



Table of Contents

Management

Science Vocabulary Research and Practice	5
What Does Research Say About Using a Roots Approach?	6
Why Teach with a Roots Approach?	7
What Is a Root?	7
Differentiating Instruction	8
How to Use This Book	9
Tips for Implementation	11
Introducing Each Unit	12
Introducing Each Lesson	14
Assessment	14
Correlation to the Standards	15
Standards Chart	16
About the Authors	17

Lessons

Unit I—Earth, Air, Fire, Water

Lesson 1: Bases <i>ge(o)-</i> and <i>terr-</i>	19
Lesson 2: Bases <i>aer(o)-</i> and <i>anem(o)-</i>	27
Lesson 3: Bases <i>pyr(o)-</i> and <i>ign-, ignit-</i>	35
Lesson 4: Bases <i>hydr(o)-</i> and <i>aqu(a/e)-</i>	44
Lesson 5: Bases <i>therm(o)-</i> and <i>cry(o)-</i>	52



Table of Contents

Unit II—Heavenly Bodies

Lesson 1: Base <i>center-</i> , <i>centr(i)-</i>	59
Lesson 2: Parallel Bases <i>heli(o)-</i> and <i>sol-</i>	67
Lesson 3: Parallel Bases <i>aster-</i> , <i>astr(o)-</i> and <i>stell-</i>	74
Lesson 4: Parallel Bases <i>scop-</i> , <i>skept-</i> and <i>spec-</i> , <i>spect-</i>	81
Lesson 5: Parallel Bases <i>phos-</i> , <i>phot(o)-</i> and <i>lumin-</i> , <i>luc-</i> , <i>lucid-</i>	89

Unit III—The Environment

Lesson 1: Base <i>spher-</i>	97
Lesson 2: Base <i>flu-</i> , <i>fluv-</i> , <i>flux-</i> , <i>fluct-</i>	104
Lesson 3: Base <i>sed-</i> , <i>sid-</i> , <i>sess-</i>	112
Lesson 4: Base <i>rupt-</i>	119
Lesson 5: Base <i>cur-</i> , <i>curs-</i> , <i>cour-</i> , <i>cours-</i>	128

Unit IV—Life and the Human Body

Lesson 1: Base <i>bi(o)-</i>	135
Lesson 2: Base <i>cardi(o)-</i>	142
Lesson 3: Bases <i>hem(o)-</i> , <i>hemat(o)-</i> , <i>-emia</i> , <i>-emic</i>	150
Lesson 4: Bases <i>odont-</i> and <i>dent-</i>	157
Lesson 5: Medical Suffixes <i>-itis</i> , <i>-osis</i> , and <i>-oma</i>	164

Appendices

Appendix A: Answer Key	172
Appendix B: References Cited	178
Appendix C: Additional Practice Activities	180
Appendix D: Contents of the Digital Resource CD	183

Science Vocabulary Research and Practice

Words are labels for key concepts in science. Although learning these words is critical to student success, teaching them can be challenging. Asking students to look words up in dictionaries or textbook glossaries and then to memorize definitions provides, at best, a short-term solution. Many scientific ideas are new to students, and most of the concepts are abstract. Moreover, students may have insufficient background knowledge to learn these new concepts well.

Over 90 percent of all academic vocabulary (including science) derives from Greek and Latin roots.

In this book, we present a systematic and research-based alternative to vocabulary memorization: a roots approach. First, we define our terms: a “root” is an umbrella term for “a word part that carries meaning.” The three kinds of roots are prefixes, bases, and suffixes. Nearly every academic word consists of these three roots. Our understanding of a word’s meaning begins not with the prefix but with the base, because the base is the root that provides the core meaning. This book presents a total of 32 Greek and Latin word roots (29 bases and 3 suffixes), which generate over 400 words from science.

The bases that lie at the foundation of scientific vocabulary are “basic” in that they express such essential and readily comprehensible ideas as water, earth, star, blood, flow, hot, cold, fire, and life. This is why we say, “Bases are basic.” When a student encounters a long scientific word, a knowledge of roots enables him or her to “divide and conquer” the vocabulary item. The student is then able to identify the basic meaning of a word, which might otherwise be confusing or overwhelming. In the word *heliocentric*, for example, a student will recognize one Greek base meaning “sun” and another Greek base meaning “center.” He or she can then deduce that a *heliocentric* orbit “centers around the sun.” Similarly, a student can understand that *subterranean* fires ignite “under the earth’s surface” because the Latin prefix *sub-* means “under” and the Latin base *terr-* means “earth.” A roots approach to vocabulary empowers students to look inside a long word and identify its basic roots that provide the keys to its meaning. As students learn these word parts and recognize them as the essential components in specific words from science, their growing verbal skills support their increasing ability to comprehend science concepts, as well as to increase and enhance their general vocabulary.

Science Vocabulary Research and Practice *(cont.)*

What Does Research Say About Using a Roots Approach?

The size and depth of students' vocabulary is associated with proficiency in reading comprehension (Baumann et al. 2002; Beck, Perfetti, and McKeown 1982; Kame'enui, Carnine, and Freschi 1982; Stahl and Fairbanks 1986).

Morphological analysis (e.g., via a roots approach) is important because it is generative and allows students to make connections among semantically-related words or word families (Nagy and Scott 2000). In fact, developing morphological awareness is an integral component of word learning (Biemiller and Slonim 2001). In a comprehensive review of 16 studies, analyzing the effect of instruction in morphological awareness on literacy achievement, Carlisle (2010) observes that people learn morphemes as they learn language.

Classroom-based studies have demonstrated the effectiveness of teaching word parts and context clues in the primary and intermediate grades (Baumann et al. 2002; Baumann et al. 2005; Biemiller 2005; Carlisle 2000; Kieffer and Lesaux 2007; Mountain 2005; Porter-Collier 2010). Research in content-area vocabulary has demonstrated the effectiveness of teaching Greek and Latin word roots, especially for struggling readers (Harmon et al. 2005). Moreover, vocabulary knowledge is associated with higher scores on high-stakes tests like the ACT; students with knowledge of Latin score significantly higher on the SAT than those without such knowledge (ACT 2006; LaFleur 1981).

No single instructional method is sufficient. Teachers need a variety of methods that teach word meanings while also increasing the depth of word knowledge (Blachowicz et al. 2006; Lehr, Osborn and Hiebert 2004). These methods should aim at fostering:

Immersion

Students need frequent opportunities to use new words in diverse oral and print contexts in order to learn them thoroughly (Blachowicz and Fisher 2006).

Metacognitive and metalinguistic awareness

Students must understand and know how to manipulate the structural features of language (Nagy and Scott 2000).

Word consciousness

Word exploration (e.g., etymology) and word play (e.g., puns, riddles, games) help students develop an awareness of and interest in words (Graves and Watts-Taffe 2002; Lehr et al. 2004).

Science Vocabulary Research and Practice (cont.)

Why Teach with a Roots Approach?

Teaching with a roots approach is efficient. Over 60 percent of the words students encounter in their reading have recognizable word parts (Nagy et al. 1989). Moreover, content-area vocabulary is largely of Greek and Latin origin (Harmon, Hedrick, and Wood 2005). Many words from Greek and Latin roots meet the criteria for “tier two” words and are appropriate for instruction (Beck, McKeown, and Kucan 2002).

Root study promotes independent word learning (Carlisle 2010). In addition, roots are multipliers—that is, knowledge of one root can help determine the meaning, pronunciation, and spelling of 10, 20, or more English words. With roots, students learn to make connections among words that are semantically related (Nagy and Scott 2000). Research suggests that the brain is a pattern detector (Cunningham 2004). Latin and Greek word roots follow linguistic patterns that can help students with the meaning, sound, and spelling of English words. Indeed, Latin and Greek roots have consistent orthographic (spelling) patterns (Rasinski and Padak 2013; Bear et al. 2011).

Many English language learners speak native languages semantically related to Latin. For example, more than 75 percent of the words in Spanish come from Latin (Chandler and Schwartz 1961, 1991). In fact, Spanish, Portuguese, French, Catalan, Italian, and Rumanian are all classified as “Romance Languages” because they derive from Latin, the language of ancient Romans. Enhancing this natural linguistic connection inherent in many of these languages can accelerate these students’ vocabulary growth (Blachowicz et al. 2006).

Many states are beginning to include a study of roots, including Latin and Greek derivations, in their elementary and middle school literacy standards. Indeed, the Common Core State Standards focus extensively on root-specific standards in the “Reading Foundational Skills” and “Language/Vocabulary Acquisition and Use” sections. According to these standards, attention to roots should begin in kindergarten.

prefix

A root at the beginning of a word. For example, in the word *retraction*, the initial *re-* is a prefix, meaning “back,” “again.”

base

The core root, which provides a word with its basic meaning. In the word *retraction*, the base is *tract*, which means “pull,” “draw,” “drag.”

suffix

A root that ends a word. In the word *retraction*, the final *-ion* is a suffix, meaning “act of,” “state of.”

Note:

You can find out more about what prefixes and suffixes do on the Digital Resource CD (filename: functions.pdf).

What Is a Root?

A *root* is a word part that contains meaning (and not merely sound). Roots are vocabulary multipliers—each root taught helps students discover the meaning to multiple words. There are three categories of roots, depending on their placement within a word, a prefix, a base, and a suffix.

Science Vocabulary Research and Practice *(cont.)*

Differentiating Instruction

Some students, such as struggling readers, may need additional support. Others may benefit from additional challenge. These ideas may help you differentiate instruction:

- ♦ Use visual aids.
- ♦ Ask students to sketch or act out words. Others can guess the depicted words.
- ♦ Reduce length of activity.
- ♦ Pair students. Encourage them to talk about the roots and the activities.
- ♦ Challenge students to create new words that contain the root. Others can guess what the made-up words mean.
- ♦ Talk students through the necessary process to complete an activity. Your aim should be to scaffold students' thinking, not to provide answers.
- ♦ Alert other teachers (social studies, etc.) of the roots you are working on with students. Ask them to include them when possible in their own instruction with students.
- ♦ Have students keep a personal vocabulary journal in which they list the roots and related words they learn. Encourage students to use their new vocabulary in their oral and written language (e.g. "use at least one word containing the [*hyper-*] root in your science journal entry today.")
- ♦ Put the roots and words derived from the roots on display in the classroom. (You may wish to move some of the displays into the hallway or other sites outside of your classroom.)
- ♦ Play word games that involve the roots with your students often. Word lists containing the roots in this book are found on the Digital Resource CD (filename: wordlists.pdf).

Students who need additional challenge can a) look for words containing the featured root in their content-area texts, b) write riddles for others to solve using several words that contain the root, or c) use an online resource to find additional words containing the root (e.g., <http://www.onelook.com/>) or to create word puzzles featuring the root (e.g., <http://www.discoveryeducation.com/free-puzzlemaker/>).

Like their peers, English language learners benefit from the focus on meaning using strategies to learn new roots and words. Especially if students' native languages derive from Latin (e.g., Spanish), make comparisons to the native languages whenever possible. (You can look online for resources to assist with this.) When Spanish speakers learn to look for roots within words, they will be able to relate many word roots in English to their counterparts in Spanish. Sharing their knowledge with other classmates will help everyone grow.

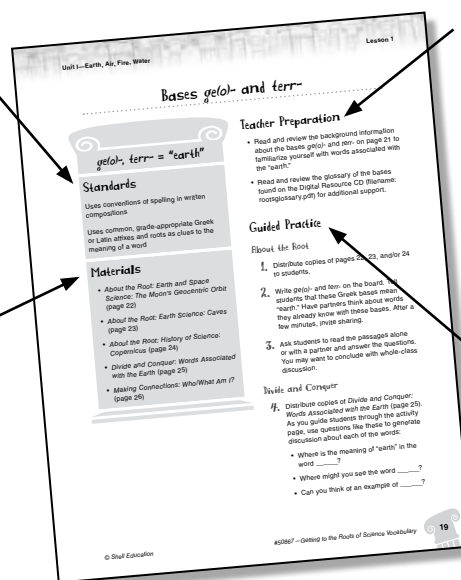
How to Use This Book

The following information will help you implement each lesson.

Lesson Overview

A list of **Standards** (McREL and Common Core State Standards) is included in each lesson.

The **Materials** listed include the activity pages for students.

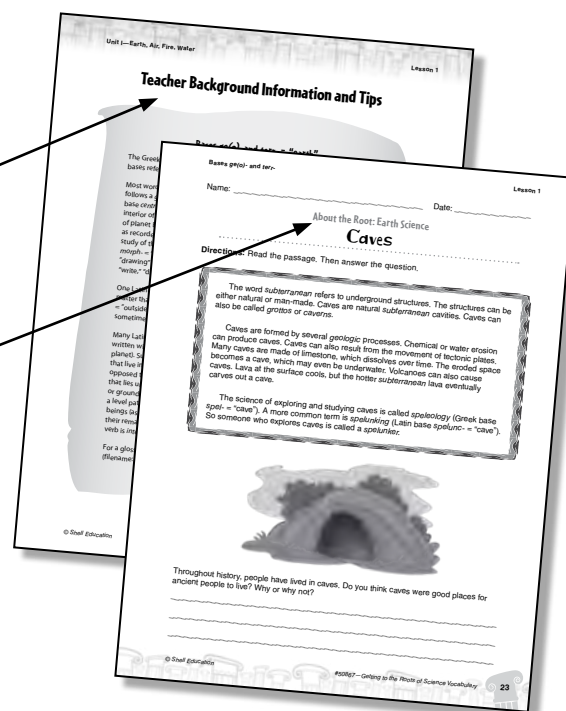


Each lesson begins with a **Teacher Preparation** that provides essential information about the root. Reading this section before you teach the lesson will provide you with a foundation to ensure student success.

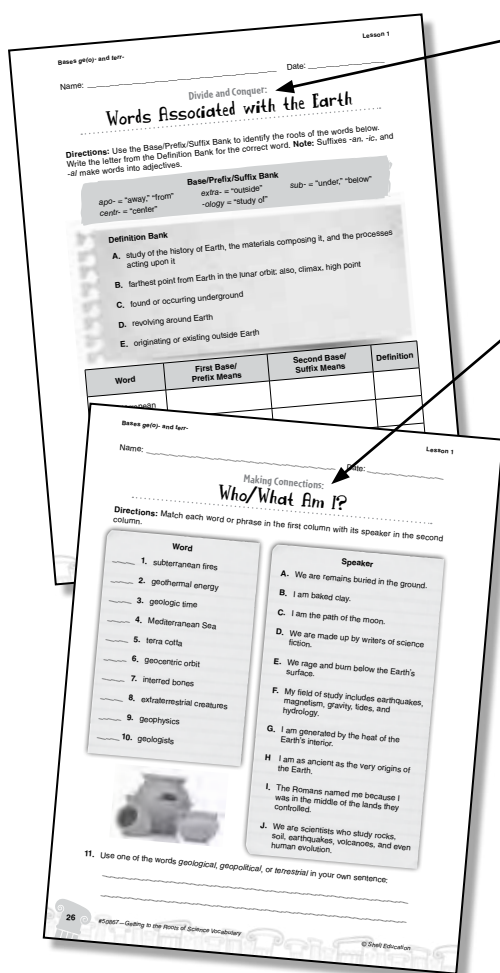
The **Guided Practice** portion of each lesson includes suggestions for implementing each of the student activity pages.

Before beginning each lesson, review the **Teacher Background Information and Tips** page to provide additional help for students. Additional information to introduce each unit can be found on pages 12–13.

The **About the Root** activities are introductions and include short passages using the root of focus. The purpose of these passages is to show students contextual use of the root in science. As students read to themselves or listen to the teacher read aloud, they identify the prefix or suffix words in extended texts that center on a wide range of interesting topics.



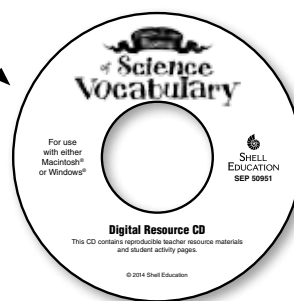
How to Use This Book *(cont.)*



The **Divide and Conquer** activities allow students to pull words apart. They dissect the parts of the words, understand the meaning of these parts, and then gain a greater understanding of the word as a whole.

The **Making Connections** activities allow students to use their knowledge of roots to make connections to vocabulary and offer students the opportunity to extend their exploration of the root(s) through activities such as word sorts, riddles, representing the roots and related words in drawings, and gamelike tasks. They may need to distinguish when to use a certain root, or which way the root is used in a word.

All of the student activity pages and additional resources such as word lists and flashcards can be found on the **Digital Resource CD**.



How to Use This Book *(cont.)*

Tips for Implementation

These tips will help you think about how to teach the lessons in this book.

- ♦ You will find many suggestions in this text, but remember that they are just that—suggestions. You should feel free to adapt the lessons to meet your students' needs.
- ♦ Plan to spend five to ten minutes per day on vocabulary related to science.
- ♦ You can teach the lessons in any order. You may want to coordinate with your curriculum. Each lesson addresses one basic science idea or concept. You can also expand on any lesson as you see fit. If students need more work on a particular root, you may wish to use some of the additional practice activities described in Appendix C.
- ♦ Before beginning a new lesson, read the Teacher Background Information and Tips page. These notes provide general information and identify many science words built on the base of the lesson.
- ♦ Talking about roots is very important for student learning. This approach to vocabulary development goes far beyond mere memorization of specific words (which, according to research, does not work). Students need to learn to think about how roots contribute to meanings. Talking this through can help them develop this realization. So, encourage students to talk, Talk, TALK!!!
- ♦ Each week, display the root(s) and meaning(s) prominently in your classroom. Encourage students to use the root as much as possible throughout the entire week. Reading, writing, speaking, and listening to words containing the root will facilitate learning. Several generic activities (see Appendix C) provide additional instruction or practice, if you or your students wish.
- ♦ You may wish to provide students with dictionaries as they work through the activities sheets.

Bases *aer(o)-* and *anem(o)-*

***aer(o)-* = “air”**

***anem(o)-* = “wind”**

Standards

Uses a variety of strategies to extend reading vocabulary

Determines the meaning of words and phrases as they are used in a text, including figurative, connotative, and technical meanings

Materials

- *About the Root: Air and Wind* (page 30)
- *About the Root: Anatomy: The Value of Aerobic Exercise* (page 31)
- *About the Root: History of Science: The Basic Principle of Aerodynamics* (page 32)
- *Divide and Conquer: Words Associated with Air and Wind* (page 33)
- *Making Connections: Who/What Am I?* (page 34)

Teacher Preparation

- Read and review the background information about the bases *aer(o)-* and *anem(o)-* on page 29 to familiarize yourself with words associated with “air” and “wind.”
- Read and review the glossary of the bases found on the Digital Resource CD (filename: rootsglossary.pdf) for additional support.

Guided Practice

About the Root

1. Distribute copies of pages 30, 31, and/or 32 to students.
2. Write *aer(o)-* and *anem(o)-* on the board. Tell students that these Greek bases mean “air” and “wind.” Explain that the *o-* often connects the base to other word parts.
3. Ask students to read the passages alone or with a partner and answer the questions. You may want to conclude with whole-class discussion.

Bases *aer(o)-* and *anem(o)-* (cont.)

Divide and Conquer

4. Distribute copies of *Divide and Conquer: Words Associated with Air and Wind* (page 33). As you guide students through the activity sheet, use questions like these to generate discussion about each of the words:

- Where is the meaning of “air” or “wind” in the word _____?
- Where might you see the word _____?
- Can you think of an example of _____?

Making Connections

5. Distribute copies of *Making Connections: Who/What Am I?* (page 34).
6. Ask students to read all of the definitions before completing the activity sheet.
7. Conclude with whole-class sharing.

Words with *aer(o)-*, *anem(o)-*

aerate
aerobatics
aerobe
aerobic
aerodynamics
aeroembolism
aerogram
aeromechanics
aerometer
aeronautics
aerophobia
aeroplane
aerosol
aerospace
aerosphere
aerostat
airplane
anaerobic
anemographer
anemography
anemometer
anemometry

A word list can be printed out for students from the Digital Resource CD (filename: wordlists.pdf).

Teacher Background Information and Tips

Bases *aer(o)*- = “air” and *anem(o)*- = “wind”

The Greek bases *aer(o)*- meaning “air” and *anem(o)*- meaning “wind” are found in scientific words from chemistry, geology, meteorology, physics, and biology.

With a minor spelling change, the base *aer-* is the same word as English “air.” The modern word *airplane* (the preferred American spelling), for example, was originally written as *aeroplane* (preferred British spelling), meaning “wanderer” in the “air” (Greek base *plan-* = “wander,” “stray”). The original Greek spelling of the base *aer-*, followed by the connecting *o*, is still retained in such technical words as *aeronautics*, *aerospace*, *aerodynamics*, *aerosol*, etc. It is interesting to observe that, as scientific and technological advances are made, we continue to turn to the ancient Greeks and Romans to create the modern words for our discoveries and inventions.

In science, the base *aer(o)*- refers to “air” in a variety of aspects and functions. In chemistry and physics, *aer(o)*- describes the motion of air and of other gaseous substances. In biology, *aer(o)*- refers to oxygen. In geology and meteorology, *aer(o)*- refers to the atmosphere, the sphere of air above the ground. The Greek base *anem(o)*-, meaning “wind,” produces a few words in meteorology and one biology word.

For a glossary of words built on these roots, see the Digital Resource CD (filename: rootsglossary.pdf).



Name: _____ Date: _____

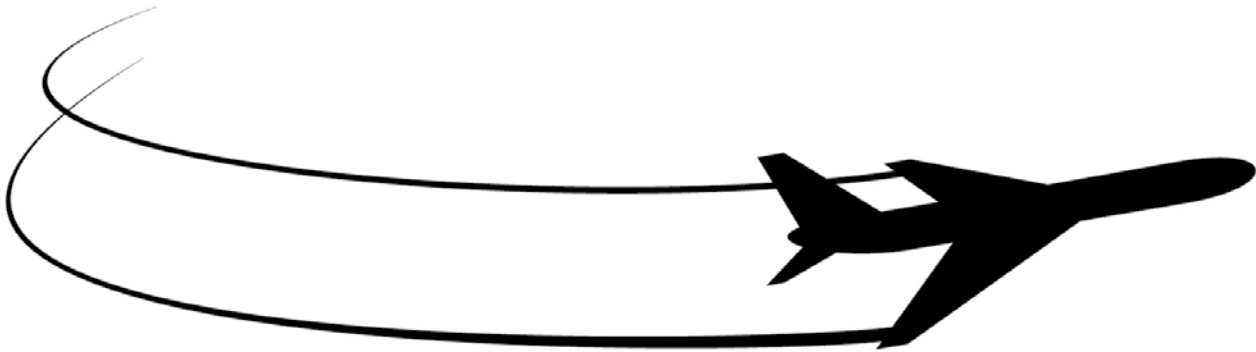
About the Root:

Air and Wind

.....

Directions: Read the information. Then answer the questions.

The Greek bases *aer(o)-* meaning “air” and *anem(o)-* meaning “wind” are found in scientific words from chemistry, geology, meteorology, physics, and biology. With a minor spelling change, the base *aer-* is the same word as English “air.” This should help you remember what *aer-* means. The Greek base *anem(o)-* means “wind.”



- ⊙ In the English language, *airplanes* were originally called *aeroplanes*. If the Greek base “*plan-*” means “to wander,” can you figure out what the words *aeroplane/airplane* originally meant?

- ⊙ If a thermometer is used to measure heat and temperatures, what function do you think is served by an *anemometer*?

- ⊙ Have you ever seen a picture of a sea *anemone*? Why do you think scientists gave this sea creature a name meaning “wind”?

Name: _____

Date: _____

About the Root: Anatomy:

The Value of Aerobic Exercise

.....

Directions: Read the passage. Then answer the question.

Aerobic exercise is a great way to stay in (or get into) shape. The term refers to a variety of low-intensity exercises. They can usually be done for long periods of time. The word aerobic means “living in air” and refers to oxygen use during exercise.

Aerobic exercise takes many forms. Those who prefer to exercise indoors can climb stairs, jump rope, or use elliptical trainers or treadmills. Cycling, jogging or running, walking, and swimming are outdoor aerobic exercises.

Aside from helping us to stay in shape, aerobic exercise has several health benefits. For example, respiratory and heart muscles are strengthened as a result of aerobic exercise. Moreover, blood pressure and even the risk of developing diabetes will be lower. And of course, aerobic exercise burns body fat.



Aerobic exercise is sometimes called “cardiovascular” exercise. Why do you think this is so? **Hint:** The Greek base *cardi(o)-* means “heart,” and the Latin base *vas-* means “vessel,” “blood vessel.”

Name: _____ Date: _____

About the Root: History of Science:

The Basic Principle of Aerodynamics

Directions: Read the passage. Then answer the question.

In 1738, a Swiss physicist named Daniel Bernoulli formulated the central principle of *aerodynamics*. *Bernoulli's Principle* says that the pressure of a moving fluid decreases as its speed increases. The fluid can be either liquid or gas. The principle also states that the total energy in a steadily flowing fluid system—such as airflow—remains constant along its path.

This principle explains why an airplane lifts off the ground. The airplane's wings are designed so that the air flows more quickly over their upper surface than their lower surface. As the plane gathers speed, pressure decreases on the upper surface of the wings. As a result, the air pressure beneath the wings increases, and the airplane is lifted from the ground as it takes off in flight.

The ancient Greeks never did learn how to fly. But modern aviation uses two Greek words to describe this discovery: *aerodynamics*, “the power of air.”



Think about an airplane wing (or look at a picture). Why does air flow more quickly over the wing's top than under its bottom?

Name: _____

Date: _____

Divide and Conquer:

Words Associated with Air and Wind

Directions: Use the Base/Prefix/Suffix Bank to identify the roots of the words below. X means that the word does not have that element. Write the letter from the Definition Bank for the correct word.

Base/Prefix/Suffix Bank*-bic-* = “living”*naut-* = “sail,” “sailor”*meter-* = “measure”*spher-* = “sphere,” “zone”**Definition Bank**

- A. the art or science of flight
- B. an instrument measuring direction and velocity of wind
- C. the body of air around Earth
- D. a marine plant with waving tentacles which appear to be wind-blown
- E. living and thriving in oxygen

Word	First Base/ Prefix Means	Second Base/ Suffix Means	Definition
1. aeronautics			
2. aerobic			
3. anemometer			
4. aerosphere			
5. anemone		X	

Name: _____ Date: _____

Making Connections:
Who/What Am I?

.....

Directions: Match each word in the first column with its speaker in the second column.

Word

- _____ 1. aerophobe
- _____ 2. aeronaut
- _____ 3. anemograph
- _____ 4. aerostat
- _____ 5. aerobe

Context

- A. I fly a hot-air balloon.
- B. I am a rigid airship that hovers in the air, such as the zeppelin or Goodyear blimp.
- C. I am afraid of drafts, gases, and airborne poisons.
- D. I am a microorganism that thrives in oxygen.
- E. I am a meteorologist who specializes in measuring wind velocity and direction.



6. Use two of the words *aerate*, *aerial*, and *aerobic* in your own sentences:
