids from Bases 24
  3.5 Acid-Base Indicators 27
  3.6 pH Meters 28
  3.7 Summary 30

CHAPTER 4 Acid-Base Neutralization 31
  4.1 Introduction 32
  4.2 Titration 33
  4.3 Plotting Data 34
  4.4 Plot of an Acid-Base Titration 36
  4.5 Summary 40
<table>
<thead>
<tr>
<th>CHAPTER 15  Earth’s Spheres</th>
<th>148</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.1 Introduction</td>
<td>149</td>
</tr>
<tr>
<td>15.2 The Spheres of Earth</td>
<td>150</td>
</tr>
<tr>
<td>15.3 Connecting the Spheres</td>
<td>153</td>
</tr>
<tr>
<td>15.4 A Delicate Balance</td>
<td>156</td>
</tr>
<tr>
<td>15.5 Summary</td>
<td>158</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CHAPTER 16  The Geosphere</th>
<th>159</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.1 Introduction</td>
<td>160</td>
</tr>
<tr>
<td>16.2 Minerals and Elements</td>
<td>162</td>
</tr>
<tr>
<td>16.3 Using Volcanoes To See Inside Earth</td>
<td>163</td>
</tr>
<tr>
<td>16.4 Using Earthquakes To See Inside Earth</td>
<td>166</td>
</tr>
<tr>
<td>16.5 How Hot Is the Core?</td>
<td>170</td>
</tr>
<tr>
<td>16.6 Summary</td>
<td>171</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CHAPTER 17  The Atmosphere</th>
<th>172</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.1 Introduction</td>
<td>173</td>
</tr>
<tr>
<td>17.2 Chemical Composition</td>
<td>173</td>
</tr>
<tr>
<td>17.3 Structure of the Atmosphere</td>
<td>175</td>
</tr>
<tr>
<td>17.4 Atmospheric Pressure</td>
<td>178</td>
</tr>
<tr>
<td>17.5 Gravity and the Atmosphere</td>
<td>180</td>
</tr>
<tr>
<td>17.6 The Greenhouse Effect</td>
<td>180</td>
</tr>
<tr>
<td>17.7 Summary</td>
<td>183</td>
</tr>
</tbody>
</table>

**Astronomy**

<table>
<thead>
<tr>
<th>CHAPTER 18  Technology in Astronomy</th>
<th>184</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.1 Introduction</td>
<td>185</td>
</tr>
<tr>
<td>18.2 Telescopes</td>
<td>186</td>
</tr>
<tr>
<td>18.3 Space Telescopes and Other Satellites</td>
<td>188</td>
</tr>
<tr>
<td>18.4 Other Space Tools</td>
<td>190</td>
</tr>
<tr>
<td>18.5 Summary</td>
<td>193</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CHAPTER 19  Time, Clocks, and the Stars</th>
<th>194</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.1 Introduction</td>
<td>195</td>
</tr>
<tr>
<td>19.2 Reading a Star Atlas</td>
<td>197</td>
</tr>
<tr>
<td>19.3 Time</td>
<td>199</td>
</tr>
<tr>
<td>19.4 Celestial Clocks</td>
<td>202</td>
</tr>
<tr>
<td>19.5 Summary</td>
<td>204</td>
</tr>
</tbody>
</table>
Chapter 3  Acids, Bases, and pH

3.1 Introduction 22
3.2 Properties of Acids and Bases 23
3.3 Acid-Base Theory 23
3.4 Distinguishing Acids from Bases 24
3.5 Acid-Base Indicators 27
3.6 pH Meters 28
3.7 Summary 30
3.1 Introduction

Modern technology has allowed chemists to explore not only the structure, size, and properties of atoms and molecules but also how atoms and molecules interact with each other during chemical reactions. Two specific types of molecules that play a role in many important chemical reactions are acids and bases.

Even before people knew what acids and bases were, these compounds were used for many different purposes. Tablets from the Babylonian culture show that people knew how to make soap from bases 2800 years ago. Some of the Babylonian people and ancient German tribes used soap to style their hair. The base they used for soap making is called lye, which is a substance found in the ashes left over after wood has burned. Different kinds of oils or animal fats were then heated with the lye, producing soap.

Some acids were also known many centuries ago. An Iranian alchemist named Abu Musa Jabir ibn Hayyan (circa 721–815 CE) discovered hydrochloric acid by mixing a salt (sodium chloride) with sulfuric acid. Jabir ibn Hayyan also developed aqua regia (royal water) by mixing nitric acid and hydrochloric acid. This material could easily dissolve gold and was often used to determine whether or not a substance appearing to be gold was, in fact, gold.
3.2 Properties of Acids and Bases

Some general properties of acids and bases are listed in the following chart. Vinegar, tomatoes, and black coffee are all acids, and all have a sour taste. It turns out that most acids are sour tasting. Grapefruit, for example, can be very sour. The juice inside a grapefruit contains a lot of citric acid.

<table>
<thead>
<tr>
<th>General Properties</th>
<th>Acids</th>
<th>Bases</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Sour in taste</td>
<td>• Bitter in taste</td>
<td></td>
</tr>
<tr>
<td>• Not slippery to the touch</td>
<td>• Slippery to the touch</td>
<td></td>
</tr>
<tr>
<td>• Dissolve metals</td>
<td>• React with metals to form precipitates</td>
<td></td>
</tr>
</tbody>
</table>

Detergents and many cleaners feel slippery. This is because many cleaners are basic and slipperiness tends to be a property of bases.

Some acids and bases are very poisonous or corrosive and can easily harm you. Battery acid, for example, can burn your skin if it happens to spill and can also make you very sick if eaten.

3.3 Acid–Base Theory

Because acids and bases are so important, chemists have developed several ways of understanding them. In 1834, Michael Faraday (1791–1867 CE) discovered that acids and bases are electrolytes, meaning they form ions when dissolved in water and can conduct electricity. Ions are atoms or molecules that have an electric charge.

Svante Arrhenius (1859–1927 CE), a Swedish chemist, took the next step in understanding acids and bases. In 1884 Arrhenius showed that acids produce hydrogen ions (H+) in water and bases produce hydroxide ions (OH−) in water. This is a useful theory for
explaining acids and bases, and the Arrhenius definitions are still widely used today. By definition, an Arrhenius acid is any molecule that releases a hydrogen ion (H+), and an Arrhenius base is any molecule that releases a hydroxide ion (OH−). When using this definition, keep in mind that it only applies to hydrogen and hydroxide ions in aqueous (water) solutions. Acids and bases can also be defined as the giving or taking of protons or electrons in non-aqueous (non-water) solutions. However, for the chemical reactions explored in this textbook, the Arrhenius definition of an acid and base will be used.

### 3.4 Distinguishing Acids from Bases

The use of litmus paper was the first method discovered for determining whether a liquid is an acid or a base. The word litmus comes from an old Norse word meaning “to dye or color.” Certain species of lichens provide the dye used in litmus paper. A lichen is an organism that consists of a fungus and algae working in partnership to form the organism. Litmus paper was first used by the Spanish alchemist Arnaldus de Villa Nova (circa 1235–1311 CE) to test whether a substance was an acid or a base.

Blue litmus paper will turn red in the presence of an acid and red litmus paper will turn blue in the presence of a base. Because litmus paper is relatively inexpensive to produce and easy to use,
it can be used in the chemistry lab to quickly determine whether an aqueous solution is an acid or a base. Litmus paper is a great tool for chemical geologists when they are out in the field and need an inexpensive and lightweight method for testing the water in ponds, rivers, and geothermal pools.

Litmus paper can be perfect for determining whether a solution is an acid or a base, but it cannot measure how concentrated an acid or a base is. Concentration is defined as the number of units in a given volume. The definition of a unit can vary, and the unit can be an atom, an electron, or even a ping-pong ball. A solution that contains many units is called concentrated (or strong), and a solution with few units is called dilute (or weak). For example, a concentrated solution of hydrochloric acid (HCl) has many HCl molecules, and a dilute solution of HCl has few HCl molecules.

The concentration of an acid or base depends on the number of acid or base ions in a solution. Using the Arrhenius definition, a concentrated acid is an acid that contains a large number of hydrogen ions (H+) and a concentrated base is a base with a large number of hydroxide ions (OH–). Conversely, a dilute acid is an acid with few hydrogen ions and a dilute base is a base with few hydroxide ions. But how do you measure the number of hydrogen or hydroxide ions in a given volume?
In 1909 while working for a brewery in Sweden, Sören Peter Lauritz Sörensen (1868-1939 CE), a Danish chemist, introduced the pH scale (pH is pronounced “P” “H”). The pH scale makes it easier for chemists to describe how many hydrogen ions are in a solution, and therefore, how acidic or basic a solution is. For the brewery, knowing the pH of their mixtures enabled them to control the acidity and make a better and more consistent product.

Specifically, pH is a measure of the concentration of hydrogen ions in a solution. According to the pH scale, an acid has a pH below 7 and a base has a pH above 7. Neutral water has a pH equal to 7.

- **pH = 7**: The solution is neither an acid nor a base—it is neutral.
- **pH less than 7**: The solution is an acid.
- **pH more than 7**: The solution is a base.

The following chart shows the pH for different solutions.

<table>
<thead>
<tr>
<th>pH</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acids</td>
<td>Battery acid</td>
<td>Stomach fluid</td>
<td>Vinegar</td>
<td>Tomatoes</td>
<td>Black coffee</td>
<td>Milk</td>
<td>Pure water</td>
<td>Blood</td>
<td>Wood ash</td>
<td>Detergents</td>
<td>Ammonia</td>
<td>Bleach</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Acidic</td>
<td>Acidic</td>
<td>Acidic</td>
<td>Acidic</td>
<td>Acidic</td>
<td>Acidic</td>
<td>Acidic</td>
<td>Acidic</td>
<td>Acidic</td>
<td>Acidic</td>
<td>Acidic</td>
<td>Acidic</td>
<td>Acidic</td>
<td>Acidic</td>
<td></td>
</tr>
<tr>
<td>Bases</td>
<td>Sodium bicarbonate</td>
<td>Water</td>
<td>Wood ash</td>
<td>Detergents</td>
<td>Ammonia</td>
<td>Bleach</td>
<td>Acidic</td>
<td>Acidic</td>
<td>Acidic</td>
<td>Acidic</td>
<td>Acidic</td>
<td>Acidic</td>
<td>Acidic</td>
<td>Acidic</td>
<td></td>
</tr>
</tbody>
</table>

Notice that the pH for blood is near 7, close to the pH of water. Our bodies are made mostly of water, and blood carries nutrients throughout our bodies. It is important that the pH of blood be near 7 since many of our cells and tissues would be damaged if the pH were much higher or much lower than 7. However, notice that the pH for stomach fluid is even lower than the pH for vinegar. Why is stomach fluid so acidic? As it turns out, your stomach makes hydrochloric acid.
**Chemistry—Chapter 3: Acids, Bases, and pH**

acid (HCl). This acid helps break down your food so that it can be carried to other places in your body. The inside of your stomach has a special lining that is designed to prevent the acidic stomach fluid from causing damage.

### 3.5 Acid-Base Indicators

Sörensen was able to create a pH scale by using a set of indicators that change color as the pH changes. Litmus paper is one type of acid-base indicator.

There are also other kinds of acid-base indicators. Some indicators change colors at very low pH, and others don’t change until the pH is very high. Some indicators even change colors twice. The following chart shows a few acid-base indicators and the pH range in which they change color.

<table>
<thead>
<tr>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>9</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>11</td>
</tr>
<tr>
<td>12</td>
</tr>
<tr>
<td>13</td>
</tr>
<tr>
<td>14</td>
</tr>
</tbody>
</table>

- **Crystal violet**: Below pH 1, crystal violet is yellow, but above pH 1 it is blue. Now look at phenolphthalein. Below pH 9 phenolphthalein is not colored, but above pH 9 it turns pink. This narrow range of some pH indicators is very useful for finding the pH of a solution and also determining how concentrated the acid or base is.
In general, any molecule that changes color when the pH changes can be considered an acid-base indicator. There are many different acid-base indicators, including red cabbage juice which is an acid-base indicator that is easy to make and fun to use.

### 3.6 pH Meters

Litmus paper and other indicators make it relatively easy to tell whether a solution is an acid or a base, but measuring hydrogen ion concentration and determining the strength or weakness of an acid or base can be more complicated.

Recall from Section 3.3 that Michael Faraday discovered that acids and bases are electrolytes that conduct electricity. A pH meter works by measuring electrical resistance in a water solution (how well electricity moves through the solution). A pH meter has a probe, or electrode, that is usually made of glass and is connected to a meter that measures how much electricity an acid or base can conduct.

In 1906 two scientists, Fritz Haber (1868–1934 CE) and Zygmunt Klemensiewicz (1886–1963 CE) tried to create the first pH meter. They made glass probes and attempted to measure pH directly by inserting a probe into a solution, but the glass needed to be very thin and the probes broke easily. They were never able to get their early pH meter to work.
In 1934 Arnold Beckman (1900–2004 CE) became the inventor of the first successful pH meter. Beckman was a chemistry professor at the California Institute of Technology (Caltech) when he was asked by the California Fruit Growers Exchange to find a way to measure the acidity of lemon juice. Members of the California Fruit Growers Exchange grew most of the citrus fruit in California at that time, and they needed a quick and easy way to see how acidic the fruit was. This information helped them decide when the fruit was ready to harvest.

After Beckman had perfected the first pH meter, he went into the business of producing and selling them. The first pH meters went on the market in 1935. Many people believed that only about 600 pH meters would be needed to supply chemistry labs around the world, but Beckman proved them wrong. Over the next couple of decades, Beckman’s company grew, developing and selling other scientific instruments as well as the pH meter, and he eventually became a millionaire. Beckman was very generous with his money, contributing over 400 million dollars to science research and education during his lifetime.

Chemists now use both portable and stationary pH meters. A portable pH meter can be transported easily in a backpack or pocket and can be used outdoors to measure the pH of rivers, ponds, geothermal pools, and other water sources. Stationary pH meters, also called benchtop meters are usually more accurate than portable pH meters and are used inside a laboratory.
3.7 Summary

- **Acids** are generally sour in taste, not slippery to the touch, and dissolve metals.

- **Bases** are generally bitter in taste, slippery to the touch, and form precipitates with metals.

- **Concentration** is defined as the number of units in a given volume.

- **Indicators** such as litmus paper can be used to determine if a solution is an acid or a base.

- The **pH** of a solution measures the ion concentration.

- **pH** can be measured by pH meters, pH paper, and acid-base indicators.
7.1 Introduction

The microscope is an instrument that makes small objects appear bigger. From examining the smallest organisms to mapping the blueprint of the cell, the microscope has dramatically changed the way we understand living things.

The invention of the first microscope is generally credited to Zacharias Janssen, although like many inventions the origin of the microscope is often debated. Zacharias Janssen was born about 1580 CE in Middelburg, the Netherlands. He became a spectacle-maker and developed an expertise in shaping and forming glass lenses. It was widely known at the time that a single, curved glass lens could correct vision and magnify objects. However, a single lens is limited as to how much it can magnify. In the late 1500s Zacharias and his father Hans Janssen solved this problem by experimenting with combining lenses. They discovered that by using two lenses together the magnification was greatly increased.

The instrument they created resembled a spyglass with two lenses housed in a cylindrical tube. Their instrument became the first primitive compound microscope. It is this advance in technology that eventually led not only to the modern microscope but also the discovery of a fascinating new world of microscopic biology.

About a century later, a Dutch lens maker named Anton van Leeuwenhoek (1632-1723 CE) perfected the polishing and grinding of lenses. Although he probably did not combine lenses to make a compound microscope, one of his lenses could
magnify samples up to 300 times. Leeuwenhoek was the first person to observe tiny creatures in pond water, bacteria, and red blood cells. Around the same time, Robert Hooke (1635-1703 CE), an English scientist, improved upon the Janssen microscope and was able to see the outline of cells in thinly sliced pieces of cork. Hooke became well known for his book *Micrographia* in which he wrote about and illustrated his observations.

Today, there are several different kinds of microscopes. The kind of microscope the Janssens invented and Hooke improved on is called a light microscope. A light microscope uses light and the interaction of light with glass lenses to focus and magnify an object. In addition to the light microscope, scientists can now use electrons and probes to image small objects. The electron microscope uses a beam of electrons to magnify objects, and a class of microscopes called probe microscopes use a stylus, or small probe, to “feel” the features on the surface of a sample. We will learn more about light, electron, and probe microscopes later in this chapter.

### 7.2 The Size of Things

How big is an insect eye, a piece of hair, a protist, or a red blood cell? We can see a fly sitting on a wall, but with our naked eyes can we see mitochondria or a cell from the inside of our cheek? What size are the smallest things the human eye can see, and what size are the smallest things microscopes can help us see?

Before we take a look at different microscopes, it’s important to explore the sizes of objects and the microscopic scale. The smallest object the unaided human eye can resolve is about the size of a strand of hair. Anything much smaller than a strand of hair needs to be magnified to be seen.
A Note About Units

The **metric scale** is the preferred unit for measuring the size of objects with a microscope. Although **metric units** can be converted to **British units**, the British scale is never used as a measurement for microscopic objects. In the metric scale the meter is the base unit used to measure length. Units larger or smaller than the meter are multiples of ten and are given a prefix attached to the word *meter* to identify them. For example, a length 100 times smaller than the meter is called the centimeter. A length 1000 times smaller than the meter is called a millimeter. The following table lists the metric units most commonly used in microscopy.

<table>
<thead>
<tr>
<th>Metric Measurement</th>
<th>Number of Times Smaller than a Meter</th>
<th>Measurement in Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 centimeter (cm)</td>
<td>$10^{-2} = 1$ hundred times</td>
<td>0.01 meter</td>
</tr>
<tr>
<td>1 millimeter (mm)</td>
<td>$10^{-3} = 1$ thousand times</td>
<td>0.001 meter</td>
</tr>
<tr>
<td>1 micrometer (um)</td>
<td>$10^{-6} = 1$ million times</td>
<td>0.000001 meter</td>
</tr>
<tr>
<td>1 nanometer (nm)</td>
<td>$10^{-9} = 1$ billion times</td>
<td>0.000000001 meter</td>
</tr>
</tbody>
</table>

### Table: Insect Wing Sizes

<table>
<thead>
<tr>
<th>Insect Wing</th>
<th>Strand of Hair</th>
<th>Protist</th>
<th>Plant Cell</th>
<th>Animal Cell</th>
<th>Red Blood Cell</th>
<th>Bacterium</th>
<th>Mitochondrion</th>
<th>Lysosome</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 mm</td>
<td>400 um</td>
<td>200 um</td>
<td>100 um</td>
<td>20 um</td>
<td>8 um</td>
<td>2 um</td>
<td>500 nm</td>
<td>200 nm</td>
</tr>
</tbody>
</table>

**Note:** These sizes are approximate. Sizes of actual objects will vary.
A strand of hair is around 0.4 mm (400 um) and is near the limit of what can be seen by the unaided human eye. Protists are around 200 um, plant cells are around 100 um, animals cells are around 20 um, and red blood cells are around 8 um. An *E. coli* bacterium is around 2 um (2000 nm), and most structures inside a cell are 200 nm and below.

### 7.3 The Light Microscope

The basic **compound light microscope** consists of an **eyepiece or ocular lens**, the **magnifying (objective) lens**, a **stage** for holding the sample, a **light source**, and various areas for adjusting **focus**, **brightness**, and **magnification**.

A light microscope works when light is passed through a sample and the lenses collect the light, bend the light to provide magnification, and separate the bent light to make details in the sample visible. In other words, a microscope *magnifies* a sample, *resolves details* in a sample, and creates *contrast* so a sample can be seen.

The **magnification** of a lens (how much a microscope can enlarge a sample) is expressed as numerical multipliers. A 2X magnification means that the lens doubles the size of the sample. In a 10X magnification the lens makes the sample 10 times larger, and a 100X magnification makes the sample 100 times larger. A modern compound microscope can magnify an object up to 1000 times!
Both the eyepiece and the objective lens magnify a sample. The eyepiece is the lens you look through, and the objective lens is the lens closest to the sample. The total magnification is the magnification of the eyepiece times the magnification of the objective lens. For example, if the eyepiece is 10X and the objective lens is 40X, the total magnification is 400X. The very smallest objects the unaided human eye can see are around 0.1 millimeter (100 micrometers), so objects smaller than 100 micrometers need to be enlarged to be seen. This is what magnification does—it enlarges small objects so we can both see them and observe details.

However, magnification of a sample is not the only important feature of a microscope. More important than magnification is the resolution of the sample by the lens. Resolution is the smallest distance between two points on a sample that a lens can clearly define as being separate. Resolution is essentially the ability of a microscope to separate fine details on a sample.

For example, imagine you have two dots on a page. If we magnify the dots, we can make them appear bigger, but if we cannot separate them, they will appear to be a single, merged dot.

The resolution depends on the wavelength of light and the quality of the objective lens. The objective lens is the lens closest to the sample, and it is the only lens that is involved in providing resolution. The ocular lens (eyepiece) only magnifies what the objective lens resolves. In other words, if you use a higher magnification on the eyepiece but the objective lens cannot separate two points, the image will look big but will be blurry.

### 7.4 The Electron Microscope

Light microscopy is limited by the wavelength of visible light. Objects below about 300 nm cannot be resolved with a light microscope. This means that many small structures inside and on the surface of cells cannot be observed. Before
the 1930s many scientists believed that it would never be possible to see things that are smaller than 300 nm. However, during the 1930s scientists began experimenting with electrons, and by the late 1950s the electron microscope had broken through the resolution limit of the light microscope.

The electron microscope uses a beam of electrons focused by a magnetic field much in the way a glass lens focuses a light beam. The “lens” for an electron microscope is called a solenoid which is a coil of wire wrapped around the outside of a tube. When an electric current is passed through the wire, an electromagnetic field is created that can be used to control the electron beam.

The resolution of the electron microscope depends on how fast the electrons are traveling. The faster the electrons travel the shorter their wavelength and the higher the resolution. With an electron microscope, samples can be magnified almost 2 million times!

Electron microscopes are very expensive pieces of equipment and are generally found only in specialized research labs. The electron microscope has a large vacuum chamber that houses an electron gun and magnetic lenses. The sample is inserted in the viewing chamber which is below the vacuum chamber, and a beam of electrons is directed from the electron gun toward the sample below. In a scanning electron microscope (SEM), an electron beam is scanned across the sample surface, and a detector picks up the electrons that have been scattered during the scan. A computer then uses this information to create an image.
SEM micrographs
Image credits: 1. Mosquito Head, CDC/Paul Howell; 2. Human neutrophil with bacteria, NIH; 3. Arabidopsis Leaf, Mark Talbot/CSIRO; 4. Insertion point of moth scale, CDC/Janice Carr, Oren Mayer; 5. Insect leg, CDC/Janice Carr; 6. Corona virus, NIAID
7.5 Scanning Probe Microscopes

How small are molecules? How small are atoms? How small is DNA, RNA, or a protein? The cells that make up living things are small, but even the smallest living cell is made up of billions of proteins, molecules, and atoms!

For a long time scientists could not observe small molecules found in cells or the atoms that make them. However, in the 1980s a new microscope technology was invented. This new device is called a scanning tunneling microscope, or STM. An STM is part of a family of microscopes called probe microscopes that make it possible to “see” small molecules and even atoms.

A scanning tunneling microscope is not a typical microscope. It does not work with light or lenses, and you don’t look through it. In fact, when using an STM, you do not actually “see” the atoms, at least not in the way that you are looking at this page in front of you.

An STM works by “scanning” the surface of an object and then projecting an image of this surface onto a computer monitor or other screen. The STM has a metal probe called a stylus that actually does the scanning. The stylus is extremely sharp—it comes to a point that is only one atom wide!

The stylus is controlled by a computer and moves back and forth over the surface of the object that is being scanned. The stylus stays very close to the surface of the object with the gap between the tip of the stylus and the object being about
as wide as one atom, or even smaller. The precision required to keep the stylus moving at the right distance from the scanning surface would not be possible without computers. As the stylus moves, it “picks up” electrons from the surface of the object. The electrons show where the atoms in the object are located. The STM electronically amplifies the signals created by these electrons and a computer then interprets the signals, creating an image on a monitor.

An STM can produce phenomenal images of a surface, but it has another amazing function. An STM can be used to “grab” individual atoms! The computer controlling the STM can then move the atoms to specific locations.

In 1990, researchers at IBM used an STM to grab individual xenon atoms. It took over 20 hours, but they were able to arrange 35 atoms into the letters I, B, and M to make the smallest company logo ever.

Since then, researchers have been discovering ways to move atoms around more quickly and how to make incredibly tiny structures, one atom at a time.
One of the drawbacks of the early scanning tunneling microscopes was that they could only be used to scan objects such as metals that conduct electricity easily. Therefore, they could not be used to create images of substances that were not conductors of electricity, such as plastics or living tissues. In the years since STMs were invented, several other types of probe microscopes have been developed. They work in slightly different ways, but all of these microscopes allow scientists to get an extremely close-up image of very small objects.

One of these probe microscopes is the atomic force microscope (AFM) which can scan many different types of surfaces, including metals and nonmetals. Like an STM, an AFM stylus has a very sharp tip. But instead of picking up electrons to create an image like an STM does, an AFM can “see” atoms by just bumping into them (that is, by measuring the force between an atom and the tip of the probe).

Because everything is made of atoms, an AFM can “see” all kinds of materials, not just those that conduct electricity. The AFM has been used to image the surfaces of cells and observe small proteins in action.
7.6 Summary

- Different types of microscopes include the **light microscope**, the **electron microscope**, and a family of **probe microscopes**.

- A **light microscope** works when light passes through a sample and lenses collect the light, provide magnification of the sample by bending the light, and separate the bent light so that details in the sample are visible.

- The amount of magnification of a **light microscope** is the magnification of the **ocular lens (eyepiece)** times the magnification of the **objective lens** (the lens closest to the sample).

- The **objective lens** determines the **resolution** of a light microscope.

- **Electron microscopes** use a beam of electrons and a magnetic “lens” to image a sample.

- **Probe microscopes**, including the **scanning tunneling microscope (STM)** and **atomic force microscope (AFM)**, scan the surface of a sample and can produce images of small molecules and atoms.
Chapter 19 Time, Clocks, and the Stars

19.1 Introduction 195
19.2 Reading a Star Atlas 197
19.3 Time 199
19.4 Celestial Clocks 202
19.5 Summary 204
19.1 Introduction

What would you do if you were on a hike with a group of friends and suddenly found yourself separated? Imagine that your compass needle is stuck and as you take your whistle from your pocket to call your friends, it falls out of sight in a crack between two big rocks that are too heavy to lift or move. The day is coming to a close and the night stars are beginning to shine. If you don’t know how to navigate with the stars, the best thing to do would be to sit down and hope that your friends or someone else will find you. However, if you do know about stars, the constellations, and how to interpret their position in the night sky, you could find your way back to the group camp or find your way home.

In ancient times people looked to the stars for inspiration, religious meaning, and navigation. One way early people gave meaning to the stars was to look for patterns, create groups of stars, and give them names. These named groups of stars are called constellations.

We don’t know the exact date the first constellations were named, but ancient Egyptians, Sumerians, and Chaldeans are believed to have known many of our present-day constellations. It appears that by 2000 BCE most of the main constellations in the Northern Hemisphere had been recorded. The Greeks and Romans took over where their ancient ancestors left off, using Greek and Latin to name many of the constellations after heroes, animals, and mythical objects.

Mapping the stars is called celestial cartography or uranography. Cartography is the art and science of making maps. Uranography comes from the Greek word uranos which means “heavens” and graphe, which means “to write,” so uranography means the “writing of the heavens.” Although constellations are visible from both the Northern and Southern Hemispheres, it wasn’t until after
the 15th century CE that constellations in the Southern Hemisphere were recorded by European explorers.

There are forty-eight original constellations which include the constellations known to ancient Greek, Roman, and western Asian people. Today, the IAU (International Astronomical Union) recognizes 88 constellations. The newer constellations are found mostly in the Southern Hemisphere and were charted by Europeans as they explored that part of the globe. However, we now know that ancient cultures all over the world recognized constellations.

Mapping the stars was a popular activity for many early astronomers, and with the invention of the telescope, modern astronomers began to focus primarily on determining the accurate position of stars and celestial objects rather than using constellations for reference. In 1875 the German astronomer Friedrich Argelander (1799–1875 CE) published a catalog of the locations of 325,000 stars. This star catalog, called the Bonner Durchmusterung, was simply a grid that showed the positions and magnitudes of stars without relating them to the constellations. This star catalog is still being used in revised and updated forms. Another star catalog still in use today is Norton’s Star Atlas which was first published in 1910 and was based on a star catalog created by Belgian astronomer Jean-Charles Houzeau. Norton’s Star Atlas has also been revised and updated many times.

From 1989–1993 the Hipparcos satellite gathered data that was used to create the Hipparcos Star Catalog which accurately mapped over 100,000 of the brightest stars and the Tycho Star Catalog which mapped over 2 million dimmer stars with slightly less accuracy. The Hubble Space Telescope has also been used to catalog stars.
Today, there are different star catalogs, or star atlases. In addition to the Hubble and Hipparcos/Tycho star catalogs, there are a number of print and computer generated star atlases that map not only the stars in our galaxy, but deep space stars, nebulae, and celestial objects. Many star maps include the constellations in addition to the positions, magnitudes (brightness), and movement of individual stars.

19.2 Reading a Star Atlas

A star atlas or star map can be quite overwhelming for the beginning astronomer. Modern star atlases map over 450,000 stars, planets, and other celestial objects. Just locating where you are relative to the stars in the sky can be daunting. Not only are there thousands of tiny dots representing the locations and brightness of the stars, but the stars’ locations in the sky are constantly changing with the seasons.

For this reason, it’s easiest to orient yourself starting with familiar landmarks like the constellations and asterisms, which are groups of stars that are smaller than constellations and may be part of a constellation. Patterns are easier to see than a single star in a cluster of stars, and by locating a constellation or asterism in the sky you can find the surrounding stars mapped in the atlas. For example, if you are in the Northern Hemisphere, one of the easiest asterisms to locate is the Big Dipper. Recall that the two stars in the part of the bowl of the Big Dipper that are farthest from the handle point to Polaris, the North Star. When you are facing Polaris, you are facing north. Polaris is in between the Big Dipper and the constellation called Cassiopeia. Cassiopeia is a W-shaped set of stars that is easy to find.
Once you find the Big Dipper, Polaris, and Cassiopeia, you can use the star atlas as a kind of road map. By holding the star map above your head, and turning it to align with the constellation landmarks, you will be able to identify stars that are outside the constellation. Star maps vary with a given day or season since the stars change position throughout the year and some are only visible at certain times of the year.

Star atlases also come as calendar charts. Each calendar chart lists the stars and constellations that are visible from different locations on Earth and shows the positions of the stars for a particular month. Some star calendars show thousands of stars, but many star calendars only show a few hundred stars, making it easier to navigate.

Star atlases not only map the location of the stars but indicate a star’s brightness. Brighter stars are shown as large dots, with less bright stars shown as smaller dots. Star atlases also map galaxies, clusters, and nebulae using different symbols such as dotted circles, closed circles, and ovals.
19.3 Time

What time is it? How do you determine the time when you need to get up in the morning, go to class during the day, or go to sleep at night? If you are like most people in the modern world, you probably use your wristwatch, wall clock, or digital time on your phone. But what is time exactly and how do you know your watch is correct?

In the morning you can see the Sun rise and in the evening you can see the Sun set. The Sun comes up over the eastern horizon and sets in the western horizon after spending a certain amount of time in the sky illuminating your day. The time it takes for the Sun to go from its highest position in the sky on one day to its highest position on the next day is called a solar day. If you use a sundial, you can measure when the Sun is at its highest position in the sky and how long it takes the Sun to go from one position in the sky to the next. A sundial records the Sun’s daily motion across the sky and gives apparent solar time. Apparent solar time is time measured from the direct observation of the Sun. But on cloudy days and at night a sundial won’t work. Although apparent solar time is a natural way to keep track of time, it isn’t accurate enough for our modern world, so other ways of keeping time have been devised.

If you live anywhere on Earth other than near the equator, you will notice that due to the tilt of Earth on its axis the length of a day changes with the seasons. In the Northern and Southern Hemispheres during the winter months the days are shorter than in the summer months. At the equator the length of a day stays about the same all year, and the farther you are from the equator,
the more variation there is in the length of the day throughout the seasons. Also, because Earth’s orbit is slightly elliptical, Earth’s distance from the Sun varies, with Earth being closer to the Sun in the fall and early winter months. This causes the length of day in apparent solar time to vary by as much as 15 minutes between the Earth’s closest position and farthest position from the Sun.

To correct for the length of the day changing over the course of a year, astronomers use mean solar time. Mean solar time is based on apparent solar time averaged over the course of a year. In other words, if you measure the length of each of the apparent solar days in a year, add together the day lengths for all the days in the year, and then divide this by the number of days in a year, the result is the average length of a solar day, which is mean solar time. A standard watch uses mean solar time that is divided into hours, minutes, and seconds. Global time zones are created using mean solar time.

Mean solar time tells us that it takes 24 hours for Earth to spin once around its axis, which is the length of one mean solar day. But at the same time that Earth is spinning on its axis, it is also rotating around the Sun. Earth travels so fast in its orbit around the Sun that by the time Earth has made one rotation on its axis, it has traveled 2.5 million kilometers in its orbit around the Sun! So, in one mean solar day, Earth has not only rotated once on its axis but has also changed its position in space relative to the Sun.

For example, let’s say you are in New York City at noon and you observe that the Sun is at its highest position in the sky. The next day you look at your watch and it is 24 hours later with the Sun once again in its highest position in the sky. On each of these days at noon in mean solar time, the Sun is directly above New York City (the Sun is in its highest position in the sky). The problem is that the Earth, as well as rotating once on its axis, has also moved 2.5 million kilometers in its orbit around the Sun from one noon to the next. Although due to Earth’s
rotation the Sun is directly above New York City at two noontimes that are 24 hours apart in mean solar time, the *actual* rotation of the Earth (or *true rotation*) has only taken 23 hours and 56 minutes. Why is this? It’s the change of the position of Earth relative to the Sun that makes the length of the mean solar day longer than the length of time for one true rotation. This results in a difference of 4 minutes between how long it takes Earth to make one true rotation on its axis and the length of one day in mean solar time. The length of time it takes for Earth to make one true rotation is called a *sidereal day*.

You can observe the difference between the length of time of one mean solar day and the length of one sidereal day (one true rotation) if you observe the same stars at the same location in the sky on several consecutive nights. When the stars arrive at the location you’ve noted, you will discover that the time on your watch will be about four minutes earlier each night. This four minute difference is the result of the difference between mean solar time and the actual rotation time of Earth.

Astronomers developed *sidereal time*, or *star time*, to measure time more accurately by using Earth’s position relative to distant stars rather than relative to the Sun. The term sidereal comes from the Latin word *sidus* which means “star.” Using sidereal time, astronomers are able to calculate the true rotation of Earth. Similar to how a mean solar day is measured by the
Sun’s highest position in the sky from one day to the next, a sidereal day is measured from the time a distant star appears in its highest position from one night to the next. Because the stars are so far away, Earth’s orbit does not affect the position of where the stars appear in the sky—only the rotation of Earth does.

Although sidereal time is a more accurate measure of Earth’s rotation on its axis, it is most useful to astronomers. For everyday use, solar time works best.

19.4 Celestial Clocks

In the modern world our days are divided up into segments of hours, minutes, and seconds. Because we no longer rely on observing the location of the Sun to tell time, we use clocks to help us make sure we get to our appointments on time, pick up the laundry on time, eat breakfast, lunch and dinner on time and go to bed on time.

Our standard clocks don’t take into account the movement of the Moon, other planets, or the stars. A celestial clock, or astronomical clock, on the other hand, is an instrument first built by ancient scholars to provide information about astronomical movements of celestial bodies as well as keeping track of time.

The first astronomical clock we know of is the Antikythera Mechanism built 2000 years ago by the ancient Greeks. Pieces of the mechanism were discovered by divers in 1900 near the tiny island Antikythera in Greece. Using x-rays to peer into the body of the device and computers to reconstruct how the device worked, scientists have suggested that it was an incredibly accurate astronomical clock able to replicate the irregular motions of the Moon, track the position of the...
Earth in its orbit around the Sun, and determine the position of Venus, Mars, Jupiter, and Saturn for any chosen date.

Another early astronomical clock was designed by Su Sung of China, built in 1092, and ran until 1126 when the Sung Dynasty was overtaken. This clock is called the Cosmic Engine and is an astronomical clock powered by falling water or falling mercury. The original clock tower was 30 feet tall with a series of interlocking gears rotating with precision. The clock displayed the positions of the Sun, Moon, and planets.

Astronomical clocks became a spectacle in the European world during the Middle Ages. One of the most famous old astronomical clocks still existing is located in the town square in Prague, the capital of the Czech Republic. The clock was built by Mikulas of Kadan in 1410 and consists of an astronomical dial, a calendar dial, and a window with rotating characters.
19.5 Summary

- Mapping the stars is called **celestial cartography** or **uranography**.
- **Apparent solar time** is the time it takes for the Earth to complete one rotation around its axis (complete one day) based on the position of the Sun.
- **Mean solar time** is the average of **apparent solar time** over a full year.
- **Sidereal time** is the actual measurement of Earth’s rotation around its axis based on the position of a fixed star.
- **Celestial clocks** record time plus movements of celestial bodies.
- A **star atlas** is like a road map of the night sky, mapping the locations and brightness of stars, planets, and other celestial bodies.
### Contents

**INTRODUCTION**
- Experiment 1 Take It Apart! 1

**CHEMISTRY**
- Experiment 2 Reading the Meniscus 12
- Experiment 3 Making an Acid-Base Indicator 20
- Experiment 4 Vinegar and Ammonia in the Balance 30
- Experiment 5 Show Me the Starch! 42

**BIOLOGY**
- Experiment 6 Using Agar Plates 50
- Experiment 7 Using a Light Microscope 60
- Experiment 8 Observing Protists 74
- Experiment 9 Moldy Growth 90

**PHYSICS**
- Experiment 10 Using Electronics 99
- Experiment 11 Moving Marbles 113
- Experiment 12 Accelerate to Win! 125
- Experiment 13 Around and Around 137

**GEOLOGY**
- Experiment 14 Hidden Treasure 146
- Experiment 15 Using Satellite Images 156
- Experiment 16 Modeling Earth’s Layers 168
- Experiment 17 Exploring Cloud Formation 179

**ASTRONOMY**
- Experiment 18 Measuring Distances 187
- Experiment 19 Using a Star Map 198
- Experiment 20 Modeling Our Solar System 208
- Experiment 21 Discovering Life on Other Planets 217

**CONCLUSION**
- Experiment 22 Working Together 227
Experiment 3

Making an Acid-Base Indicator
Introduction

Make your own acid-base indicator and use it to test different solutions.

I. Think About It

1. What solutions do you think are acids?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

2. What solutions do you think are bases?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

3. Do you think it can be useful to know if a solution is an acid or a base? Why or why not?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
4. How would find out if a solution is an acid or a base?

_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________

5. Do you think acids can be useful? Harmful? Why or why not?

_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________

6. Do you think scientists might want to know whether two solutions are acids or bases before they mix them together? Why or why not?

_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
II. Experiment 3: Making an Acid-Base Indicator

Date __________

Objective __________________________________________________________

Hypothesis __________________________________________________________

Materials

- one head of red cabbage
- distilled water
- various solutions, such as:
  - ammonia
  - vinegar
  - clear soda pop
  - milk
  - mineral water
- large saucepan
- knife
- several small jars
- white coffee filters
- eyedropper
- measuring cup
- measuring spoons
- marking pen
- scissors
- pen
- ruler

EXPERIMENT

1. Take the whole head of red cabbage and divide it into several pieces.

2. Place about .7 liter (3 cups) of distilled water in a large saucepan and bring the water to a boil. Place the cabbage in the boiling water and boil for several minutes.

3. Remove the cabbage and let the water cool. The water should be a deep purple color.

4. Take .25 liter (1 cup) of the cabbage water to use in this experiment, and REFRIGERATE the rest for the next experiment.
5 Cut the coffee filters into small strips about 2 cm (3/4 inch) wide and 4 cm (1 1/2 inches) long. Make at least 20.

6 Using the eyedropper, put several drops of the cabbage water onto each of the filter paper pieces and allow them to dry. They should be slightly pink and uniform in color. If the papers are too light, more solution can be dropped onto them, and they can be dried again. These are your acid-base indicator (pH) papers.

7 Label one of the jars Control Acid, and place 15 ml (1 tbsp.) of vinegar in the jar. Add 75 ml (5 tbsp.) of distilled water. This is your known acid.

Label another jar Control Base and add 15 ml (1 tbsp.) of ammonia to the jar. Add 75 ml (5 tbsp.) of distilled water. This is your known base.

Label a separate jar for each of the solutions you will be testing. Put into the appropriate jar 15 ml (1 tbsp.) of each of the solutions you have collected, and add 30-75 ml (2-5 tbsp.) of distilled water to each jar.

8 Carefully dip a strip of pH paper into the Control Acid. Look immediately at the pH paper for a color change and record your results in the chart on the next page. Then tape the pH paper in the pH Paper Sample column next to the section labeled Control Acid.

9 Carefully dip an unused piece of pH paper into the Control Base. Look immediately at the pH paper for a color change, and record your results in the chart on the next page. Tape the pH paper in the space next to the Control Base section.

10 Now take unused pieces of pH paper, and dip them into the other solutions you have made. Record your results. Tape the papers into the chart.
## Results

<table>
<thead>
<tr>
<th>pH Paper Sample</th>
<th>Name of Solution</th>
<th>Color of pH Paper</th>
<th>Acid or Base?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control Base:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Control Acid:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
III. Conclusions

What conclusions can you draw from your observations?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
IV. Why?

In this experiment you made your own pH paper using red cabbage juice. Before pH meters were invented, pH paper was the most common way to test for acids and bases. pH paper can still be found in most laboratories. Before pH paper and other modern techniques were available, many chemists tasted things to find out more about them. However, this is quite dangerous, and today scientists do not taste anything in the laboratory.

The exact pH of the solutions you tested couldn’t be determined by the pH paper you made. You could only find out whether a solution was acidic or basic. pH paper is made with a compound called an indicator. An indicator is any molecule that changes color as a result of a pH change. The molecules that give red cabbage its color react differently with acids and bases, turning pink in the presence of acids and green in the presence of bases.

The properties of acids and bases are quite different, and in many ways opposite. Acids are sour, not slippery, and are effective in dissolving metals. Bases are bitter, slippery, and react with metals to form precipitates. Because some acids and bases can be harmful, scientists do not test unknown solutions by putting them on their skin.

In this experiment you used controls. A control is a part of an experiment where the outcome is already known or where a given outcome can be determined. The control provides a point of reference or comparison for an experiment that uses unknowns. For example, in this experiment you tested for acidity or basicity with a pH indicator, but you did not know what the expected color change would be. By using solutions that are known to be either acidic (vinegar) or basic (ammonia), you could determine what the color change for an acid would be and what the color change for a base would be. Only then could you determine the meaning of the results of testing the unknowns.

A control can also tell the scientist when an experiment has failed. If a color change is observed in the control experiment but not in the new experiment, something may be wrong with the setup or design of the new experiment. Control experiments help scientists check for errors.
V. Just For Fun

See whether different natural materials can be used as acid-base indicators.

Crush the material you will be testing and put some of it in each of two small jars. Using the solutions you have identified as acid or base, add some acid to one jar and some base to the other jar. Does the color change? Record your results in the chart that follows.

Natural Materials for Experimentation

Turmeric
Poppyseed or cornflower petals
Madder plant (Rubiaceae family)
Red beets
Rose petals
Berries
Blue and red grapes
Cherries
Geranium petals
Morning glory
Red onion
Petunia petals
Hibiscus petals (or hibiscus tea)
Carrots
Other natural materials of your choice
<table>
<thead>
<tr>
<th>Natural Material and Its Color</th>
<th>Name of Solution Used</th>
<th>Acid or Base?</th>
<th>Final Color/Indicator?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Experiment 7

Using a Light Microscope
Introduction

Explore the world through a microscope!

I. Think About It

1. What more do you think you could observe about a strand of your hair by looking at it through a microscope instead of with just your eyes?

__________________________________________________________________________________________
__________________________________________________________________________________________
__________________________________________________________________________________________
__________________________________________________________________________________________

2. What do you think a strand of hair would look like at 40X magnification?

__________________________________________________________________________________________
__________________________________________________________________________________________
__________________________________________________________________________________________
__________________________________________________________________________________________

3. What do you think a piece of paper would look like at 10X magnification?

__________________________________________________________________________________________
__________________________________________________________________________________________
__________________________________________________________________________________________
__________________________________________________________________________________________
4. How easy do you think it is to get a sample in focus at 10X magnification?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

5. What do you think pond water would look like at 10X magnification?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

6. What do you think skin cells would look like at 100X magnification?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
II. Experiment 7: Using a Light Microscope

Objective

Hypothesis

Materials

Microscope with 4X, 10X, and 40X objective lenses. A 100X objective lens is recommended but not required.
glass microscope slides
glass microscope cover slip
immersion oil (if using 100X objective lens)
Samples:
- piece of paper with lettering
- strands of hair
- droplet of blood
- insect wing

EXPERIMENT

Part I: The Microscope

1. Move the microscope to a desk or table where you can sit for a few hours.
2. Remove the cover and familiarize yourself with the different parts.
3. Turn the revolving turret so the lowest power objective lens (4X) is clicked into position. [NOTE: Be extremely careful not to bang the lenses on the stage as you turn the turret. This can damage the lenses.]
4. Turn the coarse adjust knob and observe how the stage moves up and down.
5. Turn the fine adjust knob and observe how the stage moves up and down.

6. Turn on the light source and use the condenser to change the amount of light entering the stage.

7. Examine the stage and the clips that hold the slide in place. Move them until you are familiar with how they work.

8. Fill in the names of the parts of the microscope in the following diagram.
Part II: Observing a Sample

1. Take the small piece of paper and place it on a glass slide in the microscope. Do not put a coverslip on top.

2. With the lowest power objective (4X) in place, look through the ocular lens, and using the coarse adjust knob, slowly move the objective lens up and down until the sample is in focus.

3. Move the paper until you can see the ink.

4. Turn the fine adjust knob slowly up and down as you observe the sample. You should see some parts of the paper come into focus as other parts go out of focus. Notice the range of focus (how much of the sample is in focus). Record your observations.

5. Keeping the microscope steady, gently turn the turret until the next highest power objective lens (10X) clicks into place. Be careful not to bump the objective lens into the sample. If this looks like it will occur, move the lens up with the coarse adjust knob.

6. Look through the ocular lens and observe the sample, turning the coarse and then fine adjust knobs until the sample comes into focus. Notice the range of focus. Record your observations.
7. Using the turret, move the lowest power objective back into place. 
   [NOTE: If you have a 100X objective, do not rotate the turret through this 
   lens. Turn the turret in the opposite direction until the lowest power lens is 
   back in place. It is extremely important that the lens does NOT scrape 
   the slide or sample. This will scratch the lens and ruin it.]

8. Take a clean glass slide and place a single droplet of blood on the slide. You 
   can either let a drop of blood fall on the slide or touch your finger to the 
   slide to transfer the blood. You will need to prick your finger or the finger 
   of a brave sibling, parent, or friend. Hands should be washed first and a 
   sterile needle used.

9. Gently place a clean coverslip on the droplet. The blood droplet should 
   spread out quickly when the coverslip is in place.

10. Put the glass slide in the sample holder, and with the 4X objective in place, 
    look through the ocular lens. Focus the image with the coarse and then fine 
    adjust knobs. Record your observations and draw what you see.
11. Gently turn the turret until the 10X objective clicks in place. Rotate the lens into place slowly, being careful not to bump the slide with the objective lens. Record your observations and draw what you see.

12. Gently turn the turret until the 40X objective clicks into place. Again, rotate the lens into place slowly and do not bump the slide with the objective lens. There should be enough room to move the lens without moving the stage. Record your observations and draw what you see.
13. If you have a 100X oil immersion lens, turn the turret until the oil immersion lens is half way into position. Place a single drop of immersion oil on the glass cover slip and gently move the oil immersion lens in place.

[NOTE: It is extremely important that the lens does NOT scrape the coverslip. This can scratch the lens and ruin it. The lens will be very close to the glass coverslip if you have adjusted the focus correctly with the other lenses. If it seems like the lens will scrape the cover slip, gently back up the lens with a few turns of the fine adjust knob.]
14. Adjust the condenser if more light is needed, and using the fine adjust knob only, focus the image. [Never use the coarse adjust knob to focus an oil immersion lens—it is too easy to smash the lens against the slide.] Record your observations and draw what you see.

15. Rotate the turret to move the oil immersion lens away from the sample. With the coarse adjust knob lower the stage and remove the sample.

16. Explore other samples such as a strand of hair, pond water, or an insect wing. Always rotate the lenses from lowest power to highest power, focusing the image each time before moving to the next highest power lens.
III. Conclusions

What conclusions can you draw from your observations?

_________________________________________________________________________

_________________________________________________________________________

_________________________________________________________________________

_________________________________________________________________________

_________________________________________________________________________

_________________________________________________________________________
IV. Why?

In this experiment you explored how to operate a compound light microscope. Being able to select and then focus the correct objective lens for viewing different types of samples is an important first step towards becoming a good microscopist.

In the first part of the experiment, you magnified a piece of paper with a 4X objective, which is usually the lowest power objective lens on a standard student microscope. When combined with a 10X ocular lens, a 4X objective magnifies the sample 40X. At this magnification you can begin to see structures in paper that you can't see with your eyes alone. Moving the 10X objective lens into place magnifies the paper 100X, allowing more details to be observed.

As you increase the power of the objective lens, the depth of field decreases. In other words, you may have noticed that the focal length decreases as the magnification increases. When an objective lens is made with good optics, the working distance, or focal length, decreases as the power of the objective increases and as the resolution increases.

You may have also noticed that the field of view (the area of the sample that is visible) decreases as the magnification increases. As you move from a low power objective lens (4X) to a higher power objective lens (40X), the field of view decreases.

<table>
<thead>
<tr>
<th>Depth of Field (Focal Length)*</th>
<th>Field of View*</th>
</tr>
</thead>
<tbody>
<tr>
<td>(how far down the sample is in focus)</td>
<td>(how much of the area of the sample you can see)</td>
</tr>
<tr>
<td>4x</td>
<td>10x</td>
</tr>
</tbody>
</table>

*Relative sizes are not to scale.
The change in the field of view and in the focal length as you move from lower to higher magnification can be one of the most frustrating experiences for new microscopists. For this reason, it is important to focus and center the sample beginning with the lowest power lens, then working up to the highest magnification, focusing and centering the sample with each change of lens. If the sample is bumped or moves out of view while viewing with a high magnification lens, it is good practice to go back to a lower power objective and refocus and re-center the sample. However, if an oil immersion lens is used, often the area being viewed needs to be adjusted or a new sample created and the process of going from lowest to highest magnification repeated.

V. Just For Fun

Now that you know how to use a microscope, the world of tiny objects and microscopic organisms is at your fingertips.

Using your microscope, observe what milk, soda, clothing fibers, skin, fingernails, or other samples look like when magnified. Does your hair look the same as your dog’s or cat’s or horse’s? Do fibers from different clothing materials look the same? Which samples were the most surprising when magnified? Record your observations. Draw several of your favorite samples as seen through the microscope.

Observations Through a Microscope
More Observations Through a Microscope
Experiment 19

Using a Star Map

A constellation chart of Cassiopeia

Courtesy of IAU and Sky & Telescope
Introduction

Identify stars!

I. Think About It

1. How many stars do you think are in the night sky? Why?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

2. Do you think you could count all the stars you see? Why or why not?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

3. Do you think you would see different stars in the night sky if you were at the North Pole than if you were at the South Pole? Why or why not?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
4. If you had to map all the stars, how would you do it?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

5. If you could travel back in time to the first century, do you think your star map would look different? Why or why not?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

6. If you had an accurate map of the stars, in what ways might you use it?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
II. Experiment 19: Using a Star Map

Objective

Materials

- computer with internet access
- printer and paper
- flashlight

Optional

- binoculars or telescope

EXPERIMENT

1. Go to the Starmap site at http://www.star-map.fr/ and click on the Free Maps menu tab. This brings up a list of maps for the Northern Hemisphere. Under this list are three dots. Clicking on these will change the screen to show maps for the Equatorial Zone or the Southern Hemisphere.

Another free star map resource is http://www.skymaps.com.

[Note: Websites do change over time. If these sites are no longer available, do a browser search for “free star maps” to find a different resource.]

2. On the Starmap site, select the hemisphere where you live, the map version you want to download, and the time you want to view the stars (20 pm is 8:00 pm and 22 pm is 10:00 pm). Click to download the map. Print the map.

3. Study the star map you’ve downloaded. Check to make sure the map is for the correct hemisphere. Read the comments on the left side of the map. Many of the stars and constellations can be seen with an unaided eye, but some may require binoculars or a telescope.

4. On an evening that is clear of clouds, go outside at the time you chose for the map you printed. Spend some time looking at the stars.

If you live in a city that has too much light at night for many stars to be seen, you may need to find a darker location away from city lights.
Hold the map above your head so you are looking up at it and the sky. See if you can orient the map to match the stars you observe in the sky. Note which stars you are able to identify.

In the space provided in the Results section, use the star map as a guide to make your own star map by recording the constellations you saw and the magnitude of the stars. Add planets or other objects and their location.

Results

<table>
<thead>
<tr>
<th>Star Map</th>
<th>Date __________________________</th>
</tr>
</thead>
</table>

![Star Map Image]
III. Conclusion

A. Questions

1. Based on your observations how easy was it to locate the constellations? Why?

2. How many constellations were you able to record? Which ones?

3. Were there any constellations you were not able to find? Why?

4. How does artificial lighting affect your viewing of the stars?
If you were to view the stars for several hours, do you think you would be able to observe whether the constellations move? Why or why not?

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

B. Conclusions

Based on your observations, what conclusions can you draw?

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________
IV. Why?

By using a star map or star atlas you can become familiar with the stars. Like using a road map to find landmarks on Earth, you can learn landmarks in the night sky. If you were to study the night sky every night, you would become so familiar with it that you could navigate by the stars without using a star map.

There are many different kinds of star maps and star atlases available today. Some star maps show just the stars with the overlapping constellations. Some star maps have thousands of stars to observe and some only have a few hundred. There are also 3D star maps and planetary sphere maps that show star locations relative to your Earth position in a three-dimensional shape.

There are also deep space star maps that map the stars seen by the Hubble and Hipparcos telescopes. As astronomers continue to explore the cosmos, more stars and other celestial bodies are being added to star atlases.

V. Just For Fun

Repeat the experiment in a month. Download a new star map for that date and make your own star map based on the current location of the stars.

Compare your two star maps. What can you observe that is the same and what is different? The following pages provide space for your map and observations.
Star Map 2

Date ____________________________
Star Map Comparisons

Star Map 1

Star Map 2
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 6 Laboratory Notebook accompanies the Building Blocks of Science Book 6 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>
</tr>
</thead>
<tbody>
<tr>
<td>an old digital camera, cell phone, radio, computer, or other small electronic device that is no longer needed small tools such as screwdriver, tweezers, pick rubber gloves, 1-2 pairs library or internet resources chemical glass etching kit glass items for etching (if needed, may be obtained at a thrift store)</td>
<td>10 ml glass graduated cylinder glass eyedropper 60 ml (1/4 cup) water 60 ml (1/4 cup) rubbing alcohol 60 ml (1/4 cup) vegetable oil waterproofing substance, such as car wax, floor wax, silicone spray, or Scotch-Gard (small amount) additional water and vegetable oil (small amount)</td>
<td>red cabbage, 1 head distilled water, about 1 liter (1 quart) various solutions, such as: ammonia vinegar clear soda pop milk mineral water large saucepan knife several small jars white coffee filters eyedropper measuring cup measuring spoons marking pen scissors ruler See experiment for list of suggested natural materials for Just For Fun section</td>
<td>red cabbage indicator (from Experiment 3) household ammonia vinegar large glass jar measuring spoons measuring cup household solutions chosen by students (to test for acidity and basicity)</td>
<td>tincture of iodine a variety of raw foods, including: pasta bread celery potato banana (ripe) other fruits 1 unripe (green) banana liquid laundry starch (or equal parts borax and corn starch mixed in water) absorbent white paper eye dropper cookie sheet marking pen knife</td>
</tr>
<tr>
<td>Optional disposable glass tube Goo Gone or similar cleaner</td>
<td>Optional disposable glass tube Goo Gone or similar cleaner</td>
<td>Optional disposable glass tube Goo Gone or similar cleaner</td>
<td>Optional disposable glass tube Goo Gone or similar cleaner</td>
<td>Optional disposable glass tube Goo Gone or similar cleaner</td>
</tr>
<tr>
<td>[see page viii for product sources]</td>
<td>[see page viii for product sources]</td>
<td>[see page viii for product sources]</td>
<td>[see page viii for product sources]</td>
<td>[see page viii for product sources]</td>
</tr>
</tbody>
</table>

### Experiment 6
- plastic petri dishes*
- dehydrated agar powder*
- distilled water
- K-12 safe E. coli bacterial culture*
- inoculation loop*
- candle or gas flame candle
- mixing spoon
- oven mitt or pot holder
- measuring spoons
- measuring cup
- black permanent marker
- red marker
- rubber gloves, 2 pairs

* (See experiment for product sources.)
[see page viii for product sources]

### Experiment 7
- microscope with 4X, 10X, 40X objective lenses. A 100X objective lens is recommended but not required.*
- glass microscope slides*
- glass microscope cover slips*
- immersion oil (if using 100X objective lens)*
- Samples:
- piece of paper with lettering
- strands of hair
- droplet of blood
- insect wing

*(See experiment for information about how to choose a microscope and for supply sources.)
[see pages viii & ix for more information]

### Experiment 8
- microscope with a 10X objective*
- microscope depression slides*
- 10 or more eyedroppers
- fresh pond water or water mixed with soil (small amount)
- protozoa study kit *
- methyl cellulose*
- measuring cup and measuring spoons
- baker’s yeast
- distilled water
- Eosin Y stain*

*(See experiment for product sources.)
[see page viii for product sources]

### Experiment 9
- dehydrated agar powder*
- distilled water
- cooking pot
- measuring spoons
- plastic petri dishes*
- permanent marker
- oven mitt or pot holder
- jar with lid (big enough to hold 235 ml (about 1 cup) liquid
- 1 slice of bread, preferably preservative free
- small clear plastic bag
- white vinegar
- bleach
- borax
- mold or mildew cleaner
- 1-2 pairs rubber gloves

*(See experiment for product sources.)
[see page viii for product sources]

### Experiment 10
- One electronic circuit kit (see Experiment 10 for recommendations)

[see page viii for product sources]

### Experiment 11
- several glass marbles of different sizes
- several steel marbles of different sizes
- cardboard tube, .7-1 meter [2.5-3 ft] long
- scissors
- black marking pen
- ruler
- letter scale or other small scale or balance
<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>stopwatch</td>
<td>pencil or pen</td>
<td>pencil, pen,</td>
<td>computer with</td>
<td>Some suggestions</td>
</tr>
<tr>
<td>compass</td>
<td>marking pen</td>
<td>colored pencils</td>
<td>internet access</td>
<td>for student chosen</td>
</tr>
<tr>
<td>an open space</td>
<td>thumbtack or</td>
<td>with a small jar or container</td>
<td>(a program that</td>
<td>model making materials:</td>
</tr>
<tr>
<td>large enough</td>
<td>pushpin</td>
<td>with a lid</td>
<td>unzips files may be needed)</td>
<td>modeling clay of</td>
</tr>
<tr>
<td>to run (park,</td>
<td>pieces of string —</td>
<td>small items to place in</td>
<td>various colored cakes</td>
<td></td>
</tr>
<tr>
<td>schoolyard,</td>
<td>approximate sizes:</td>
<td>jar (student selected</td>
<td>materials for making</td>
<td></td>
</tr>
<tr>
<td>playground,</td>
<td>10 cm [4 in.]; 15 cm</td>
<td></td>
<td>paper mache</td>
<td></td>
</tr>
<tr>
<td>backyard, etc.)</td>
<td>6 in.]; 20 cm [8 in.]</td>
<td></td>
<td>Styrofoam balls</td>
<td></td>
</tr>
<tr>
<td>5 markers of</td>
<td>tape</td>
<td>ruler (metric)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>students'</td>
<td>large piece of white</td>
<td>large piece of paper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>choice to mark</td>
<td>paper (bigger than</td>
<td>(bigger than 30 cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>distances</td>
<td>10 cm [4 in.]; 15 cm</td>
<td>12 in.] square</td>
<td></td>
<td></td>
</tr>
<tr>
<td>blank paper</td>
<td>6 in.]; 20 cm</td>
<td>(can be several pieces</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a group of friends</td>
<td>[8 in.]</td>
<td>of paper taped)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>firm surface at least as</td>
<td>tape</td>
<td>firm surface at least as</td>
<td></td>
<td></td>
</tr>
<tr>
<td>large as the paper and</td>
<td>ruler (metric)</td>
<td>large as the paper and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>that a thumbtack can</td>
<td>large piece of white</td>
<td>that a thumbtack can</td>
<td></td>
<td></td>
</tr>
<tr>
<td>be pinned into</td>
<td>paper</td>
<td>be pinned into</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Experiment 17</th>
<th>Experiment 18</th>
<th>Experiment 20</th>
<th>Experiment 21</th>
<th>Experiment 22</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 liter (2 quart) plastic bottle with cap</td>
<td>two sticks (used for marking locations)</td>
<td>8 objects of different sizes to represent the planets</td>
<td>pencil colored pencils</td>
<td>computer with internet access</td>
</tr>
<tr>
<td>warm water</td>
<td>two rulers</td>
<td>ruler (in centimeters)</td>
<td>Optional</td>
<td>materials as needed for project chosen by students</td>
</tr>
<tr>
<td>matches</td>
<td>tape</td>
<td>marking pen</td>
<td>printer and paper</td>
<td>blank paper or notebook</td>
</tr>
<tr>
<td>blank paper</td>
<td>string, several meters long (several yards)</td>
<td>large flat surface for drawing — 1 x 1 meter (3 x 3 feet), such as a large piece of cardboard or several sheets of construction paper</td>
<td>several sheets</td>
<td></td>
</tr>
</tbody>
</table>

| Experiment 19 |   |   |   |   |
|---------------|   |   |   |   |
| computer with internet access |   |   |   |   |
| printer and paper |   |   |   |   |
| flashlight |   |   |   |   |
| Optional |   |   |   |   |
| binoculars or telescope |   |   |   |   |
| star map app and mobile device |   |   |   |   |
## Materials

### Quantities Needed for All Experiments

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Foods</th>
</tr>
</thead>
<tbody>
<tr>
<td>bottle, plastic, 2 liter (2 quart) with cap</td>
<td>baker’s yeast</td>
</tr>
<tr>
<td>compass</td>
<td>banana, 1 unripe (green)</td>
</tr>
<tr>
<td>computer with internet access</td>
<td>bread, 1 slice, preferably preservative free</td>
</tr>
<tr>
<td>cookie sheet</td>
<td>cabbage, red, 1 head</td>
</tr>
<tr>
<td>electronic circuit kit (see Chapter 10 for recommendations)</td>
<td>foods, raw-including: pasta, bread, celery, potato, banana (ripe),</td>
</tr>
<tr>
<td>electronic device, old-unneeded: digital camera, cell phone,</td>
<td>misc. fruits</td>
</tr>
<tr>
<td>radio, computer, or other small electronic device</td>
<td>vegetable oil, somewhat more than 60 ml (1/4 cup)</td>
</tr>
<tr>
<td>flashlight</td>
<td>vinegar</td>
</tr>
<tr>
<td>graduated cylinder, glass, 10 ml</td>
<td>vinegar, white</td>
</tr>
<tr>
<td>inoculation loop</td>
<td>water</td>
</tr>
<tr>
<td>knife</td>
<td></td>
</tr>
<tr>
<td>marbles, glass, several different sizes</td>
<td></td>
</tr>
<tr>
<td>marbles, steel, several different sizes</td>
<td></td>
</tr>
<tr>
<td>measuring cup</td>
<td></td>
</tr>
<tr>
<td>measuring spoons</td>
<td></td>
</tr>
<tr>
<td>microscope with 4X, 10X, 40X objective lenses. A 100X objective</td>
<td></td>
</tr>
<tr>
<td>lens is recommended but not required.</td>
<td></td>
</tr>
<tr>
<td>natural materials for Just For Fun section (see Exper. 2)</td>
<td></td>
</tr>
<tr>
<td>oven mitt or pot holder</td>
<td></td>
</tr>
<tr>
<td>pot, cooking</td>
<td></td>
</tr>
<tr>
<td>printer and paper or mobile device</td>
<td></td>
</tr>
<tr>
<td>protractor</td>
<td></td>
</tr>
<tr>
<td>ruler (in centimeters)</td>
<td></td>
</tr>
<tr>
<td>rulers, 2</td>
<td></td>
</tr>
<tr>
<td>saucepan, large</td>
<td></td>
</tr>
<tr>
<td>scale: letter, or other small scale or balance</td>
<td></td>
</tr>
<tr>
<td>scissors</td>
<td></td>
</tr>
<tr>
<td>spoon, mixing</td>
<td></td>
</tr>
<tr>
<td>stopwatch</td>
<td></td>
</tr>
<tr>
<td>tools, small - such as screwdriver, tweezers, pick</td>
<td></td>
</tr>
<tr>
<td>Optional</td>
<td></td>
</tr>
<tr>
<td>binoculars or telescope</td>
<td></td>
</tr>
<tr>
<td>mobile device</td>
<td></td>
</tr>
<tr>
<td>safety goggles</td>
<td></td>
</tr>
<tr>
<td>trowel, garden</td>
<td></td>
</tr>
</tbody>
</table>

1, 2, 3 [See following pages viii & ix for more information]
## Materials

### Quantities Needed for All Experiments

<table>
<thead>
<tr>
<th>Materials</th>
<th>Materials (continued)</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>agar powder, dehydrated</td>
<td>paper, blank</td>
<td>computer program that unzips files (may be needed)</td>
</tr>
<tr>
<td>ammonia, household</td>
<td>paper, blank, or notebook</td>
<td>flame, candle or gas</td>
</tr>
<tr>
<td>bag, clear plastic, small</td>
<td>paper, white (bigger than 30 cm [12 in.]) square (can be several pieces of paper taped)</td>
<td>friends, several</td>
</tr>
<tr>
<td>bleach</td>
<td>pen</td>
<td>open space at least 3 meters (10 feet) square</td>
</tr>
<tr>
<td>blood, 1 droplet</td>
<td>pen, black marking</td>
<td>open space large enough to run (park, schoolyard, playground, backyard, etc.)</td>
</tr>
<tr>
<td>borax</td>
<td>pen, marking</td>
<td>resources, library or internet</td>
</tr>
<tr>
<td>cleaner, mold or mildew</td>
<td>pencil</td>
<td>surface, firm, at least 30 cm [12 in.] square that a thumbtack can be pinned into surface, large, flat, for drawing: 1 x 1 meter (3 x 3 feet), such as a large piece of cardboard or several sheets of construction paper</td>
</tr>
<tr>
<td>coffee filters, white</td>
<td>pencils, colored</td>
<td>Optional</td>
</tr>
<tr>
<td>E. coli bacterial culture, K-12 safe</td>
<td>petri dishes, plastic</td>
<td>star map app (Exper. 19)</td>
</tr>
<tr>
<td>Eosin Y stain</td>
<td>protozoa study kit</td>
<td></td>
</tr>
<tr>
<td>eyedropper, glass, 1-2 dozen</td>
<td>pushpin or thumbtack</td>
<td></td>
</tr>
<tr>
<td>glass etching kit, chemical</td>
<td>rubbing alcohol, 60 ml (1/4 cup) solutions, household, chosen by students to test for acidity and basicity solutions, various—such as: ammonia, vinegar, clear soda pop, milk, mineral water starch, liquid laundry (or equal parts borax and corn starch mixed in water) sticks, 2 (used for marking locations) string, one meter (3 feet) long string, several meters long (several yards) string, 3 pieces—approximate sizes: 10 cm [4 in.]; 15 cm [6 in.]; 20 cm [8 in.] tape</td>
<td></td>
</tr>
<tr>
<td>glass items for etching (if needed, may be obtained at a thrift store)</td>
<td>tube, cardboard, .7-1 meter [2.5-3 ft] long water, distilled, 2 liters or more water, fresh pond water or water mixed with soil (small amount) waterproofing substance, such as car wax, floor wax, silicone spray, or Scotch-Gard (small amount)</td>
<td></td>
</tr>
<tr>
<td>gloves, 4-6 pairs, rubber</td>
<td>water</td>
<td></td>
</tr>
<tr>
<td>hair, several strands</td>
<td>matches</td>
<td></td>
</tr>
<tr>
<td>immersion oil (if using 100X objective lens)</td>
<td>materials as needed for project chosen by students</td>
<td></td>
</tr>
<tr>
<td>insect wing</td>
<td>methyl cellulose</td>
<td></td>
</tr>
<tr>
<td>iodine, tincture of</td>
<td>microscope cover slips, glass</td>
<td></td>
</tr>
<tr>
<td>items, misc. small, to place in jar (student selected treasure)</td>
<td>microscope slides, glass, depression</td>
<td></td>
</tr>
<tr>
<td>jar with lid (big enough to hold 235 ml (about 1 cup liquid)</td>
<td>microscope slides, glass, regular</td>
<td></td>
</tr>
<tr>
<td>jar, glass, large</td>
<td>objects of students’ choice to mark distances</td>
<td></td>
</tr>
<tr>
<td>jar, small with lid, or small container with lid</td>
<td>paper, 5 items of students’ choice to mark distances</td>
<td></td>
</tr>
<tr>
<td>jars, small, several markers, black permanent</td>
<td>matches</td>
<td></td>
</tr>
<tr>
<td>marker, red</td>
<td>optional model making materials, such as:</td>
<td></td>
</tr>
<tr>
<td>markers, 5 items of students’ choice to mark distances</td>
<td></td>
<td>clay, modeling, different colors</td>
</tr>
<tr>
<td>matches</td>
<td></td>
<td>ball, steel, or marble</td>
</tr>
<tr>
<td>materials as needed for project chosen by students</td>
<td></td>
<td>ingredients for various colored cakes</td>
</tr>
<tr>
<td>methyl cellulose</td>
<td></td>
<td>paper mache materials</td>
</tr>
<tr>
<td>microscope cover slips, glass</td>
<td></td>
<td>balls, Styrofoam</td>
</tr>
<tr>
<td>microscope slides, glass, depression</td>
<td></td>
<td></td>
</tr>
<tr>
<td>microscope slides, glass, regular</td>
<td></td>
<td></td>
</tr>
<tr>
<td>objects of students’ choice</td>
<td></td>
<td></td>
</tr>
<tr>
<td>objects, 8 of different sizes to represent the planets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>paper with lettering, small piece</td>
<td></td>
<td></td>
</tr>
<tr>
<td>paper, absorbent white</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[1, 2, 3] [See following pages viii & ix for more information]
Materials information for Experiments 6, 7, 8, 9, 10

Suggested source for the following supplies (except Experiment 10):
(Suppliers may discontinue items from time to time. Substitutes can be found by doing an internet search.)

Experiment 6 Using Agar Plates

- plastic petri dishes: A stack of 20 can be ordered from:
- dehydrated agar powder
  http://www.hometrainingtools.com/nutrient-agar-8-g-dehydrated/p/CH-AGARN08/
- K-12 safe E. coli bacterial culture
- inoculation loop

Experiment 7 Using a Light Microscope

- glass microscope slides — MS-SLIDP72 or MS-SLIDEPL
- glass microscope cover slip — MS-SLIDCV
- immersion oil — MI-IMMOIL
- How To Buy a Microscope [see page ix]

Experiment 8 Observing Protists

- Glass Depression Slides, MS-SLIDC72 or MS-SLIDC12
- Basic Protozoa Set, LD-PROBASC (must be used within 1-2 days of arrival)
- Methyl Cellulose, CH-METHCEL
- Eosin Y, CH-EOSIN

Experiment 9 Moldy Growth

See Experiment 6 above for petri dishes and agar

Experiment 10 Using Electronics

One of the following recommended electronic circuit kits:
- Snap Circuits: http://www.snapcircuits.net/Snap Circuits Jr. 100 Kit

Note: Websites and product availability change over time. If these products are no longer available, do an internet search on children's electronic circuit kits to find a kit suitable for this experiment.
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.
## Contents

### INTRODUCTION
- Experiment 1  
  Take It Apart!  
  
### CHEMISTRY
- Experiment 2  
  Reading the Meniscus  
- Experiment 3  
  Making an Acid-Base Indicator  
- Experiment 4  
  Vinegar and Ammonia in the Balance  
- Experiment 5  
  Show Me the Starch!  

### BIOLOGY
- Experiment 6  
  Using Agar Plates  
- Experiment 7  
  Using a Light Microscope  
- Experiment 8  
  Observing Protists  
- Experiment 9  
  Moldy Growth  

### PHYSICS
- Experiment 10  
  Using Electronics  
- Experiment 11  
  Moving Marbles  
- Experiment 12  
  Accelerate to Win!  
- Experiment 13  
  Around and Around  

### GEOLOGY
- Experiment 14  
  Hidden Treasure  
- Experiment 15  
  Using Satellite Images  
- Experiment 16  
  Modeling Earth’s Layers  
- Experiment 17  
  Exploring Cloud Formation  

### ASTRONOMY
- Experiment 18  
  Measuring Distances  
- Experiment 19  
  Using a Star Map  
- Experiment 20  
  Modeling Our Solar System  
- Experiment 21  
  Discovering Life on Other Planets  

### CONCLUSION
- Experiment 22  
  Working Together  


## Experiment 3

Making an Acid-Base Indicator

### Materials Needed

- one head of red cabbage
- distilled water, about 1 liter (1 quart)
- various solutions, such as: 
  - ammonia
  - vinegar
  - clear soda pop
  - milk
  - mineral water
- large saucepan
- knife
- several small jars
- white coffee filters
- eyedropper
- measuring cup
- measuring spoons
- marking pen
- scissors
- ruler

### Suggested Natural Materials for Just For Fun (help students select several)

- Turmeric
- Poppyseed or cornflower petals
- Madder plant (Rubiaceae family)
- Red beets
- Rose petals
- Berries
- Blue and red grapes
- Cherries
- Geranium petals
- Morning glory
- Red onion
- Petunia petals
- Hibiscus petals (or hibiscus tea)
- Carrots
- Other strongly colored plant materials of students’ choice
Objectives

In this experiment students will be introduced to the concepts of acids, bases, pH, and pH indicators.

The objectives of this lesson are for students to:

- Observe that acids and bases have different properties that can be tested for.
- Use controls in an experiment.

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 do you think an acid is?
- What liquids can you think of that are acids?
- What do you think a base is?
- What liquids can you think of that are bases?
- How would you find out if a solution is an acid or a base?
- Do you think you use acids and bases in your everyday life? Why or why not?

II. Experiment 3: Making an Acid-Base Indicator

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

Objective: Have the students write an objective. An example:

- We will make an acid-base indicator from red cabbage and use it to determine whether solutions are acidic or basic.

Hypothesis: Have the students write a hypothesis. An example:

- We can use an indicator to identify solutions as acidic or basic.
EXPERIMENT

In this experiment the students will use “controls.” A control is an experiment where the outcome is already known or where a given outcome can be determined. The control provides a point of reference or comparison for experiments that use unknowns. For example, in this experiment the students will test for acidity or basicity with a pH indicator, but they do not know what the expected color change will be. By doing controls with solutions that they know are either acidic (vinegar) or basic (ammonia), they can determine what the color change for an acid is and what the color change for a base is. Only then can they test the “unknown” solutions.

The liquids in the materials list include both acids and bases. Milk in neutral. Have the students be careful when handling ammonia. Other suggested items to test include:

- water (neutral)
- Windex or other glass cleaner (basic)
- Lemon juice or orange juice (acidic)
- White grape juice (acidic)

1-3 Have the students prepare red cabbage juice indicator. Have them cut a head of red cabbage into several pieces, put the pieces in about .7 liter (3 cups) of boiling distilled water, and boil the cabbage for several minutes until the liquid is a deep purple color. Have them remove the cabbage and let the water cool.

4 Have the students set aside .25 liter (1 cup) of the red cabbage juice and refrigerate the rest to use in the next experiment. It is important to refrigerate the cabbage juice or it will spoil and cannot be used for the next experiment. It should keep about two weeks in the refrigerator.

5 Have the students cut 20 or more strips of coffee filter paper that are about 2 cm (3/4 in.) by 4 cm (1½ in.) for testing the solutions.

6 Students will make pH paper by using an eyedropper to put several drops of the red cabbage juice on each strip of coffee filter paper and letting it dry. If the cabbage indicator is added to the strips of paper several times and dried in between, the color change when testing the liquids will be more dramatic.

7 Have the students label one jar Control Acid. They will make the control acid by putting in the jar 15 ml (1 tbsp.) of vinegar and 75 ml (5 tbsp.) of distilled water.

A second jar will be labeled Control Base. Students will make the control base by putting in the jar 15 ml (1 tbsp.) of ammonia and 75 ml (5 tbsp.) of distilled water.

Have the students label a jar for each of the solutions they will be testing and then put 15 ml (1 tbsp.) of each substance in the appropriate jar along with 30-75 ml (2-5 tbsp.) of distilled water.
Students will test the Control Acid and the Control Base by dipping an unused strip of pH paper into each. Have them record their results and tape the pH papers into their Laboratory Notebook in the chart in the Results section.

The vinegar (control acid) should turn the paper pink.
The ammonia (control base) should turn the paper green.

The color change of the pH paper may be quick and noticeable or it may be subtle. It is best to have the students look at the paper immediately after it has been dipped into the solution. If it is too difficult to determine the color change of the paper, the cabbage indicator can be used directly in the solution. Have the students pour a small amount (5-10 ml [1-2 teaspoons]) into the solution and record the color change.

Have the students test the remaining solutions and record their results.

III. Conclusions

Have the students review the results they recorded for this experiment. Have them draw conclusions based on the data they collected. Help the students to be specific and to make valid conclusions from their data. If a solution did not change color, but the experimental controls worked, it is probably true that the solution is neutral or near neutral. However, if no color change is observed or if the result is ambiguous, it may not be true that the solution is neutral, and it may be true that the color change is too subtle to be easily perceived.

Have the students draw conclusions even if they experienced difficulties with the experiment.

IV. Why?

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

V. Just For Fun

Students will test different natural materials to see if they are acid-base indicators.

Help the students select and gather the materials to be tested. Have them use several materials from the list provided, and they can also try other natural materials that have a strong color. Students can use their control acid and base or other solutions that they have identified as acidic or basic.

Have the students crush (or chop) the material to be tested and put some of it in each of two small jars. They then will add an acid to one jar and a base to the other and note whether there is a color change. If there is no color change, you can direct them to make a stronger solution of the acid and base they have chosen and see if this makes a difference. They can also experiment with adding a little distilled water to the material being tested before adding the acid or base. In the chart provided, have the students record their results including whether or not they think the material is an acid-base indicator.
Some examples:

- Turmeric powder will turn red in a base (will be yellow at pH 7.4 and red at pH 8.6).
- Poppyseed or cornflower petals contain the same chemical as red cabbage and will undergo a similar color change.
- Madder plant (Rubiaceae) will turn from yellow to red in a weak base (yellow at pH 5.5 and red at pH 6.8).
- Cherries and cherry juice turn from red to purple in a base.

**Additional Notes**

An acid-base reaction is a type of exchange reaction. In the example illustrated in this chapter of the textbook, the molecules are not drawn with the bonds showing, and on first inspection it appears that the central carbon of both molecules has broken the rule of “4 bonds for carbon.” Also, two of the oxygens appear to have broken the rule for “2 bonds for oxygen.” However, in each case the bond between the central carbon atom and one of the oxygen atoms is a double bond. Double bonds are beyond the scope of this level, but all of the bonding rules are satisfied.

pH is actually a measure of the hydrogen ion concentration (written as [H]). The pH scale is important, but mathematically and conceptually the actual definition of pH is too difficult for this level. (The mathematical expression for pH is: $pH = -\log [H]$)

The higher the hydrogen ion concentration, the lower the pH; the lower the hydrogen ion concentration, the higher the pH. The hydrogen ion concentration is the real definition of what is meant by “acid” in this chapter.

Scientists measure pH with pH meters, pH paper, or solution indicators, with the use of the pH meter being the most common laboratory technique. There are a variety of pH meters and electrodes available. The most common electrode is called a glass electrode. There is a small glass ball at the end of this electrode that senses the pH electrically.

Before pH meters, pH paper was the most common way to measure pH. Litmus paper can still be found in most laboratories along with other types of pH paper. Litmus paper is made with a compound called an indicator. An indicator is any molecule that changes color as a result of a pH change.

There are two types of litmus paper—blue litmus paper tests for acidic solutions, and red litmus paper tests for basic solutions. Litmus paper is not suitable for determining the exact pH; it can only indicate whether a solution is acidic or basic. Other types of pH paper can more accurately determine the actual pH.

The chart in this section of the *Student Textbook* shows some common indicators used in the laboratory and is meant to illustrate that there are a variety of pH indicators that can be used over a wide range of pH. Often pH indicators are mixed so that more than one pH range can be detected. The names of some of these indicators are difficult to pronounce, but many of them can be looked up in a dictionary, encyclopedia, or online for pronunciation guidance.
Experiment 7

Using a Light Microscope

Materials Needed

- microscope with 4X, 10X, and 40X objective lenses. A 100X objective lens is recommended but not required.
- glass microscope slides
- glass microscope cover slips
- immersion oil (if using 100X objective lens)
- Samples:
  - piece of paper with lettering
  - strands of hair
  - droplet of blood
  - insect wing

Suggested source: http://www.hometrainingtools.com/

1 glass microscope slides
   MS-SLIDP72 or MS-SLIDEPL
2 glass microscope cover slip
   MS-SLIDCV
3 immersion oil
   MI-IMMOIL
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.
You can see as the magnification increases the numerical aperture increases (which means the resolution increases) and the working distance decreases.

Choosing the right lens for the right sample is part of the art of microscopy.

Most student projects can be achieved with a 40X objective, however a 100X objective lens can be added to make observing bacteria and small cell structures possible.

Below is a general chart showing the recommended objective lens to use for different types of samples.

<table>
<thead>
<tr>
<th>Magnification</th>
<th>Numerical Aperture</th>
<th>Working Distance (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4X</td>
<td>0.10</td>
<td>30.00</td>
</tr>
<tr>
<td>10X</td>
<td>0.25</td>
<td>6.10</td>
</tr>
<tr>
<td>20X</td>
<td>0.40</td>
<td>2.10</td>
</tr>
<tr>
<td>40X</td>
<td>0.65</td>
<td>0.65</td>
</tr>
<tr>
<td>60X</td>
<td>0.80</td>
<td>0.30</td>
</tr>
<tr>
<td>100X (oil)</td>
<td>1.25</td>
<td>0.18</td>
</tr>
</tbody>
</table>
In this experiment students will explore how to use a microscope.

**Objectives**

The objectives of this lesson are for students to:

- Practice using a microscope.
- Observe small details.

**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 a 10X lens will magnify more than a 4X? Why or why not?*
- *Do you think a 100X lens will magnify more than a 10X? Why or why not?*
- *Do you think it will be easier or harder to focus a 4X objective than a 10X objective? Why or why not?*
- *Do you think it will be easier or harder to focus a 10X objective than a 100X objective? Why or why not?*

**II. Experiment 7: Using a Light Microscope**

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

**Objective:** Have the students think of an objective for this experiment (What will they be learning?).

**Hypothesis:** Have the students write a hypothesis. The hypothesis can restate the objective in a statement that can be proved or disproved by their experiment. Some examples:

- *Paper magnified 40X will show fibers.*
- *The ink on paper will look different at 40X and 100X.*
- *I will be able to see blood cells at 40X.*
- *I will only be able to see blood cells at 100X.*
EXPERIMENT

NOTE: As students are turning the turret to change lenses, help them be extremely careful not to bang the lenses on the stage or glass slide. This can damage the lenses.

Part I: The Microscope

1-6 Have the students follow the instructions in the Laboratory Notebook to observe the parts of the microscope and how the different parts work. Have them label the parts of the microscope in the diagram provided.

Part II: Observing a Sample

Help the students avoid scraping any of the samples with the objective lenses.

1-6. Have the students take a small piece of paper that has lettering on it and place it on a glass slide in the microscope without a cover slip. Have them examine it using the 4X and 10X objective as instructed. Paper is considered a “bulky” sample, so the low magnification lenses are used. Do not have the students use a higher power lens because it could get damaged. In the spaces provided, have them record their observations.
7. Have the students turn the turret to move the lowest power objective back into place.  
**[NOTE: If they have a 100X objective, do not let them rotate the turret through this lens.  
If the lens scrapes the slide, it can ruin the lens. Instead, have them turn the turret in the  
opposite direction until the lowest power lens is back in place]**

8–14. Have the students create a glass slide with fresh blood. Have them wash their hands  
and then collect a drop of blood by pricking a finger with a needle that has been sterilized  
in a candle flame. Blood is a great sample to observe in a microscope because it will flow for  
a few minutes before it dries which will coat the area under the coverslip, making it easy to  
find and focus. Have the students start with the lowest power objective lens (4X) and move  
to the higher powered objective lenses one at a time, focusing each one as they go. If you  
plan to have them use a 100X objective lens, help them place a drop of immersion oil on  
the coverslip and very carefully rotate the turret to click the lens into place. It is very easy to  
smash the sample surface and ruin the lens, and if this seems about to happen, have them  
back the lens up one or two turns with the fine adjust knob. Have them always use only the  
fine adjustment knob with the 100X lens to avoid hitting the slide.

Have them adjust the condenser to get more light.

Each time the students look at the sample through a different lens, have them record their  
observations in writing and by drawing what they see.

15. Have the students rotate the turret to move the 100X immersion lens away from the sample.  
Then they can use the coarse adjustment knob to lower the stage and remove the sample.

16. Have them repeat the experiment with other samples, such as hair, pond water, or an insect  
wings. Have them look at each sample beginning with the lowest power lens and rotating  
through to the highest power, focusing the image each time before moving to the next  
highest power lens.

### III. Conclusions

Discuss how easy or difficult the students found the use of the microscope. Using a microscope  
is an art, and learning how to use one correctly takes time and patience. Have the students note  
whether their conclusions support or do not support their hypothesis.

### IV. Why?

Read this section of the *Laboratory Notebook* with your students.  
Discuss how the different objectives magnified the samples with different degrees of resolution  
and focal length.

### V. Just For Fun

Have the students use the microscope to observe other samples of their choice. Have them  
write and draw their observations.
Experiment 19

Using a Star Map

Materials Needed

• computer with internet access
• printer and paper
• flashlight

Optional

• binoculars or telescope
• star map app and mobile device
Objectives

In this experiment students will learn how to use a star map to identify stars.

The objectives of this lesson are to have students:

- Learn how to use a star map.
- Observe how a star map changes with the months and seasons.

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 many stars do you think are in the night sky? Why?*
- *Do you think you could see more stars with a telescope than with your unaided eyes? Why or why not?*
- *If your job was to map all the stars you could see, how would you do it? Do you think there is more than one way to map stars?*
- *Do you think astronauts need to know anything about the stars? Why or why not?*

II. Experiment 19: Using a Star Map

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

**Objective:** Have the students think of an objective for this experiment (What will they be learning?)

**Hypothesis:** This is an observational experiment so there is no hypothesis.

**EXPERIMENT**

1. Have your students go to the Starmap site at http://www.star-map.fr/ and click on the Free Maps menu tab. A list of star maps for the Northern Hemisphere will come up. Under this list are three dots that when clicked will bring up a screen for maps of either the Equatorial Zone or the Southern Hemisphere.

Another resource for free star maps is the website www.skymaps.com.

[Note: Should these websites becomes unavailable, do a browser search for “free star maps” to find another resource.]
On the Starmap site, the students will select the hemisphere for their location, the map version to be downloaded, and the time they are to view the stars (20 pm is 8:00 pm and 22 pm is 10:00 pm). Have them click the correct link to download the map. Have them print the map.

This site also has inexpensive apps for mobile devices: however, these apps locate the stars when the mobile device is pointed at them, so have the students first make observations by using the downloadable star maps. Other apps are also available and can be found with a browser search.

Have the students make sure the map they’ve downloaded is for the correct hemisphere, then have them study the map. Read the comments on the left side of the map with your students. Note that many of the stars and constellations can be seen with the unaided eye, but some require a pair of binoculars or a telescope.

On an evening that is clear of clouds, have your students go outside at the time recommended for the map they’ve downloaded. Have the students first spend some time just observing the stars.

If you live where it is difficult to see many stars because of artificial outdoor lighting, you may need to travel to a darker location.

Have the students hold the map face down above their head so they can see it and the night sky. Then have them orient the map to the stars in the sky.

Using the star map as a guide, have the students look for constellations as landmarks. Once they have found a few constellations, have them make their own star map by recording the constellations they see. On the map they create, have them note the magnitude of the stars, planets, or other objects and their location. Space is provided in the Results section for the map to be drawn.

Results

Space is provided for drawing a star map.

III. Conclusions

Have the students answer the questions and draw conclusions based on their observations.

IV. Why?

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

V. Just For Fun

Have the students repeat the experiment in a month, making a second map. Then have them compare their two maps to determine whether the star locations have changed and to note any other observations they may have.
Exploring The BUILDING BLOCKS of SCIENCE Book 6 LESSON PLAN

REBECCA W. KELLER, PhD
LESSON PLAN INSTRUCTIONS

This Lesson Plan is designed to accompany Exploring the Building Blocks of Science Book 6 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.
# LESSON PLAN—Exploring the BUILDING BLOCKS of SCIENCE BOOK 6

## CHAPTER 3: ACIDS, BASES, AND pH

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

### Objectives
- To explore the nature of acids and bases.

### Educational Standard*
- Content Standard B: Physical Science: Grade 5-8
  Substances are often placed in groups if they react in similar ways.


### Activity
- Laboratory Experiment 3
- Other _____________________

### Connections
- History
  - Look up Michael Faraday and discuss his contribution to our understanding of acids and bases.
- Philosophy
  - Look up the philosopher Empedocles and discuss how his ideas may or may not have contributed to our understanding of the nature of acids and bases.
- Art, Music, Math
  - Explore how acids and bases are used in creating a variety of artistic works (e.g., chemical etchings)
- Technology
  - Discuss how the development of the pH meter helped further research in the area of acid-base chemistry.
- Language
  - Look up the word *concentrated* in a dictionary or encyclopedia. Discuss the meaning of the word *concentrated*.

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

### Notes
### LESSON PLAN—Exploring the BUILDING BLOCKS of SCIENCE BOOK 6

#### CHAPTER 7: THE MICROSCOPE

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

**Objectives**
- To explore how the microscope has helped us study biology.

**Educational Standard***
- Content Standard E: Science and Technology: Grade 5-8
  - Technology is essential to science because it provides instruments that enable observations of objects that would otherwise be unobservable.


**Activity**
- □ Laboratory Experiment 7
- □ Other _____________________

**Connections**
- □ History Discuss the history of the microscope and how early microscopes helped open new doors for biology.
- □ Philosophy Discuss how the microscope has changed our understanding of life.
- □ Art, Music, Math Explore how color, shape, and form help microscopists create meaningful images for scientific study.
- □ Technology Discuss how the microscope has shaped the science of biology.
- □ Language Look up the word *microscope* in a dictionary or encyclopedia. Discuss the meaning of the word *microscope*.

**Assessment**
- □ Self-review
- □ Self-test
- □ Other _____________________

**Notes**
LESSON PLAN — Exploring the BUILDING BLOCKS of SCIENCE BOOK 6

CHAPTER 19: TIME, CLOCKS, AND THE STARS

<table>
<thead>
<tr>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
</tr>
</thead>
<tbody>
<tr>
<td>🌨️</td>
<td>🌟</td>
<td>🎨</td>
<td>🕹️</td>
<td>🎬</td>
</tr>
</tbody>
</table>

**Objectives**  
To explore the nature of time.

**Educational Standard**
Content Standard D: Earth and Space: Grade 5-8  
Most objects in the solar system are in regular and predictable motion.


**Activity**
- ☑️ Laboratory Experiment 19
- ☑️ Other _____________________

**Connections**
- ☑️ History  
  Look up Friedrich Argelander and discuss his work.
- ☑️ Philosophy  
  What are some philosophical ideas about time and space?
- ☑️ Art, Music, Math  
  Explore how art is used to illustrate the cosmos.
- ☑️ Technology  
  Explore the types of technology used to study the stars.
- ☑️ Language  
  Look up the word *uranography* in a dictionary or encyclopedia. Discuss the meaning of the word *uranography*.

**Assessment**
- ☑️ Self-review
- ☑️ Self-test
- ☑️ Other _____________________

**Notes**
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 _____________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________

__________________________________________________________________
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.
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

What is soap?
Explain with words or pictures the relationship between soap as a **product** and the **components** it is made of.

Product:

Do you like coffee? 😊
Pick a random liquid in your kitchen and try to guess where it would land on the acid-base scale.

Why do you think this?

How could you test it?
CHAPTER VII

How do you think Hans Janssen’s work as a lens maker led to the creation of the microscope?
How does light interacting with glass allow us to see things differently?
What is the importance of scale to observing things in the world?

Why is something small and why is something big?

What kind of microscope would you like to use?
CHAPTER XIX

Make your own Star Atlas.
How does solar time work?
If you could live by any type of time you chose, what would it be?
Building Blocks of Science Book 6
Midterm 1 Chapters 1-11, 30 questions, 10 points each
Sample questions Chapters 3 & 7

4. In chemistry concentration is defined as... (Check all that apply.) (10 points)
   - The number of units in a given volume.
   - An acid-base reaction.
   - An acid-base indicator.
   - How hard you can think.
   - Paper made with lichens.
   - How strong or weak a solution is.

5. Scientists use a pH meter to accurately determine the strength or weakness of an acidic or basic solution. (10 points)
   - True
   - False

6. Some properties of an acid are that it... (Check all that apply.) (10 points)
   - Is always pink or red.
   - Tastes bitter.
   - Never reacts with a base.
   - Is not slippery to the touch.
   - Is sour tasting.
   - Can dissolve metals.
   - Has a neutral pH.

16. 1 micrometer is smaller than 1 nanometer. (10 points)
   - True
   - False

17. The amount of detail that can be seen clearly through a light microscope is determined by... (10 points)
    - The quality of the objective lens.
    - The scanner.
    - The probe.
    - The quality of the eyepiece.
    - The electrons.
18. Probe microscopes...
   (Check all that apply.) (10 points)
   - Scan the surface of a sample and project an image of it onto a computer monitor.
   - Are controlled by a computer.
   - Cannot visualize atoms.
   - Use light and objective lenses to view a sample.
   - Make it possible to "see" atoms.

Building Blocks of Science Book 6
Midterm 1 Chapters 1-11, 30 questions, 10 points each
Sample questions Chapters 3 & 7

4. The number of units in a given volume., How strong or weak a solution is.
5. True
6. Is not slippery to the touch., Is sour tasting., Can dissolve metals.

16. False
17. The quality of the objective lens.
18. Scan the surface of a sample and project an image of it onto a computer monitor., Are
   controlled by a computer., Make it possible to "see" atoms.
Building Blocks of Science Book 6  
Midterm 2 Chapters 12-22, 30 questions, 10 points each  
Sample questions Chapter 19

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

- Star map
- Constellation
- Sideral time
- Sundial
- Mean solar time
- Celestial clock
- Uranography

a. Measures time and also the astronomical movements of celestial bodies.
b. The mapping of the stars.
c. An average of apparent solar time.
d. Measures time based on the position of a distant star.
e. Certain named groups of stars.
f. Measures apparent solar time.
g. Shows the locations of stars and other celestial bodies.

23. If you want a "road map" of the night sky that maps the location and brightness of stars, planets, and other celestial bodies, you would get a... (10 points)

- Sideral timepiece.
- IAU.
- Star atlas.
- Sundial.
- Telescope.

24. The stars change position in the sky from one month to the next and during the night. (10 points)

- True
- False

Answer Sheet
Building Blocks of Science Book 6
Final Quiz Chapters 1-22, 40 questions, 10 points each
Sample questions Chapters 3, 7, 19

3. **Svante Arrhenius developed a theory that...** (10 points)
   - In water acids produce hydrogen ions (H+) and bases produce hydroxide ions (OH-).
   - Acids and bases are very similar.
   - pH meter probes can break.
   - Acids and bases react.
   - Litmus paper can be useful.

4. **pH can be tested by using...** (Check all that apply.) (10 points)
   - □ A digital scale.
   - □ A volumetric pipet.
   - □ Acid-base indicators.
   - □ pH paper.
   - □ pH meters.
   - □ A Roberval balance.

11. **Some parts of a light microscope include...** (Check all that apply.) (10 points)
    - □ Light source.
    - □ Stage.
    - □ Adjustment knobs.
    - □ Solenoid.
    - □ Objective lens.
    - □ Electron gun.
    - □ Ocular lens.
    - □ Protist.
    - □ Stylus.

12. **Some scanning probe microscopes can move atoms to specific locations and make tiny structures.** (10 points)
    - □ True
    - □ False
35. Sidereal time and apparent solar time are the same thing. (10 points)
   - True
   - False

36. Constellations... (Check all that apply.) (10 points)
   - Are obsolete.
   - Can be made up by anyone.
   - Can be used for navigation.
   - Are often shown on star maps.
   - Are certain patterns of stars that have names.
Concentrated solution of hydrochloric acid (HCl) in water

Dilute solution of hydrochloric acid (HCl) in water
SEM micrographs
Image credits: 1. Mosquito Head, CDC/Paul Howell; 2. Human neutrophil with bacteria, NIH; 3. Arabidopsis Leaf, Mark Talbot/CSIRO;
4. Insertion point of moth scale, CDC/Janice Carr, Oren Mayer; 5. Insect leg, CDC/Janice Carr; 6. Corona virus, NIAID
OK, I'VE GOT THIS LINED UP WITH POLARIS.