ACTIVITY 8.1.2 ***Advance Organizers in Your Science Text***

Textbook authors and publishers use "traffic signs" to inform readers about the structure and content of the book. Research has shown that these advance organizers help students learn and remember new material by developing structures or schemas into which new information can be placed. Sadly, many students ignore these signs and spend much more time reading than necessary, yet with minimal understanding and retention.

Before reading a textbook, you should study its structure and features. Complete the following activity for a chapter that your science instructor assigns. By understanding the structure of the text, you will understand the structure of the discipline and be better able to integrate new ideas into your existing mental outline.

Organization of the Book

Special features: What are the unique or special features of this book? Most authors write a preface to explain their purpose in writing and describe the special features of their work.

Themes: What are the major themes of your textbook? Most authors group chapters in units with names that reflect the major themes of the book.

Topics: What are the main topics of the unit you are studying? This can generally be deduced from the chapter titles.

Organization of the Chapter

Objectives: What are the goals or objectives of the chapter you are studying? These are frequently listed at the beginning of the chapter.

Subtopics: What are the subtopics of the chapter? The subtopics are the division headings within chapters, often shown in **BOLDFACE CAPITALS**.

Major points: What are the major points of the section you are now studying? The major points are generally shown in **lowercase bold letters.**

Key terms: What are the key terms of the section you are now studying? In most textbooks, the key terms are shown in *italics* or **bold** letters.

8.2 Orders of Magnitude: The Universe in Powers of Ten

"How wide is the Milky Way galaxy?" "How small is a carbon atom?" These questions may sound simple, but their answers are virtually impossible to comprehend since nothing in our realm of experience approximates either of these measures. To grasp the magnitude of such dimensions is perhaps impossible, but it is relatively easy to express such dimensions by scaling up or down (expressing them in orders of magnitude greater or smaller) from things with whose dimensions we are familiar. An order of magnitude is the number of powers of 10 contained in the number and gives a shorthand way to describe scale. An understanding of scale allows us to organize our thinking and experience in terms of size and gives us a sense of dimension within the universe.

ACTIVITY 8.2.1 ***Understanding Powers of Ten***

Note: This is an Internet-based activity.

To simplify the expression of very large and small numbers, scientists often use *scientific notation.* Scientific notation involves writing a number as the product of two numbers. The first one, the digit value, is always more than 1 and less than 10. The other, the exponential term, is expressed as a power of 10. Table 8.3 compares decimal and scientific notation.

The diameter of the Milky Way Galaxy is believed to be about 1,000,000,000,000,000,000,000 meters. By contrast, the diameter of the nucleus of a carbon atom is only approximately 0.000 000 000 000 01 meters. In scientific notation, the diameter of the Milky Way is 1×10^{21} m, and the diameter of the carbon nucleus is 1×10^{-14} m. The Milky Way is therefore approximately 10^{35} times (35 orders of magnitude) larger than the carbon atom. Calculators and computers may express the dimensions of the Milky Way and the carbon nucleus as 1.0E21 and 1.0E-14, where E stands for the exponential term. The speed of light, approximately 300 million (299,792,458) m

Table 8.3 Decimal and Scientific Notation

Decimal Notation	Scientific Notation	Order of Magnitude	Decimal Notation	Scientific Notation	Order of Magnitude
.001	1×10^{-3}	-3	10	1×10^{1}	1
.01	1×10^{-2}	-2	100	1×10^{2}	2
.1	1×10^{-1}	-1	1,000	1×10^{3}	3
1	1×10^{0}	0	10,000	1×10^{4}	4

per second, is expressed in scientific notation as approximately 3.0×10^{8} m/s (3.0E8). Avogadro's number, the number of molecules in a mole (602 213670000000000000000), is expressed as 6.02×10^{23} (6.02E23).

Scientific notation is particularly helpful when trying to express the scale of the universe. In 1957, Dutch educator Kees Boeke published *Cosmic View: The Universe in 40 Jumps,* in which he helped readers visualize the size of things in the known universe with reference to a square meter (10^{0} $m^{2} = 1$ m^{2}).[2] In this book, Boeke showed successively smaller pictures, each one a tenth the dimension of the previous (10^{-1} m, 10^{-2} m, 10^{-3} m, and so on) as well as successively larger pictures, each ten times larger than the previous (10^{1} m, 10^{2} m, 10^{3} m, and so on). A number of moviemakers[3] and Web developers have followed Boeke's idea in an effort to help people understand the scale of things in the universe. After examining "powers of ten" resources online (look on *sciencesourcebook.com* or www.powersof10.com, or search "powers of ten"), perform the following investigation.

Figure 8.2 displays millimeter graph paper. The tiny black square in the upper left corner is 1 mm on a side, (10^{-3} meters). The sides of the gray square in the upper left corner are an order of magnitude greater than the black square (10 mm per side, 10^{-2} m). Finally, the sides of the entire sheet, with 100 mm per side (10^{-1} m), are two orders of magnitude greater than the black square and one order of magnitude greater than the gray square.

Working with your classmates, create a square meter (1000 mm on a side) by taping 100 of these squares together in a 10×10 square. This is 1 square meter with sides and area three orders of magnitude greater than the square millimeter represented by the tiny black box. Measuring with a meter stick, place markers at the four corners of a 10 m square in one corner of your school's football field. This is four orders of magnitude greater than the original black square (1×10^{4} times larger). If space permits, mark out a 100 m square as shown in Figure 8.3. This square has sides that are five orders of magnitude larger (1×10^{5}) than the original black square.

You may continue to increase the order of magnitude by using satellite photos of your campus that are available on the Internet (look on *sciencesourcebook.com*, satellite view at maps.google.com, or earth.google.com). By zooming out of the satellite photo such that the football field represents approximately only one-tenth of

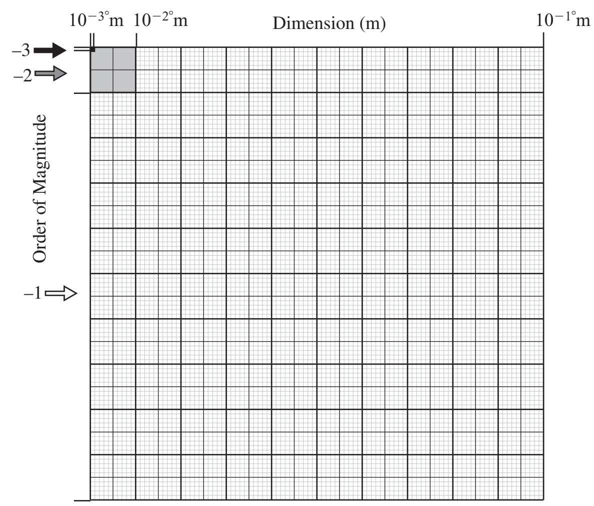

Figure 8.2 Orders of Magnitude $-3, -2, -1$

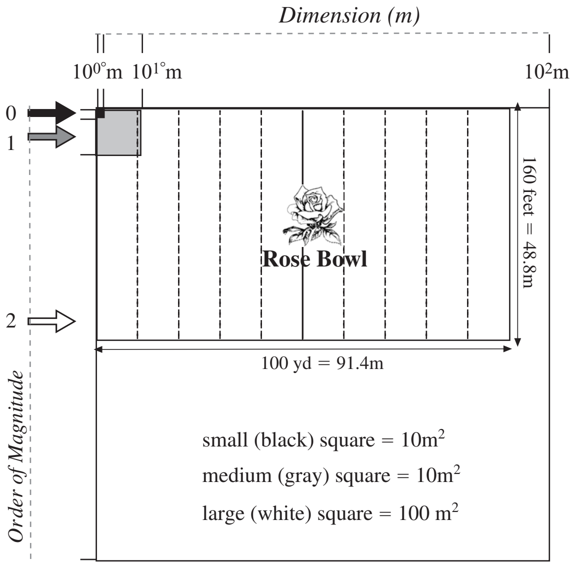

Figure 8.3 Orders of Magnitude 0, 1, 2

the field of view (Figure 8.4), you have reached the sixth order of magnitude.

Some mapping programs may allow you to zoom out to the diameter of the Earth, approximately 1.3×10^{10} mm, or ten orders of magnitude greater than the 1 m square you started with. If you have a digital microscope, continue the process in the reverse direction by viewing a leaf to 1×10^{-5} m (one-hundredth of a millimeter). Now that you have experienced a range in orders of magnitude, identify one or more common items for each of the sizes listed in Table 8.4.

ACTIVITY 8.2.2 *Making a "Powers of Ten" Poster*

Note: This is an Internet-based activity.

Table 8.4 Orders of Magnitude in Length: Common Items

Item	Length (m)	Item	Length (m)
	1×10^{-3}		1×10^{1}
	1×10^{-2}		1×10^{2}
	1×10^{-1}		1×10^{3}
	1×10^{0}		1×10^{4}

Each student in the class will be assigned one or more of the items in Table 8.5. In the upper left corner of a standard 8.5" × 11" sheet of paper, write in large or bold characters the approximate dimension of your object in scientific notation. For example, if you are assigned the Earth, you will write "10^8 m" In the upper right corner, identify the object ("the Earth"). In the center of the sheet, place a picture of the object. Internet-based image search engines (see *sciencesourcebook.com* or google.com) may be useful in acquiring pictures that can be copied or drawn. Below the image, give a brief description of the object. As a class, arrange the photographs around the room from smallest to largest, as shown in Figure 8.5.

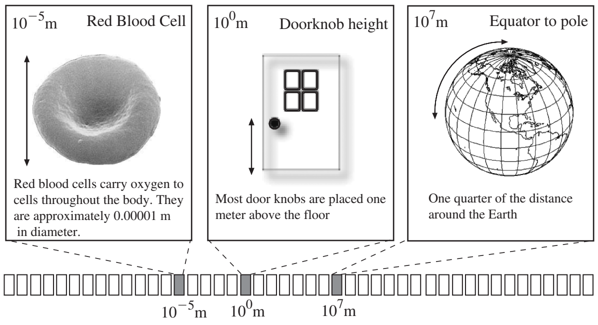

Figure 8.5 Powers of Ten Posters

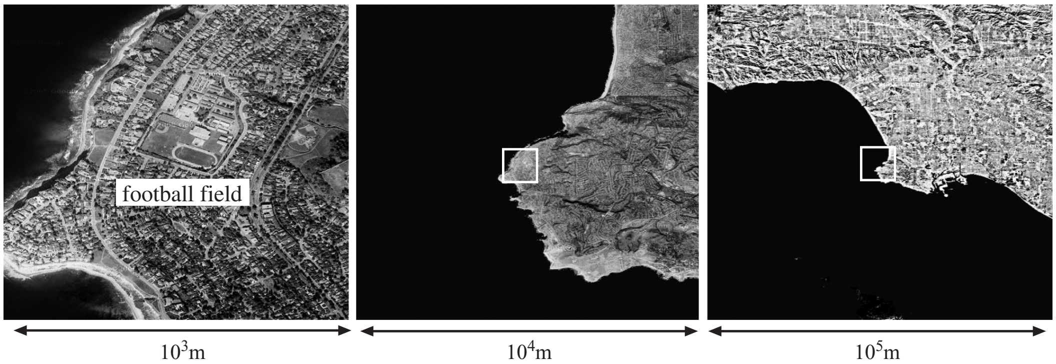

Figure 8.4 Orders of Magnitude 3, 4, 5

Table 8.5 Items to Illustrate When Making Powers of Ten Posters

Distance	Comparison (Approximate)	Distance	Comparison (Approximate)
10^{0} m	Distance from floor to door knob	10^{26} m	Radius of observable universe
10^{-1} m	Width of hand	10^{25} m	Distance to the 3C273, brightest quasar
10^{-2} m	Width of fingernail on smallest finger	10^{24} m	Distance to the nearest large supercluster
10^{-3} m	Thickness of a U.S. dime	10^{23} m	Distance to galaxies beyond our local group
10^{-4} m	Length of a dust mite	10^{22} m	Distance to Andromeda galaxy
10^{-5} m	Diameter of human red blood cells	10^{21} m	Diameter of the disc of the Milky Way
10^{-6} m	Diameter of small bacteria	10^{20} m	Diameter of the Small Magellanic Cloud
10^{-7} m	Length of a virus	10^{19} m	Approximate thickness of the Milky Way
10^{-8} m	Thickness of bacteria flagellum	10^{18} m	Diameter of a typical globular cluster
10^{-9} m	Width of DNA helix	10^{17} m	Distance from Earth to Vega
10^{-10} m	Width of ice or quartz cell	10^{16} m	Inner radius of Oort cloud
10^{-11} m	Radius of a hydrogen atom	10^{15} m	100 × diameter of the solar system
10^{-12} m	Wavelength of X-rays	10^{14} m	10 × diameter of the solar system
10^{-13} m	Wavelength of an electron	10^{13} m	Diameter of solar system
10^{-14} m	Diameter of a nucleus	10^{12} m	Distance from Sun to Saturn
10^{-15} m	Diameter of a proton	10^{11} m	Distance from Sun to Venus
10^{-16} m	One-tenth the diameter of a proton	10^{10} m	One half the distance light travels in a minute
10^{-17} m	One-hundredth the diameter of a proton	10^{9} m	Diameter of the Sun
10^{-18} m	Radius of an electron	10^{8} m	Diameter of Saturn
		10^{7} m	North Pole to equator
		10^{6} m	Length of California (north to south)
		10^{5} m	Length of Connecticut (north to south)
		10^{4} m	Depth of Mariana Trench, deepest point
		10^{3} m	One kilometer; 2.5 times around a track
		10^{2} m	One side of a running track
		10^{1} m	Distance for a first down in football
		10^{0} m	Distance from floor to door knob

Increasing Size →

8.3 Organizational Hierarchy in Biology

Biology is a complex science with many levels of organization, and an understanding of these levels is essential to an understanding of biology. The following description of the organizational hierarchy starts with the smallest and most basic item and works toward the largest and most complex:

• *Fundamental particles:* We now believe that there are two basic types of fundamental, structureless particles of which all matter is made: *quarks* (up, down, charm, strange, top, bottom) and *leptons* (electron neutrino, electron, muon neutrino, muon, tau neutrino, tau). Future research may show that even these particles, with radii less than 10^{-19} m, are themselves composed of smaller particles.

• *Subatomic particles: Protons* and *neutrons* are made of quarks. Electrons are a type of lepton, and hence also considered to be fundamental particles. Acids are substances that can donate protons, and bases are electron pair donors. All living systems