General Academic or Domain-Specific Vocabulary?:

The Impact of Word Selection in High School Biology

BY

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THESIS

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This work is dedicated to my children. Dream big.

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SUMMARY

The purpose of this study was to determine the impact of learning various types of words in biology on students' reading comprehension, vocabulary performance, and science content knowledge. The study involved 315 ninth grade biology students who were placed in one of four groups and spent two weeks for ten minutes per day working on independent vocabulary packets in which they practiced a set of 15 words. Group one's list was a combination of domain-specific and general academic words, group two's list was a set of general academic words, and group three's list was a set of domain-specific words. The fourth group, the control group, did no formal vocabulary work but instead completed lessons involving the ecology content. In this quasi-experiment, the independent variable was the instructional group assignment, and the dependent variables were the students' performances on the reading comprehension, vocabulary (broken into various categories), and content assessments.

Descriptive statistics for the majority of the vocabulary items and for the comprehension and content post-test measures revealed that the third group had the highest overall achievement. Throughout the two weeks of treatment, the third group worked only with domain-specific words related to ecology. A multivariate analysis of covariance (MANCOVA) found the differences to be statistically significant. The individual dependent variables were analyzed and found two question types on the vocabulary test, the domain-specific and general academic, to be significant in the test of between-subjects effects. Further, instructional group assignment did not have an effect on reading comprehension and content knowledge. Though its advantage was small, this study suggests that the domain-specific approach to disciplinary vocabulary instruction is best.

CHAPTER ONE

INTRODUCTION

Evaluating and estimating vocabulary size is one of the oldest topics of study in vocabulary research (Beck & McKeown, 1991). It has also been a point of much disagreement over the years, with estimates of size varying considerably, depending on the methods used and the samples of subjects considered. Several estimates of vocabulary size suggest that students learn approximately 3,000 to 4,000 words each year, accumulating roughly 50,000 words by the time a child finishes high school (Anderson & Nagy, 1992; Anglin, 1993; Graves & Watts-Taffe, 2002; Nagy & Anderson, 1984; White, Graves, & Slater, 1990). Such figures can be daunting to teachers when they consider how to utilize classroom time in delivering effective vocabulary instruction. For secondary teachers in the disciplines, (English, history, mathematics, and science), the task of delivering vocabulary instruction can be even more daunting. Academic disciplines have been described as complex social groups in which literacy practices are highly dependent on the use of specialized language (Shanahan & Shanahan, 2008), so vocabulary instruction would be of particular importance, and yet, instruction in the disciplines is limited to relatively brief instructional periods (e.g., from about 40-50 minutes per day in high school).

<u>Vocabulary Knowledge in Disciplinary Literacy</u>

One cannot discount the importance of vocabulary, either in schooling or in life. It is language that allows a person to understand and respond to the demands of the world. In schooling, language is the means through which one acquires new information, and in return, through which mastery of that knowledge is expressed. In grades 4 through 12, as students approach learning in the disciplines, reliance on language poses an even greater challenge (Chall, 1983). For many reasons, the texts students face in disciplinary settings cause them to struggle. The complex and uncommon vocabulary words that are frequent in content area texts can be blamed for much of the difficulty students face (Harmon, Hedrick, & Wood, 2005). Harmon, Hedrick and Wood summarize the "reading nightmares" of content area teachers who argue that the critical component of students' difficulty understanding textbooks is their lack of vocabulary knowledge. Over time, research has shown a connection between readers' vocabulary knowledge and their understanding of what they have read (Blachowicz, Fisher, Ogle, & Watts-Taffe, 2006). These studies reveal a strong correlation between reading comprehension and vocabulary size (Mezynski, 1983; National Institute of Child Health and Human Development, 2000; Stahl & Fairbanks, 1986); students with more developed vocabularies do better with reading comprehension than do students who lack this resource.

Vocabulary knowledge within a discipline yields gains beyond improved reading comprehension alone. Disciplinary literacy requires students not only to read content area textbooks, but also to participate in a discourse community (Gee, 1996) where members engage in literate practices and share a specialized language: "What's in a name is that everyone in a language community tacitly agrees to use a particular sound to convey a particular idea" (Pinker, 1999, p. 2). It is through these interactions that learning takes place, which is why a student's vocabulary knowledge plays a critical role in his or her learning of disciplinary content. In this sense content and language are inseparable: "…language and content are never separate…'content' in school contexts is always presented and assessed through language; and that as the difficulty of the concepts we want students to learn increases, the language that construes those concepts also becomes more complex and distanced from ordinary uses of language" (Schleppegrell, 2004, p. 155). Language evolves to keep up with expanding intricacies of knowledge and the functions it needs to serve (Halliday, 1973).

From Michael Halliday's functional grammar perspective is the idea that learning and learning new language occur simultaneously (Halliday 1993 as cited in Schleppegrell, 2004). Halliday proposes a system of "learning language, learning through language, and learning about language" (1993, p. 113). Some content teachers leave the "learning about language" process , which certainly encompasses more than just vocabulary instruction, up to the English teachers, which does not help students in their work to strengthen disciplinary literacy skills. In explaining the necessity of learning to be linked with learning about language, Schleppegrell (2004) describes how everyday and scientific concepts are learned differently. The language that the academic disciplines of math, science, and history are constructed in is different than the language of everyday concepts (Vygotsky, 1986 as cited in Schleppegrell, 2004). A conflict occurs, which can be confusing to students, often because "scientific explanations sometimes contradict the interpretations common sense would suggest" (Schleppegrell, 2004, p. 137). Because the differences in language between the two categories exist, there needs to be an inevitable link in the curriculum between learning the content and learning about the language of the content area. Students need to understand the language to apply it in forming connections to the content they already know. Content and language should be equally important in disciplinary literacy, as language is the transmission of culture. Students are learning not only content, but also how to discuss and express their knowledge in the culture of academia (Halliday, 1973).

Differences in “epistemologies, methodologies, and pedagogies” in the academic disciplines of mathematics, science, and social science have led to unique types of discourse in each field (Schleppegrell, 2004, p. 113). Such developments have been necessary because ordinary language cannot always express the unique tasks required by the discipline. This can be troublesome for secondary students trying to be consumers and producers of content area texts, as the discourse becomes more unfamiliar and specialized. In his piece on the conflicts that everyday words can pose to students for learning specialized terminology, Laferriere (1987) discusses the need for precise language in botany, where it is not uncommon for new species to be discovered. Scientists in this realm rely on the preciseness of language to describe and categorize their work to others in the research community. Instruction in disciplinary literacy should convey the purposes of language to students. Rubenstein (2002) addresses the goal of getting children to understand the function of new words by structuring activities for them to “realize that terms come from people thinking about new ideas” (p. 109). The words uniquely serving a specific community serve authentic purposes, and students need to be reminded of this.

Being able to communicate effectively and have a command for the words within a particular discourse is important in all academic disciplines. Weber and Word (2001) explain how critical it is for scientists to be able to communicate knowledge not only to each other, but to the public, as well, in pursuing advancements in science. Chen and Li (2008) describe the same to be true in mathematics: “Learning to communicate mathematically is now seen as a central aspect of what it means to learn mathematics, and language is taken to play an important role in shaping students’ mathematics thinking” (p. 91). To be able to communicate effectively in a discipline, one must have a command of the vocabulary specific to that group.

Vocabulary is a challenge for students in all academic disciplines. Deck (1952) more than fifty years ago cited difficult vocabulary terms as the main reason why students struggle to read in science. Cardinale (1992) attributed learning new terminology as a barrier to understanding biology, with middle school science textbooks having twice as many new words as a foreign language textbook. Caldwell and Goldin (1987) included vocabulary as an important measure of the difficulty level in mathematical word problems. McClanahan (2008) argued that unfamiliar vocabulary words in history are often the first obstacle for all students in acquiring new content knowledge. In her editorial on the role of vocabulary in the biology classroom, MacKenzie (2007) discussed the surprise of her pre-service biology teachers who found that an exorbitant amount of class time needed to be spent on learning vocabulary words. In all of the academic disciplines, addressing the component of challenging vocabulary is an issue that cannot be avoided.

One reason why vocabulary in all disciplines poses problems for students is that often students are learning both a new concept and a new label for that term (Graves, 1986). For example, in teaching a child the meaning of the word “frigid”, the child already has an understanding of the concept of what it means to be cold. It is just a new label for a familiar concept that the student must come to know. In teaching a student the meaning of the word "mitosis", it is likely that he has no previous understanding of the concept to help him learn the term. The relationship between vocabulary and conceptual understanding in disciplinary literacy is an important one. Beck, McKeown, and Kucan (2008) address the issue of teaching technical words as not necessarily being a vocabulary issue, but as a conceptual one. In the example from biology of the term mitosis, they argue that a definition must be taught within the context of the content domain it represents. Without offering a definitive answer on how teachers should address this in the classroom, they pose the question: "So is this a vocabulary issue?" (p. 31). Their question indicates the need for further study in informing disciplinary practice.

Just as students are struggling to become literate in their various academic disciplines and must learn new labels for new concepts, it is important to acknowledge that the demand of learning new conceptual knowledge can be brought on by familiar labels or words, as well. There is a distinction between teaching new labels for familiar concepts and teaching new labels for unfamiliar concepts (Graves, 1986). This phenomenon occurs regularly in math; for example, a word such as negative is generally known to students in everyday language, but has a specialized meaning in the context of mathematics. Equally confusing in math is the use of both familiar and unfamiliar words that assume specialized meaning in the discipline, making it difficult for students to determine what a problem is asking them to do (Fang & Schleppegrell, 2008). Schleppegrell (2007) explains that teachers should identify these language features with students and provide explicit modeling on how to work through them. In doing so, Lemke (2003) recommends that math teachers use both ordinary and technical language interchangeably to assist students with learning the mathematical register (Halliday, 1978). This register in math is composed of both everyday language and school language to serve new functions that can be incredibly precise (Shanahan & Shanahan, 2008). In exposing the rules of the mathematical register, teachers should provide students with embedded and authentic uses of mathematics so students can see how such disciplinary literacy will be applied.

There are some aspects of vocabulary in different disciplines that are unique to that particular content area. Schleppegrell, Achugar, & Oteíza (2004) argue that one of the unique features of history or social studies texts is that they can rarely be experienced hands-on, such as how a science text might. For example, a biology teacher can show a model to help students understand what a cell nucleus is, but a social studies teacher cannot as easily illustrate a concept such as democracy. Because of this, history teachers generally rely heavily on textbooks or other writing to teach content, placing considerable reading demands on students. Further, it would be impossible to translate history textbooks into everyday language to make them less abstract. Doing so would reduce the complexity of the content and would not be representative of the degree of knowledge required by disciplinary practices. Instruction in how to utilize features of language may be even more critical in social studies, due to the dependency on text.

A unique aspect of the discipline of science is that a majority of the technical vocabulary words often have Greek or Latin origins. Providing students with direct instruction in the meaning of roots and affixes can allow for more precise understanding of the discipline (Fang, 2006). Within the science community, there are distinct disciplinary practices that can vary considerably:

> …it must be recognized that science prose in intermediate grade science textbooks cannot be summarized as following a single distinct pattern but may be a mixture of styles, ideas, and vocabularies from several disciplines. Subject area differences must be considered in evaluating the reading difficulty of science writing. (Cohen & Steinberg, 1983, p. 100)

Even within the discipline of science, there are several different sciences that may lend themselves to different linguistic patterns, such as biology, physical science, or chemistry. It may not be prudent to classify all sciences as equal. Vocabulary instruction must be suited to the particular literacy needs of each discourse community.

While explicit teaching of morphology makes sense in science due to the prevalence of Greek and Latin words, it is an instructional practice recommended for all of the secondary disciplines. Some knowledge of morphology is correlated with reading ability in high school (Nagy & Scott, 2000). If a child can apply morphological knowledge and contextual strategies, he should be able to understand an additional one to three words for every one word he knows (Nagy & Anderson, 1984). This instructional strategy offers huge gains and should be included in classroom practice, especially when there are limitations such as time.

One topic of great debate in the field of vocabulary research concerning time involves incidental or intentional instruction. Learning in academic disciplines should provide a mixture of opportunities for intentional and incidental vocabulary strategy instruction. The results of Stahl and Fairbanks's meta-analysis (1986) suggest that deliberate "vocabulary instruction is a useful adjunct to the natural learning from context" (p. 100). Both methods deserve a place in adolescent vocabulary instruction programs. Even though the majority of words that students will learn may come via incidental learning, direct instruction of selected words remains an important method, particularly in the content areas. Because of the correlation between vocabulary knowledge and reading comprehension, teachers in all disciplines should provide intentional teaching of selected vocabulary in reading of difficult content textbooks (Blachowicz, Fisher et al., 2006).

Another issue of disagreement in vocabulary research that was discussed at the start of this chapter includes measurements of vocabulary size. Many researchers (Blachowicz, Fisher et al., 2006; Fillmer, 1977; Graves, 1986; Jenkins, Matlock, & Slocum, 1989) acknowledge the problem as one that stems from different definitions of what it means to know a word. Vocabulary knowledge is incremental, meaning that there are degrees of knowing a word (Graves & Watts-Taffe, 2002). Students need many exposures to words to reach high levels of understanding. McKeown et. Al (1985) found that even 40 high quality instructional encounters with a word may not be enough. This is increasingly challenging in content areas where the words students are learning are context-specific, and not reinforced in other settings.

The concern of limited exposure is a valid one of vocabulary learning in the disciplines (Chen & Li, 2008; Laferriere, 1987; Rubenstein, 2002). One of the features of the academic registers is Greek and Latin words that some students see only in their school texts (Schleppegrell, 2004). Students get even fewer opportunities to practice the words specific to each discipline. Instead of being professionals immersed in a single community, students must balance their time between discourse communities. Often such practice is limited to the individual classroom, which makes sophisticated language development a challenge. Unfortunately, the exclusivity of the academic registers isn't without purpose, and must remain so to accomplish the demands of the discipline: "Because each discipline has evolved a way of using language that interprets the world in its own terms, students need to learn the language of the different school disciplines if they are to be effective in doing school-based tasks" (Schleppegrell, 2004, p. 157). Teachers and students will have to find opportunities for extended practice if students are to access and participate in these language communities.

Given the limitations of time and opportunities for practice, vocabulary instruction in the content areas must be well-designed, purposeful, and efficient. Unfortunately, with few empirical studies, not much is known about vocabulary instruction in disciplinary settings, or more specifically, the types of words that should be studied in such settings. Investigation into an appropriate language curriculum for secondary students is needed. While there is considerable knowledge about an appropriate language curriculum for elementary students, less is known about such a curriculum for students once academic discourse becomes more specialized. At the heart of the matter of an appropriate language curriculum is the question of which words to teach. Teachers cannot begin to teach all of the words students will need to learn. Given this, what types of words should be taught to help students learn the content of a particular discipline?

Though not designed specifically for secondary disciplines, Beck, McKeown, and Kucan (2002) use a classification system to sort words into three categories. Tier 1 words are those that are likely to be known by children through spoken language experiences. Tier 2 words are more sophisticated than Tier 1 words, but are of high utility for literate language users. Tier 3 words are those content-specific, technical vocabulary words that do not appear in multiple contexts. It is typically the Tier 3 words that are thought to complicate a text and make the reading and interpretation of a text more challenging, but there is no definitive answer as to which words should be taught in content area classrooms. Beck, McKeown, and Kucan (2008) are advocates of teaching high frequency Tier two words, as are others in the field: "Most educators would suggest that the words encountered most frequently in English are good candidates for learning and that various word lists can help teachers select words appropriate to various grade levels and content areas" (Blachowicz, Fisher et al., 2006, p. 531). Despite these recommendations, there is not much empirical evidence to support the teaching of some words over others in specialized disciplines. If language is a tool to teach content, improved vocabulary methods may help students develop greater understanding of the content in their specialized area.

Blachowicz et al. (2006) suggest that despite all we know about vocabulary instruction, very little has changed in classroom vocabulary instruction. Considerable questions remain about how secondary students can better use language to expand their learning and what instruction should look like to help them be able to do so. Changes in vocabulary instruction at the secondary level are needed, as many students do not meet the target of learning 50,000 words by the time they graduate. Greater command of the language in different academic registers will allow students to construct meaning at deeper levels and graduate with the ability to articulate what they have learned.

While this dissertation will address effective vocabulary instruction, particularly in reviewing past research, the focus of this study is not one that measures the quality of a particular instructional type. This research was conducted from the perspective that before appropriate instructional methods are employed, teachers must have a sound curriculum. In vocabulary, such a curriculum would include which types of words to teach. This is the focus of this research study. Unfortunately, very few empirical studies exist that compare vocabulary word types within disciplinary classrooms. In order to make appropriate connections to the existing body of research, this dissertation addresses vocabulary studies measuring the impact of instructional methods. Some of the research methods employed in the study differ from what constitutes good vocabulary instruction. For example, during the treatment, subjects completed vocabulary lesson packets individually in brief increments over the course of two weeks. A more effective instructional method would be for students to engage in more natural interactions with the words, such as through class discussion. However, such a controlled design was necessary to protect the quality of the quasi-experiment to minimize instructional differences in multiple classrooms. Given such a design, this study focused exclusively on evaluation of the word type selection process, and not effective instructional methods. The term “instruction” as used throughout this dissertation refers to the treatment of students working independently in the vocabulary lesson packets.

Purpose

Because vocabulary has been identified as a significant challenge for students in their academic content areas, more research is needed to determine the types of vocabulary words that will maximize students' success within that particular field. The purpose of this dissertation research was to test the implications of studying general academic or domain-specific words within 9th grade biology classrooms to determine which types of words should be taught to help students use the texts in that content area. In the context of this study, the focus is not on specific words, but on the specific types of words that make greater affordances in student achievement. In this quasi-experimental study, students were assigned to one of four groups, with the treatments varying the category of vocabulary words with which the students were engaged in word-study. Measurement tools included reading comprehension, content, and vocabulary assessments. The current study investigated if the type of vocabulary words taught has an impact on student reading comprehension, science knowledge, and vocabulary performance in 9th grade biology classrooms.

CHAPTER TWO

REVIEW OF RELEVANT LITERATURE

"School language…may be the most complicated 'tool set' in the world to learn how to use" (Zwiers, 2008, p. 1).

Introduction

Many issues have been relevant to the study of vocabulary since its beginning, such as vocabulary acquisition, vocabulary size, incidental and intentional vocabulary learning, what it means to know a word, effective instructional techniques, vocabulary's relationship to reading comprehension, and which words should be taught. Several of these issues become intertwined and dependent on each other in order to fully understand the impact of words in people's daily and professional or academic lives. This dissertation research pursued the question of which types of words should be taught in content area settings, but also takes into account the literature of some of the other concerns mentioned above.

In this chapter, literature is reviewed in six sections. The first examines the historical line of vocabulary research, particularly those studies relating to the correlation that has been documented between vocabulary and reading comprehension. This chapter then addresses direct vocabulary instruction and some instructional methods that have been researched. In addition, a brief description of how the measurement of vocabulary knowledge has impacted vocabulary research is given. The next section describes how the growing interest in the study of academic vocabulary has led to a multitude of definitions to describe this concept. The final sections in this chapter examine research on word selection for vocabulary instruction, and then look more specifically to the word selection studies available to teachers of science.

Past Vocabulary Research

Vocabulary has long been a topic of interest among psychologists, linguists, and educational researchers. More than one hundred years ago, Kirkpatrick (1891) evaluated the vocabulary capacity of individuals by counting words in dictionaries and novels. His work led to the conclusion that a person's vocabulary at age thirty-one varied from 10,000 to 100,000 words depending on the person's level of education. Kirkpatrick also claimed that children could learn more than two words per day.

Another example of early research on vocabulary is from the work of E. L. Thorndike. One of his early pieces (1917) noted the relationship between vocabulary and reading comprehension, showing that comprehension is largely dependent on the understanding of word meanings. This work paved the way for many other researchers to study the relationship between vocabulary and comprehension. Thorndike also brought vocabulary research into discussions of curriculum and instructional practices used in schools. His seminal piece, *The Teachers' Word Book* (1921), had a significant impact on education in that it influenced the type of vocabulary used in school textbooks (Graves & Watts-Taffe, 2002). Almost one hundred years later, the vocabulary words that appear in textbooks continue to drive vocabulary instruction in schools.

As the study of vocabulary fluctuated over the years, Becker's (1977) work brought it back into the spotlight. His research highlighted the importance of vocabulary development by showing a correlation between vocabulary size and the academic achievement of disadvantaged students. He attributed vocabulary deficiencies as the primary cause of academic failure of disadvantaged students in grades three through 12. One of Becker's observations included the difficulty in sustaining early gains in reading due to inadequate vocabulary that widens gaps between students in upper-elementary grades and beyond. This work is important with regard to this dissertation study, as it highlights the problems associated with academic and specialized vocabulary that students face in the older grades.

One study concerning the importance of vocabulary instruction in relation to academic performance in the content areas was completed by Jackson and Phillips (1983). Working with seventh-grade math students, the authors investigated if five to ten minutes of vocabulary instruction over the course of a single unit would increase student performance in both verbal and computational measures in mathematics. During the course of normal instruction in a unit on ratio and proportion, students in the treatment group worked on vocabulary-oriented activities for four weeks for five to ten minutes daily. While the treatment group completed the vocabulary work, the students in the control group did additional computational practice. At the end of the experiment, students in the treatment group performed significantly better in both verbal and computational measures than the control group. The authors concluded that the increase in computational achievement was due to the increase in comprehension of mathematical terms.

As concerns for struggling readers have become more prominent in public policy, research supporting the link between comprehension and vocabulary has grown. Michael Graves (1986) reviewed several studies involving the relationship between comprehension and vocabulary. His review was especially critical of research that claimed to prove a strong link. Of 14 studies, he found 8 with positive effects, but noted that five of those studies were questionable due to limited descriptions of the interventions and because the comprehension measures seemed inappropriate. However, three studies by Beck, McKeown, and colleagues (Beck, Perfetti, & McKeown, 1982; McKeown, Beck, Omanson, & Perfetti, 1983; McKeown, Beck, Omanson, & Pople, 1985) did show promising results. Graves acknowledged that these studies by Beck and her colleagues provided “convincing evidence that teaching vocabulary can increase comprehension of texts containing the words taught”(p. 61). His review led to recommendations that vocabulary instruction aimed at increasing reading comprehension be of sufficient duration, be multifaceted, promote many encounters with words, provide semantic associations among words, require active processing of meaning, and develop automaticity of response.

Stahl and Fairbanks’s meta-analysis (1986) also supports the close relationship between reading comprehension and vocabulary. Analyses of studies of vocabulary instruction with reading comprehension as a dependent measure revealed a range of significant effects that depended on the nature of the assessments used. Thus, students who did not work with the target words prior to the post-tests, generally did not do well relative to those who were taught those words. However, the relationship of the comprehension tests and the instruction made a big difference. If the vocabulary selected for instruction was drawn from the reading passages used to test comprehension, then the effect size was quite large (.97). If, on the other hand, the interventions taught vocabulary that was not specifically drawn from the test passages, then the impact was much more modest (.37); but even this small-to-moderate effect was statistically significant. The researchers concluded that comprehension was improved when instruction allowed for deep processing, multiple exposures to words, and an inclusion of both definitional and contextual information about words, consistent with the findings of Grave’s

(1986) review. In another study, Chall, Jacobs, and Baldwin (1990) examined a group of second-, fourth-, and sixth-grade children from low-income families to determine how different aspects of literacy learning developed. The authors followed the students over a period of two years, using an array of measures and comparisons. In second and third grades the students from poverty performed on grade level in vocabulary development, but by fourth grade those students tested below on vocabulary measures. The well-cited “fourth-grade slump” tends to worsen as students progress in school, while facing more specialized content textbooks. This study reported that vocabulary was the biggest reading problem for these children. What is promising about this research is that it attributed teachable literacy skills, as opposed to cognitive factors, to explain why low-income students struggle. Disciplinary teachers can support vocabulary development by providing students with multiple opportunities to interact with words in different contexts.

Other more recent reviews have continued to emphasize the overall importance of vocabulary. The National Reading Panel (National Institute of Child Health and Human Development, 2000) reviewed forty-seven studies relating to vocabulary instruction in its descriptive analysis of the relationship between vocabulary instruction and reading comprehension. The NRP concluded that vocabulary instruction does lead to gains in comprehension, recommending that: “there is a need for direct instruction in vocabulary items required for a specific text” (p. 4-4). Similar to the findings of Graves (1986), and Stahl and Fairbanks (1986), the NRP noted the importance of active engagement in vocabulary learning tasks. The need for direct instruction of selected words is important as it relates this proposed dissertation research. More research is needed to identify which types of words will allow for the greatest gains in reading comprehension.

The RAND Reading Study Group (2002) report also provided relevant information involving vocabulary instruction. Noting the complex relationship between vocabulary instruction and comprehension, the report cited challenges with “relationships among vocabulary knowledge, conceptual and cultural knowledge, and instructional opportunities”(pp. 35-39) as it is not clear to what extent vocabulary instruction fulfills a functional need in reading (teaching the meanings of words necessary to understanding particular texts) or whether vocabulary knowledge is a proxy for a much more dynamic body of understanding and experience that may play an interpretive or mnemonic role in reading comprehension. The authors also provided the critique that:

> …some of the strongest demonstrations on the effects of vocabulary instruction in reading comprehension…used rather artificial texts heavily loaded with unfamiliar words. Little, if any, research addresses the question of which conditions—the types of texts, words, readers, and outcomes—can actually improve comprehension. (p. 36)

In its outline of the most important literacy topics that will need to be addressed in the immediate future, the RAND Reading Study Group identified vocabulary in its link to reading comprehension as one of the most critical topics in literacy research.

One recent change in an important reading assessment suggests the rising influence of vocabulary once again. In the 2009 NAEP Reading Framework (National Assessment Governing Board, 2008), vocabulary was reported both separately and as a portion of the overall comprehension score (Pearson, Hiebert, & Kamil, 2007). This is considered a more systematic approach to vocabulary assessment than previous NAEP frameworks. A move to change the NAEP assessment to be more inclusive of vocabulary assessment is significant as it acknowledges the importance of vocabulary as an indicator of reading success (National Assessment Governing Board, 2008).

The studies reviewed in this chapter emphasize the importance of vocabulary in regards to reading comprehension. However, there is a need to determine more specifically which types of words should be the target for instruction if comprehension gains are expected. Often, these studies artificially inflated the impact of vocabulary by teaching the words needed to understand the specific texts used for assessment and then projected general gains as to the overall benefits of teaching vocabulary. Additional research will be helpful in determining if teaching students specific types of vocabulary words improves their comprehension of texts that include those words.

Vocabulary Instruction for the Teaching of Individual Words

While more is known today than ever before about vocabulary instruction, research reveals that there has not been much change in classroom vocabulary teaching (Blachowicz, Watts-Taffe, & Fisher, 2006). Many teachers devote attention to vocabulary instruction, but they do so using methods not supported by research. For example, one widely-adopted approach to teaching vocabulary that has been found to be ineffective (Anderson & Nagy, 1992; Beck et al., 2002) is having students study a list of definitions, compose sentences using the words, and then taking a weekly test on the words. Blachowicz et al. also noted that most vocabulary instruction occurs prior to reading, which may not allow for the rich, multiple exposures to words that are essential to meaningful vocabulary acquisition.

In contrast, many not-so-widely-used methods have proven to be effective. It is important to note, however, that multiple reviews (Blachowicz, Fisher et al., 2006; National Institute of Child Health and Human Development, 2000) have found no single method of vocabulary method to be the most effective. Rather, vocabulary instruction should be suited to match the learning purposes and should rely on a combination of methods. The current dissertation study attempted to be inclusive of a number of principles and methods that have been found to be effective in studies of the direct instruction of vocabulary words for the student work packets. For example, the intervention included various independent vocabulary activities aimed at increasing student exposure to the target words in research-supported ways. It is important to reiterate that this study evaluated the impact of learning different word types; it was not an evaluation of effective vocabulary instruction. The researcher approached this study using the premise that selecting types of vocabulary words must occur first before implementing effective instructional vocabulary methods. Still, so few studies exist comparing word types that this literature review extends its discussion into studies of vocabulary instruction, particularly those related to gains in reading comprehension.

Many methods for teaching vocabulary words in order to improve reading comprehension have proven successful (Graves, 1986). Gipe (1979) compared various methods for teaching vocabulary. With a pool of 93 third graders and 78 fifth graders, Gipes's subjects were taught using four different techniques of vocabulary instruction over two-week periods of time. The different methods included: word association, which involved matching synonyms and antonyms; categorization; context, in which the target words are inserted into gaps in sentences; and the dictionary method, in which students look up the meanings of unknown words in dictionaries and copy the definitions. In explaining her rationale for the study, Gipe found that the context method to be the most effective. However, she was unable to replicate these findings in a later study (Gipe, 1981).

Other studies focusing on specific techniques for the direction instruction of vocabulary have also identified effective procedures. The keyword method, which is a mnemonic device, has shown significant impact in helping students remember the meanings of words (Levin, Levin, Glasman, & Nordwall, 1992; Pressley, Levin, & McDaniel, 1987; Pressley, Ross, Levin, & Ghatala, 1984). Another technique with proven success is the use of semantic maps, which assists students in visualizing the interconnections among words (Baumann & Kame'enui, 1991). Graphic organizers (Moore & Readence, 1984) and other techniques that help children categorize, such as the Concept of Definition Map (Schwartz & Raphael, 1985), have also been shown to improve vocabulary learning. Such methods can be of great value in the content areas where the vocabulary terms may be both technical and symbolic.

One of the challenges of vocabulary instruction for teachers is in balancing the cost of time to seek appropriate gains. Content teachers, who are not only teaching new labels for familiar concepts but teaching new labels for new concepts, are faced with considerable challenges. A time-intensive, yet effective instructional method is the Frayer model (Frayer, Fredrick, & Klausmeier, 1969). In this method, students interact with the target words using several steps. First, the student defines the new concept by naming its essential attributes. The student then differentiates between essential and nonessential properties of instances of the concept. Next, the student gives both examples and non-examples of the concept, and finally relates to concept to other concepts. Again, while this is a time-intensive method of vocabulary instruction, it can yield considerable gains for disciplinary teachers.

Measurement of Vocabulary Knowledge

One concern that has resonated across decades in vocabulary literature involves the concern with measurement of vocabulary knowledge. Researchers in the field note frustration with wide disparities in the attribution of vocabulary size or in determining the effectiveness of instructional approaches. Researchers acknowledge that these problems stem from the variety of measures used to estimate vocabulary knowledge (Blachowicz, Fisher et al., 2006; Fillmer, 1977; Graves, 1986; Jenkins et al., 1989). Students may have varying degrees of word knowledge, and assessments differ in how well they capture those variations.

If a study measures how well students can associate a word with a definition or synonym, as is often the case in standard multiple-choice vocabulary tests, then a definition method of instruction might be sufficient to improve student performance. However, Beck and McKeown (1991) argue that the goal of vocabulary instruction should be to enhance students' engagement in complex language situations. Such a goal often goes beyond the tasks required of students in standardized vocabulary assessments, and one assumes that a richer and more intrusive approach to vocabulary teaching would be needed to end with this kind of result.

Beck and McKeown (1991) noted in their review of vocabulary acquisition that multiple-choice format is the most widely used measure of word knowledge, both in school and research settings. One issue of concern with this category of tests is that distracters may unfairly confuse students, providing a measure of something different than vocabulary knowledge (Anderson & Freebody, 1981). Yet one advantage of multiple-choice tests lies in the ability to manipulate distracters to assess varying levels of word knowledge. However, there is a degree of flatness to multiple-choice tests that does not provide researchers or teachers with a clear estimate of the degree to which students understand the words. Curtis (1987) stresses positive aspects of multiple-choice tests, such as a strong correlation with measures of reading comprehension and intelligence. Such assessments can also provide reliable data about a student's vocabulary range, particularly in relation to his or her peers.

Research comparing multiple-choice assessments to alternative assessments has not provided solutions to the problem. Curtis (1987) compared fifth-grade students' word knowledge using several different measures. On a self-reporting checklist, where students indicated whether they knew a word or not, the students reported "yes" to knowing the word 80% of the time. Students were then asked to explain the meaning of words, and could do so 70% of the time. When students were asked to give an example or slight explanation, only 50% did so with accuracy. Giving synonyms or complete explanations was something that only 20% could do. In comparison, a multiple-choice test resulted in an average score of 50%, suggesting that this particular assessment was comparable to one that only reveals partial knowledge.

Other attempts to compare assessments of word knowledge have revealed similar findings. Stallman et. Al (1995) interviewed children to examine the validity of three different paper-and-pencil tests of word knowledge. The first test was a standardized vocabulary test, and the others were experimenter-designed tests. The standardized test involved questions where students had to identify a synonym to a word in a limited context. The first experimenter-designed test targeted three different levels of word knowledge by using three multiple-choice items per word. The second experimenter-designed test required that students make a decision about whether or not a word was used appropriately in context, with five choices. The authors found that all three measures had reliability, but provided different affordances. For example, the standardized test more accurately provided an overall picture of students' word ability, but did not reveal the extent of knowledge that students knew about the particular words. In this study, the authors concluded that the context test was the best overall measurement in terms of reliability and in allowing for instructional validity.

The available research on assessment of word knowledge points to the need for improvements to enhance both future research and classroom instruction. Blachowicz, Fisher, and Ogle (2006) are optimistic about the potential for improvements in this area:

> Perhaps the renewed interest in content learning and its related academic vocabulary development will provide a context to assess more clearly students' word learning and its relation to comprehension, because the corpus of academic terms in a particular discipline is more constrained than the measure of general vocabulary that are characteristic of standardized reading assessments. (p. 534)

Clearly, more research is needed during this time of renewed interest to increase understanding and to improve measurement tools.

Defining Academic Vocabulary

The study of academic vocabulary has witnessed a surge in recent years (Nagy & Townsend, 2012). Nagy and Townsend offer a definition for academic language, calling it "the specialized language, both oral and written, of academic settings that facilitates communication and thinking about disciplinary content" (p. 92). They go on to explain that such language exists due to its need to "convey abstract, technical, and nuanced ideas and phenomena that are not typically examined in settings that are characterized by social and/or casual conversation" (p. 92). The interconnectedness of academic language and its advancement of academic thinking are important to note, as well. Being proficient in academic language allows people to learn to do new things that one could not have done with other words. General academic words are those words that are not specific to any single content area, but that are used more generally across or among the various content areas. These words are sometimes referred to as "tier two" words (Beck et al., 2002; Nagy & Townsend, 2012). Tier one words are so common to oral language that they do not require explicit instruction and tier three words are those that are highly specialized usually to a single content area, such as science, or perhaps even just one field of science. These general academic words or tier two words are often abstract and have multiple meanings. For example, the word *function* is quite abstract and would be challenging for a student to learn simply by memorizing a definition. A word like *function* also takes on multiple meanings, depending on its context. Generally, it means the purpose for which something is used, but in the context of mathematics, it is the relationship between two sets of numbers or mathematical objects. Research on the teaching of general academic words suggests that students must have multiple exposures to read and interact with such words if they are to be mastered adequately.

Another category of words, domain-specific academic words or tier three words, includes those words whose usage is limited to a particular discipline. As Baumann and Graves (2010) have outlined, this category of words has been given multiple labels in the literature. The terms that will be used most frequently in this dissertation research to refer to the different categories of words will be *general academic* and *domain-specific*. Other labels include Hiebert and Lubliner's (2008) *content-specific vocabulary,* Fisher and Frey's (2008) *technical vocabulary*, Harmon, Wood, and Medina's (2009) *technical terms, and* Jetton and Alexander's (2004) "'*language' of academic domains*" (p. 17).

These domain-specific words can be either technical (that is, specific to a single field, such as a word like *cytoplasm*) or abstract (that is, words which are difficult to visualize, such as *federalism*). Although these words are by definition specialized in that they are used within only specific fields of study, Marzano and Pickering (2005) argue for the value of their instruction: "Teaching specific terms in a specific way is the strongest action a teacher can take to ensure that students have the academic background knowledge they need to understand the content they will encounter in school" (p. 1). Nagy and Townsend (2012) agree that these words are essential to building conceptual knowledge in the disciplines, yet warn that knowledge of these words is not a guarantee that students will be able to access the texts in the discipline. Their point is that even if students gain access to the discipline-specific domain-specific words, they still may not be able to make sense of the discipline-specific texts because they still may not have sufficient grasp of the Tier 2 words that may be affecting their comprehension. It is important to note that vocabulary instruction is highly outcome-driven; what teachers want students to accomplish with their newly-acquired vocabulary, whether it is to understand text, analyze or synthesize text, or apply it to the creation of new text, should match the types of words taught and the type of instruction used.

Despite the growing body of work on teaching vocabulary to improve reading comprehension, it is not evident which types of words should receive greater instructional emphasis. Obviously teachers cannot teach all of the words that might matter for a given text, but where should the priority be given? Depending on the goal, is it better to focus instructional time on general academic vocabulary or upon the domain-specific vocabulary of a particular discipline?

Research on Word Selection for Vocabulary Instruction

There are two approaches to developing vocabulary (National Institute of Child Health and Human Development, 2000): indirect and direct. With indirect approaches students are simply encouraged to increase their reading with the idea that reading exposure will increase knowledge of words. On the other hand, direct instruction refers to those "situations in which word-meaning is intentionally made available to the student" (Beck & McKeown, 1991, p. 804). Although there is clearly a role to play for both indirect and direct approaches to vocabulary development, it is direct approaches that must be concerned with the topic of this research study: how do teachers appropriately select words for instruction that will increase reading comprehension with disciplinary reading materials? Many recommendations are offered to teachers with regard to selecting words for direct vocabulary instruction. Such recommendations are important considering that students are likely to learn only about 400 words per school year through explicit instruction, as opposed to the 4,000 words per year they may learn incidentally from context (Beck et al., 2002). Many recommendations are useful if some general: select words that are important to the text, useful in various situation, and uncommon in everyday language though prevalent in text (Juel & Deffes, 2004). Similarly, Cooper (1997) recommends that the selected words be frequently encountered in other texts and disciplines, be important to understanding the main idea of a text, be words that students do not know, and that are unlikely to be learned independently through context or structural analysis. Beck and McKeown (1991) note the challenge of time in direct instruction and therefore recommend that selected words be "of high frequency in a mature vocabulary and of broad utility across domains of knowledge" (p. 810). While such general guidance is useful, it does not address the dilemma of disciplinary teachers facing limited instructional time to cover both content and word-learning strategies. The advice for the most part sounds as if it is recommending the teaching only of the more general vocabulary, but is this really the most effective approach in a biology or algebra class?

Several classification systems have been proposed to aid teachers with their word-selection dilemma. Marzano and Pickering (2005) propose that middle and high school content teachers teach the words that appear in their lists of academic words in various content areas. Teachers are to identify domain-specific words from the appropriate level, and then to select words critical for instruction. Such critical words may be those which appear in the textbook, curriculum, or state/national standards. If the terms are important to the content, the words should be organized according to the curriculum. Fisher and Frey (2008) offer a similar plan for teachers to prioritize the words selected for vocabulary instruction. According to them, teachers should look at texts within their discipline and identify words that fit into the general academic and domain-specific categories. Once the words are classified, teachers should consider if the words are critical to concepts that will allow for understanding of the text, and whether such words will be used repeatedly in the course. Or, Graves (2006, 2009) recommends that teachers first look at existing word lists, such as Coxhead's (2000) Academic Word List, to compare the words in the texts of their content area. He then suggests that teachers use teacher-created assessments to identify words that their students do not know.

His final step involves teachers considering how critical the word is for students to be able to understand a specific concept. Baumann and Graves (2010) describe a modified classification scheme for sorting academic words into five categories: “domain-specific academic vocabulary, general academic vocabulary, literary vocabulary, metalanguage, and symbols” (p. 9). Another four-tier classification system comes from Flanigan and Greenwood (2007). They categorize words in the following manner: “critical ‘before’ words, ‘foot-in-the door’ words, critical ‘after’ words, and words not to teach” (p. 229). Using these different categories, Flanigan and Greenwood suggest that teachers make an appropriate match between their students, the words, the instructional purposes, and the instructional strategies that will be used to effectively select words.

This is an impressive collection of theoretical recommendations, but it is important to remember that these systems or plans have not been validated by research. It is not clear what the implications are of the various schemes, or whether any of them would lead to more, or less, student learning in a disciplinary subject. Recommendations such as these may be costly for school districts to implement, too, as they may require professional development support for teachers to be able to use these plans consistently and efficiently.

One of the seminal works involving words in the general academic category is Coxhead’s (2000) Academic Word List. Her list consists of the 570 most common general academic word families pulled from college-level texts in four disciplines. Researchers and educators have responded positively to the list because it offers a useful guideline as to high-frequency words that may challenge students as they access their academic texts. However, some uses of the Academic Word List have drawn criticism. For one, the list was created using primarily college-level texts from New Zealand and Britain, which might not align as closely with K-12 materials in the U.S., so it might not emphasize the right academic vocabulary (Baumann & Graves, 2010). As such, some scholars discourage its prescriptive use in schools (Hancioglu, Neufeld, & Elridge, (2008). Just because words appear in multiple disciplines, does not mean that those words will have the same definitions in each disciplinary context (Hyland & Tse, 2007), so some words might not be as widespread as is presumed (e.g., rational has very different meanings in a history text than in a math text). Nagy and Townsend (2012) illustrate the polysemous nature of words, giving the examples of *force* and *function.* These two terms have discipline-specific meanings in math and physics, but are used more generally in other contexts. Such examples illustrate the importance for students to learn academic words in their appropriate contexts, and not in isolation. Furthermore, they argue that the frequency counts of these words is determined to some extent by the morphological relatives of the words, which may or may not be pertinent to the language experiences the students are likely to have.

Research on Word Selection in Science

There is a growing body of research on word selection specific to the discipline of science. Much of the existing research supports the teaching of general academic words, but little research actually compares the relative impact of teaching the different categories of words as it relates to performance in the discipline.

Two decades ago Marshall and Gilmour (1991) worked with students in New Guinea, grades 7-12, to determine how their comprehension would be impacted by nontechnical, or general academic, words in science text. The authors found that students typically had a superficial understanding of nontechnical words, such as *component*, *consistent*, *exclude*, and *interpret*. These nontechnical terms appear frequently in science textbooks, but rarely receive instructional attention by teachers, probably because such terms are not viewed as being part of the content being taught. In their study, the authors found the nontechnical terms prevented students from effectively communicating science ideas to others in the classroom.

Marco (1999) reviewed the procedural vocabulary (words that state conceptual relationships) in scientific discourse. The importance of these words is in their ability to provide a contextual link among conceptually loaded words. Procedural vocabulary would include words and phrases such as: *be similar to*, *be considered*, *be different from*, *be characteristic of*, and *be the result of*. Marco found the procedural vocabulary to be of considerable importance in conveying complex ideas in content areas such as the sciences.

Townsend and Collins (2009) used a language workshop intervention to improve middle school language-minority students' knowledge of academic vocabulary. The researchers selected the 60 most frequent words from Coxhead's (2000) Academic Word List and provided 37 students with multiple exposures to the words in an after-school setting. The words were presented in the context of specific content from social studies and science. Students' gains in the target words were measured by a modified format of the Vocabulary Knowledge Scale (Paribakht & Wesche, 1997), which asks students to do things as explain the meaning of words and the contexts where the words would be used. The authors found that the intervention was effective in increasing students' depth of knowledge of the target words, and the meanings were found to have been maintained in delayed post-testing.

Lesaux et. Al (2010) also studied the effectiveness of an intervention aimed at teaching general academic words. The intervention, Academic Language Instruction for All (ALIAS), consisted of two 8-week instructional units where students had multiple exposures to eight or nine general academic words from the Academic Word List (Coxhead, 2000). The lessons, which were taught to 476 sixth graders, were facilitated by teachers and included five vocabulary assessments. The authors found that students made significant vocabulary knowledge gains as measured by three out of the five assessments. The first assessment in which students made significant gains was an experimenter-designed multiple-choice test on the target words (d = 0.39). The second was a morphological decomposition test (d = 0.22), and the third was an experimenter-designed test on students' understanding of the target words in context (d = 0.20). Of the tests that did not result in significant findings, one was an experimenter-designed measure of depth of knowledge of the target words, and the second was a standardized reading vocabulary test. The intervention resulted in gains on a standardized measure of reading comprehension that barely missed significance (d = 0.15, p = .06).

Snow et. Al (2009) tested general academic word knowledge with the Word Generation program. The intervention is a 24-week program that introduces students to five general academic words per week using high-interest topics. The program is delivered by math, social studies, science, and English language arts teachers. The study used a treatment sample of 697 middle school students, and reported effect sizes ranging from 0.33 to 0.56. The gains were also significant predictors of performance on state standardized achievement tests. The intervention provided students with both instruction and practice in authentic contexts of the general academic words.

Such studies are promising in illustrating the potential impact of teaching general academic vocabulary. However, this still leaves the issue about where teacher attention should be devoted. Should science teachers teach the technical words of their subject, these more general, but useful words within science, or some combination of the two? Past research demonstrates the potential value of general academic words, and content teachers usually are justifiably committed to the teaching of domain-specific words since they are usually so central to the content being taught. However, time for vocabulary instruction is necessarily limited in secondary school classrooms, so studies need to determine which types of words should be prioritized for such attention.

This research is guided by a theoretical perspective that words are important tools that promote learning within a discipline. Nagy and Townsend (2012) describe “words as tools” (p. 92) in their theoretical review, and such a metaphor guides the perspective of this dissertation research, as well. Within academic disciplines, the learning of domain-specific vocabulary words is not the end goal. Instead, those words are tools to achieve new understanding, and in turn, to communicate those new ideas to others.

One possibility why the existing recommendations in regards to domain-specific vocabulary instruction are so vague might rest in the inseparable relationship between language and content. In considering the nature of domain-specific vocabulary, it is impossible to draw a firm line between content and word knowledge. To be proficient in a discipline, a network of understanding is needed beyond basic word knowledge. Students must have conceptual understanding about new elements, relationships, and processes, as well as the labels for these concepts (Anderson & Nagy, 1992). The labels, or the vocabulary words themselves, make it possible for students to distinguish those items from others, read about them, talk about them, and in general, deepen their conceptual understanding. Because of this, disciplinary vocabulary instruction cannot be separated from disciplinary content instruction. The two should be administered in a way that is closely embedded, with words being the tool to allow for something new to be built.

For some, a conflict exists between the role of general academic and domain-specific words within the walls of a disciplinary classroom. The use of instructional time to teach domain-specific vocabulary words has even been criticized, with some considering these words to be of much less value than general academic words (Bates, 2008). General academic vocabulary words certainly have a role in the disciplinary classroom, but likely not an exclusive one. Disciplinary teachers cannot avoid domain-specific words for the reason that they are so closely related to the content that is at the heart of their curriculum. Still, general academic words have an important role. It is often these words that are embedded in the definitions of the domain-specific words, and thus, they are especially important (Snow, 2010).

This research was administered with the philosophy that both categories of words have value within academic disciplines, as the Common Core Standards suggest (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). However, empirical evidence is needed to understand the measurable affordances provided by each.

CHAPTER 3

METHODOLOGY

Purpose

The purpose of this research was to determine what types of words should be studied in secondary science classrooms. That is, this project tested the implications of studying either general academic or domain-specific words within ninth-grade biology classrooms to determine which words confer the greatest learning advantage to students using science texts. General academic words are those words that carry meanings that are not specialized to science (e.g., compare, analyze, transport). Such words are rarely recommended exclusively as the focus of science instruction, though the meaning of science texts is often dependent on such words. Domain-specific words, on the other hand, are the technical words or specialized words of the content area (e.g., cellular, molecules, respiration). The issue is whether the increased familiarization with either type of word allows students to better comprehend science texts or to learn the science information more readily. The methodology for collecting quantitative data in this inquiry is the focus of this chapter.

Research Questions

This study addresses the following research questions in regards to the learning outcomes that result from these different approaches to vocabulary word selection in ninth grade biology classrooms:

1. What is the effect of the treatment (studying a specific category of words) on learning, as measured by tests of reading comprehension vocabulary understanding, and content knowledge?

2. Do the treatments differ in their relative impacts on reading comprehension or vocabulary knowledge?
3. Do the treatments lead to significant differences in the learning of science content?

Study Design

In this quasi-experimental study, high school students were assigned to one of four treatment and control groups, with the treatments varying in terms of the type of vocabulary words with which the students were engaged in word-study. Outcomes were determined by examining the impact of these different vocabulary learning conditions upon reading comprehension, vocabulary learning, and performance on science content assessments. As described in chapter one, the term "instruction" is used as it applies to this research study to describe the treatment that students received. The instructional treatment consisted of students working independently in vocabulary activity packets. The design of this study was not to measure best instructional practices in vocabulary; rather, the design of this research was to measure the impact of studying various word types.

Participants and Site Description

This study took place with teachers and students from a suburban high school located west of Chicago. The high school is one of two high schools in a unit district and includes students from a range of income levels and ethnic backgrounds. The school site is a traditional four-year campus, with seven 50-minute class periods per day.

West High School (a pseudonym), is located in a middle-class suburban community. West High School has a population of 1,833 students that includes 44.6% White, 16.5% Black, 33.2% Hispanic, 3.4% Asian/Pacific Islander, 0% Native American, and 2.3% multiracial students. The low-income rate, as measured by free and reduced lunch, is 47.2%. The percentage of students categorized as having Limited English Proficiency (LEP) is 0.7%. The percentage of students with a special education Individualized Education Program (IEP) is 13.3%.

Subject Selection

All students, as a graduation requirement, are required to take biology or honors biology at the ninth grade level. This research includes subjects in both standard and honors level biology classes, along with students with special needs in collaborative co-taught classes. While all of the school's ninth-grade class took part in the research activities, 315 students completed all parts of the study and provided consent for their data to be used. The data for two students' were removed from the statistical analysis because they fell outside the normal range, resulting in 313 total subjects. The researcher used an alphabetical list of all subjects to assign students to treatment and control groups individually, as opposed to assigning intact classroom groups to the treatments and control.

Teacher Selection

Teacher participation in the research was voluntary, but all teachers in the school who teach either standard or honors biology agreed to take part in the study. This included five standard-level biology teachers and two honors-level biology teachers. One of the five standard-level biology teachers is a special education teacher who co-teaches with a regular education teacher. Two of the teachers are male and five of the teachers are female.

Procedures & Materials

This study involved the use of three instructional treatment groups, and a control group. Students were assigned to each of the three treatments and the control. All three of the treatment groups read excerpts from a chapter on ecology in a biology textbook and completed word learning activities focused on an assigned category of vocabulary words. The three intervention treatments varied only in the type of vocabulary words with which students were engaged in word practice study. The content used during this quasi-experiment had not yet been covered in the class, and was presumably new to all of the students. The choice was made by the researcher to conduct the quasi-experiment prior to the unit being studied during the course of the class in an attempt to control for variations in instruction provided by the different teachers. That is, the ecology content used in the study was new material to the subjects. With content knowledge being one of the dependent variables, limiting exposure of the content exclusively to the research study was a deliberate choice to better assess the impact of the treatment.

During the class time in which the treatment groups were receiving the vocabulary treatment, the control group read passages from a biology chapter of the same topic, and answered content questions about this chapter. However, though the control group did not receive any direct vocabulary instruction, teachers were instructed to answer questions about the meaning of the words, if posed by the students. Similarly, teachers were also instructed to answer any questions from treatment students about the meanings of any words, including those not selected for teaching. The teachers reported that student-generated questions during the course of the study were rare.

Prior to the treatment, the students completed a researcher-created vocabulary pretest (Appendix D). This pretest was in multiple-choice format; each question began with a word and students had to select any answer choices that correctly defined the word. When completing this pre and post-test, students were instructed to select all answers that they believed to correctly define the word and that many of the questions had more than one correct answer. This format allowed students to demonstrate their general academic and domain-specific understanding of the words with the general academic words including both science and non-science definitions. For example, question number one stated:

1. Abundant
    a. A small amount
    b. A large amount
    c. A way to describe a species that has seen a population decrease
    d. A way to describe a species that has seen population growth

In this example, a general academic word that had multiple correct answers was being tested. Answer choice *b* was the general academic definition, and answer choice *d* was the domain-specific definition of the word. Though many of the questions had more than one correct answer, some questions only had a single correct answer. In terms of question type, this test included all of the selected general academic and domain specific vocabulary words that were the focus of this study, along with additional distractor words in each category to prevent students from pre-identifying the target words and contaminating the treatment. The 50-item vocabulary pre and post tests, which were identical tests (Appendix D), were coded into eight question types as follows:

Table 1. Vocabulary test coding categories.

Category Number	Item Type	Number of Test Items
1	Standard item with 1 correct answer (general academic)	2
2	Standard item with 1 correct answer (domain-specific)	15
3	Multiple correct answers (general academic)	13
4	Multiple correct answers (domain-specific)	0
5	Distractor with 1 correct answer (general academic)	1
6	Distractor with 1 correct answer (domain-specific)	7
7	Distractor with multiple correct answers (general academic)	7
8	Distractor with multiple correct answers (domain-specific)	5

For each category, students' scores could range from zero to the number of items included in that category, as illustrated in Table 1. As will be discussed further in chapter four, categories 1, 4, and 5 were dropped from analysis for containing so few items. Instead of a single composite score, the subjects received five separate coded vocabulary pre and post-test scores.

In addition to the vocabulary pre-test, students also took a science knowledge test on the subject of ecology as a pretest measure (Appendix E). The students later took the same test as a post-test at the conclusion of the study. This pre- and post-test is a 20-question multiple-choice assessment created by the biology teachers that focused on information from the unit of study and contained many of the targeted general academic and domain-specific words. Scores could range from zero to twenty points. In typical format of a standardized science assessment, the test contained several scientific diagrams. Many of the general academic words and domain-specific words appear in the question stems and answer choices. For example, question three states:

(3) What happens to the total amount of carbon as it moves through the carbon cycle?

(a) It increases

(b) It diminishes

(c) It stays the same

(d) It disappears

The correct answer to this question is *d*. In this example, the domain-specific word *carbon cycle* appears in the question stem, and the general academic word *diminishes* appears in the answer choices. In order to correctly answer the question, students need to have an understanding of the domain-specific term *carbon cycle* to know that it causes the amount of carbon to stay the same. An understanding of the general academic word *diminishes* is only needed for this question in the sense that students eliminate it as a possible answer choice.

It is important to note that when students completed both the pre and post-content tests, their only exposure to the science content was limited to the course of the research study; no additional ecology-related instruction took place until after the study was completed.

Other information that was collected from students prior to the treatment included their eighth grade scores on the EXPLORE reading test and their 8^{th} grade spring scores on the Measure of Academic Progress (MAP) reading test.

After the instructional treatments were implemented over the course of approximately two weeks for ten-minutes per day, students completed a succession of post-tests. The post-tests included a vocabulary measure, a test of content knowledge, and a reading comprehension test. The vocabulary measure was the same vocabulary instrument used for the pre-test. The students took the same science content test used prior to treatment, as well.

Additionally, the students completed a researcher-created reading comprehension measure (Appendix F). This comprehension assessment included three passages on ecology with corresponding multiple-choice questions. The first passage was adapted from a biology textbook describing the topic of ecology. The textbook passage was of comparable difficulty to the one that the students see in their daily coursework in the biology class. The second test passage resembles one that students might see on the ACT test, which students at the school take as eleventh-graders. ACT features one natural science passage on the reading portion of its college-entry exam. The types of passages and question types used in the comprehension post-test measure for this study have been designed to resemble those question stems used on this portion of the ACT, as this standardized instrument is one that is highly valued by the school. The third passage of the comprehension assessment contains a selection adapted from a science article on the topic of ecology. These three passage types, taken collectively, were chosen to be representative of the type of reading that students are expected to accomplish in high school science courses. The comprehension test contained 16 questions, with possible scores ranging from 0 to 16. All of the selected passages were slightly modified to include a mixture of the general academic and domain specific words that were studied by the groups during the treatments. It was the intent of this assessment for the targeted words to be distributed in the passages in a way that would be essential for comprehension. For example, the first paragraph of the second passage, a text about cold blooded vertebrates, states:

> Comparatively few freshwater species of fishes are limited in their **distribution** to a single river system, yet not many are found on both sides of a high mountain ridge, such as the Rocky Mountains in North America. That is to say, the fishes of the Mississippi Valley are generally different and **distinct** from those of the Pacific slope.

In this paragraph, the general academic words *distribution* and *distinct* appear. In understanding the ways that freshwater species appear in nature, it does seem that an understanding of what it means to be *distributed* would help a student grasp this concept. In the example using the word *distinct*, it is paired with the synonym *different*, which would certainly assist in understanding that different species appear in different geographic bodies of water. However, many struggling or less proficient readers fail to use such clues in enhancing comprehension. To recap, this assessment was created to represent the nature of the readings that students might face in a typical biology course, while also incorporating the targeted words in ways that would be critical to understanding the text.

Treatments

As discussed in chapter 2, this dissertation research uses Fisher and Frey's (2008) classification of tiers of words into two categories: general academic words and domain-specific words. The instructional treatment involved subjects working independently in vocabulary activity packets. In this study, group one's packets included excerpts from a science textbook and independent work requiring the use of both general academic and domain specific words. Group two's packets included excerpts from a science textbook and independent work that required the use of the general academic words only. Group three's packets included excerpts from a science textbook and independent work that emphasized use of the domain-specific words. The instructional treatment, or time spent when students were completing the individual vocabulary activity packets, took place in the context of students' regular biology classrooms for approximately ten minutes per day over the course of two weeks (Appendices G, H, & I).

The researcher created independent vocabulary activities for the subjects in each group to complete over the two-week period. While the process of studying vocabulary independently is not what most would consider best practice, some of the activities in the lesson packets were chosen for being widely accepted as effective tools. For example, the lesson packets begin with students indicating their familiarity with each of the words assigned to them (Allen, 1999). Other activities in the lesson packets included using graphic organizers such as a modified version of the Frayer model (Frayer, Fredrick, & Klausmeier, 1969). Despite this attempt by the researcher to include proven tools for the vocabulary lesson packets, this study is not an evaluation of effective vocabulary instruction, but rather a precursor to the study of effective vocabulary instruction. Instead, the focus is on evaluation of types of vocabulary words to provide baseline data for future research. In terms of the packets for each of the three treatment groups, though the words differed across treatment groups, the vocabulary activities were the same for each group.

Due to the nature of the lesson packets as independent work, students in the classes proceeded at different paces. While some of the activities included subjective responses such as creating an image to help remember a word, other lessons allowed for more objective answers. For the objective activities, students were instructed in the packets to stop after such a lesson and get answer sheets from their teacher. Students were asked to check their work and note incorrect responses. In the absence of interaction with the teacher, which was prohibited to protect against contamination of the group differences, the answer keys supplemented the feedback a student might otherwise receive in the classroom setting, and it did so in a systematic and consistent manner across study conditions.

Control Group

The control group for this dissertation research read the same excerpts from a biology textbook and completed questions relating to the science content, but received none of the independent vocabulary work activities that the treatment groups received. The control group and the treatment groups read the same segments of text (Appendix J). The only exception is that the control group's work included additional reading passages and questions on the ecology content to account for the difference in work time due to the vocabulary work provided to the treatment groups. Even given the additional reading passages and questions, the control group had higher lesson completion rates. Some teachers reported a few students completed the lesson packets before the study was over, and those students were usually from the control group. The four passages that the control group shared with the treatment groups came first in their packets, with the 6 additional passages that are being provided only to the control group coming last. The format for the control group's work was to read a passage and answer questions about the passage, with no specific vocabulary work included (although the vocabulary words do appear in the passages and questions).

Word Selection

The instructional treatment used in the study varies by the type of words with which students worked. Each group worked with a total of fifteen vocabulary words during the two weeks of the study as follows:

- Group 1 — A combination of 15 general academic and domain specific words
- Group 2 — 15 general academic words
- Group 3 — 15 domain-specific words

The domain-specific words that were included in the study were selected first by consulting lists of vocabulary words that the biology teachers had already identified for the unit in ecology. These words largely correspond with the identified concepts in the textbook used for the course (SEPUP, 2011). The approved textbook for the course is not a traditional textbook with lengthy reading passages, but instead includes a number of hands-on activities in which students engage into to master the content. Because of this, additional textbooks were consulted to identify potential general academic words that students might face in a more typical high school biology textbook. Accordingly, general academic words that appeared frequently in chapters of ecology, that were critical to understanding the content, and seemed likely to appear in multiple contexts were chosen (Beck et al., 2008). Once the general academic and domain specific words were identified, the standard frequency index (SFI) was determined for each using *The Educator's Word Frequency Guide* (Zeno, Ivens, Millard, & Duvvuri, 1995); this guide is based upon 60,527 text samples drawn from over 6,000 textbooks, literary works, and nonfiction used in U.S. schools. An SFI score of 40 indicates that a word is used fairly frequently, appearing at least once per million words. The purpose of the SFI scores was to ensure that the general academic words appear frequently enough in text to justify instructional attention, per the theories that emphasize the importance of general academic vocabulary. Likewise, the SFI should show that the domain-specific words do not appear often in text, which would be the reason why content teachers may be expected to give these words additional attention.

Also, the Zeno, et al. (1995) guide provides a measure of dispersion, which is a calculation based on how often the words appear in various content areas. The dispersion score ranges from 0 (meaning that it only appears in texts drawn from a single content area) to a 1 (meaning it appears in all kinds of texts). General academic vocabulary gains its utility from being employed in a variety of contents, so choices in this category were limited to words with a high dispersion index. And, again, since words with low dispersions would, by definition, only or mainly appear within a single content context, alternative theories would call for their instruction in a content area, since it would be the specialized nature of these words that would merit attention. The SFI and dispersion scores are included in Table 2 for the General Academic Vocabulary used in this study, and in Table 3 for the Domain-Specific Vocabulary used in this study.

These tables show striking differences in the frequencies in dispersions of the words that the treatment groups will study. The general academic vocabulary to be used in this study appears in texts with significantly higher frequency than is true of the domain-specific vocabulary, and the dispersions are also significantly different. Several of the domain-specific words were so infrequent that they do not even appear in the Zeno list.

Table 2. Standard Frequency Index (SFI) and Dispersion Index for General Academic Vocabulary Words.

General Academic Vocabulary	**SFI[1]**	**Dispersion[2]**
abundance/abundant	49.1	.8331
adaptation	48.6	.7735
diminish***	42	.6789
dispersion	41.1	.7066
distributed***	51.3	.9078
facilitate***	45.7	.7884
function***	57.8	.8986
immigrated***	32.4	.3492
inhabited	44	.7772
interval***	50.8	.8593
migratory	40.4	.5872
minimize***	45.3	.8082
regulate***	50.9	.8674
sustain	45.2	.8854
variation	51.4	.8478
Mean	46.4	.7712
Standard deviation	5.9	.1416

[1] 40 = 1 type per million tokens
[2] Dispersion across content areas (1 = high)
*** The word appears on Coxhead's Academic Word List (Coxhead, 2000)

Table 3. Standard Frequency Index (SFI) and Dispersion Index for Domain-Specific Vocabulary Words

Domain-Specific Vocabulary	SFI[3]	Dispersion[4]
amensalism		
carbon cycle		
cellular respiration		
commensalism	28.1	.0000
dead zone		
disturbance	22.1	.0000
ecological succession		
eutrophication	24.2	.0000
mutualism	32.8	.1340
parasitism	30.6	.1801
photosynthesis	22.1	.0000
primary succession		
resilience	27.6	.1929
secondary succession		
symbiosis	36.4	.2171
Mean	27.99	.0780
Standard deviation	14.16	.0866

[3] 40 = 1 type per million tokens
[4] Dispersion across content areas (1 = high)

Definitions for the vocabulary words included were gathered from a variety of sources. To be sure that the definitions were disciplinary appropriate, some definitions were taken directly from word lists created by the teachers. Additional domain-specific definitions were taken from the course textbook. The remaining definitions came from the *Oxford English Dictionary* (2012) and its specialized *Dictionary of Ecology* (Allaby, 2012).

<u>Teacher Involvement and Preparation</u>

The science content to be used for instruction in this study was determined in collaboration with the science department administrators and the biology teachers of the students participating in the study. This ensured that the treatments aligned well with the regular curriculum and prevented any loss of instructional time towards curricular goals for any of the groups. A unit on ecology was chosen as the topic for the study, as the proposed timing of the study would take place prior to instruction in that unit of the curriculum. Teacher buy-in to devote classroom time to the study was rationalized as it provided teachers with pre-assessment data of the students' content knowledge before that unit was taught in class. The participating teachers also accepted the importance of content area literacy in science, but possessed varying degrees of knowledge of how to implement such practices in their classrooms.

Since the teachers who participated acted as co-investigators in research by delivering the treatment of the study, they complied with the university's IRB approval process of training. The researcher met with the group of teacher several times in planning for the content assessments that were included in the study, along with IRB procedures. Though teachers acted as co-investigators, their participation was limited in that they needed only to distribute the materials daily to students and monitor students while they worked independently in the word study activities. Additionally, teachers administered assessments and took note of additional variables, such as student absences. All of these responsibilities fell within the normal expectations of classroom teachers.

Source of Materials

At the time of this research, the biology classes involved were in their second year of using a new textbook program. This new series is less traditional than most programs, relying less on a text-heavy book, and more on a lab-based activity model with integrated content instruction. Though the new series has less reading for students to do in the textbook, the program integrates reading and writing through hands-on activities.

Materials included in this study were largely made up of passages drawn from textbooks and other lesson materials with some modifications made by the researcher to the original texts. For example, the text selections the researcher used for the independent lesson packets and the comprehension test came from other textbooks, articles, and sample ACT tests on the topic of ecology. Modification of original texts was needed so that the content reflected the necessary vocabulary in the various categories of words included for each group. Another pre- and post-test measure included a science content test. The researcher modified an existing test created by the biology teachers to incorporate more of the targeted general academic and domain-specific words. The pre- and post-test vocabulary measure was created by the researcher using definitional answer choices taken from the Oxford English Dictionary (2012) and its specialized Dictionary of Ecology (Allaby, 2012), along with the course textbook. As described earlier in the chapter, the lesson packets also were created by the researcher, along with the inclusion of textbook excerpts and questions from the publishers.

Analysis

These data were analyzed using multivariate analysis of covariance (MANCOVA). The instructional group assignment is the independent variable, and the performances on the vocabulary, comprehension, and content tests are the dependent outcome measures. MANCOVA was used because these dependent measures were highly correlated with each other (i.e., students who do well on one measure are likely to do well on the other); and, thus, the analysis had to account for the covariance shared by these variables. MANCOVA allowed for a powerful determination of an overall effect of the treatment on this collection of outcome measures.

MANCOVA requires certain statistical assumptions and various analyses were made to ensure that these assumptions were satisfied. For instance, MANCOVA requires that the dependent measures be normally distributed within the groups. Because such a wide range of student performance (e.g., special education, regular classroom placements, honors track) is being included in this analysis, it was necessary to check the normality of the variables for the full distribution of students to ensure that there were no outliers. It is also essential that there was a linear relationship among the dependent measures and that the variances and covariances of these measures were homogeneous, and tests of each of assumptions were conducted prior to the MANOVA.

This multivariate analysis first indicated whether or not these treatment differences led to different levels of learning across the groups, as measured by reading comprehension, vocabulary understanding, and content knowledge. Additional analysis examined the individual effect of the dependent variables on group assignment, or if the treatments varied in their relative impacts on reading comprehension, vocabulary knowledge, or science content.

The student activity packets that students used during the course of the study were collected for dosage analysis. Packets were analyzed for a basic completion score as follows to determine if the differences across groups were comparable:

Table 4. Lesson Packet Completion Scoring Rubric

	Zero Completed (0 pts)	**Partially Completed** (1 pt.)	**Completed** (2 pts.)
Lesson #1			
Lesson #2			
Lesson #3			
Lesson #4			
Lesson #5			
Lesson #6			
Lesson #7			
Lesson #8			
Lesson #9			
Lesson #10			
	Total Points:	**/20 pts.**	

CHAPTER 4

RESULTS

Given the challenge academic vocabulary can pose for secondary students, the purpose of this study was to examine the implications of learning general academic or domain specific types of words within ninth-grade biology classrooms. In this quasi-experimental study, students were assigned to one of four groups, with the treatments varying the type of vocabulary words students worked with during word-study. Even though the treatment groups engaged in the same types of activities, group one was exposed to a combination of 15 general academic and domain-specific words, group two was exposed to 15 general academic words, and group three was exposed to 15 domain-specific words. The control group, group four, did no formal vocabulary work but instead was exposed to activities directly linked to the ecology science content. Several pre-test measures were gathered, including a vocabulary and science content test, along with existing standardized reading test data, such as eighth-grade Explore and MAP scores. Post-test measures included a vocabulary assessment, a science content assessment, and a reading comprehension assessment. Over the course of three weeks, this quasi-experimental study investigated whether the type of vocabulary words studied had any impact on student reading comprehension, vocabulary performance, and science knowledge in ninth-grade biology classrooms.

Analysis Plan

A multivariate analysis of covariance (MANCOVA) was used to analyze these data. The instructional group assignment is the independent variable, and the performances on the vocabulary, comprehension, and content tests are the dependent outcome measures. To account for any pre-existing group differences, the vocabulary pre-test codes, content pre-test, Explore reading test, and MAP reading scores were used as covariates. MANCOVA was used because these dependent measures are highly correlated with each other (i.e., students who do well on one measure are likely to do well on the others); and, thus, the analysis must account for the covariance shared by these variables. Given the amount of shared covariance among these measures, MANCOVA can provide an appropriate determination of an overall effect of the treatment on this collection of outcome measures.

Except for the existing pre-treatment standardized test data, all assessments were administered in the students' regular biology classes by the classroom teachers.

Demographics of Subject Population

The data for this research were collected from ninth-grade biology students enrolled in one public high school. The potential participants included 439 ninth graders. However, 54 students did not give consent for their data to be included, leaving a pool of 385 students. By the end of the three-week treatment period, 315 of the students had actually completed all parts of the experiment; this attrition was due to student absences, students who dropped the course, and students on extended home leave who were unable to complete all assessments and daily vocabulary or content work. Two students were removed during the statistical analysis for outlier scores, resulting in 313 total students.

Each of the four groups included honor students, regular education students, and students with Individualized Education Plans (IEP). The group sizes were distributed as follows: Group 1 (N = 75), Group 2 (N = 80), Group 3 (N = 73), and Group 4 (N = 85).

Statistical Data Analysis

To determine if there were differences in vocabulary and reading comprehension achievement among the instructional groups, a one-way multivariate analysis of covariance (MANCOVA) was performed using the Statistical Package for the Social Sciences (SPSS). Because MANCOVA determines population group differences across several simultaneous dependent variables, this test analyzed the assessment performances of the different groups. Instructional treatment group assignment was the independent variable, with the dependent variables being the students' performance on the reading comprehension test, post-test vocabulary assessment split into several different codes, and the post-test content assessment. Treatment group assignment is a nominal scale, and the dependent measures data were all on interval scales. An alpha level of .05 was set to analyze the significance of any differences that were found.

Prior to using MANCOVA, the dependent measures were analyzed for univariate and multivariate normality. The descriptive statistics are shown in Tables 5 and 6.

Table 5. Descriptive statistics for pre-test measures.

		Statistic	Std. Error
MAP Reading Test	Mean	19.72	3.90
	Std. Deviation	69.02	
	Skewness	-2.44	.14
	Kurtosis	4.27	.28
Explore Reading Test	Mean	12.05	.33
	Std. Deviation	5.89	
	Skewness	-1.00	.14
	Kurtosis	.73	.28
Content Pre-Test	Mean	8.91	.19
	Std. Deviation	3.32	
	Skewness	. 24	.14
	Kurtosis	-.22	.28
Vocab Code 1	Mean	1.14	.04
	Std. Deviation	.75	
	Skewness	-.24	.14
	Kurtosis	-1.20	.28
Vocab Code 2	Mean	6.77	.14
	Std. Deviation	2.38	
	Skewness	-.02	.14
	Kurtosis	-.17	.28
Vocab Code 3	Mean	34.65	.32
	Std. Deviation	5.66	
	Skewness	-.70	.14
	Kurtosis	1.04	.28
Vocab Code 5	Mean	.55	.03
	Std. Deviation	.50	
	Skewness	-.21	.14

	Kurtosis	-1.97	.28
Vocab Code 6	Mean	2.68	.08
	Std. Deviation	1.41	
	Skewness	.22	.14
	Kurtosis	-.32	.28
Vocab Code 7	Mean	17.70	.20
	Std. Deviation	3.53	
	Skewness	-.23	.14
	Kurtosis	.33	.28
Vocab Code 8	Mean	12.21	.15
	Std. Deviation	2.63	
	Skewness	-.36	.14
	Kurtosis	-.07	.28

Table 6. Descriptive statistics for post-test measures.

		Statistic	Std. Error
Comprehension Test	Mean	12.05	.33
	Std. Deviation	5.89	
	Skewness	-1.00	.14
	Kurtosis	.73	.28
Content Post-Test	Mean	8.91	.19
	Std. Deviation	3.32	
	Skewness	. 24	.14
	Kurtosis	-.22	.28
Vocab Code 1	Mean	1.14	.04
	Std. Deviation	.75	
	Skewness	-.24	.14
	Kurtosis	-1.20	.28
Vocab Code 2	Mean	6.77	.14
	Std. Deviation	2.38	
	Skewness	-.02	.14
	Kurtosis	-.17	.28
Vocab Code 3	Mean	35.19	.29
	Std. Deviation	5.06	
	Skewness	-.41	.14
	Kurtosis	.10	.28
Vocab Code 5	Mean	.59	.03
	Std. Deviation	.49	
	Skewness	-.39	.14
	Kurtosis	1.86	.28
Vocab Code 6	Mean	3.37	.10
	Std. Deviation	1.77	
	Skewness	.08	.14

	Kurtosis	-.86	.28
Vocab Code 7	Mean	17.80	.20
	Std. Deviation	3.49	
	Skewness	-.10	.14
	Kurtosis	-.04	.28
Vocab Code 8	Mean	12.64	.14
	Std. Deviation	2.55	
	Skewness	-.35	.14
	Kurtosis	-.12	.28

As described in chapter 3, the vocabulary pre and post-tests were coded into eight different categories displayed in Table 7.

Table 7. Vocabulary Test Coding Categories.

Category	Item Type	Number of Test Items
1	Standard item with 1 correct answer (general academic)	2
2	Standard item with 1 correct answer (domain-specific)	15
3	Multiple correct answers (general academic)	13
4	Multiple correct answers (domain-specific)	0
5	Distractor with 1 correct answer (general academic)	1
6	Distractor with 1 correct answer (domain-specific)	7
7	Distractor with multiple correct answers (general academic)	7
8	Distractor with multiple correct answers (domain-specific)	5

A review of the pre and post-test descriptive statistics revealed a lack of normality with codes 1 and 5, possibly because so few items are included in each category. Consequently, those two codes were eliminated from analysis. No question types fit category 4. The remaining five categories used in the analysis were: 2, 3, 6, 7, and 8.

To identify univariate outliers, the raw scores were converted into standard z scores. These calculations allowed the researcher to detect two students with z scores that ranged from -3.29 to -4.9. Because such scores were more than two standard deviations away from the mean, they were removed from the subsequent analysis. Additional univariate outlier screening included graphical analysis of stem-and-leaf plots.

A test for multivariate normality was conducted, as well. Multivariate outliers were evaluated based on Mahalanobis Distance values. With seven dependent variables, the Mahalanobis Distance values were calculated with *p* values ranging from .97 to 1, indicating no multivariate outliers for seven degrees of freedom.

An analysis of variance (ANOVA) was completed to ensure that there were no significant differences between the treatment and control groups on the pre-test measures. Table 8 shows that there were no statistically significant differences between groups on the vocabulary, content, or standardized reading pre-test measures.

Table 8. Analysis of variance of pre-test data.

		Sum of Squares	df	Mean Square	F	Signif.
Vocab Code 2	Between	23.02	3	7.67	1.36	.255
	Within	1744.42	309	5.65		
	Total	1767.44	312			
Vocab Code 3	Between	21.61	3	7.20	.22	.880
	Within	9985.44	309	32.32		
	Total	10007.04	312			
Vocab Code 6	Between	8.12	3	2.71	1.36	.254
	Within	613.93	309	1.99		
	Total	622.05	312			
Vocab Code 7	Between	42.73	3	14.24	1.14	.332
	Within	3847.44	309	12.45		
	Total	3890.17	312			
Vocab Code 8	Between	25.88	3	8.623	1.25	.291
	Within	2130.21	309	6.89		
	Total	2156.08	312			
Content Pre-Test	Between	69.41	3	23.14	.65	.584
	Within	3368.91	309	10.90		
	Total	3438.31	312			
Explore Reading	Between	67.83	3	22.61	1.71	.165
	Within	10769.35	309	34.85		

	Total	10837.18	312	
MAP Reading	Between	24241.95	3	8080.65
	Within	1461915.30	309	4731.12
	Total	1486157.26	312	

MANOVA requires that multiple dependent variables must be statistically correlated with each other. In this study, correlations between multiple dependent variables were checked prior to completing the MANCOVA. As Table 9 reveals, the dependent variables were significantly correlated with one another ($p < .01$).

Table 9. Post-test correlations (Pearson r)[5].

	1	2	3	4	5	6	7
Content Post-Test	1.00**	.60**	.68**	.65**	.57**	.51**	.45**
Comprehension Test	.60**	1.00**	.60**	.58**	.53**	.48**	.50**
Vocab Post-Test Code 3	.68**	.60**	1.00**	.61**	.60**	.52**	.46**
Vocab Post-Test Code 3	.65**	.58**	.61**	1.00**	.54**	.60**	.47**
Vocab Post-Test Code 6	.57**	.53**	.60**	.54**	1.00**	.44**	.48**
Vocab Post-Test Code 7	.51**	.48**	.52**	.60**	.44**	1.00**	.41**
Vocab Post-Test Code 8	.45**	.50**	.46**	.47**	.43**	.41**	1.00**

[5]Correlation significant at .01 level, N=313

An additional assumption of the MANCOVA is that there is equality of covariance matrices. Box's test of equality of covariance matrices, Table 10, shows that the covariance matrices did not differ significantly when evaluating this highly sensitive test at $p < .001$ (M = 114.74, F (84, 211552), p = .03).

Table 10. Box's Test of Equality of Covariance Matrices[6].

Box's M	114.74
F	1.31
df1	84
df2	211512
Signif.	.03

[6]Design: Intercept + ContentPretestScores20 + ScaleReadingScore + SpringMAPReading + VocabPretestCode2 + VocabPretestCode3 + VocabPretestCode6 + VocabPretestCode7 + VocabPretestCode8 + GroupNumberAssigned

Levene's Test of equality of error variances was also completed, as seen in Table 11. This test found no differences in variances of the four treatment groups. This means that the variance across groups was homogenous and that it is appropriate to compare the performances of these samples.

Table 11. Levene's Test of Equality of Error Variances[7].

	F	df1	df2	Sig.
Content Post-test	.93	3	309	.428
Comprehension Test	1.30	3	309	.276
Vocab Post-test Code 2	1.80	3	309	.147
Vocab Post-test Code 3	1.64	3	309	.180
Vocab Post-test Code 6	.21	3	309	.889
Vocab Post-test Code 7	1.24	3	309	.296
Vocab Post-test Code 8	2.18	3	309	.091

[7] Design: Intercept + ContentPretestScores20 + ScaleReadingScore + SpringMAPReading + VocabPretestCode2 + VocabPretestCode3 + VocabPretestCode6 + VocabPretestCode7 + VocabPretestCode8 + GroupNumberAssigned

The reliability analysis of the post-test measures showed adequate internal consistency of the test scores. For the standard vocabulary items with one correct answer (codes 2 and 6), as well as for the comprehension and content post-tests, a Kuder Richardson (KR-20) analysis found an overall reliability of .84. Using Cronbach's coefficient alpha for the vocabulary post-test codes that had multiple correct answers (codes 3, 7 and 8), an overall reliability of .72 was found.

Based on the testing results, it was determined that a one-way MANCOVA would provide an appropriate analysis of these data. The MANCOVA was run with the pre-test data and demographics as covariates. This included the vocabulary pre-test codes, content pre-test, Explore test, and spring MAP reading test.

Results of the Multivariate Analysis of Covariance (MANCOVA)

From the results of the post-test measures, group means revealed that group three, or the group whose treatment included domain-specific words, had higher mean scores than the other groups on the content post-test, comprehension test, and the vocabulary post-test for codes 2, 6, and 7. Table 12 illustrates the group means on the assessments below:

Table 12. Descriptive statistics for post-test measures.

	Group	Mean	Std. Dev.	N
Content Post-test	1	9.55	3.55	75
	2	9.90	3.74	80
	3	10.14	3.75	73
	4	9.80	3.82	85
	Total	9.84	3.71	313
Comprehension Test	1	7.40	3.44	75
	2	7.76	3.27	80
	3	7.86	2.99	73
	4	7.69	3.14	85
	Total	7.68	3.20	313
Vocab Post-test Code 2	1	7.89	2.95	75
	2	7.78	2.88	80
	3	9.58	3.24	73
	4	7.74	2.89	85
	Total	8.21	3.07	313
Vocab Post-test Code 3	1	34.84	5.14	75
	2	36.03	4.96	80
	3	35.34	4.40	73
	4	34.56	5.56	85
	Total	35.19	5.06	313

Vocab Post-test Code 6	1	3.20	1.71	75
	2	3.19	1.85	80
	3	3.68	1.77	73
	4	3.42	1.73	85
	Total	3.37	1.77	313
Vocab Post-test Code 7	1	17.60	3.45	75
	2	17.73	3.53	80
	3	18.74	3.20	73
	4	17.22	3.62	85
	Total	17.80	3.49	313
Vocab Post-test Code 8	1	12.23	2.75	75
	2	12.43	2.48	80
	3	12.74	2.64	73
	4	13.11	2.23	85
	Total	12.64	2.55	313

Table 13 reports the MANCOVA for the impact of the independent variables on the dependent variables.

Table 13. Results of the Multivariate Analysis of Covariance.[8,9]

Effect		Value	F	Signif.	Partial Eta Squared	Noncent. Parameter	Observed Power
Intercept	Pilai's Trace	.45	34.73	.00	.45	243.13	1.00
	Wilk's Lambda	.55					
	Hotelling's Trace	.82					
	Roy's Largest Root	.82					
Content Pre-Test	Pilai's Trace	.23	12.58	.00	.23	88.08	1.00
	Wilk's Lambda	.77					
	Hotelling's Trace	.30					
	Roy's Largest Root	.30					
Explore Reading Test	Pilai's Trace	.03	1.41	.20	.03	9.87	.60
	Wilk's Lambda	.97					
	Hotelling's Trace	.03					
	Roy's Largest Root	.03					
MAP Reading Test	Pilai's Trace	.01	.374	.92	.01	2.62	.17
	Wilk's Lambda	.99					
	Hotelling's Trace	.01					
	Roy's Largest Root	.01					
Vocab Pre-	Pilai's Trace	.10	4.77	.00	.10	33.42	1.00
	Wilk's Lambda	.90					

[8] Hypothesis Degrees of freedom (Hdf): For the analysis of Group Membership, the Hdf for Pilai's Trace = 21, for Wilk's Lambda = 21, for Hotelling's Trace = 21, and for Roy's Root = 7. For all other analyses, the HdF = 7.

[9] Error degrees of freedom (Edf): For the analysis of Group Membership, the Edf for Pilai's Trace = 891, for Wilk's Lambda = 848, for Hotelling's Trace = 881, and for Roy's Root = 297. For all other analyses, the EdF = 295.

Test Code 2	Hotelling's Trace	.11
	Roy's Largest Root	.11

Table 13. Results of the Multivariate Analysis of Covariance (cont.)[10, 11]

Effect		Value	F	Signif.	Partial Eta Squared	Noncent. Parameter	Observed Power
Vocab Pre-Test Code 3	Pilai's Trace	.20	10.83	.00	.20	75.82	1.00
	Wilk's Lambda	.80					
	Hotelling's Trace	.26					
	Roy's Largest Root	.26					
Vocab Pre-Test Code 6	Pilai's Trace	.04	1.84	.08	.04	12.86	.73
	Wilk's Lambda	.96					
	Hotelling's Trace	.04					
	Roy's Largest Root	.04					
Vocab Pre-Test Code 7	Pilai's Trace	.08	3.66	.00	.08	25.61	.97
	Wilk's Lambda	.92					
	Hotelling's Trace	.09					
	Roy's Largest Root	.09					
Vocab Pre-Test Code 8	Pilai's Trace	.03	1.13	.34	.03	7.92	.49
	Wilk's Lambda	.97					
	Hotelling's Trace	.03					
	Roy's Largest Root	.03					

[10] Hypothesis Degrees of freedom (Hdf): For the analysis of Group Membership, the Hdf for Pilai's Trace = 21, for Wilk's Lambda = 21, for Hotelling's Trace = 21, and for Roy's Root = 7. For all other analyses, the HdF = 7.

[11]Error degrees of freedom (Edf): For the analysis of Group Membership, the Edf for Pilai's Trace = 891, for Wilk's Lambda = 848, for Hotelling's Trace = 881, and for Roy's Root = 297. For all other analyses, the EdF = 295.

Group Membership	Pilai's Trace	.21	3.10	.00	.07	65.18	1.00
	Wilk's Lambda	.81	3.16	.00	.07	63.34	1.00
	Hotelling's Trace	.23	3.20	.00	.07	67.20	1.00
	Roy's Largest Root	.15	6.28	.00	.13	43.92	1.00

As Table 13 shows, a MANCOVA using Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root statistic found the group differences to be statistically significant, favoring the group number assigned. Thus hypothesis 1 was confirmed, meaning that instructional group assignment does have an overall impact on vocabulary, comprehension, and content performance.

Given the significant differences found for the group number assigned, the individual dependent variables were analyzed, as well. As the tests of between subjects Table 14 shows, the difference due to the vocabulary post-test for code 2 is significant, (F (3, 43.90) = 10.55, p = .000, partial eta square = .10, power = 1.00). The table also shows significant values for code 3 of the vocabulary test, (F (3, 35.59) = 10.55, p = .039, partial eta square = .03, power = .68).

Table 14. Tests of Between-Subjects Effects.

Source	Dependent Variable	Type III sum of squares[12]	df	Mean square	F	Sig.	Partial eta	Noncent. parameter	Observed power[13]
Group	1	3.78	3	1.26	.22	.88	.01	.65	.09
	2	.90	3	.30	.05	.98	.00	.16	.06
	3	131.69	3	43.90	10.55	.00	.10	31.66	1.00
	4	106.76	3	35.59	2.83	.04	.03	8.48	.68
	5	5.943	3	1.98	.99	.40	.01	2.98	.27
	6	54.820	3	18.27	2.39	.07	.02	7.18	.60
	7	32.02	3	10.67	2.25	.08	.02	6.74	.57
Error	1	1743.65	301	5.79					
	2	1731.07	301	5.751					
	3	1252.22	301	4.16					
	4	3790.62	301	12.59					
	5	599.59	301	1.99					
	6	2298.41	301	7.64					
	7	1430.63	301	4.75					

[12] Dependent variables: 1= Content Post-Test; 2= Comprehension Test; 3=Vocabulary Post-Test Code 2; 4= Vocabulary Post-Test Code 3; 5= Vocabulary Post-Test Code 6; 6= Vocabulary Post-Test Code 7

[13] Computed using alpha = .05

Given the significant differences found favoring codes 2 and 3 of the vocabulary post-test, pair-wise comparisons were completed to identify any differences between the four groups. As Table 15 shows, for vocabulary code 2 (domain-specific questions with one correct answer), group three (the group that worked exclusively with domain-specific words) was significantly different from the other groups. The pair-wise comparisons also show that for vocabulary code 3 (general academic questions with multiple answers) there were significant differences between groups two (general academic group) and four (control group).

Table 15. *Pairwise Comparisons*[14], [15].

Dependent Variable	(I) Group	(J) Group	Mean difference (I-J)	Std. error	Sig.[16]	95% confidence interval for difference[17]	
						LB bound	UB bound
Content Post-test	1	2	.27	.40	.50	-.51	1.05
		3	.28	.40	.49	-.51	1.07
		4	.24	.39	.54	-.53	1.00
	2	1	-.27	.40	.50	-1.05	.51
		3	.01	.40	.98	-.77	.79
		4	-.03	.38	.93	-.78	.72
	3	1	-.28	.40	.49	-1.07	.51
		2	-.01	.40	.98	-.79	.77
		4	-.04	.39	.91	-.81	.73
	4	1	-.24	.39	.54	-1.00	.53
		2	.03	.38	.93	-.72	.78
		3	.04	.39	.91	-.73	.81
Compre-hension Test	1	2	.14	.40	.73	-.64	.91
		3	.12	.40	.76	-.67	.91
		4	.05	.39	.91	-.72	.81
	2	1	-.14	.40	.73	-.91	.64
		3	-.01	.40	.97	-.80	.77

[14] The mean difference is significant at the .05 level.

[15] Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

		4	-.09	.40	.81	-.84	.66
	3	1	-.12	.40	.76	-.91	.67
		2	.01	.40	.97	-.77	.79
		4	-.08	.40	.84	-.84	.69
	4	1	-.05	.39	.91	-.81	.72
		2	.09	.38	.81	-.66	.84
		3	.08	.39	.84	-.69	.84
Vocabulary Post-test Code 2	1	2	.65	.34	.06	-.02	1.31
		3	-1.05*	.34	.00	-1.72	-.38
		4	.54	.33	.10	-.10	1.19
	2	1	-.65	.34	.06	-1.31	.02
		3	-1.70*	.34	.00	-2.36	-1.03
		4	-.10	.32	.75	-.74	.53
	3	1	1.05*	.34	.00	.38	1.72
		2	1.70*	.34	.00	1.03	2.36
		4	1.59*	.33	.00	.94	2.24
	4	1	-.54	.33	.10	-1.19	.10
		2	.10	.32	.75	-.53	.74
		3	-1.59*	.33	.00	-2.24	-.94
Vocabulary Post-test Code 3	1	2	-.85	.59	.15	-2.00	.31
		3	.11	.59	.86	-1.06	1.27
		4	.78	.57	.17	-.35	1.91
	2	1	.85	.59	.15	-.31	2.00
		3	.95	.59	.11	-.20	2.11
		4	1.63*	.56	.00	.52	2.73
	3	1	-.11	.59	.86	-1.27	1.06
		2	-.95	.59	.11	-2.11	.20
		4	.68	.58	.24	-.46	1.81
	4	1	-.78	.57	.17	-1.91	.35
		2	-1.63*	.56	.00	-2.73	-.52
		3	-.68	.58	.24	-1.81	.46

Vocabulary Post-test Code 6	1	2	.20	.23	.39	-.26	.66
		3	-.18	.24	.48	-.65	.28
		4	-.07	.29	.75	-.52	.37
	2	1	-.20	.23	.39	-.66	.26
		3	-.39	.23	.10	-.84	.07
		4	-.28	.22	.22	-.72	.16
	3	1	.18	.29	.48	-.28	.65
		2	.39	.23	.10	-.07	.84
		4	.11	.23	.63	-.34	.56
	4	1	.07	.23	.75	-.37	.52
		2	.28	.22	.22	-.16	.72
		3	-.11	.23	.63	-.56	.34
Vocabulary Post-test Code 7	1	2	-.07	.46	.87	-.97	.82
		3	-.64	.46	.17	-1.55	.27
		4	.56	.45	.21	-.32	1.44
	2	1	.07	.46	.87	-.82	.97
		3	-.57	.46	.22	-1.46	.33
		4	.63	.44	.15	-.23	1.49
	3	1	.64	.46	.17	-.27	1.55
		2	.57	.46	.22	-.33	1.46
		4	1.20*	.45	.09	.32	2.08
	4	1	-.56	.45	.21	-1.44	.32
		2	-.63	.44	.15	-1.49	.28
		3	-1.20*	.45	.01	-2.08	-.36
Vocabulary Post-test Code 8	1	2	.03	.36	.94	-.68	.73
		3	-.14	.37	.70	-.86	.58
		4	-.75*	.35	.03	-1.44	-.06
	2	1	-.03	.36	.94	-.73	.68
		3	-.17	.36	.65	-.87	.54
		4	-.78*	.35	.03	-1.46	-.10

		1	.14	.37	.70	-.58	.86
	3	2	.17	.36	.65	-.54	.87
		4	-.61	.35	.09	-1.31	.09
	4	1	.75*	.35	.03	.06	1.44
		2	.78*	.35	.03	.10	1.46
		3	.61	.35	.09	-.09	1.31

Summary

This quasi-experiment set out to determine whether it mattered which types of words students studied in a science class in terms of reading comprehension, vocabulary, and science content knowledge. The MANCOVA results showed that the mean scores on comprehension, content and vocabulary for group three were significantly higher than those obtained by the other groups for codes 2, 6, and 7. These group differences were statistically significant, confirming that instructional group assignment has an overall impact on vocabulary, comprehension, and content performance. As analysis of the individual dependent variables found, two codes of the vocabulary post-test were significant in the test of between-subjects effects, those involving the domain-specific and general academic words respectively. Further analysis of the pair-wise comparisons found differences for vocabulary code 2, the domain-specific words, between group three, the domain-specific treatment group, and all of the other groups. Pair-wise comparisons also found statistically significant differences for vocabulary code 3, the general academic words, between groups two (general academic treatment group) and four (control group).

Chapter 5 will discuss the implications of the findings set forth in this chapter.

CHAPTER 5

DISCUSSION

The previous chapter presented data analysis using MANCOVA to determine the impact of learning various types of words in biology on students' reading comprehension, vocabulary performance, and science content knowledge. Ninth-grade biology students were placed in one of four groups and spent two weeks for ten minutes per day working on independent vocabulary packets in which they practiced a set of 15 words. Group one's list was a combination of domain-specific and general academic words, group two's list was a set of general academic words, and group three's list was a set of domain-specific words. The fourth group, the control group, did no formal vocabulary work but instead completed lessons involving the ecology content. In this quasi-experiment the independent variable was the instructional group assignment, and the dependent variables were the students' performance on the reading comprehension, vocabulary, and content assessments.

Summary of Results

Descriptive statistics for the post-test measures, including some of the vocabulary test codes, comprehension test, and content test, revealed that the third group had higher mean scores. Throughout the two weeks of treatment, the third group worked only with domain-specific words related to ecology. A one-way MANCOVA found the differences in group assignment to be statistically significant. Tests of the between-subjects effects to assess the individual dependent variables found significance in two of the vocabulary test codes. The dependent variables with significant differences involved categories of the domain-specific words (code 2) and general academic words (code 3). Additional analysis of the pairs showed statistically significant differences on questions for code two between the domain-specific group and all of the other groups. For the vocabulary test code three, the general academic group was statistically significant from the control group, but not the other groups.

Discussion of Results

This dissertation study set out to offer guidance to disciplinary teachers who wonder which types of words to target for instruction. While the results are certainly more suggestive than definitive, in this study the results indicate that working with the domain-specific words had some learning advantage. Certain limitations did exist in this study and are important to consider alongside analysis of the results.

One major limitation of this research was the brief duration of the study and the narrowness of the curricular test. Due to an ever-expanding curriculum, time was a constraint of this quasi-experiment. The study was carried out over the course of three-weeks, with two-weeks of ten minutes per day being allotted for the individual vocabulary treatment and content control work to be completed. The remaining week was dispersed before and after the treatment and control for the pre- and post-test assessments to be administered. Such a limited time period was necessary to gain access to the teachers and students, and to appease school administrators. A more lengthy and intensive treatment over an extended period of time may have allowed a better understanding of the dynamics of the different treatments across a greater variety of science content. While this study only touched on one unit in the students' biology curriculum, a lengthier study might prudently be administered during multiple units of study during the school year, and would allow for an analysis of any kind of accumulation effect. Such an effect would be most likely to appear with the general academic vocabulary intervention since such words would be most likely to re-occur from unit to unit. Of course, this also might suggest a ceiling effect on the influence of such a treatment, as students might eventually master those non-content words that are used most often to explain the content words. If that were the case, then the impact of the domain-specific vocabulary instruction might be even greater in the long run, since new technical vocabulary is a certainty in science, whether students study new topics or go more deeply into topics previously studied.

Additional limitations came up during the course of the study. The two honors teachers reported that they each had a couple of students who finished the individual lesson packets before the ten days of allotted time were up. In making improvements to the current study, additional lesson work would need to be created so that the treatment can be equally applied to all subjects. Through dosage analysis, the student work packets were evaluated and it appeared that the overall performance on the work packets by all four groups was comparable.

An additional limitation to this study would be the researcher-created reading comprehension assessment. While results on this test were correlated to other standardized reading assessments, the EXPLORE and MAP tests, it would have been more reliable to use a standardized reading comprehension post-test. However, given the prescribed combination of vocabulary words needed, the researcher was unable to identify such a test. Such an approach would make sense for a much longer intervention, but not for this one.

Another challenge came in designing this study to control for the quality of instruction students received in the treatment. Given that all treatment groups were present in each of the teachers' classrooms, it was necessary that the treatment and control group activities be in the form of independent work for the students. Such independent work provided limitations in how children typically acquire new vocabulary, particularly in being able to discuss new words and engage in open word play. In these attempts to control for the quality of the instructional treatment, a low floor effect performance did occur. As shown in chapter four, mean scores reveal that all groups on all of the assessments scored particularly low, suggesting that the assessments were quite challenging. Differing the level of assessments or finding some way to improve the instructional treatment may have improved the resulting performances.

It should also be noted that statistical significance is quite different than educational significance. While tests found statistically significant differences between the groups students were assigned to, the actual impact in an educational setting is quite modest. For example, most teachers would be unlikely to implement changes if overall gains were less than a point on an assessment with sixteen questions. Still, the resulting findings raise some possible insight and will be discussed in the following section.

Making Sense of the Findings

While more research is needed to achieve greater confidence in how the results may transfer to other classrooms, these results do provide some insight. According to the analysis, the domain-specific word group had higher overall achievement, and it would be easy to conclude that focusing specifically and solely on these words would make the greatest sense. There is no question that the domain-specific vocabulary group outperformed the other groups. However, it was only on some aspects of the vocabulary instrument that statistically significant differences were found, and not on the comprehension or content measures. In considering why classroom teachers teach vocabulary, most do so for reasons extended beyond greater performance on vocabulary assessments. Thus, the results in this study that do not extend to individual gains in content mastery or reading comprehension performance are disappointing in scope.

However, the results do provide some promise in the analysis of the groups' performance on the varying vocabulary categories. On the vocabulary questions of domain-specific words (code 2), the domain-specific treatment group was statistically different from all of the other groups. Further, on the vocabulary questions of general academic words (code 3), the general academic treatment group was statistically different only from the control group. Thus, the argument that the general academic words are more beneficial to learning than the domain specific words did not hold up (Beck et al., 2002; National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010), but it is evident that there must have been some benefits to the academic word teaching, albeit not as great as that of the domain-specific words, at least over the short haul. Whether the relative advantages of these two approaches would change over a period of time is a question for future research. Clearly, in the short run, it appears that the domain-specific approach would make the greatest sense, though its actual advantage was quite small.

Furthermore, there is circularity to the advantage provided by the domain-specific vocabulary instruction. What is the content that students need to learn in a science class? First, they clearly need to learn the basic disciplinary concepts and terminology of the subject. Second, they need to gain an understanding of the various processes or cycles and the relationships among the concepts and processes. Third, they should gain an ability to read and comprehend that can generalize to other texts, at least to texts that have some content relationship with what they have studied. However that description of learning –which was the basis for the conceptualization of this study and the selection of the assessments —gives great advantage to domain-specific vocabulary. This study confirms the challenges addressed in the second chapter in regards to the measurement of vocabulary. Certainly in this study, the results do not illustrate the full degree to which students learned the targeted words. Faced with the limitations of multiple choice tests, the researcher utilized the vocabulary assessments with multiple correct answers to gather a fuller picture of students' knowledge of certain words. This format posed challenges in itself, as it is relatively unfamiliar to students and this feature may have impacted performance.

Another issue to consider alongside the results of this study is repetition. The nature of domain-specific words in a science text is such that they are repeated throughout the chapter or particular text because the content revolves around such terms. However, while many different general academic words may be used in a particular chapter, it seems that this type of word is repeated far less within small sections of text. Greater repeated exposure may explain why the domain-specific group in this study had performance so different than that of the other groups. The domain-specific group may have also had an advantage due to the interrelationships of words in this category that are less likely to occur in the general academic word types. For example, in the domain-specific word list, the words *amensalism* and *commensalism* appear; these two words are conceptually related, so knowing one reinforces an understanding of the other. This is not the case with the general academic words in this study, so the domain-specific group may have had another advantage in learning their targeted words.

Another aspect of the results that provides some insight is the grammatical part of speech that the words serve in the different categories. Table 16 shows how many words of each part of speech appear in the different groups' word lists:

Table 16. Group Word List Breakdown by Parts of Speech.

Group number	Number of nouns	Number of verbs	Number of adjectives
1 (mixed words)	9	6	0
2 (general academic words)	5	8	2
3 (domain-specific words)	15	0	0

As Table 16 shows, the general academic word group had the most grammatically diverse mixture of words in its word list. The domain-specific group had all nouns in its word list. This study did not assess how differing parts of speech impact aspects of comprehension, content, or vocabulary knowledge. However, it is worth considering the relationship these parts of speech had with the different texts students faced in the study. Given that the different categories of words, general academic and domain-specific, lend themselves more to certain parts of speech, do certain parts of speech make text more critical for understanding? From the higher achievement by the domain-specific group in this study, perhaps nouns offer greater learnability than adjectives or verbs and allow for greater transfer in this particular setting. Perhaps also the nouns that appear in the domain-specific category are easier to master than some of the general academic words which take on more specialized meaning when used in the context of an academic discipline.

As past research involving the study of parts of speech suggests, part of speech does make a difference in vocabulary learning. Morgan and Bonham (1944) found that students learn nouns more easily than other parts of speech such as adverbs, verbs, pronouns, prepositions, and adjectives. Such research may offer the greatest explanation as to why in this study the domain-specific group, with all nouns in its word list, performed so differently from the other groups. The unbalance of parts of speech in the current study may have posed limitations to the findings in that students in the various groups may not have had equal opportunities to learn the words. Future research evaluating classification of word types in academic disciplines should take this concept into account and see that a more equal balance of parts of speech appears across the different groups' word lists. Doing so would allow for a more accurate assessment of how studying general academic or domain-specific word types impact vocabulary learning, reading comprehension, and content knowledge.

In educational settings as disciplinary teachers are constructing their vocabulary curriculum and allotting time for instruction of such words, this idea should be taken into consideration. Less time should be spent on words that are easier to learn, which has been documented as nouns (Morgan & Bonham, 1944). As the results of this study have found, the domain-specific category of words is much more densely packed with nouns. Such findings may resonate with other research recommendations (Bates, 2008) to spend less instructional time on the teaching of domain-specific vocabulary word types and instead spend greater time on general academic words for this reason.

Other research supports the argument that considering words alone is not enough; instead, it is important for students to learn both the lexical choices and their grammatical contexts. Schleppegrell (2004) contends that a functional approach emphasizing grammar does not mean the teaching of the parts of speech in isolation from text. Instead, functional grammar examines the roles that both grammar and lexis play in constructing meaning. From this perspective, it seems artificial to examine linguistic resources separately because academic registers are born out of the collaboration of the various resources. In relation to future research, perhaps more attention should be given not only to lexis as was done in this study, but also to grammatical contexts to fully measure the depth of students' knowledge.

In the current study, if grammatical parts of speech did give the domain-specific group an unequal advantage in potential learnability, the vocabulary learning of that group still did not provide it with any benefits in comprehension or content knowledge. Such results suggest that in the context of the study, students learned the words superficially, and not enough to make a substantial impact. While the current study was unable to prove that word learning of particular types of words can impact other behaviors such as reading and content knowledge, this theory should not be discounted. Perhaps for word learning to affect other facets of knowledge, the word learning must be especially thorough, meaningful, and flexible. As was described in the second chapter, measurement of vocabulary knowledge has been especially tricky throughout its history. The current study was limited in that the only measurement of vocabulary knowledge came in the form of multiple-choice assessments. Such tools provide information about whether or not students know a word well enough to select the correct answer on a multiple-choice assessment, but they do not provide information as to whether students can use the word on their own, understand how it is similar or different to other words, and so on. This study could not determine with certainty if students developed extensive understanding of their targeted words, but the results suggest that they did not.

The current study was not only limited in the way it measured vocabulary knowledge, but also in the ways in which students came to learn the targeted word types. As has been discussed throughout this dissertation, the actual time allotted for the treatment was quite brief, with ten minutes per day scheduled for two weeks. Changes would need to be implemented in follow-up studies by providing extended time, but also possibly by structuring different activities for word study in order to foster deeper learning of the targeted word types through more integration of research-based methods.

It was the researcher’s intent to limit the scope of this study to the evaluation of word types, and not make claims about effective vocabulary instruction. In the end, perhaps such a distinction is an impossible one, as instruction of the administered treatment did limit what the researcher intended to evaluate. This research was based on theoretical assumptions that the selection of a vocabulary curriculum chronologically precedes the type of vocabulary instruction that must be administered. However, low performance scores and limited impact in the areas of comprehension and content suggest that quality of instruction does matter and must always be a consideration, particularly in research design.

In considering current practices, the reason content area teachers focus so heavily on domain-specific vocabulary is not only because such vocabulary may enable or support more extensive learning (e.g., one might comprehend better if these concepts are understood), but because understanding those concepts is a central purpose of teaching the discipline. What is evident from the analysis is not only that the domain-specific group did best, but that their advantage was specifically in learning the vocabulary of the domain. Without the vocabulary outcome test, these students would not have been much different than the other groups. Past research suggests that, over a longer period with a more ambitious program of instruction, the advantages of the domain-specific vocabulary may be even greater, since this vocabulary instruction may foster a deeper grasp of the conceptualization of the subject. For example, the modestly superior performance of the domain-specific vocabulary group here may also be consistent with Jackson and Phillips (1983) study on math vocabulary words where the treatment group did several minutes of vocabulary work per day while the control group continued with computational practice. They found that the treatment group who worked on vocabulary performed better on computational tests, even though the control group had extended time for such computational practice. The authors attributed this outcome to the close relationship of vocabulary to conceptual understandings that ultimately help a person carry out the content in a particular academic domain. In that context, it makes sense that the domain-specific group performed the best overall; as with the Jackson and Phillips's (1983) study, conceptual understanding does seem closely related to the words of a particular discipline. In this study, the control group, whose time during the course of two-weeks was spent working on content, did not perform better as some might expect on the post-content test.

Implications

Despite the small scale of this particular study, the results are potentially important and suggest several possibilities for additional research. These findings, along with additional research of this kind, would be worthwhile given the increasing instructional demands placed on secondary disciplinary teachers. In a time of increased accountability and more rigorous academic standards, teachers are pressed to maximize the effectiveness of their instructional time. Disciplinary teachers must balance a substantial amount of content within their curriculum, while at the same time modeling for students how one discusses and writes about that content. Coupling these challenges with the burgeoning numbers of content-specific words with specialized meanings that are part of their subjects, disciplinary teachers have their work cut out for them.

This study provides provocative results, and raises several questions for further research. One question that has not been answered definitively by this study is whether over a more extended period of time, and across multiple units, whether the relative benefits and advantages of these approaches would be the same as was found here, and whether those advantages would extend to comprehension and content knowledge beyond understanding the domain-specific words themselves. Future research may also examine which category of vocabulary words would hold the greatest retention over time.

Recommendations provided by the national Common Core Standards (2010) strongly support the teaching of general academic words for several reasons:

> …many Tier Two words are far less well defined by contextual clues in the texts in which they appear and are far less likely to be defined explicitly within a text than are Tier Three words. Yet Tier Two words are frequently encountered in complex written texts and are particularly powerful because of their wide applicability to many sorts of reading. Teachers thus need to be alert to the presence of Tier Two words and determine which ones need careful attention. (p. 33)

Other researchers (Beck et al., 2002) are particularly supportive of the teaching of general academic words, as well. These recommendations also seem to argue for a combination approach — that is teaching both some of the domain-specific words along with some of those academic words that are used to contextualize and explain the domain-specific words. However, in this study, that approach was not effective. Future studies should concentrate on identifying different ways of combining these words to ensure that approach is thoroughly examined.

The strong advocacy for the teaching of general academic words seems to be based on the idea that such words may benefit students across the course of their overall academic career. However, this study suggests an evident and more immediate benefit of domain-specific word instruction in biology classes. This study may not be sufficient to discredit the theories supporting direct instruction in general academic words, but it does suggest the need for a more careful consideration of the importance of domain-specific vocabulary instruction, as well.

Future research could also more deeply investigate the characteristics of the different words themselves. Even within the categories (domain-specific or general academic) differences exist and future studies could tackle the question of what makes certain domain-specific words more challenging for students than others. Words can differ in pronounceability, confusability, whether they have multiple meanings, and in learnability; making sure that the learning demands are truly equivalent for all groups. Such research, particularly for the combined vocabulary approach, should consider not only the nature of the words themselves, but the relations among the words that are taught, and the relative importance or value of the words for making sense of the texts to be read.

Some scholars may disagree with the concept of categorizing word types altogether. Classifying words into categories does rely on assumptions of frequency and usage that may in some ways generalize the literacy practices of individuals. Making recommendations for a vocabulary curriculum based on such categorization may also not take into account prior knowledge of students. As with many ways of conceptualizing or attempting to sort out items, there is going to be some considerable overlap. Certainly this was the case in this study. For example, the word *disturbance* appeared on the domain-specific group's word list based on its standard frequency index, as described in the third chapter. Still, common sense could argue that such a word might be better placed into the general academic category, showing how no system is without exceptions. Additionally, the word *dispersion* appeared in the general academic word list for the purpose of this study, but certainly takes on more specialized meaning in other contexts, such as the field of statistics. Even with such complications in categorization, some may continue to argue that classification is unnecessary because it does not reflect how children acquire new vocabulary words. Still, this study suggests that there may be some potential learning impact from using such categories, with more opportunities to be investigated. With the limited guidelines that exist for disciplinary teachers to select an appropriate vocabulary curriculum, the use of categories provides a manageable way of incorporating the words that students need to learn to be successful. As schools face greater regulations and accountability, the Common Core Standards (2010) utilize such a classification system, which suggests that teachers should at least consider word types in this way, as well.

The purpose of this study was to assist teachers in determining what types of vocabulary words to teach within the field of biology. Though this study suggests that more impact can be gleaned from domain-specific words, this study makes no recommendations about what type of instruction can most benefit students within a discipline. More research will be needed before clear and practical guidelines could be beneficially provided to disciplinary teachers, while also noting that the implications will likely be different at different developmental levels of learning.

Summary and Conclusion

This quasi-experimental study explored how learning different types of vocabulary words within biology can impact reading comprehension, vocabulary achievement, and content knowledge. The findings of the 315 student participants across four treatment and control groups revealed that the group whose treatment emphasized domain-specific vocabulary words had the highest overall achievement. Statistical analysis revealed that instructional group assignment did have an effect on vocabulary knowledge, but not reading comprehension and content knowledge.

As educational standards continue to gain rigor, research of this kind will be increasingly in demand. Teachers simply cannot teach everything, and careful planning must guide instructional decision-making, including decisions about which types of words should be taught. Within secondary classrooms, language is the epicenter of learning. It is the way knowledge is disseminated, it is how students demonstrate their understanding, and it is how new ideas are formed. Knowing which types of words are most critical to enhancing the disciplinary practices must be a priority for secondary teachers, particularly with national standards mandating the shared role of literacy across the content areas.

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APPENDICES

APPENDIX A. Word List for Group 1 (Mixed Words)

Group 1 Words	Definition	Example of word in context
diminish	to make or become less; to reduce in size	If a fire burns part of the meadow, the insects' food resources diminish, and the carrying capacity declines.
distributed	to be passed out; a population that follows a normal pattern of being spread out	The quadrant method assumes that organisms are distributed fairly evenly throughout the study area.
facilitate	to make an action or process easier; to allow for	Individuals may live close together in groups in order to facilitate mating, gain protection, or access food resources.
function	something dependent on another factor or factors; something that serves an important purpose, such as in animal survival	Population growth is a function of the environment".
immigrated	come to live permanently in a different environment; to cause the movement of genes into a population	When one or two fruit flies found the banana, they immigrated into your backpack.
Interval	a space between things, a gap	The constant time interval is 20 minutes. So every 20 minutes, the population is multiplied by 2.
regulate	to control or maintain the rate or speed so that something operates properly; to monitor population growth	Photosynthesis also helps to regulate Earth's environment.
sustain	to strengthen or support; all that a particular environment can handle	You will look more closely at how carbon and oxygen are continuously cycled by organisms and how these elements sustain both the organisms and ecosystems.
carbon cycle	The cycle in which carbon moves between reservoirs	The movement of carbon between these reservoirs is known as the carbon cycle.
cellular respiration	The process by which cells break down complex molecules, such as sugars, to release energy	Cellular respiration is the process by which cells release stored energy from sugars.
ecological succession	The natural process in which a disturbed area is gradually taken over by a species or groups of species that was not there before	Ecological succession is the natural process in which a disturbed area is gradually taken over by a species or groups of species that were not there before.
eutrophication	A dramatic increase in nutrients in an aquatic environment, resulting in increased plant growth, especially of algae.	When a large amount of nutrient-rich water flows into an area, causing an increase in plant growth--an occurrence known as eutrophication--the conditions are prime for a dead zone to develop.

photosynthesis	The process by which the cells of producers, such as plants and phytoplankton, capture the sun's energy and store it in sugars, releasing oxygen as a by-product.	Photosynthesis is the process in which producer cells use carbon dioxide, water, and nutrients to produce glucose and oxygen.
primary succession	Ecological succession that starts in an area where there are essentially no living organisms.	Primary succession is ecological succession that starts in an area where there are essentially no living organisms.
secondary succession	Ecological succession that occurs in an area where there is some component of the ecosystem, including soil, remaining after a disturbance.	Primary succession is ecological succession that starts in an area where there are essentially no living organisms.

APPENDIX B. Word List for Group 2 (General Academic Words)

Group 2 Words	Definition	Example of word in context
abundant	available in very large quantities; a way to describe a species that has seen population growth	If resources such as food and water are abundant, or plentiful, a population may grow.
adaptation	Any change in the structure or functioning of following generations of a population that makes it better suited to its environment	Several adaptations help prey avoid being eaten.
diminish	to make or become less; to reduce in size	If a fire burns part of the meadow, the insects' food resources diminish, and the carrying capacity declines.
dispersion	the act or process of spreading things or people over a wide area; the pattern of a population	Geographic dispersion of a population shows how individuals in a population are spaced.
distributed	to be passed out; a population that follows a normal pattern of being spread out	"The quadrant method assumes that organisms are distributed fairly evenly throughout the study area" (C768).
facilitate	to make an action or process easier; to allow for	Individuals may live close together in groups in order to facilitate mating, gain protection, or access food resources.
function	something dependent on another factor or factors; something that serves an important purpose, such as in animal survival	Population growth is a function of the environment.
immigrated	come to live permanently in a different environment; to cause the movement of genes into a population	When one or two fruit flies found the banana, they immigrated into your backpack.
inhabited	to be lived in or occupied in	Your large intestine is inhabited by millions of bacteria.
interval	a space between things, a gap	The constant time interval is 20 minutes. So every 20 minutes, the population is multiplied by 2.
migratory	moving from one part of something to another	Urbanization in this area is depleting the resources these migratory birds need during their trek to nesting grounds in northern Canada and in Alaska.
minimize	to reduce to the smallest possible amount or degree; to make the differences within a species less	To lessen this problem, researchers try to minimize the effects of trapping on the captured animals.
regulate	to control or maintain the rate or speed so that something operates properly; to monitor population growth	Photosynthesis also helps to regulate Earth's environment.
sustain	to strengthen or support; all that a particular environment can handle	You will look more closely at how carbon and oxygen are continuously cycled by organisms and how these elements sustain both the organisms and ecosystems.

variation	The differences or changes between individuals of a plant or animal species	When scientists notice changes in population densities over time, they work to determine whether the changes are the result of environmental factors are simply due to normal variation in the life history of a species.

APPENDIX C. Word List for Group 3 (Domain-Specific Words)

Group 3 Words	Definition	Example of word in context
amensalism	A symbiotic relationship in which one species is harmed, while the other species neither benefits nor is it harmed	Amensalism is one type of relationship that exists in nature.
carbon cycle	The cycle in which carbon moves between reservoirs	The movement of carbon between these reservoirs is known as the carbon cycle.
cellular respiration	The process by which cells break down complex molecules, such as sugars, to release energy	Cellular respiration is the process by which cells release stored energy from sugars.
commensalism	A symbiotic relationship in which one species benefits, while the other species does not benefit but is not harmed	Commensalism is a relationship between two organisms in which one receives an ecological benefit from another, while the other neither benefits nor is harmed.
dead zone	An area of water that is so depleted of oxygen that organisms must migrate away from it or die	A dead zone is an area in a body of water where the water at the bottom has little or no dissolved oxygen.
disturbance	An abrupt event in an ecosystem that suddenly and significantly changes the resources available, the number or type of organisms, or the kinds of species present.	An ecosystem's ability to return to a stable state after a disturbance is a measure of its resilience.
ecological succession	The natural process in which a disturbed area is gradually taken over by a species or groups of species that was not there before	Ecological succession is the natural process in which a disturbed area is gradually taken over by a species or groups of species that were not there before.
eutrophication	A dramatic increase in nutrients in an aquatic environment, resulting in increased plant growth, especially of algae.	When a large amount of nutrient-rich water flows into an area, causing an increase in plant growth--an occurrence known as eutrophication--the conditions are prime for a dead zone to develop.
mutualism	A symbiotic relationship in which both species benefit.	Mutualism is an interspecies interaction in which both organisms benefit from one another.

parasitism	A symbiotic relationship in which one species benefits, while the other species is harmed, but not killed.	Parasitism is a relationship similar to predation in that one organism benefits while the other is harmed. But unlike a predator, which quickly kills and eats its prey, a parasite benefits by keeping its host alive for days or years.
photosynthesis	The process by which the cells of producers, such as plants and phytoplankton, capture the sun's energy and store it in sugars, releasing oxygen as a by-product.	Photosynthesis is the process in which producer cells use carbon dioxide, water, and nutrients to produce glucose and oxygen.
primary succession	Ecological succession that starts in an area where there are essentially no living organisms.	Primary succession is ecological succession that starts in an area where there are essentially no living organisms.
resilience	The ability of an ecosystem to recover after a major disturbance. The level of resilience depends on the state of the area prior to the disturbance.	An ecosystem's ability to return to a stable state after a disturbance is a measure of its resilience.
secondary succession	Ecological succession that occurs in an area where there is some component of the ecosystem, including soil, remaining after a disturbance.	When an ecosystem undergoes a disturbance and the soil remains, secondary succession develops instead of primary succession. This might occur after a wildfire, or in a now-unused field where generations of ranchers had grazed cattle. Often there are still plants that survived the disturbance.
symbiosis	The close ecological relationships between organisms.	The close relationship of organisms in an ecosystem is known as symbiosis.

Appendix D. Pre and Post Vocabulary Assessment

Vocabulary Test

Directions: For each of the following terms, select all answer choices that describe the definition of the word. <u>Note that there may be more than one correct answer</u>, so be sure to select all of the definitions that correctly describe the term.

1. Abundant
    a. A small amount
    b. A large amount
    c. A way to describe a species that has seen a population decrease
    d. A way to describe a species that has seen population growth
2. Biosphere
    a. All of the parts of the planet that are inhabited by living things
    b. All of the Earth's ecosystems
    c. The combination of carbon, water, and hydrogen molecules
    d. A round space at the top of the Earth
3. Amensalism
    a. A relationship where one species is harmed and the other species neither benefits nor is harmed
    b. A relationship where both species are harmed
    c. A relationship where there is no interaction between the two species
    d. A relationship where one species is harmed and the other species benefits
4. Adaptation
    a. Something that is destroyed
    b. Something that is better suited to survive
    c. The adjustments that occur in animals with respect to their environments
    d. Any animal that is larger than everything else in the same group
5. Microscopic
    a. Within the scope of reason
    b. Conducted with the use of a microscope
    c. Undetectable
    d. Lacking any important parts
6. Carbon cycle
    a. The cycle where oxygen and carbon combine to filter the air that humans breathe
    b. The cycle where carbon disappears from the atmosphere forever
    c. The cycle where carbon moves between bodies of water
    d. Another term for the hydrogen cycle

7. Diminish
    a. To make less
    b. To increase
    c. To stay the same
    d. To reduce in size
8. Biomass pyramid
    a. Represents the amount of dry mass in each trophic level of an ecosystem
    b. Another term for the food pyramid
    c. Shows how different animals rank in an ecosystem
    d. The most dense layer within a cell
9. Cellular respiration
    a. The process where cells of producers take the sun's energy and store it as sugars, releasing oxygen
    b. The process where cells break down to complex molecules, like sugars, to release energy
    c. The process where the atmosphere absorbs energy and releases it in many different forms, such as water
    d. The process of how some animals breathe underwater
10. Dispersion
    a. The act of changing things from one region
    b. The internal pattern of a population
    c. The act of spreading things over a large area
    d. The act of collecting things from a large area
11. Commensalism
    a. A relationship where one species benefits, while the other species does not benefit but is not harmed
    b. A relationship where both species benefit
    c. A relationship where there are equally shared resources
    d. A relationship where one species benefits , while the other species is harmed
12. Contaminant
    a. Something that corrupts a mixture
    b. An organelle in plant cells
    c. Where cell division occurs
    d. A substance that makes another impure
13. Distributed
    a. To be collected
    b. A population that follows a normal pattern of being spread out
    c. To be changed into another form
    d. To be passed out*

14. Mitochondrion
    a. The organelle that is attached to the chloroplast
    b. The organelle that is the site of aerobic cellular respiration
    c. The organelle that has a round shape
    d. The organelle that is the same size as a plant cell
15. Dead zone
    a. Water that lacks oxygen so any organisms must leave or they will die
    b. Water that has an abundance of oxygen so plants flourish there, but any animals will die
    c. Water that has not had any organism living in it for at least a year
    d. Water with many dead animal carcasses in it
16. Facilitate
    a. To teach
    b. To make something easier
    c. To allow for
    d. To grow for a short period of time
17. Disturbance
    a. An ecosystem that does not undergo changes
    b. An event that dramatically changes an ecosystem
    c. An organism that will not leave an ecosystem
    d. Any place that plants cannot grow
18. Function
    a. Something that serves an important purpose, such as in animal survival
    b. Something that can be divided by any integer
    c. Something that is a variable all on its own
    d. Something dependent on another thing
19. Ecological succession
    a. The process of how a disturbed area begins to change with the growth of new species
    b. The process where survival of the fittest is illustrated
    c. The process that focuses on the destruction of natural resources because of humans
    d. The process describing how animals become extinct
20. Nitrification
    a. A ring of carbon and nitrogen atoms found in nucleic acids
    b. The process of reducing water molecules
    c. The process by which certain bacteria convert ammonium to nitrates
    d. Where nitrogen originates
21. Immigrated
    a. To settle into a new place
    b. To cause the movement of genes into a population
    c. To disappear from an ecosystem
    d. To change a place permanently

22. Eutrophication
    a. A decrease in oxygen in water, leading to decreased plant growth
    b. An increase in nutrients in water, leading to increased plant growth
    c. A water environment where plant life remains the same
    d. An area of water so depleted of oxygen that organisms must leave or die
23. Inhabited
    a. To be altered or changed
    b. Where an organism dies
    c. A type of habitat that allows for water organisms
    d. To be lived in
24. Vulnerable
    a. Easily wounded
    b. A plant that is new to a particular ecosystem
    c. An animal with newly adapted features
    d. A species that may be close to extinction
25. Mutualism
    a. A relationship where both species benefit
    b. A relationship where neither species benefits nor is harmed
    c. A relationship where one species benefits and the other is not harmed
    d. A relationship where there is no interaction between the two organisms
26. Interval
    a. A small amount of a liquid
    b. An unknown answer
    c. Milliseconds
    d. A period of time
27. Parasitism
    a. A relationship where one species benefits, while the other species is killed
    b. A relationship where one species benefits, while the other species is harmed, but not killed
    c. A relationship where one species is harmed and the other is killed
    d. A relationship where there is no interaction between the organisms
28. Migratory
    a. Traveling from one place to another
    b. Staying in one place
    c. Changing from gas to liquid
    d. The path birds take when they fly south in the winter

29. Photosynthesis
    a. The process where cells of producers take the sun's energy and store it as sugars, releasing oxygen*
    b. The process where cells break down to complex molecules, like sugars, to release energy
    c. The process where cells multiply at an exponential rate
    d. The process where the atmosphere absorbs energy and releases it back in many different forms, such as water
30. Mortality
    a. The number of deaths in a given period
    b. A factor influencing population dynamics
    c. Unique adaptations that help an organism survive
    d. A condition that affects plants in water ecosystems
31. Minimize
    a. To reduce
    b. To grow
    c. To multiply the growth rate of a species
    d. To make the differences within a species less
32. Primary succession
    a. Succession that occurs where there is some component of the ecosystem remaining after a disturbance
    b. Succession that is both natural and deliberate in a given area
    c. Succession that is mysterious and unnatural
    d. Succession that starts in an area where there are no living organisms
33. Tragedy of the Commons
    a. A theory that the more people who have unlimited access to a resource, the more they will take advantage of it
    b. A theory that describes the place where many animals go to die
    c. A theory that states some organisms share a common trait that is harmful to them
    d. A theory that there are more than enough resources to go around for everyone
34. Ecosystem diversity
    a. Variation within the earth's ecosystems
    b. Variation between the earth's ecosystems
    c. A lack of variation within the earth's ecosystems
    d. A lack of variation between the earth's ecosystems
35. Regulate
    a. To underestimate population growth
    b. To be regular
    c. To control
    d. To monitor population growth

36. Resilience
    a. An ecosystem's ability to bounce back after a disturbance
    b. An ecosystem's ability to grow new plants in a set period of time
    c. The time it takes for an ecosystem to be completely destroyed
    d. An ecosystem's ability to destroy all parasites
37. Sustain
    a. All that a particular environment can handle
    b. All the changes that a particular environment needs to make
    c. To lessen
    d. To maintain
38. Solitary
    a. Standing alone
    b. Related to the military
    c. Being confined to one area
    d. The opposite of colonial
39. Secondary succession
    a. Succession that occurs where there is some component of the ecosystem remaining after a disturbance
    b. Succession that is both natural and deliberate in a given area
    c. Succession that results in an identical environment that existed previously
    d. Succession that starts in an area where there are no living organisms
40. Variation
    a. A change*
    b. Differences displayed by individuals within a species
    c. Mistakes displayed by individuals within a species
    d. A loss
41. Symbiosis
    a. The way that change occurs in an ecosystem
    b. How organisms get the energy required for their survival
    c. A disease that plants get when they receive too much natural sunlight
    d. The close ecological relationships between organisms
42. Deplete
    a. To remove nutrients from soil
    b. To increase
    c. To empty
    d. To improve
43. Invasive species
    a. A species with many adaptations to survive
    b. An endangered species
    c. A species that enters a new area and disrupts the area
    d. A nonnative species that may harm humans

44. Emit
    a. To give off something, such as radiation or particles
    b. To absorb carbon dioxide from the environment
    c. To issue
    d. To reduce
45. Abiotic
    a. Describes factors in an environment that are living
    b. Describes factors in an environment that are not living
    c. Describes plants in an environment that use phosphorous
    d. Describes animals that require very little food to survive
46. Niche
    a. A dial used to monitor the earth's rotation
    b. How an animal is able to survive with limited resources
    c. The status or role of an organism in its environment
    d. An indentation in a wall
47. Aquaculture
    a. The growing of fish for humans to consume
    b. A hip group of people who only enjoy water sports
    c. An ancient culture of Aquarians
    d. Animals that only drink water
48. Scarcity
    a. Not enough of something
    b. Extremely low body temperature
    c. An unfortunate situation
    d. A cancerous cell
49. Secretion
    a. The process by which something is pumped out
    b. The process of transforming a liquid into gas
    c. The discharge of specific substances by cells
    d. To change a cell's inner workings
50. Zooplankton
    a. Plankton capable of photosynthesis
    b. Plankton with remarkable disease-fighting capacity
    c. Plankton that require limited sun exposure
    d. Plankton that receive energy from the food that they eat

Ecology Content Test

Multiple Choice

Identify the choice that best completes the statement or answers the question.

(1) Carbon is transferred from animals to plants by which molecule?
- (a) Carbon dioxide
- (b) Oxygen
- (c) Sugars
- (d) Water

(2) Which of these is the largest reservoir of carbon?
- (a) soil
- (b) atmosphere
- (c) ocean
- (d) vegetation
- (e) sedimentary rocks

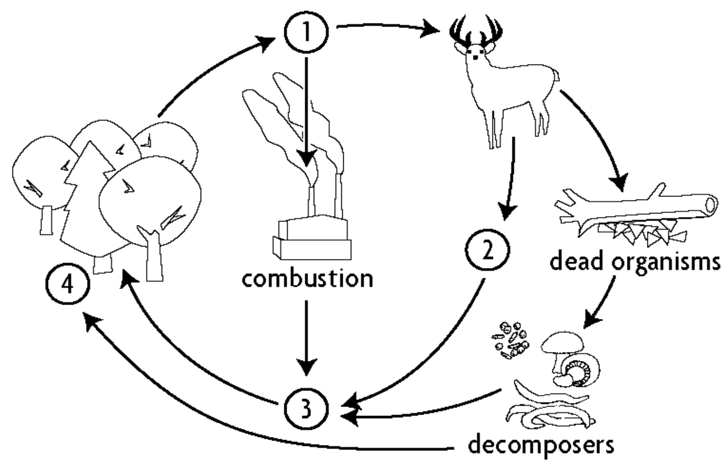
(3) What happens to the total amount of carbon as it moves through the carbon cycle?
- (a) It increases
- (b) It diminishes
- (c) It stays the same
- (d) It disappears

(4) Which of the following would lead to an increase of carbon dioxide distributed in the atmosphere?
- (a) A decrease in respiration
- (b) A decrease in eutrophication
- (c) An increase in photosynthesis
- (d) An increase in the usage of cars

(5) The amount of which gas is INCREASED if there is an increase in the rate of photosynthesis?
- (a) Hydrogen
- (b) Oxygen
- (c) Carbon dioxide
- (d) Carbon monoxide

(6) Where in the cell does cellular respiration occur?
- (a) Nucleus and chloroplasts
- (b) Nucleus and mitochondria
- (c) Cytoplasm and chloroplasts
- (d) Cytoplasm and mitochondria

(7) Which two processes are involved in the cycling shown in the diagram at right?
- (a) Succession and resilience
- (b) Photosynthesis and cellular respiration
- (c) Commensalism and mutualism
- (d) Eutrophication and resistance



(8) Which of the following best describes the inputs and outputs of photosynthesis?
- (a) Plants take in carbon dioxide and light energy to produce carbohydrates; oxygen is given off.
- (b) Plants take in water, oxygen, and light energy to produce carbohydrates; carbon dioxide is given off.
- (c) Plants take in water, carbon dioxide, and light energy to produce carbohydrates; carbon dioxide is given off.

(d) Plants take in water, carbon dioxide, oxygen, and light energy to produce carbohydrates.

(9) Which of the following best describes the inputs and outputs of cellular respiration?
(a) Organisms take in carbohydrates, oxygen, and light energy, and produce energy, with water and carbon dioxide as waste products.
(b) Organisms take in carbohydrates and carbon dioxide, and produce energy, with water and oxygen as waste products.
(c) Organisms take in oxygen, and produce water and carbon dioxide as waste products.
(d) Organisms take in carbohydrates and oxygen, and produce water and carbon dioxide as waste products.

(10) Cyanide is a poison that prevents the cell from using oxygen. As a result, what process would the cell NOT be able to perform?
(a) Eutrophication
(b) Photosynthesis
(c) Cellular respiration
(d) Symbiosis

(11) Eggs of a wasp species are deposited inside the body of a gypsy moth caterpillar. The inhabited wasp eggs hatch into larvae, which feed on the caterpillar. What is the relationship that exists between the wasp larvae and the caterpillar known as?
(a) Mutualism
(b) Parasitism
(c) Commensalism
(d) Amensalism

(12) A clown fish lives inside of a sea anemone. The sea anemone protects the small clown fish from larger predators and gives it a way to sustain. The sea anemone is not helped or hurt by the clown fish living there. What type of relationship is this?
(a) Mutualism
(b) Parasitism
(c) Commensalism
(d) Amensalism

(13) Leeches often attach to the tongue of a crocodile and feed on the crocodile's blood. The Egyptian plover is a bird that flies into the mouth of the crocodile and eats the leeches.

The crocodiles do not harm the plover. What term describes the relationship between the plover and the crocodile?
(a) Commensalism
(b) Mutualism
(c) Parasitism
(d) Prey-predator

(14) Which of these is an example of parasitism?
(a) A finch eating ants
(b) Algae and fungi providing food and shelter for each other
(c) A tapeworm inhabited inside a dog
(d) A clown fish gaining shelter while the anemone is neither helped nor harmed

(15) Under certain conditions, a type of plankton that lives inside marine mussels causes organisms that eat the mussels to become very ill or die, but does not have an effect on the mussels. What is the relationship between the plankton and the organisms that eat the mussels?
(a) Parasitism
(b) Mutualism
(c) Amensalism
(d) Commensalism

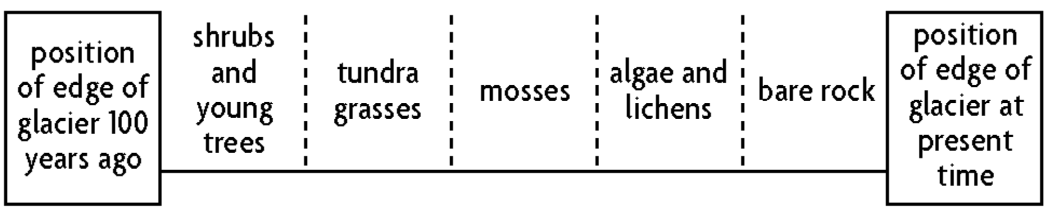
(16) A symbiotic relationship exists between two organisms of the same species. Only one organism benefits from the relationship, while the other is not harmed. What is the relationship known as?
(a) Commensalism
(b) Mutualism
(c) Parasitism
(d) Amensalism

(17) Which event normally takes place after a wildfire destroys a pine forest ecosystem?
(a) Ecological succession, which helps reestablish and regulate the pine forest
(b) Hibernation of insects in the ground
(c) Increased mutations in the surrounding trees
(d) Rapid breeding of animal species that sustain the fire

(18) Several years after a severe forest fire, grasses began to grow in the burned area. After 10 years, there is variation, with small bushes and trees replacing the grasses. What is this pattern of plant growth known as?
(a) Biological control
(b) Eutrophication
(c) Ecological succession
(d) Ecosystem management
(a) An increase in insect populations in oak forests

(19) An ecosystem that is stable and able to quickly return to stability after a disturbance is termed resilient. Ecosystem resilience is aided by:
(a) over-population
(b) biodiversity
(c) fast changes in abiotic factors
(d) invasive species

(20) The diagram below represents a map showing different zones in an area once covered by a glacier.



What does the map represent?

(a) A food chain
(b) Ecological succession
(c) An energy pyramid
(d) Nutritional relationships

APPENDIX F. Comprehension Assessment

Reading Comprehension Test

Directions: Read the following three passages and answer the questions that follow. All of the answers can be found in the information contained in each passage. Select the best answer choice for each question.

PASSAGE #1

The following passage is adapted from a biology textbook describing the carbon and nitrogen cycles.

The Carbon and Oxygen Cycle

Since many of the movements of carbon in an ecosystem are closely linked to those of oxygen, their paths are sometimes described together as the carbon and oxygen cycle. In the atmosphere, carbon is found in inorganic form as carbon dioxide gas (CO_2). Significant amounts of inorganic carbon are also found in water in dissolved form as HCO_3^-). Producers use the carbon and oxygen atoms of these inorganic compounds to form organic compounds during photosynthesis. Some of this organic carbon cycles to consumers as food.

During cellular respiration, both producers and consumers break down organic compounds such as sugars and release carbon dioxide gas as a waste product. Carbon dioxide also is released to the atmosphere as decomposers break down detritus.

Nonliving processes also play a role in the carbon cycle. Burning fossil fuels-- oil, coal, and natural gas--releases carbon dioxide to the atmosphere. (Fossil fuels form over hundreds of millions of years from the remains of living things.) Burning wood, both from natural forest fires and from human activities, also releases carbon dioxide gas. Geologic events such as volcanic eruptions add more carbon dioxide gas to the atmosphere.

Carbon Cycle Impacts

As you have read, the burning of wood and fossil fuels is one source of carbon dioxide in the atmosphere. As nations have become industrialized, atmospheric carbon dioxide levels have risen steadily. Deforestation, the clearing of forests for agriculture, lumber, and other uses, also affects the carbon cycle by minimizing plants that absorb carbon dioxide during photosynthesis. Sometimes after being cut down, the trees are then burned, distributing more carbon dioxide. Burning after deforestation in the tropics accounts for about 20 percent of the carbon dioxide added to the atmosphere by human activities. Worldwide burning of fossil fuels accounts for most of the other 80 percent.

Nitrogen Cycle Impacts

Human activities impact the nitrogen cycle primarily by moving large amounts of nitrogen compounds into the water or the air. For example, some sewage treatment plants release dissolved nitrogen compounds into streams and rivers. Fertilizers applied to crops are another source of nitrogen compounds—excess fertilizer may run off into nearby streams and ponds. The high levels of nitrogen, often along with the phosphates, feed the rapid growth of algae in these bodies of water, a condition called eutrophication. As the algae die, the bacteria decomposing them can use up so much of the oxygen in the water that there is no longer enough to sustain other organisms.

Eutrophication has become an increasing problem in estuaries, areas where fresh water from streams and rivers mixes with salt water from the ocean. Much of the sewage flowing from population-dense coastal areas has been treated only to minimize the volume of organic matter, not nutrients. When the fresh water carrying the sewage flows into salt water, it floats on top because it is less dense. Heat from the summer sun warms the top layer and further reduces its density. The result is dispersion between the super-fertilized phytoplankton and oxygen-rich surface waters from the bottom water, where dead phytoplankton and other detritus become abundant. The surface-water material consumes more and more oxygen as it decomposes, starving the bottom water of oxygen for all or part of the summer season.

The Gulf of Mexico, the Baltic Sea, Chesapeake Bay, Long Island Sound and even the lagoon of Venice have all displayed the unsavory symptoms of oxygen depletion, including fish kills and the rotten-egg smells associated with dead fish and decaying plant matter. The introduction of more effective sewage-treatment techniques to regulate the problem, including the use of sewage-eating bacteria and plants, holds promise to help reverse this trend.

1. According to the passage, all of the following can be blamed for adding more carbon dioxide into the atmosphere EXCEPT:
    a. The destruction of forests for agriculture
    b. The burning of wood
    c. The destruction of fresh water streams
    d. The burning of fossil fuels

2. Which of the following statements best summarizes the impact deforestation has on carbon cycles?
    a. Fewer producers to absorb carbon dioxide from the atmosphere increases carbon dioxide in the atmosphere.
    b. More producers to absorb carbon dioxide from the atmosphere decrease carbon dioxide in the atmosphere.
    c. Fewer trees mean that people look to fossil fuels more for energy sources.
    d. Fewer trees mean that the habitats of animals are disturbed, and will lead to less carbon dioxide in the area.

3. Which of the following statements would the author of the passage most likely agree with in regards to the nitrogen cycle?
    a. Nitrogen in fertilizer is helpful for crops and the environment.
    b. Nitrogen does not impact algae growth.
    c. Humans are mostly to blame for increasing nitrogen that is released into the air.
    d. Humans should avoid areas where nitrogen levels are high.

4. According to the passage, why might coastal areas be affected by eutrophication?
    a. Coastal areas tend to have freshwater mixing with salt water.
    b. Coastal areas have more wildlife that are prone to high levels of nitrogen.
    c. Coastal areas tend to be dense in population.
    d. Coastal areas tend to get a great deal of sunlight.

5. Which of the following is to blame for odors in areas like the Gulf of Mexico and Chesapeake Bay?
    a. A surplus in the fish population
    b. A lack of oxygen
    c. Effective sewage-treating techniques
    d. A new species of fish

PASSAGE #2

The following passage is adapted from the article "Cold Blooded Vertebrates" by Samuel F. Hildebrand.

Comparatively few freshwater species of fishes are limited in their distribution to a single river system, yet not many are found on both sides of a high mountain ridge, such as the Rocky Mountains in North America. That is to say, the fishes of the Mississippi Valley are generally different and distinct from those of the Pacific slope.

While it is a well-known fact that the fish life in no two river systems, even though they empty into the sea on the same side of a divide, is identical, such streams do have many species in common, even though some variation is to be expected. The principal rivers of the Atlantic slope of the United States, for example, are inhabited by several species common to all of them, including the bullhead catfish, the bluegill sunfish, and the largemouth bass, reminding us of the symbiosis of relationships between organisms. None of these species can endure salt water, so they cannot be migratory from one river system to another. On the other hand, the more northern streams contain species not found in the southern ones, and vice versa. The common pike, for example, is found in the Atlantic streams from Maryland northward, and the brook trout and yellow perch occur only in the streams from North Carolina southward.

It is unsure how the present distribution came about, what event or disturbance facilitated it, or what function it serves. It is quite probably that some of the streams, including those on opposite sides of a divide, may have been connected at one time. Again, streams may be entirely separate during normal weather, but an exceptionally heavy rainfall or the sudden melting of snow in the uplands sometimes causes floods which may form a temporary connection between them, providing a passageway for fishes. It is possible, also, that water birds may accidentally carry fish or spawn from one stream to another, or that man may be instrumental in such dispersion.

Evidently, then, freshwater fishes may become distributed far beyond the confines of the stream of their origin. The chief factor in limiting the still wider distribution of species is temperature. This forms such an efficient barrier that comparatively few species of freshwater fishes of the United States extend their range into Mexico. In Panama only one fish common to the fresh waters of the States has been found, and that is the eel, which is not strictly a freshwater form, as it enters salt water to spawn and is taken in fairly salty water at other times.

6. The freshwater fish life found in two river systems at approximately the same latitude and on the same side of a continental divide is:
    a. Never just the same
    b. Likely to be very different

   c. Always just the same
   d. Often just the same

7. According to the passage, exceptionally heavy rains or the melting of large amounts of snow may explain:
   a. Sudden rises in freshwater fish populations
   b. Sudden declines in freshwater fish populations
   c. Why fish of the same species may be found in different water systems
   d. Why fish of different species are seldom found in water systems on different sides of a high mountain ridge

8. Which of the following statements helps to explain why the freshwater system on one side of a high mountain ridge has so few species in common with the freshwater system on the other side?
   I. It is possible that the streams on both sides of the ridge were once connected.
   II. Most species of freshwater fish cannot endure salt water.
   III. Water birds that cross mountain ridges often carry fish spawn from one stream to another.

   a. I only
   b. II only
   c. I and III only
   d. II and III only

9. According to the passage, the chief obstacle to a wider spreading of the species of freshwater fish is:
   a. Water pollution
   b. The loss of habitat due to human invasion on nature
   c. Temperature
   d. The salt level of the oceans

10. One should expect the largest number of freshwater fish species found in the northeastern United States to be found also in:
    a. Mexico
    b. Canada
    c. Panama
    d. Peru

11. The best title for this passage would be:
    a. Temperature, Geography, and the Distribution of Fish
    b. North American Fish and Their Separation by Mountain Ridges
    c. The Distribution of Freshwater Fish Species in North America
    d. The Distribution of Freshwater Fish and Its Results

PASSAGE #3

The following passage is adapted from an article called "Ecological Succession."

Ecological Succession

On the morning of May 18, 1980, Mount St. Helens, a volcano in the Cascade Mountains of Washington State, violently erupted. Its explosion of gases and pulverized rock released the energy equal to five hundred atomic bombs! The shock wave from the blast snapped trees as if they were toothpicks. Temperatures approaching 350°C (662°F) scorched nearby forests. Mudflows, more than 18 m (59 ft) high and traveling down the slopes at speeds of 161 km/h (100 mph), covered the landscape.

In an instant, entire ecological communities were destroyed. However, just below the surface, there were survivors, showing the resilience of this ecosystem. Beneath the ash, gophers dug their way back to the surface, mixing soil with ash. The soil contained fungus spores. The growing fungi provided an environment for algae to absorb nutrients from the ash. Algae further changed the soil's chemistry and made it suitable for moss to grow. Then lichens joined the community. Wind blew soil into the cracks of the lava—enough for ferns to take hold. Animals visited the black lava fields to nibble on the ferns. Organic material from the plants and animals enriched the soil, facilitating its ability to hold water. Wind-blown seeds could now germinate. The re-colonizing of life on the slopes of Mount St. Helens is an example of ecological succession. Succession is a process that involves a series of changes in a community over time. The example of Mount St. Helens would be considered secondary succession, because some component of the ecosystem was able to remain after the disturbance.

Ecological disturbances like volcanic eruptions, forest fires, floods, and even mowing a lawn can trigger succession. Whatever the reason, when habitats change or niches open, the process of succession can occur – even in a climax community, which is the final stage of succession.

The first species to arrive after a disruption tend to be small, hardy, fast growing, and able to live on very few resources. They are the pioneer species that cause adaptations to the environment, creating new niches for other species to fill. As new species build the community, succession slows down. When all available niches are filled, the community stabilizes to become a climax community, or a stable ecological environment.

Mount St. Helens will never be the same as it was before the 1980 eruption. Through the process of succession, grasslands and forests will return and animals will have immigrated back to graze on its slopes. A new, but different, community will develop and become stable—at least until the next eruption.

12. According to the passage, which statement is true regarding the process of succession after the eruption of Mount St. Helens?
    a. The process took only a week for the ecosystem to rebuild.
    b. The process began with life that survived the eruption below the soil.
    c. Algae and lichen played the most important role in restoring the land.
    d. The wind made the process more difficult.

13. In the first paragraph, the author's attitude toward the eruption of Mount St. Helens could best be described as:
    a. Amazed by
    b. Saddened by
    c. Disappointed by
    d. Overjoyed by

14. Which of the following statements best summarize something that can trigger or begin a series of changes to a community over time?
    a. The triggers are always dramatic events, like a fire or volcanic eruption.
    b. The triggers can be dramatic events, like a fire or volcanic eruption, or be a less dramatic event that also affects an environment.
    c. The triggers do not prevent the environment from returning to its original state.
    d. The triggers always improve the environment from its condition before the changes occur.

15. According to the passage, which of the following statements is true about the community at Mount St. Helens?
    a. The 1980 eruption did not have a significant impact on the community.
    b. The 1980 eruption killed all existing life forms, so new animals and plants had to be brought in to restore the community.
    c. The community at Mount St. Helens today is better than it ever was before the 1980 eruption.
    d. The community at Mount St. Helens is different than it ever was before the 1980 eruption.

16. Which of the following words best describes an organism that arrives first after a disruption to a community and helps to restore it?
    a. Flexible
    b. Weak
    c. Wild
    d. Interesting

Subject ID #______________________

Thank you for participating in this study about vocabulary words in biology. Here is some information about the following lesson packet:

- You will work in this packet on your own for about two weeks in class. Do as much as you can each day in the time provided and begin each day where you left off from the day before.

- There is a mix of short reading passages and vocabulary activities. For the reading passages, please read the passage and answer the questions that are listed in the middle or at the end of the passage.

- To help you complete the vocabulary activities in this packet, use the list of words and definitions provided by your teacher.

- All of the words you will be learning are at the bottom of each page in this lesson packet.

- Read the instructions before each lesson.

- At the end of some of the lessons, there is a stop sign with directions for you to get an answer sheet from your teacher. Make sure that you follow these directions and check your work to see what you missed.

- Turn this packet and your word list into your teacher at the end of class each day.

- Thank you in advance for trying your best throughout the research study. Your participation and effort are appreciated!

Lesson #1: How Familiar Are You with These Words?

*Directions: For each of the following words, check the **ONE** column that best describes how well you know that word.*

Word	Know It	Sort of Know It	Don't Know It at All
diminish			
distributed			
facilitate			
function			
immigrated			
interval			
regulate			
sustain			
carbon cycle			
cellular respiration			
ecological succession			
eutrophication			
photosynthesis			
primary succession			
secondary succession			

Lesson #2: Basic Definition Practice

Directions: Take a few minutes to read the list of fifteen vocabulary words on the attached sheet. You will be completing activities with these words for two weeks and will need to refer back to the words, definitions, and examples of those words in context. The words are also printed on the bottom of each page.

Using the definitions provided, along with your own understanding of the words, answer the questions below.

1. Which term describes how something is strengthened or supported?

   ____

2. Which term refers to a type of succession that begins in a place with no living organisms?

   ____

3. Which term refers to a way of making something easier?

   ____

4. Which term describes a slow process in which an area is overcome by a new species or group of species?

   ____

5. Which term describes how something permanently changes environments?

   ____

6. Which term describes a process where producers, such as plants, take energy and then release oxygen as a by-product?

   ____

7. Which term describes how speed is controlled?

   ____

8. Which term refers to a type of succession that takes place in an area where some part of the ecosystem remains after the area has been dramatically changed?

   ____

9. Which term describes something that is dependent upon other factors?

   ____

10. Which term describes how cells break down complex molecules to release energy?

    ____

11. Which term means a gap between things?

    ____

12. Which term describes carbon's movement?

    ____

13. Which term describes a way of reducing the amount of something?

    _____________________________ ____

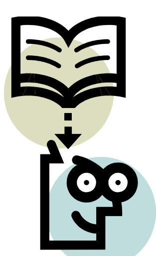
14. Which term describes how increasing nutrients in water can lead to an increase of plants like algae?

    ____

15. Which term describes how something might be spread out over a large area?

    ____

<u>See your teacher for an answer sheet to check your answers for lesson #2 before moving on.</u>



<u>Lesson #3: Reading Passage – "Overview of Cellular Respiration"</u>

Read the passage on the following pages, answering the questions in the middle of the passage, along with questions #1-7 that follow.

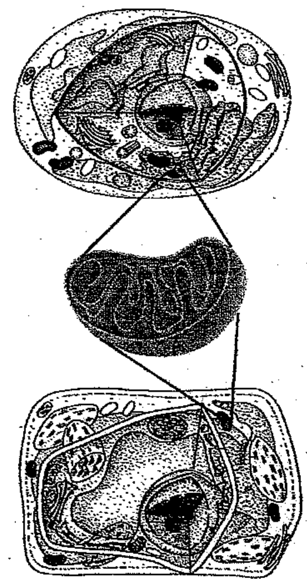
SECTION

Student text pages 113–115

4.4 Overview of Cellular Respiration

KEY CONCEPT The overall process of cellular respiration converts sugar into ATP using oxygen.

By breaking down sugars, cellular respiration makes ATP. **ATP** is a high-energy molecule that has energy that cells can use within its bonds.

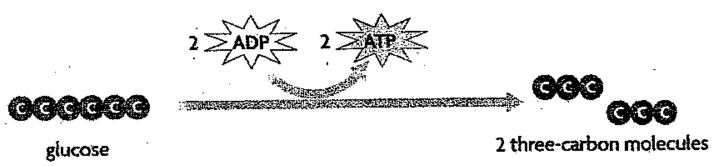


Mitochondria (middle) are found in both animal (top) and plant (bottom) cells. They make ATP through cellular respiration.

You probably know that you need to breathe oxygen to survive. But how does your body use that oxygen? That oxygen helps your body to release chemical energy that is stored in sugars and other carbon-based molecules. The energy isdispersedto produce ATP. This process of using oxygen to produce ATP by breaking down carbon-based molecules is called **cellular respiration.** Cellular respiration makes most of the ATP that a cell needs. Cellular respiration is an aerobic process. **Aerobic** (air-OH-bihk) means that it needs oxygen to function.

Cellular respiration takes place in mitochondria. These organelles are sometimes called the cell's "powerhouses" because this is where most of the cell's ATP is made. Mitochondria do not make ATP directly from food. ATP is made through many chemical reactions.

Before cellular respiration can happen, food has to be broken down into smaller molecules. Food gets broken down into smaller molecules like glucose. Then, glucose gets broken down. Remember that glucose is a six-carbon sugar. **Glycolysis** (gly-KAHL-uh-sihs) breaks glucose into two molecules that each have three carbons.



Glycolysis breaks glucose into 2 three-carbon molecules.

Glycolysis is an anaerobic process. **Anaerobic** means that it does not need oxygen to happen. Glycolysis happens in the cell's cytoplasm. The three-carbon molecules from glycolysis then enter the mitochondria. The products of glycolysis—the three-carbon molecules—enter the mitochondria and are used in cellular respiration.

INSTANT REPLAY Why is cellular respiration called an aerobic process?

____

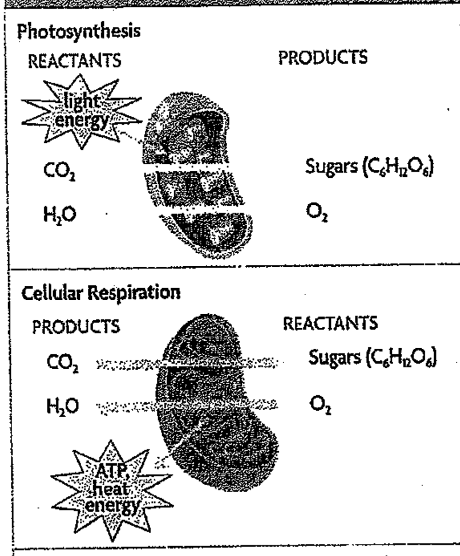
Cellular respiration is like a mirror image of photosynthesis.

A mirror image is like an opposite—the same thing, but in reverse. Cellular respiration and photosynthesis are not really opposites, but it can be helpful to think about them in that way. Photosynthesis makes sugars and cellular respiration breaks down sugars. The chemical equations of the two processes are basically opposites.

The structures of mitochondria and chloroplasts are very similar. Remember that part of photosynthesis happens inside the stroma—the fluid in the chloroplast—and part of photosynthesis happens inside the membrane of the thylakoid. Similarly, part of cellular respiration happens in the fluid inside the mitochondria, called the matrix. The other part of cellular respiration happens in the inner membrane of the mitochondria.

After glycolysis, the three-carbon molecules enter the mitochondria and begin the process of cellular respiration. There are two main parts of cellular respiration:

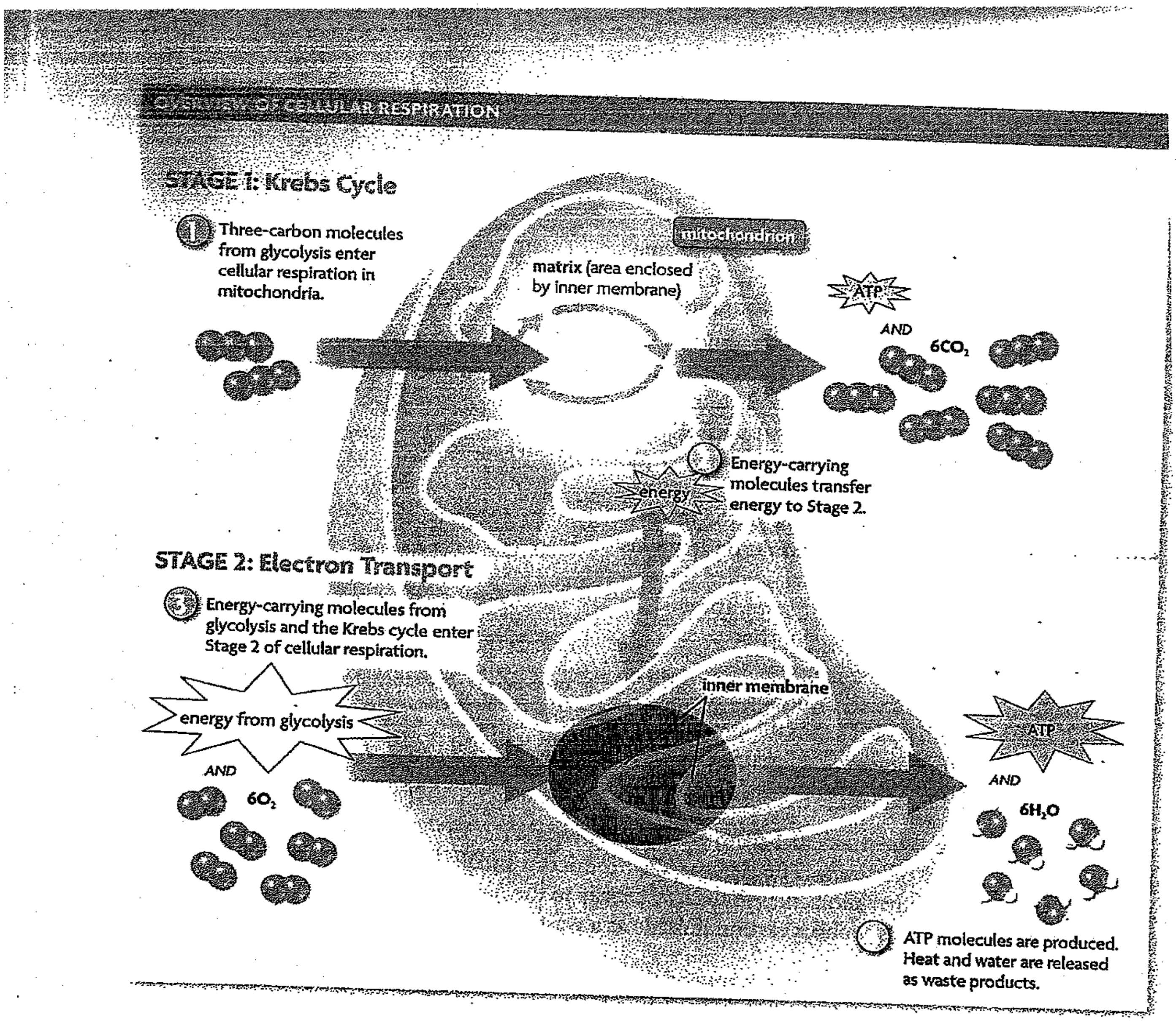
COMPARING PROCESSES



The products of photosynthesis—sugars and O_2—are the reactants in cellular respiration.

Stage 1: Krebs cycle The molecules from glycolysis enter a series of reactions called the Krebs cycle. The **Krebs cycle** produces a small amount of ATP and other molecules that carry energy to the next part of cellular respiration. It also makes carbon dioxide as a waste product.

Stage 2: Electron Transport Energy is moved through a chain of proteins and a large number of ATP molecules are made. Oxygen enters the process here. The oxygen is used to make water molecules, which are waste products.



Up to 38 ATP molecules are made from the breakdown of one glucose molecule. The equation for cellular respiration is shown below. You can see that there are many arrows between the reactants—$C_6H_{12}O_6$ and $6O_2$—and the products—$6CO_2$ and $6H_2O$. These arrows are there to tell you that there are many steps in the process. For example, the equation for cellular respiration includes glycolysis. Many enzymes also play important roles in the production of ATP.

$$\underset{\text{a sugar}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2} \rightarrow \rightarrow \rightarrow \rightarrow \underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O}$$

Follow the steps of cellular respiration shown on in the figure on the previous page.

INSTANT REPLAY Circle the products of cellular respiration in the figure on the previous page.

4.4 Vocabulary Check

cellular respiration
aerobic
glycolysis
anaerobic
Krebs cycle

Mark It Up

Go back and highlight each sentence that has a vocabulary word in **bold.**

1. Which two terms are opposites? ______________________

2. Which term is a process that must happen in the cell's cytoplasm before cellular respiration? ______________________

3. Which term is a process that happens within the mitochondria as part of cellular respiration? ______________________

4. Which term is the name for this chemical equation:

$$\underset{\text{a sugar}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2} \rightarrow \rightarrow \rightarrow \rightarrow \underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O}$$

____

4.4 The Big Picture

5. In which organelle does cellular respiration take place?

____

6. What are the products and the reactants for cellular respiration?

____

7. Where is most of the ATP made during cellular respiration?

____

Lesson #4: Forming More Personal Connections to Word Meanings

Using the definitions provided, along with your own understanding of the words, respond to the questions below.

1. Would it be good or bad if your supply of wealth was diminishing? Explain why.

2. Lakes where ____________________ has occurred commonly have reduced amounts of oxygen, due to the number of bacteria feeding on decaying organic matter.

3. From the time a person begins high school to the time he graduates is typically an interval of four years. What factors might cause this interval to be longer?

4. Which statement best describes the importance of photosynthesis?
    a. Photosynthesis keeps plants green.
    b. Photosynthesis makes water available to the plant.
    c. Photosynthesis provides the plant with sugar.
    d. Photosynthesis build plant DNA.

5. Explain if you agree or disagree with the following statement: Social media like Facebook and Twitter have helped to facilitate stronger relationships among friends.

6. The word *primary* means first and the word *secondary* means following after the first. How do these terms explain the difference between the two types of ecological succession: primary succession and secondary succession?

7. Give an example of a situation where a human or animal may have immigrated.

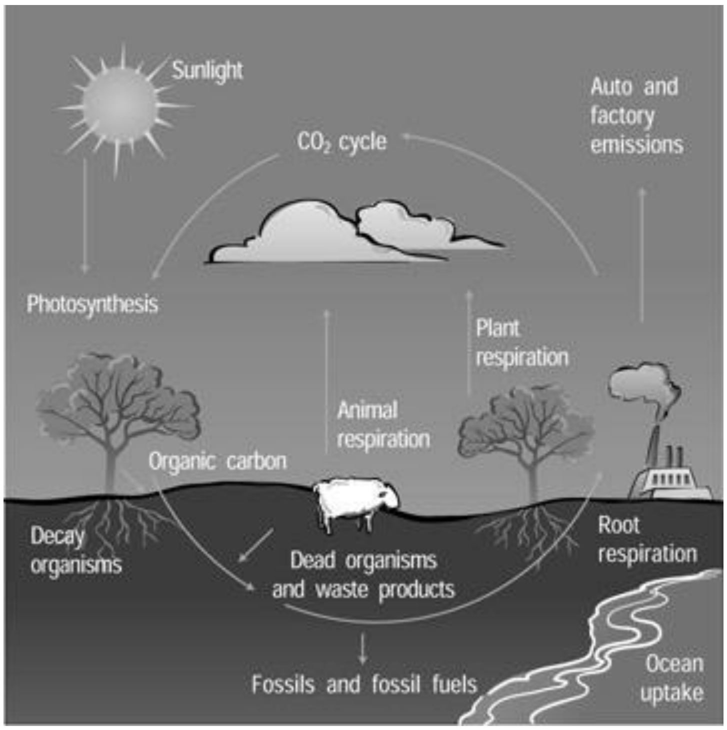
8. Eutrophication has to do with water ecosystems. Imagine that eutrophication has occurred in a pond near your school. Draw a sketch below of what the pond would look like.

9. What do vaccines help to regulate?

10. Cellular respiration is important since it is the process that releases the chemical energy stored in food. First we eat the plant, the food to survive. Then we need oxygen to help break down and digest the food, releasing the chemical energy and nutrients our bodies need to stay healthy and active. Knowing this, which of the following organisms would seem to use cellular respiration: plants, humans, fungi, fish, and reptiles? Explain your answer.

11. How well your brain functions during a difficult test might be a function of what other factors?

12. The diagram below shows how the processes of photosynthesis and the carbon cycle ($C0_2$) are related. Refer to it to answer the following question.



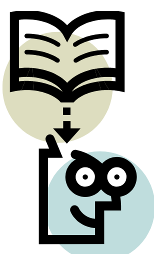
In photosynthesis, carbon is taken from the atmosphere by plants. The carbon is later transferred to animals that eat plants. When plants and animals die, much of their carbon is returned to the atmosphere as the organisms decompose, as part of the carbon cycle. Carbon becomes trapped in the earth , instead of returning to the atmosphere, when plants or animals do not decompose right away. Over millions of years, more and more carbon becomes trapped within earth. Humans release more carbon into the atmosphere by burning fossil fuels for energy.

Answer the following: how are humans disrupting the delicate balance of the carbon cycle and photosynthesis?

13. Explain or give an example of how charity groups sustain others during difficult economic times.

14. If your teacher says that grades on the last exam were widely distributed, what does she mean?

See your teacher for an answer sheet to check your answers for lesson #4 before moving on.



Lesson #5: Reading Passage – "Cycling of Matter"

Read the passage on the following pages, answering the questions in the middle of the passage, along with questions #1-5 that follow.

SECTION

13.5 Cycling of Matter

KEY CONCEPT Matter cycles in and out of an ecosystem.

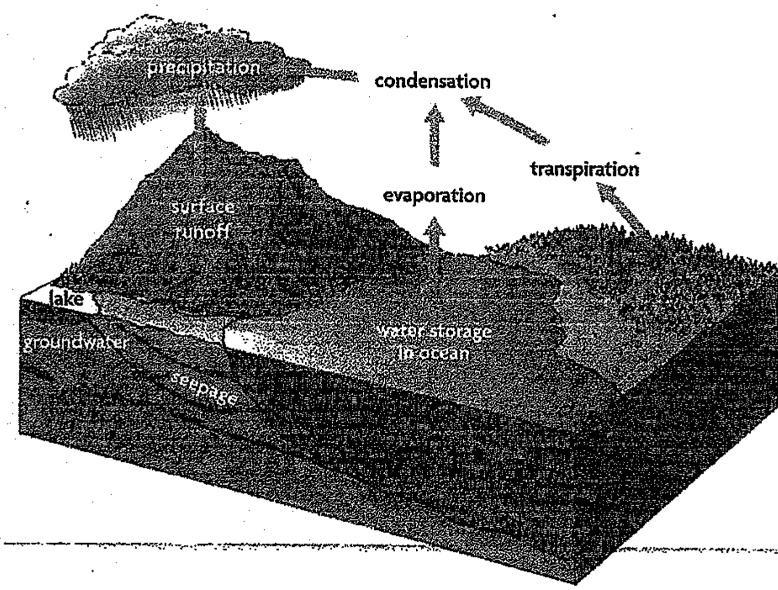
Student text pages 412–416

Water cycles through the environment.

Water moves continuously through the water cycle. The water cycle, or the **hydrologic cycle** (HY-druh-LAHJ-ihk), is the circular pathway of water on Earth—from the atmosphere, to the surface, below ground, and back into the atmosphere again. On Earth's surface, living things—including you—are part of the water cycle.

HYDROLOGIC CYCLE

The hydrologic cycle is the circular pathway of water on Earth.



During precipitation, water falls to the ground as rain or snow. Water may trickle through the ground in the process of seepage. Liquid water becomes vapor in the process of evaporation. When water evaporates from plants, it's called transpiration. Water vapor becomes liquid water again during condensation.

INSTANT REPLAY Name two ways that water can enter the atmosphere.

____

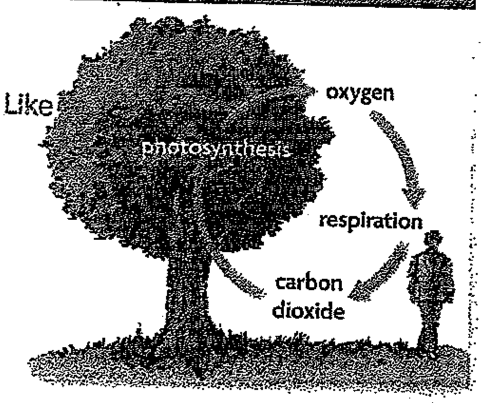
* ACADEMIC VOCABULARY

vapor the gaseous state of a substance

Elements essential* for life also cycle through ecosystems.

Oxygen, carbon, nitrogen, hydrogen, phosphorus, and sulfur are some of the elements necessary to sustain for life. Like water, these elements also cycle through ecosystems. The movement of a particular chemical through the living and nonliving parts of an ecosystem is called a **biogeochemical cycle** (BY-oh-JEE-oh-KHEM-ih-kuhl). Here you will read about four biogeochemical cycles: the oxygen cycle, the carbon cycle, the nitrogen cycle, and the phosphorus cycle.

OXYGEN CYCLE



In the oxygen cycle, oxygen is produced through photosynthesis. Living organisms take in this oxygen and release it as carbon dioxide through respiration.

The Oxygen Cycle

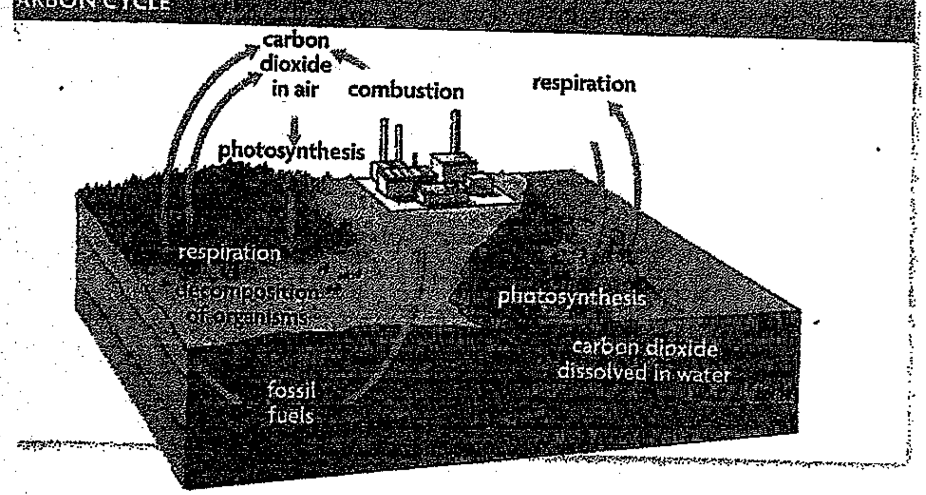
Most organisms use oxygen for cellular respiration. Recall that plants and other photosynthesizing organisms release oxygen as a waste product.

The Carbon Cycle

Carbon is a main component of carbohydrates, proteins, fats, and all of the other molecules that make up living things. Carbon can be inhabited in many different forms—as gas in the atmosphere, dissolved in water, in fossil fuels such as oil and coal, in rocks such as limestone, and in the soil.

Plants convert carbon dioxide from the air into carbohydrates. Carbohydrates get distributed through the living world as one organism eats another. Processes such as respiration and the burning of fossil fuels return carbon to the atmosphere as part of this migratory process.

ARBON CYCLE



Carbon dioxide from the atmosphere is used by plants during photosynthesis. Respiration releases carbon dioxide back into the atmosphere. The burning of fossil fuels, such as oil and gas, releases carbon dioxide into the atmosphere as well. Carbon dioxide is distributed in the atmosphere as dead organisms decompose.

ACADEMIC VOCABULARY

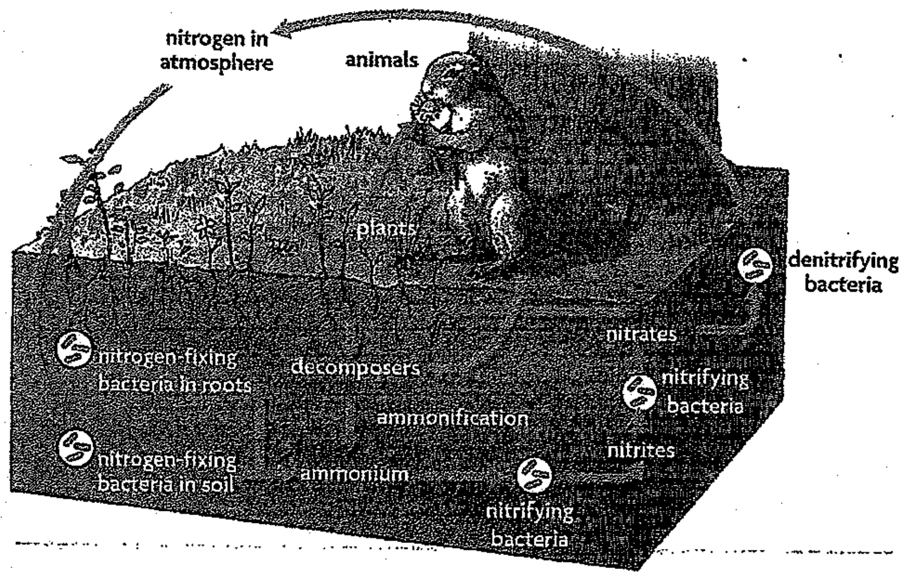
sential necessary, required for

The Nitrogen Cycle

An abundance, or about 78%, of the atmosphere is made of nitrogen gas. Organisms need nitrogen to live, but most organisms cannot use nitrogen in a gas form. Instead, most organisms can only use nitrogen when it is in the form of ions such as ammonium (NH_4^+) or nitrate (NO_3^-). Certain types of bacteria can turn nitrogen gas into ammonia through a process called **nitrogen fixation.**

Much of the nitrogen cycle is regulated underground. After nitrogen fixation, other bacteria turn the product, ammonia, into nitrates. Nitrates are used by plants to make amino acids and proteins. Nitrogen migrates through the living world as one organism eats another. Some types of bacteria also use nitrates, and release nitrogen gas back into the atmosphere.

NITROGEN CYCLE



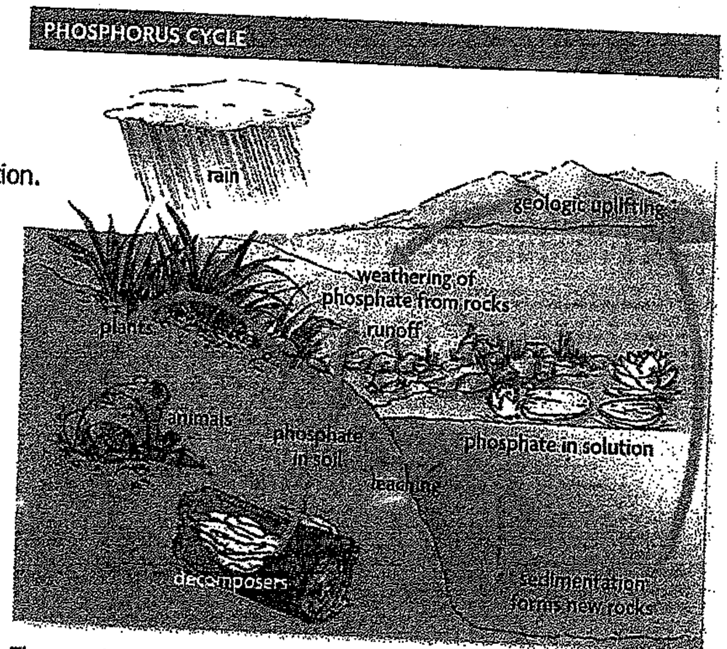
Nitrogen gas in the atmosphere is changed into ammonia by nitrogen-fixing bacteria. Ammonia becomes ammonium, which nitrifying bacteria change into nitrates. Plants use nitrates to make amino acids and proteins. This nitrogen is passed through the food web. Denitrifying bacteria change nitrates back into nitrogen gas, which is released into the atmosphere.

The Phosphorus Cycle

The oxygen, carbon, and nitrogen cycles all have some part that involves atmospheric gases. The phosphorus cycle has some variation. Most of the phosphorus cycle takes place at ground level.

Phosphate is released by the slow breakdown of rocks. Plants take up phosphate through their roots. Phosphorus then moves through the food web. When dead organisms are broken down by decomposers, phosphorus is released back into the environment.

INSTANT REPLAY Underline the main difference between the phosphorus cycle and the other cycles in this section.



The weathering of rocks releases phosphates into soil and water. Plants take up phosphates, which are then passed through the food web. Phophates are released back into the soil when these organisms die. Some phosphates sink to the botttom of water bodies, where they may become rock over thousands of years.

13.5 Vocabulary Check

hydrologic cycle
biogeochemical cycle
nitrogen fixation

Mark It Up

Go back and highlight each sentence that has a vocabulary word in **bold**.

1. List four biogeochemical cycles:

__________ __________ __________ __________

2. Nitrogen fixation changes __________ into __________.
3. The hydrologic cycle is the path of what substance? __________

13.5 The Big Picture

4. What two main biologcal processes are responsible for the cycling of oxygen? ____________________

5. What is the difference between a dead zone and eutrophication?

____

____

If an area of water becomes so depleted of oxygen that organisms must leave it, the area is considered a dead zone. If there is a dramatic increase in nutrients in a water ecosystem, resulting in increased plant growth, it is a process called eutrophication.

Lesson #6: Using Graphic Organizers to Learn Word Meanings

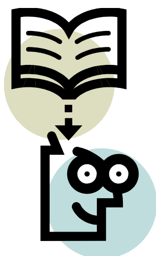
Complete the chart below for each of the 15 vocabulary words. Some parts of the chart have been filled in for you as examples.

Word	Definition in my own words	A picture, graphic or symbol representing the term & brief explanation of image	Some words related to this term
Distributed	This means to hand something out so that is spread all over.		
Diminish		 This picture shows a woman applying lotion to her face. I've heard the word "diminish" in commercials that promise their moisturizers diminish or reduce the appearance of fine lines and wrinkles. I'm not sure if these things really work!	
Primary succession			Disturbance Ecological succession Secondary succession

Word	Definition in my own words	A picture, graphic or symbol representing the term & brief explanation of image	Some words related to this term
Secondary succession			
Ecological Succession			
Facilitate			
Regulate			

Word	Definition in my own words	A picture, graphic or symbol representing the term & brief explanation of image	Some words related to this term
Sustain			
Function			
Interval			
Carbon Cycle			

Word	Definition in my own words	A picture, graphic or symbol representing the term & brief explanation of image	Some words related to this term
Cellular respiration			
Photosynthesis			
Eutrophication			
Immigrated			



Lesson #7: Reading Passage – "Community Interactions"

Read the passage on the following pages, answering the questions in the middle of the passage, along with questions #1-5 that follow.

SECTION

Student text pages 431–434

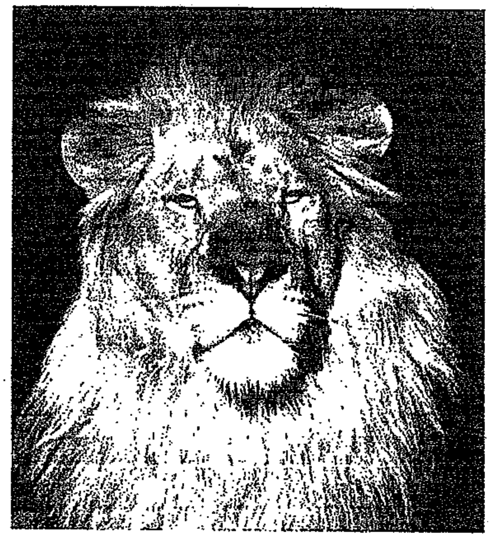
14.2 Community Interactions

KEY CONCEPT Organisms interact as individuals and as populations.

Competition and predation are two important ways in which organisms interact.

There are many different types of interactions between species in an ecosystem. Two important interactions are competition and predation.

- **Competition** occurs when two organisms fight for the same diminished resources. Members of different species may compete for the same resources. Members of the same species may also compete with each other for the same resources.
- **Predation** occurs when one organism captures and feeds upon another organism. Lions and hawks are well known as predators. But herbivores are predators, too. A deer, for example, preys on grass.


Lions are predators, animals that hunt and feed on other organisms.

INSTANT REPLAY Why can a deer be considered a predator?

____

____

Symbiosis is a close relationship between species.

Symbiosis is a close ecological relationship between two or more organisms of different species. One example of symbiosis is the relationship between certain bees and flowering plants. Flowers are often inhabited by bees for short intervals of time. Bees collect pollen or nectar from flowers, and in the process they pollinate the flower. In this case, both species benefit. There are four major types of symbiosis: mutualism, commensalism, parasitism, and amensalism.

- **Mutualism** is an interaction in which both organisms benefit.
- **Commensalism** is a relationship in which one organism benefits and the other organism neither benefits nor is harmed.
- **Parasitism** is a relationship in which one species benefits and the other is harmed. The species that gets harmed is called the host and the species that benefits is called the parasite.
- **Amensalism** is a relationship in which a product of one organism has a negative effect on another organism. One organism is harmed, while the other is neither affected nor benefited.

Predation is also a relationship in which one species benefits and the other is harmed. Parasitism is different from predation because a parasite does not immediately kill its host. Some parasites may lead to the death of the host after days or even years. Other parasites, like fleas or lice, harm the host but do not necessarily kill it.

INSTANT REPLAY Which type of symbiosis benefits one organism and harms the other? ______________________________

14.2 Vocabulary Check

competition
predation
symbiosis
amensalism
mutualism
commensalism
parasitism

Mark It Up

Go back and highlight each sentence that has a vocabulary word in **bold.**

Fill in the blanks with the correct term from the list above.

1. What are four types of symbiosis? ______________________________
____

2. What type of interaction occurs between organisms fighting for the same resources? ______________________________

3. What type of interaction occurs when one organism captures and feeds on another organism? ______________________________

14.2 The Big Picture

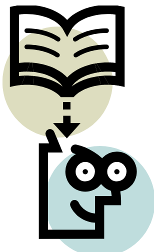
4. Your body is currently involved in many different symbiotic relationships. For example, microscopic organisms called mites live at the base of each of your eyelashes. The mites benefit from the relationship by eating dead skin cells and oils released by your skin. You are not harmed, nor does this benefit you. What type of symbiosis is this?
____

5. With both predation and parasitism, one organism benefits and the other is harmed. What is the main difference between parasitism and predation? ______________________________
____
____

Lesson #8: Connect Two

Your task in this lesson is to identify relationships between pairs of the vocabulary words. Try to identify as many connections as possible. Words can be paired more than once. Write the two words you are connecting and a brief explanation as to what their relationship is. Refer to the 15 words at the bottom of the page. See the example below.

#	Word #1	Word #2	The connection is…
1.	Distributed	Immigrated	Sometimes plant seeds are distributed by animals, which explains how those plants can be immigrated, or moved to a new environment.
2.			
3.			
4.			
5.			
6.			
7.			
8.			



Lesson #9: Reading Passage – "Ecological Succession"

Read the passage on the following pages, answering questions #1-3 that follow.

SECTION

Student text pages 445–447

4.5 Ecological Succession

KEY CONCEPT Ecological succession is a process of change in the species that make up a community.

Succession occurs following a disturbance by an ecosystem.

Succession is a sequence of adaptations that recreates a damaged community or facilitates a new community in an area that was not inhabited before. The ability of an ecosystem to recover after a major disturbance is referred to as its resilience.

Connecting CONCEPTS

Symbiosis A lichen is a symbiotic relationship between fungi and algae. The fungi collect water and the algae make food through photosynthesis.

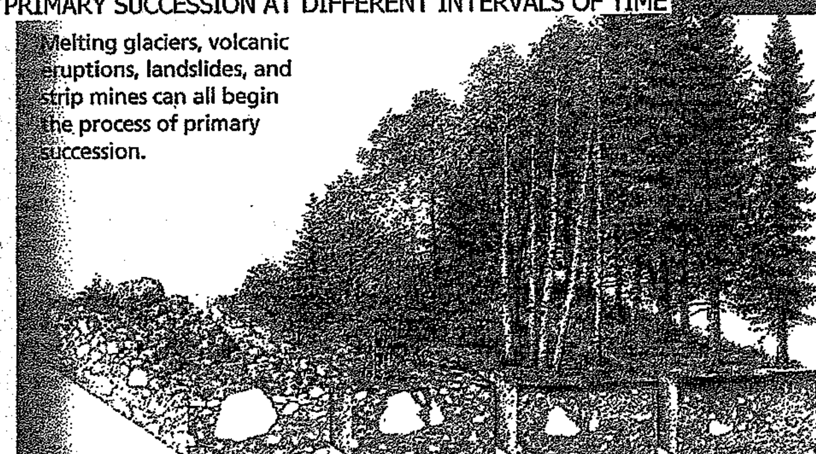
Primary Succession

Primary succession is the development of an ecosystem in an area that was not inhabited before. This type of succession might begin on cooled lava, after a volcano erupts. Or it might begin on bare rock that is exposed when a glacier melts. The first organisms that have immigrated into an area like this are called pioneer species.

Lichens and some mosses are pioneer species. They live on rock, and can minimize rock down into smaller pieces. Dead lichens and mosses mix with rock pieces to form a thin soil. Over time, seeds get blown in and grow in the soil. The soil continues to thicken, and eventually can sustain trees.

PRIMARY SUCCESSION AT DIFFERENT INTERVALS OF TIME

Melting glaciers, volcanic eruptions, landslides, and strip mines can all begin the process of primary succession.



0–15 years Moss, lichens, grasses	15–80 years Shrubs, cottonwoods, alder thicket	80–115 years Transition to forest, alder, spruce	115–200 years Hemlock-spruce forest

ACADEMIC VOCABULARY

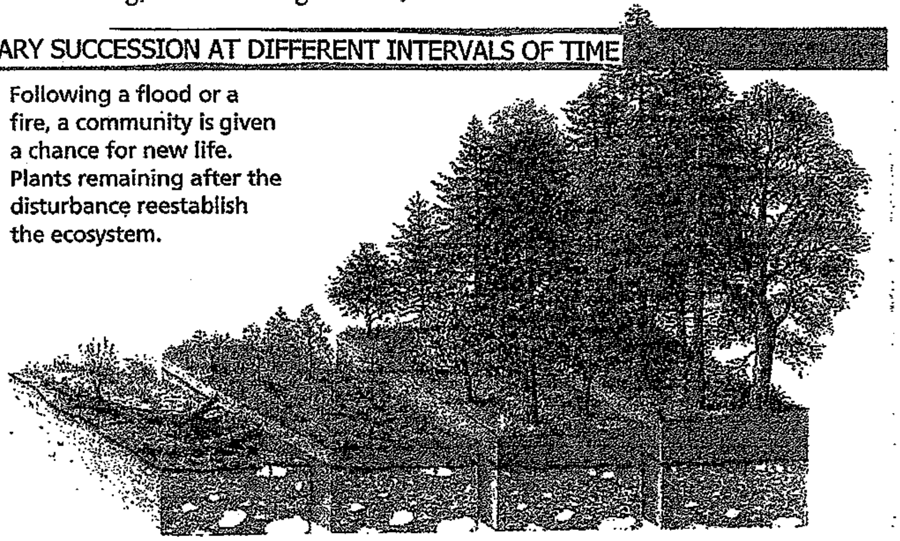
pioneer the first to do a certain thing

Secondary Succession

Secondary succession is the regrowth of a damaged ecosystem in an area that still has healthy soil. This may occur after a small event, such as a tree falling, or after a larger event, such as a hurricane.

SECONDARY SUCCESSION AT DIFFERENT INTERVALS OF TIME

Following a flood or a fire, a community is given a chance for new life. Plants remaining after the disturbance reestablish the ecosystem.



0–2 years Horseweed, crabgrass, asters | 2–18 years Grass, shrubs, pine seedlings | 18–70 years Pine forest and young hardwood seedlings | 70–100 years Oak-hickory forest

INSTANT REPLAY Underline two examples of pioneer species.

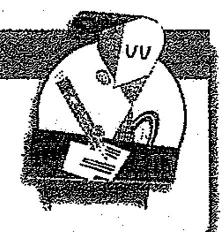
14.5 Vocabulary Check

succession
pioneer species
primary succession
secondary succession

Fill in the blanks with the correct term from the list above.

Mark It Up

Go back and highlight each sentence that has a vocabulary word in **bold**.



1. The first species to inhabit an area is a(n) ______________________.
2. Succession in an area that was not previously inhabited is called ______________________.

14.5 The Big Picture

3. What trend do you see in the changes in plant communities over the course of ecological succession? ____________________________
____

Lesson #10: Applying Word Knowledge to Writing

Think about the concepts you have been learning during this unit on ecology. Imagine that you needed to teach this unit to a group of 6th grade students in a way that they could understand it. Your task for this lesson is to write several paragraphs explaining the key points from the unit (such as: ecological succession, photosynthesis, carbon cycle, symbiosis) while using as many of the fifteen vocabulary words at the bottom of the page in your description. Underline the vocabulary words when you use them.

diminish	distributed	facilitate	function	immigrated	interval
regulate	sustain	carbon cycle	cellular respiration	ecological succession	
eutrophication	photosynthesis	primary succession	secondary succession		

Appendix H. Group 2 Student Lesson Packet

Subject ID #______________________

Thank you for participating in this study about vocabulary words in biology. Here is some information about the following lesson packet:

- You will work in this packet on your own for about two weeks in class. Do as much as you can each day in the time provided and begin each day where you left off from the day before.
- There is a mix of short reading passages and vocabulary activities. For the reading passages, please read the passage and answer the questions that are listed in the middle or at the end of the passage.
- To help you complete the vocabulary activities in this packet, use the list of words and definitions provided by your teacher.
- All of the words you will be learning are at the bottom of each page in this lesson packet.
- Read the instructions before each lesson.
- At the end of some of the lessons, there is a stop sign with directions for you to get an answer sheet from your teacher. Make sure that you follow these directions and check your work to see what you missed.
- Turn this packet and your word list into your teacher at the end of class each day.
- Thank you in advance for trying your best throughout the research study. Your participation and effort are appreciated!

Lesson #1: How Familiar Are You with These Words?

*Directions: For each of the following words, check the **ONE** column that best describes how well you know that word.*

Word	Know It	Sort of Know It	Don't Know It at All
Abundant			
adaptation			
diminish			
dispersion			
distributed			
facilitate			
function			
immigrated			
inhabited			
interval			
migratory			
minimize			
regulate			
sustain			
variation			

Lesson #2: Basic Definition Practice

Directions: Take a few minutes to read the list of fifteen vocabulary words on the attached sheet. You will be completing activities with these words for two weeks and will need to refer back to the words, definitions, and examples of those words in context. The words are also printed on the bottom of each page.

Using the definitions provided, along with your own understanding of the words, answer the questions below.

16. Which term refers to a way of making something easier?
    ____

17. Which term describes the process of how something moves from one part to another?
    ____

18. Which term describes how speed is controlled?
    ____

19. Which term means that there is plenty of something?
    ____

20. Which term describes something that is dependent upon other factors?
    ____

21. Which term means a gap between things?
    ____

22. Which **TWO** terms describe a way of reducing the amount of something?
    ______________________ ______________________

23. Which term describes the differences between individuals of a species?
    ____

24. Which **TWO** terms describe how something might be spread out over a large area?
    ______________________ ______________________

25. Which term describes how something permanently changes environments?
    ____

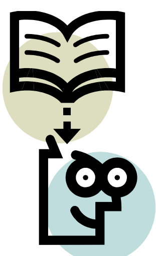
26. Which term describes how something is strengthened or supported?

____

27. Which term describes the improvements in a structure of a species?

____

See your teacher for an answer sheet to check your answers for lesson #2 before moving on.



Lesson #3: Reading Passage – "Overview of Cellular Respiration"

Read the passage on the following pages, answering the questions in the middle of the passage, along with questions #1-7 that follow.

SECTION

4.4 Overview of Cellular Respiration

Student text pages 113–115

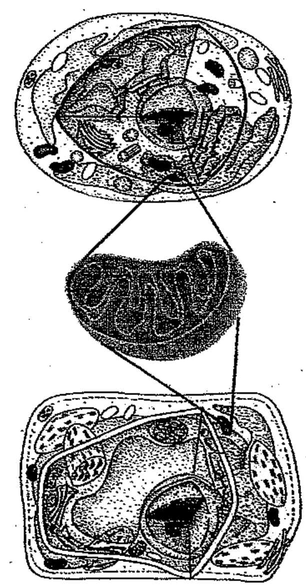
KEY CONCEPT The overall process of cellular respiration converts sugar into ATP using oxygen.

By breaking down sugars, cellular respiration makes ATP. **ATP** is a high-energy molecule that has energy that cells can use within its bonds.

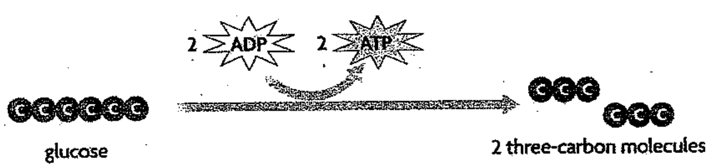
You probably know that you need to breathe oxygen to survive. But how does your body use that oxygen? That oxygen helps your body to release chemical energy that is stored in sugars and other carbon-based molecules. The energy isdispersedto produce ATP. This process of using oxygen to produce ATP by breaking down carbon-based molecules is called **cellular respiration.** Cellular respiration makes most of the ATP that a cell needs. Cellular respiration is an aerobic process. **Aerobic** (air-OH-bihk) means that it needs oxygen to function.

Cellular respiration takes place in mitochondria. These organelles are sometimes called the cell's "powerhouses" because this is where most of the cell's ATP is made. Mitochondria do not make ATP directly from food. ATP is made through many chemical reactions.

Before cellular respiration can happen, food has to be broken down into smaller molecules. Food gets broken down into smaller molecules like glucose. Then, glucose gets broken down. Remember that glucose is a six-carbon sugar. **Glycolysis** (gly-KAHL-uh-sihs) breaks glucose into two molecules that each have three carbons.



Mitochondria (middle) are found in both animal (top) and plant (bottom) cells. They make ATP through cellular respiration.



Glycolysis breaks glucose into 2 three-carbon molecules.

Glycolysis is an anaerobic process. **Anaerobic** means that it does not need oxygen to happen. Glycolysis happens in the cell's cytoplasm. The three-carbon molecules from glycolysis then enter the mitochondria. The products of glycolysis—the three-carbon molecules—enter the mitochondria and are used in cellular respiration.

INSTANT REPLAY Why is cellular respiration called an aerobic process?

____

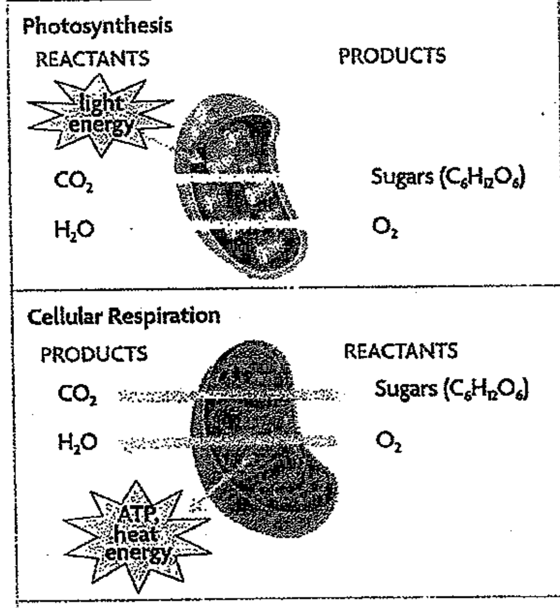
Cellular respiration is like a mirror image of photosynthesis.

A mirror image is like an opposite—the same thing, but in reverse. Cellular respiration and photosynthesis are not really opposites, but it can be helpful to think about them in that way. Photosynthesis makes sugars and cellular respiration breaks down sugars. The chemical equations of the two processes are basically opposites.

The structures of mitochondria and chloroplasts are very similar. Remember that part of photosynthesis happens inside the stroma—the fluid in the chloroplast—and part of photosynthesis happens inside the membrane of the thylakoid. Similarly, part of cellular respiration happens in the fluid inside the mitochondria, called the matrix. The other part of cellular respiration happens in the inner membrane of the mitochondria.

After glycolysis, the three-carbon molecules enter the mitochondria and begin the process of cellular respiration. There are two main parts of cellular respiration:

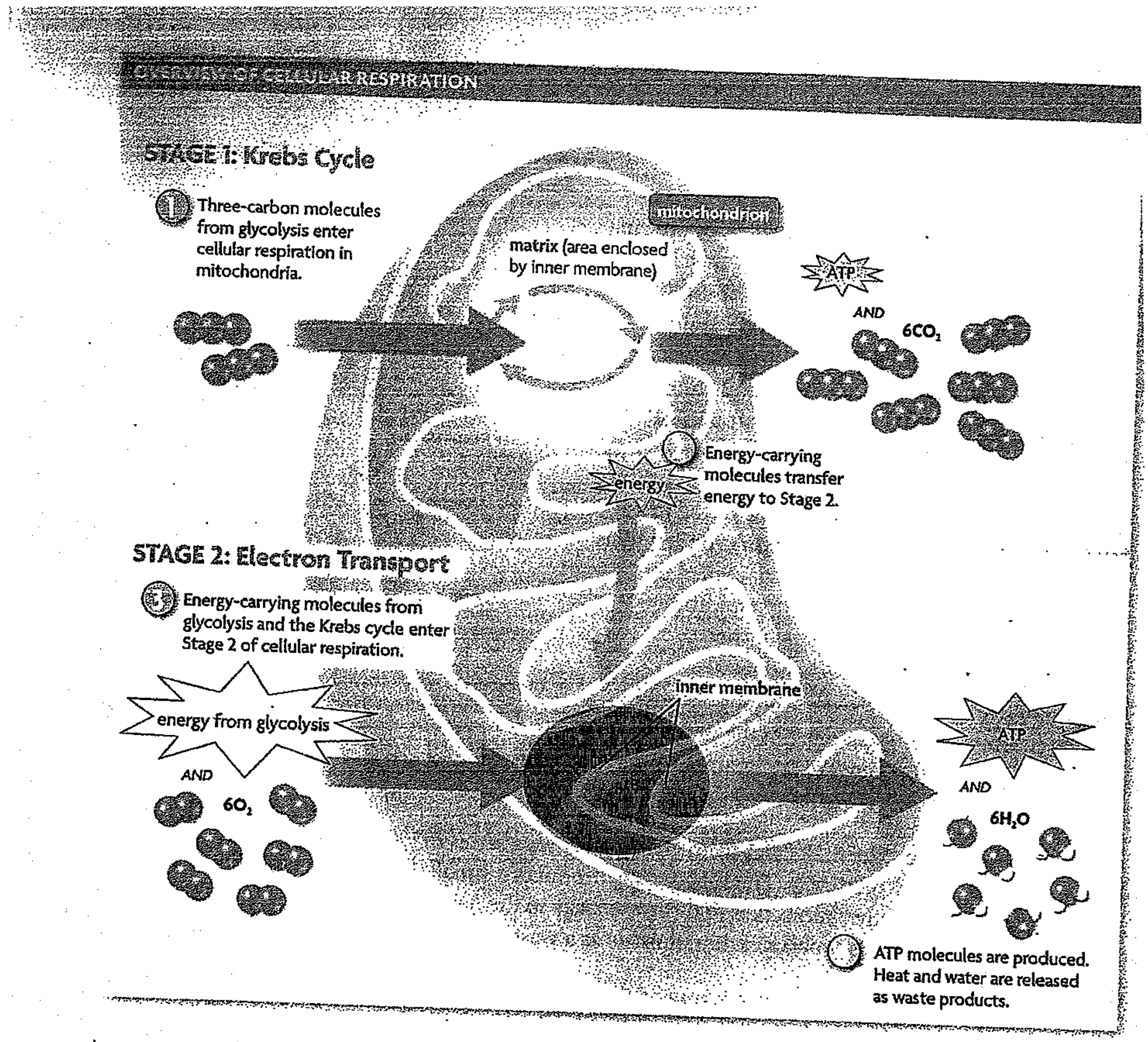
COMPARING PROCESSES



The products of photosynthesis—sugars and O_2—are the reactants in cellular respiration.

Stage 1: Krebs cycle The molecules from glycolysis enter a series of reactions called the Krebs cycle. The **Krebs cycle** produces a small amount of ATP and other molecules that carry energy to the next part of cellular respiration. It also makes carbon dioxide as a waste product.

Stage 2: Electron Transport Energy is moved through a chain of proteins and a large number of ATP molecules are made. Oxygen enters the process here. The oxygen is used to make water molecules, which are waste products.



Up to 38 ATP molecules are made from the breakdown of one glucose molecule. The equation for cellular respiration is shown below. You can see that there are many arrows between the reactants—$C_6H_{12}O_6$ and $6O_2$—and the products—$6CO_2$ and $6H_2O$. These arrows are there to tell you that there are many steps in the process. For example, the equation for cellular respiration includes glycolysis. Many enzymes also play important roles in the production of ATP.

$$\underset{\text{a sugar}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2} \rightarrow \rightarrow \rightarrow \rightarrow \underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O}$$

Follow the steps of cellular respiration shown on in the figure on the previous page.

INSTANT REPLAY Circle the products of cellular respiration in the figure on the previous page.

4.4 Vocabulary Check

cellular respiration
anaerobic
aerobic
Krebs cycle
glycolysis

Mark It Up

Go back and highlight each sentence that has a vocabulary word in **bold.**

1. Which two terms are opposites? ____________________
2. Which term is a process that must happen in the cell's cytoplasm before cellular respiration? ____________________
3. Which term is a process that happens within the mitochondria as part of cellular respiration? ____________________
4. Which term is the name for this chemical equation:

$$\underset{\text{a sugar}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2} \rightarrow \rightarrow \rightarrow \rightarrow \underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O}$$

____

4.4 The Big Picture

5. In which organelle does cellular respiration take place?

____

6. What are the products and the reactants for cellular respiration?

____

7. Where is most of the ATP made during cellular respiration?

____

Lesson #4: Forming More Personal Connections to Word Meanings

Using the definitions provided, along with your own understanding of the words, respond to the questions below.

15. What is something that might be abundant in a school?

16. Would it be good or bad if your supply of wealth was diminishing? Explain why.

17. What are some signs that a home is no longer being inhabited?

18. From the time a person begins high school to the time he graduates is typically an interval of four years. What factors might cause this interval to be longer?

19. If there is a dispersion of hazardous waste into a water ecosystem, what has happened?

20. Explain if you agree or disagree with the following statement: Social media like Facebook and Twitter have helped to facilitate stronger relationships among friends.

21. What is an adaptation that you think future generations of humans should have to make them more powerful in their environment?

22. What is alike and different about the terms immigrated and migratory?

23. What do vaccines help to regulate?

24. How well your brain functions during a difficult test might be a function of what other factors?

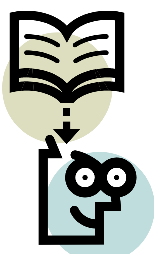
25. What is an example of something that people hope to minimize in their lives?

26. If there is a variation between two types of birds, are they more alike or more different? Explain your answer.

27. Explain or give an example of how charity groups sustain others during difficult economic times.

28. If your teacher says that grades on the last exam were widely distributed, what does she mean?

See your teacher for an answer sheet to check your answers for lesson #4 before moving on.



Lesson #5: Reading Passage – "Cycling of Matter"

Read the passage on the following pages, answering the questions in the middle of the passage, along with questions #1-5 that follow.

SECTION

Student text p... 412–416

13.5 Cycling of Matter

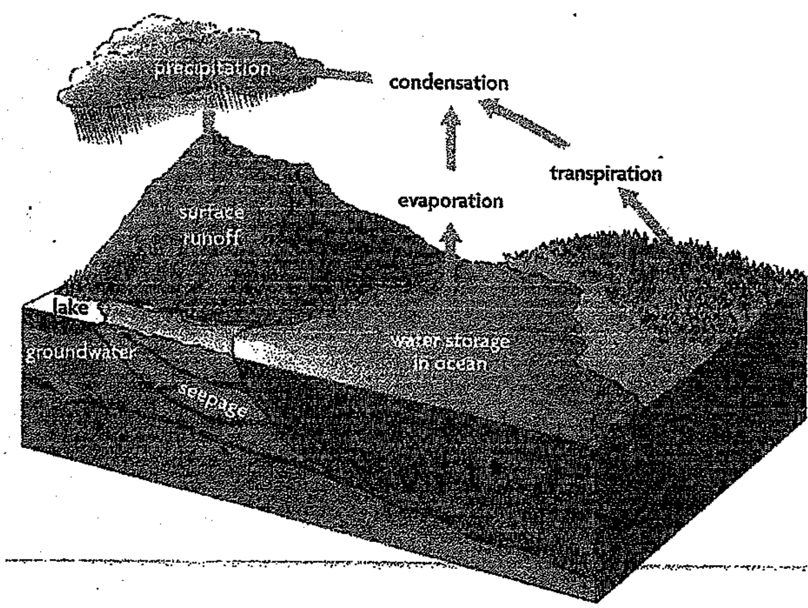
KEY CONCEPT Matter cycles in and out of an ecosystem.

Water cycles through the environment.

Water moves continuously through the water cycle. The water cycle, or the **hydrologic cycle** (HY-druh-LAHJ-ihk), is the circular pathway of water on Earth—from the atmosphere, to the surface, below ground, and back into the atmosphere again. On Earth's surface, living things—including you—are part of the water cycle.

HYDROLOGIC CYCLE

The hydrologic cycle is the circular pathway of water on Earth.



During precipitation, water falls to the ground as rain or snow. Water may trickle through the ground in the process of seepage. Liquid water becomes vapor in the process of evaporation. When water evaporates from plants, it's called transpiration. Water vapor becomes liquid water again during condensation.

INSTANT REPLAY Name two ways that water can enter the atmosphere.

____

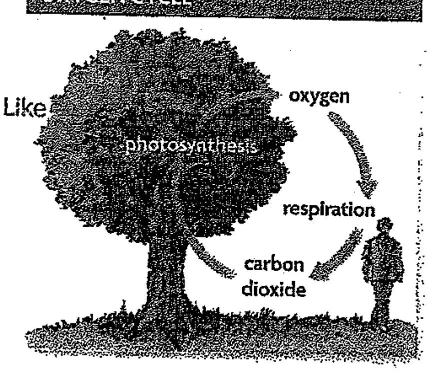
* ACADEMIC VOCABULARY

vapor the gaseous state of a substance

Elements essential* for life also cycle through ecosystems.

Oxygen, carbon, nitrogen, hydrogen, phosphorus, and sulfur are some of the elements necessary to sustain for life. Like water, these elements also cycle through ecosystems. The movement of a particular chemical through the living and nonliving parts of an ecosystem is called a **biogeochemical cycle** (BY-oh-JEE-oh-KHEM-ih-kuhl). Here you will read about four biogeochemical cycles: the oxygen cycle, the carbon cycle, the nitrogen cycle, and the phosphorus cycle.

OXYGEN CYCLE



In the oxygen cycle, oxygen is produced through photosynthesis. Living organisms take in this oxygen and release it as carbon dioxide through respiration.

The Oxygen Cycle

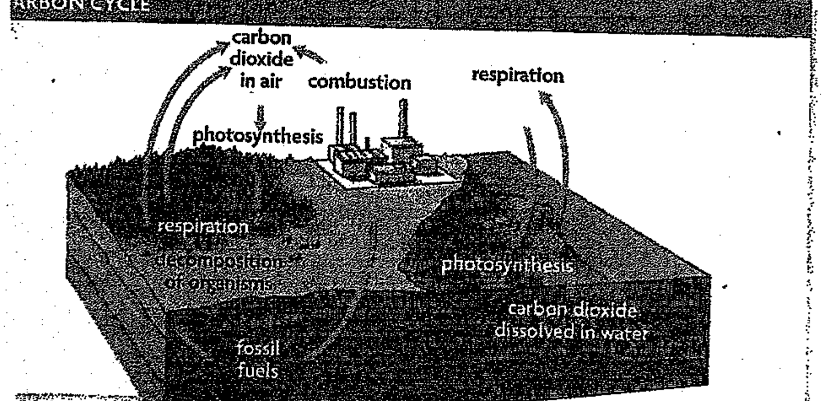
Most organisms use oxygen for cellular respiration. Recall that plants and other photosynthesizing organisms release oxygen as a waste product.

The Carbon Cycle

Carbon is a main component of carbohydrates, proteins, fats, and all of the other molecules that make up living things. Carbon can be inhabited in many different forms—as gas in the atmosphere, dissolved in water, in fossil fuels such as oil and coal, in rocks such as limestone, and in the soil.

Plants convert carbon dioxide from the air into carbohydrates. Carbohydrates get distributed through the living world as one organism eats another. Processes such as respiration and the burning of fossil fuels return carbon to the atmosphere as part of this migratory process.

ARBON CYCLE



Carbon dioxide from the atmosphere is used by plants during photosynthesis. Respiration releases carbon dioxide back into the atmosphere. The burning of fossil fuels, such as oil and gas, releases carbon dioxide into the atmosphere as well. Carbon dioxide is distributed in the atmosphere as dead organisms decompose.

ACADEMIC VOCABULARY

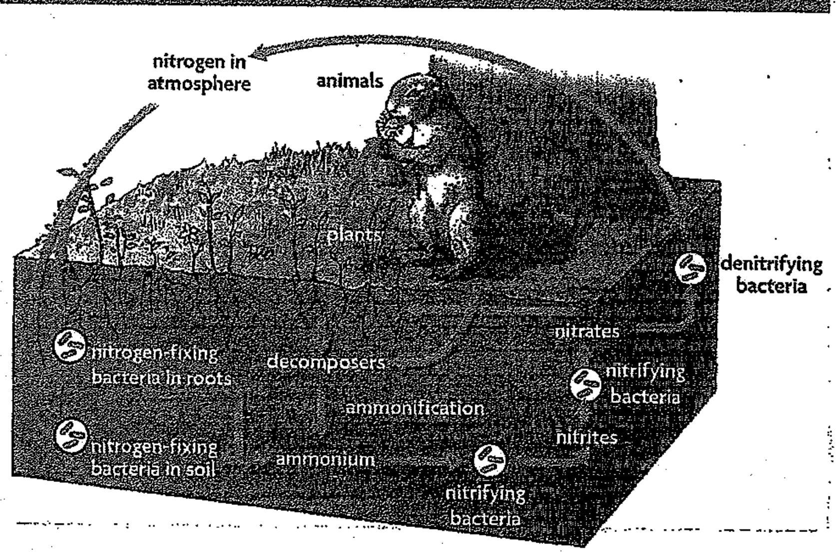
sential necessary, required for

The Nitrogen Cycle

An abundance, or about 78%, of the atmosphere is made of nitrogen gas. Organisms need nitrogen to live, but most organisms cannot use nitrogen in a gas form. Instead, most organisms can only use nitrogen when it is in the form of ions such as ammonium (NH_4^+) or nitrate (NO_3^-). Certain types of bacteria can turn nitrogen gas into ammonia through a process called **nitrogen fixation.**

Much of the nitrogen cycle is regulated underground. After nitrogen fixation, other bacteria turn the product, ammonia, into nitrates. Nitrates are used by plants to make amino acids and proteins. Nitrogen migrates through the living world as one organism eats another. Some types of bacteria also use nitrates, and release nitrogen gas back into the atmosphere.

NITROGEN CYCLE



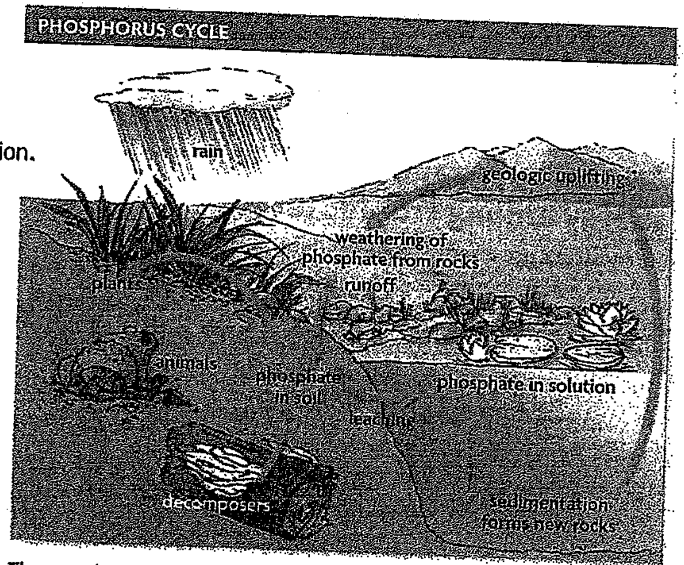
Nitrogen gas in the atmosphere is changed into ammonia by nitrogen-fixing bacteria. Ammonia becomes ammonium, which nitrifying bacteria change into nitrates. Plants use nitrates to make amino acids and proteins. This nitrogen is passed through the food web. Denitrifying bacteria change nitrates back into nitrogen gas, which is released into the atmosphere.

The Phosphorus Cycle

The oxygen, carbon, and nitrogen cycles all have some part that involves atmospheric gases. The phosphorus cycle has some variation. Most of the phosphorus cycle takes place at ground level.

Phosphate is released by the slow breakdown of rocks. Plants take up phosphate through their roots. Phosphorus then moves through the food web. When dead organisms are broken down by decomposers, phosphorus is released back into the environment.

INSTANT REPLAY Underline the main difference between the phosphorus cycle and the other cycles in this section.



The weathering of rocks releases phosphates into soil and water. Plants take up phosphates, which are then passed through the food web. Phophates are released back into the soil when these organisms die. Some phosphates sink to the botttom of water bodies, where they may become rock over thousands of years.

13.5 Vocabulary Check

hydrologic cycle
biogeochemical cycle
nitrogen fixation

Mark It Up

Go back and highlight each sentence that has a vocabulary word in **bold.**

If an area of water becomes so depleted of oxygen that organisms must leave it, the area is considered a dead zone. If there is a dramatic increase in nutrients in a water ecosystem, resulting in increased plant growth, it is a process called eutrophication.

1. List four biogeochemical cycles:

______ ______ ______ ______

2. Nitrogen fixation changes ______ into ______.
3. The hydrologic cycle is the path of what substance? ______

13.5 The Big Picture

4. What two main biologcal processes are responsible for the cycling of oxygen? ______

5. What is the difference between a dead zone and eutrophication?

______

______

Lesson #6: Using Graphic Organizers to Learn Word Meanings

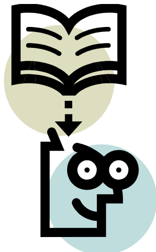
Complete the chart below for each of the 15 vocabulary words. Some parts of the chart have been filled in for you as examples.

Word	Definition in my own words	A picture, graphic or symbol representing the term & brief explanation of image	Some words related to this term
abundant	An abundant amount of something means that I have A LOT of it.		
Diminish		 This picture shows a woman applying lotion to her face. I've heard the word "diminish" in commercials that promise their moisturizers diminish or reduce the appearance of fine lines and wrinkles. I'm not sure if these things really work!	
Minimize			Reduce Maximize (opposite) Diminish

Word	Definition in my own words	A picture, graphic or symbol representing the term & brief explanation of image	Some words related to this term
Dispersion			
Distributed			
Inhabited			
Immigrated			

Word	Definition in my own words	A picture, graphic or symbol representing the term & brief explanation of image	Some words related to this term
Migratory			
Sustain			
Adaptation			
Variation			

Word	Definition in my own words	A picture, graphic or symbol representing the term & brief explanation of image	Some words related to this term
Regulate			
Function			
Interval			
Facilitate			



Lesson #7: Reading Passage – "Community Interactions"

Read the passage on the following pages, answering the questions in the middle of the passage, along with questions #1-5 that follow.

SECTION

Student text pages 431–434

14.2 Community Interactions

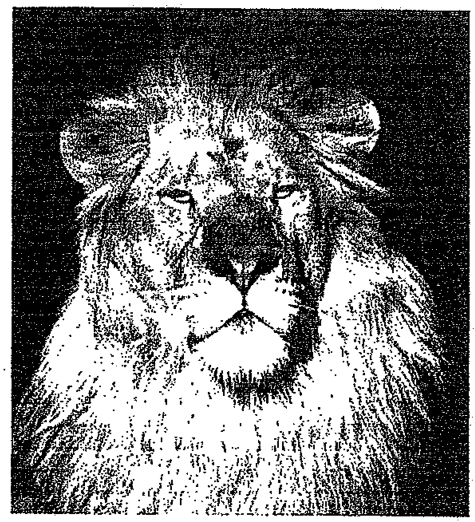
KEY CONCEPT Organisms interact as individuals and as populations.

Competition and predation are two important ways in which organisms interact.

There are many different types of interactions between species in an ecosystem. Two important interactions are competition and predation.

- **Competition** occurs when two organisms fight for the same diminished resources. Members of different species may compete for the same resources. Members of the same species may also compete with each other for the same resources.
- **Predation** occurs when one organism captures and feeds upon another organism. Lions and hawks are well known as predators. But herbivores are predators, too. A deer, for example, preys on grass.

INSTANT REPLAY Why can a deer be considered a predator?



Lions are predators, animals that hunt and feed on other organisms.

Symbiosis is a close relationship between species.

Symbiosis is a close ecological relationship between two or more organisms of different species. One example of symbiosis is the relationship between certain bees and flowering plants. Flowers are often inhabited by bees for short intervals of time. Bees collect pollen or nectar from flowers, and in the process they pollinate the flower. In this case, both species benefit. There are four major types of symbiosis: mutualism, commensalism, parasitism, and amensalism.

- **Mutualism** is an interaction in which both organisms benefit.
- **Commensalism** is a relationship in which one organism benefits and the other organism neither benefits nor is harmed.
- **Parasitism** is a relationship in which one species benefits and the other is harmed. The species that gets harmed is called the host and the species that benefits is called the parasite.
- **Amensalism** is a relationship in which a product of one organism has a negative effect on another organism. One organism is harmed, while the other is neither affected nor benefited.

Predation is also a relationship in which one species benefits and the other is harmed. Parasitism is different from predation because a parasite does not immediately kill its host. Some parasites may lead to the death of the host after days or even years. Other parasites, like fleas or lice, harm the host but do not necessarily kill it.

INSTANT REPLAY Which type of symbiosis benefits one organism and harms the other? ______________________________

14.2 Vocabulary Check

competition	mutualism
predation	commensalism
symbiosis	parasitism
amensalism	

Mark It Up

Go back and highlight each sentence that has a vocabulary word in **bold**.

Fill in the blanks with the correct term from the list above.

1. What are four types of symbiosis? ______________________________

   ____

2. What type of interaction occurs between organisms fighting for the same resources? ______________________________

3. What type of interaction occurs when one organism captures and feeds on another organism? ______________________________

14.2 The Big Picture

4. Your body is currently involved in many different symbiotic relationships. For example, microscopic organisms called mites live at the base of each of your eyelashes. The mites benefit from the relationship by eating dead skin cells and oils released by your skin. You are not harmed, nor does this benefit you. What type of symbiosis is this?

   ____

5. With both predation and parasitism, one organism benefits and the other is harmed. What is the main difference between parasitism and predation? ______________________________

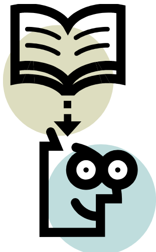
   ____

   ____

Lesson #8: Connect Two

Your task in this lesson is to identify relationships between pairs of the vocabulary words. Try to identify as many connections as possible. Words can be paired more than once. Write the two words you are connecting and a brief explanation as to what their relationship is. Refer to the 15 words at the bottom of the page. See the example below.

#	Word #1	Word #2	The connection is…
1.	Adaptation	Variation	Adaptations and variations both have to do with plants, animals, and humans changing to be more suited for their environment.
2.			
3.			
4.			
5.			
6.			
7.			
8.			



Lesson #9: Reading Passage – "Ecological Succession"

Read the passage on the following pages, answering questions #1-3 that follow.

SECTION

Student text pages 445–447

4.5 Ecological Succession

KEY CONCEPT Ecological succession is a process of change in the species that make up a community.

Succession occurs following a disturbance by an ecosystem.

Succession is a sequence of adaptations that recreates a damaged community or facilitates a new community in an area that was not inhabited before. The ability of an ecosystem to recover after a major disturbance is referred to as its resilience.

Connecting CONCEPTS

Symbiosis A lichen is a symbiotic relationship between fungi and algae. The fungi collect water and the algae make food through photosynthesis.

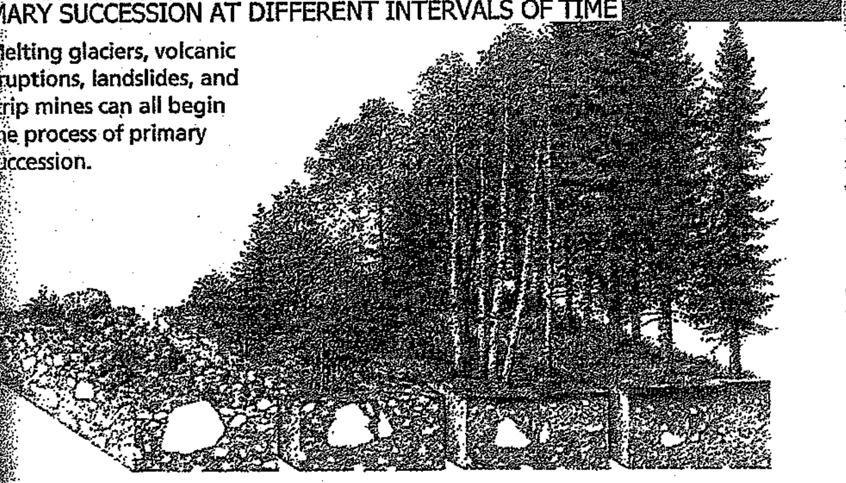
Primary Succession

Primary succession is the development of an ecosystem in an area that was not inhabited before. This type of succession might begin on cooled lava, after a volcano erupts. Or it might begin on bare rock that is exposed when a glacier melts. The first organisms that have immigrated into an area like this are called pioneer species.

Lichens and some mosses are pioneer species. They live on rock, and can minimize rock down into smaller pieces. Dead lichens and mosses mix with rock pieces to form a thin soil. Over time, seeds get blown in and grow in the soil. The soil continues to thicken, and eventually can sustain trees.

PRIMARY SUCCESSION AT DIFFERENT INTERVALS OF TIME

Melting glaciers, volcanic eruptions, landslides, and strip mines can all begin the process of primary succession.



0–15 years Moss, lichens, grasses

15–80 years Shrubs, cottonwoods, alder thicket

80–115 years Transition to forest, alder, spruce

115–200 years Hemlock-spruce forest

ACADEMIC VOCABULARY

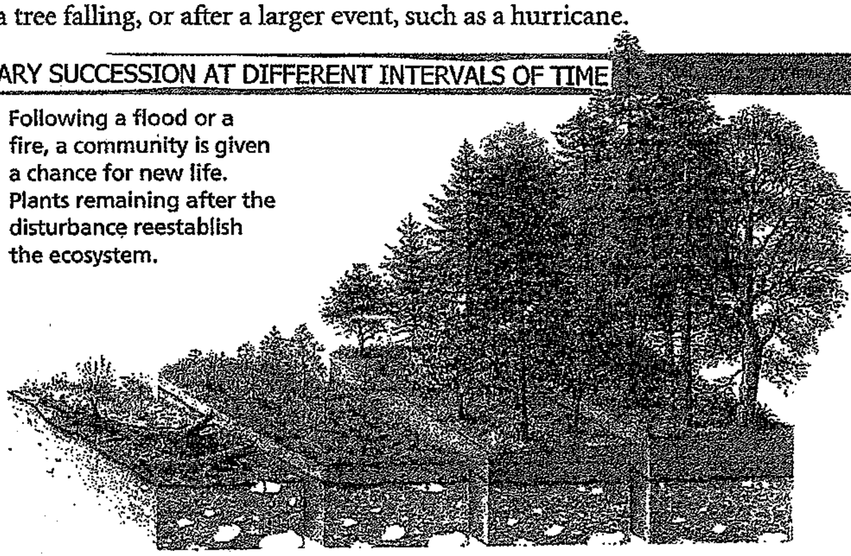
pioneer the first to do a certain thing

Secondary Succession

Secondary succession is the regrowth of a damaged ecosystem in an area that still has healthy soil. This may occur after a small event, such as a tree falling, or after a larger event, such as a hurricane.

SECONDARY SUCCESSION AT DIFFERENT INTERVALS OF TIME

Following a flood or a fire, a community is given a chance for new life. Plants remaining after the disturbance reestablish the ecosystem.



INSTANT REPLAY: Underline two examples of pioneer species.

14.5 Vocabulary Check

succession	pioneer species
primary succession	secondary succession

Fill in the blanks with the correct term from the list above.

1. The first species to inhabit an area is a(n) ______________________.
2. Succession in an area that was not previously inhabited is called ______________________.

Mark It Up

Go back and highlight each sentence that has a vocabulary word in **bold**.

14.5 The Big Picture

3. What trend do you see in the changes in plant communities over the course of ecological succession? ______________________________
____

<u>Lesson #10: Applying Word Knowledge to Writing</u>

Think about the concepts you have been learning during this unit on ecology. Imagine that you needed to teach this unit to a group of 6th grade students in a way that they could understand it. Your task for this lesson is to write several paragraphs explaining the key points from the unit (such as: ecological succession, photosynthesis, carbon cycle, symbiosis) while using as many of the fifteen vocabulary words at the bottom of the page in your description. <u>Underline the vocabulary words when you use them.</u>

abundant adaptation diminish dispersion distributed facilitate function

immigrated inhabited interval migratory minimize regulate sustain variation

Subject ID #______________________

Thank you for participating in this study about vocabulary words in biology. Here is some information about the following lesson packet:

- You will work in this packet on your own for about two weeks in class. Do as much as you can each day in the time provided and begin each day where you left off from the day before.

- There is a mix of short reading passages and vocabulary activities. For the reading passages, please read the passage and answer the questions that are listed in the middle or at the end of the passage.

- To help you complete the vocabulary activities in this packet, use the list of words and definitions provided by your teacher.

- All of the words you will be learning are at the bottom of each page in this lesson packet.

- Read the instructions before each lesson.

- At the end of some of the lessons, there is a stop sign with directions for you to get an answer sheet from your teacher. Make sure that you follow these directions and check your work to see what you missed.

- Turn this packet and your word list into your teacher at the end of class each day.

- Thank you in advance for trying your best throughout the research study. Your participation and effort are appreciated!

Lesson #1: How Familiar Are You with These Words?

Directions: For each of the following words, check the ***ONE*** *column that best describes how well you know that word.*

Word	Know It	Sort of Know It	Don’t Know It at All
amensalism			
carbon cycle			
cellular respiration			
commensalism			
dead zone			
disturbance			
ecological succession			
eutrophication			
mutualism			
parasitism			
photosynthesis			
primary succession			
resilience			
secondary succession			
symbiosis			

Lesson #2: Basic Definition Practice

Directions: Take a few minutes to read the list of fifteen vocabulary words on the attached sheet. You will be completing activities with these words for two weeks and will need to refer back to the words, definitions, and examples of those words in context. The words are also printed on the bottom of each page.

Using the definitions provided, along with your own understanding of the words, answer the questions below.

28. Which term refers to a general way to classify relationships between organisms?

    ____

29. Which term describes a symbiotic relationship where one species is harmed and another species benefits?

    ____

30. Which term refers to a type of succession that begins in a place with no living organisms?

    ____

31. Which term refers to a relationship where one species is not affected, while the other species is harmed?

    ____

32. Which term describes a slow process in which an area is overcome by a new species or group of species?

    ____

33. Which term describes a process where producers, such as plants, take energy and then release oxygen as a by-product?

    ____

34. Which term refers to a type of succession that takes place in an area where some part of the ecosystem remains after the area has been dramatically changed?

    ____

35. Which term describes how cells break down complex molecules to release energy?

    ____

36. Which term describes a sudden event in an ecosystem that changes the resources, organisms, or species?

    ____

37. Which term describes carbon's movement?

    ____

38. Which term describes a situation where both species benefit from the symbiotic relationship?

    ____

39. Which term describes how likely an ecosystem is able to recover after a significant change?

    ____

40. Which term describes how increasing nutrients in water can lead to an increase of plants like algae?

    ____

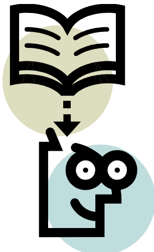
41. Which term describes a part of water without enough oxygen for organisms to survive?

    ____

42. Which term describes a situation where one species is not affected and the other species benefits from the relationship?

    ____

See your teacher for an answer sheet to check your answers for lesson #2 before moving on.



Lesson #3: Reading Passage – "Overview of Cellular Respiration"

Read the passage on the following pages, answering the questions in the middle of the passage, along with questions #1-7 that follow.

SECTION

4.4 Overview of Cellular Respiration

Student text pages 113–115

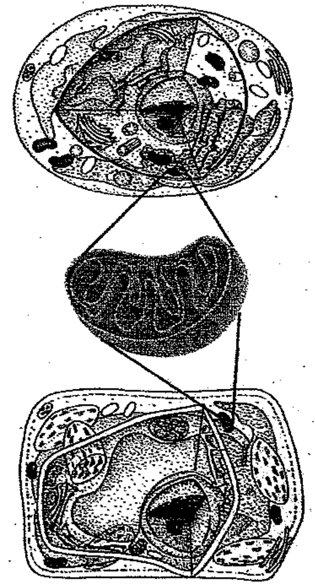
KEY CONCEPT The overall process of cellular respiration converts sugar into ATP using oxygen.

By breaking down sugars, cellular respiration makes ATP. **ATP** is a high-energy molecule that has energy that cells can use within its bonds.

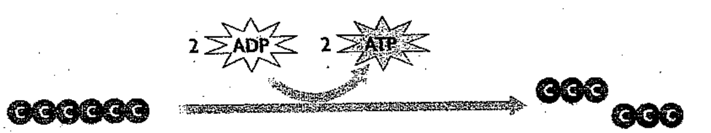
You probably know that you need to breathe oxygen to survive. But how does your body use that oxygen? That oxygen helps your body to release chemical energy that is stored in sugars and other carbon-based molecules. The energy isdispersedto produce ATP. This process of using oxygen to produce ATP by breaking down carbon-based molecules is called **cellular respiration.** Cellular respiration makes most of the ATP that a cell needs. Cellular respiration is an aerobic process. **Aerobic** (air-OH-bihk) means that it needs oxygen to function.

Cellular respiration takes place in mitochondria. These organelles are sometimes called the cell's "powerhouses" because this is where most of the cell's ATP is made. Mitochondria do not make ATP directly from food. ATP is made through many chemical reactions.

Before cellular respiration can happen, food has to be broken down into smaller molecules. Food gets broken down into smaller molecules like glucose. Then, glucose gets broken down. Remember that glucose is a six-carbon sugar. **Glycolysis** (gly-KAHL-uh-sihs) breaks glucose into two molecules that each have three carbons.



Mitochondria (middle) are found in both animal (top) and plant (bottom) cells. They make ATP through cellular respiration.



Glycolysis breaks glucose into 2 three-carbon molecules.

Glycolysis is an anaerobic process. **Anaerobic** means that it does not need oxygen to happen. Glycolysis happens in the cell's cytoplasm. The three-carbon molecules from glycolysis then enter the mitochondria. The products of glycolysis—the three-carbon molecules—enter the mitochondria and are used in cellular respiration.

INSTANT REPLAY Why is cellular respiration called an aerobic process?

____

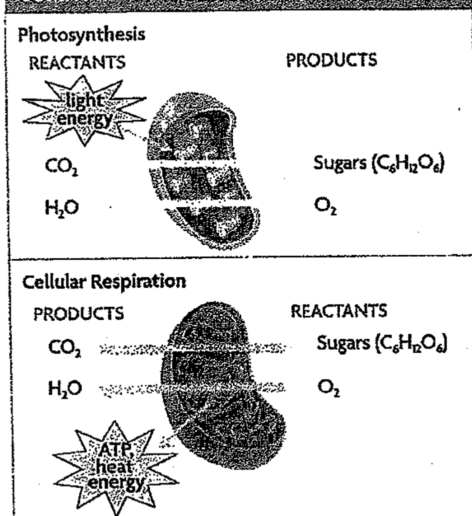
Cellular respiration is like a mirror image of photosynthesis.

A mirror image is like an opposite—the same thing, but in reverse. Cellular respiration and photosynthesis are not really opposites, but it can be helpful to think about them in that way. Photosynthesis makes sugars and cellular respiration breaks down sugars. The chemical equations of the two processes are basically opposites.

The structures of mitochondria and chloroplasts are very similar. Remember that part of photosynthesis happens inside the stroma—the fluid in the chloroplast—and part of photosynthesis happens inside the membrane of the thylakoid. Similarly, part of cellular respiration happens in the fluid inside the mitochondria, called the matrix. The other part of cellular respiration happens in the inner membrane of the mitochondria.

After glycolysis, the three-carbon molecules enter the mitochondria and begin the process of cellular respiration. There are two main parts of cellular respiration:

COMPARING PROCESSES

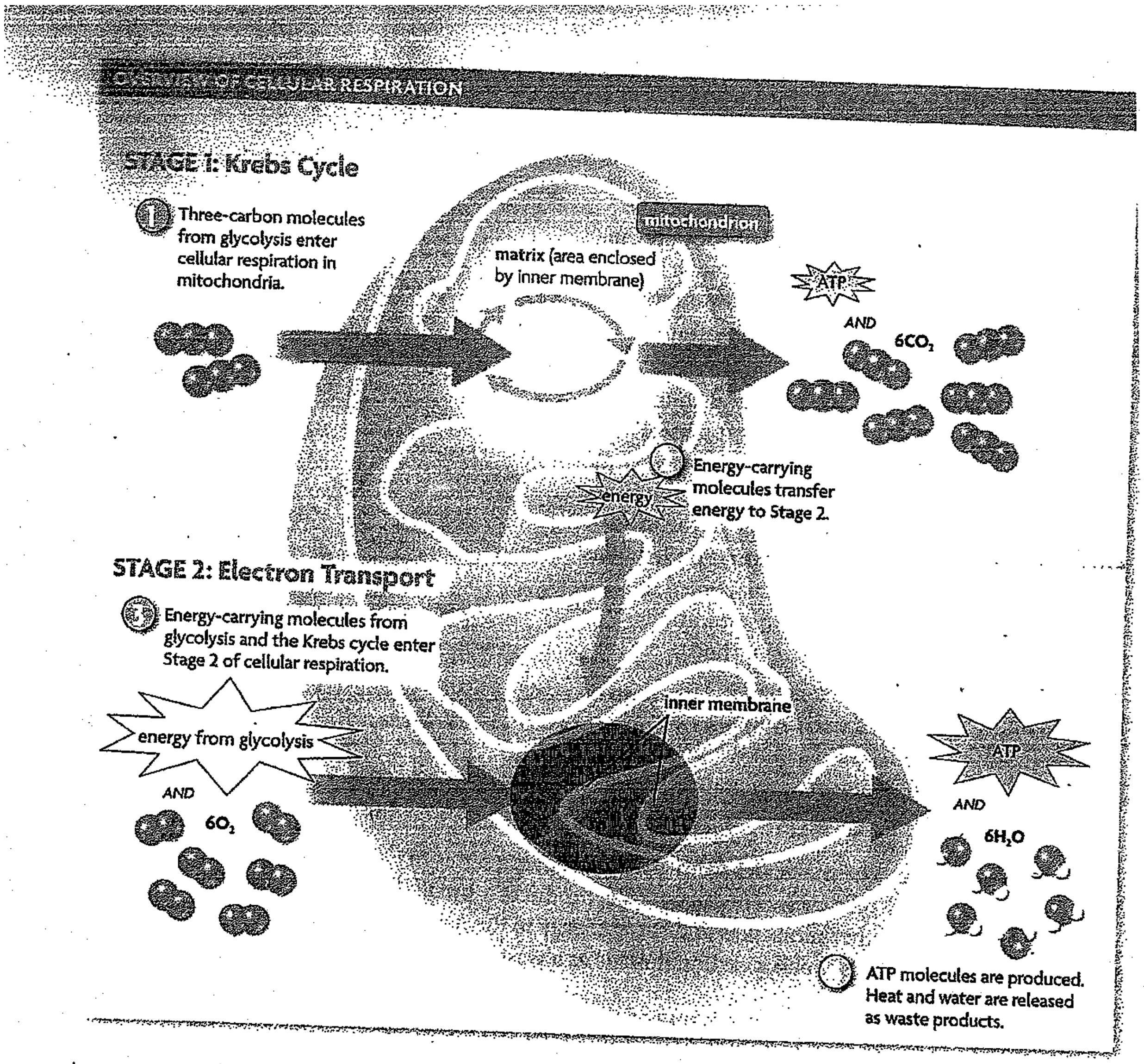


The products of photosynthesis—sugars and O_2—are the reactants in cellular respiration.

Stage 1: Krebs cycle The molecules from glycolysis enter a series of reactions called the Krebs cycle. The **Krebs cycle** produces a small amount of ATP and other molecules that carry energy to the next part of cellular respiration. It also makes carbon dioxide as a waste product.

Stage 2: Electron Transport Energy is moved through a chain of proteins and a large number of ATP molecules are made. Oxygen enters the process here. The oxygen is used to make water molecules, which are waste products.

APPENDIX I. (continued)



Up to 38 ATP molecules are made from the breakdown of one glucose molecule. The equation for cellular respiration is shown below. You can see that there are many arrows between the reactants—$C_6H_{12}O_6$ and $6O_2$—and the products—$6CO_2$ and $6H_2O$. These arrows are there to tell you that there are many steps in the process. For example, the equation for cellular respiration includes glycolysis. Many enzymes also play important roles in the production of ATP.

$$\underset{\text{a sugar}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2} \rightarrow \rightarrow \rightarrow \rightarrow \underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O}$$

Follow the steps of cellular respiration shown on in the figure on the previous page.

INSTANT REPLAY Circle the products of cellular respiration in the figure on the previous page.

4.4 Vocabulary Check

cellular respiration
aerobic
glycolysis
anaerobic
Krebs cycle

Mark It Up

Go back and highlight each sentence that has a vocabulary word in **bold.**

1. Which two terms are opposites? ______________________
2. Which term is a process that must happen in the cell's cytoplasm before cellular respiration? ______________________
3. Which term is a process that happens within the mitochondria as part of cellular respiration? ______________________
4. Which term is the name for this chemical equation:

$$\underset{\text{a sugar}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2} \rightarrow \rightarrow \rightarrow \rightarrow \underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O}$$

____

4.4 The Big Picture

5. In which organelle does cellular respiration take place?

____

6. What are the products and the reactants for cellular respiration?

____

7. Where is most of the ATP made during cellular respiration?

____

Lesson #4: Forming More Personal Connections to Word Meanings

Using the definitions provided, along with your own understanding of the words, respond to the questions below.

29. A volcanic eruption, forest fire, flood, or drought would be examples of which term?

30. The relationship between a dog and a deer tick is an example of which term?

31. Lakes where _____________________ has occurred commonly have reduced amounts of oxygen, due to the number of bacteria feeding on decaying organic matter.

32. Which statement best describes the importance of photosynthesis?
    a. Photosynthesis keeps plants green.
    b. Photosynthesis makes water available to the plant.
    c. Photosynthesis provides the plant with sugar.
    d. Photosynthesis build plant DNA.

33. Two robins are eating worms on the same lawn. Would this be an example of mutualism, commensalism, parasitism, ammensalism, or none of the following? Explain your answer.

34. The word *primary* means first and the word *secondary* means following after the first. How do these terms explain the difference between the two types of ecological succession: primary succession and secondary succession?

35. Aphids, or small insects, eat the sap from plants and leak sticky waste that ants eat. The ants protect the aphids from predators. Would this interaction be an example of mutualism, commensalism, parasitism, or ammensalism? Explain your answer.

36. Both dead zones and eutrophication have to do with water ecosystems. Explain how a dead zone is different than what occurs in eutrophication.

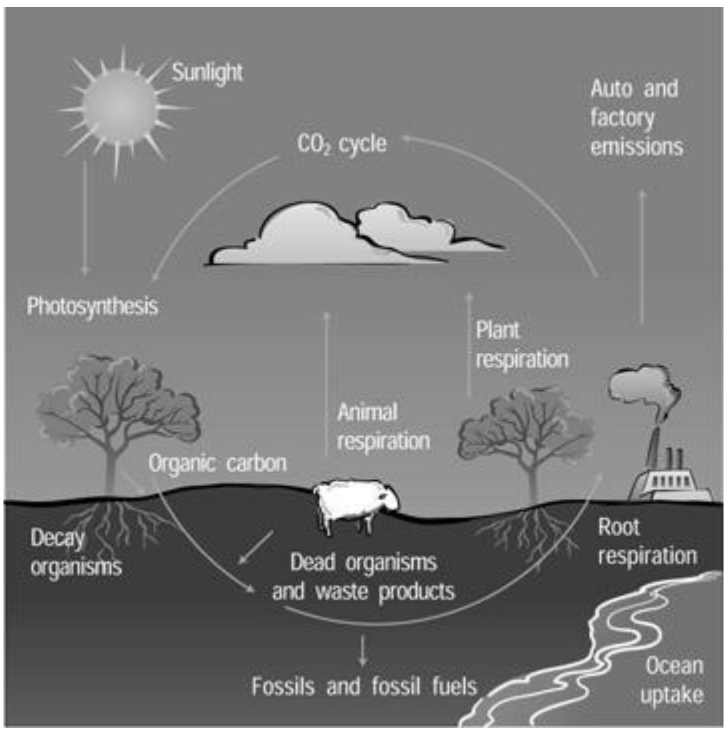
37. Symbiosis is a term to categorize the different relationships between organisms. Which other four terms from the definition list are types of relationships under this category of symbiosis?

38. How would you explain the difference between the terms disturbance and resilience to someone else?

39. Cellular respiration is important since it is the process that releases the chemical energy stored in food. First we eat the plant, the food to survive. Then we need oxygen to help break down

and digest the food, releasing the chemical energy and nutrients our bodies need to stay healthy and active. Knowing this, which of the following organisms would seem to use cellular respiration: plants, humans, fungi, fish, and reptiles? Explain your answer.

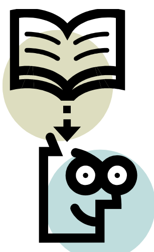
40. The diagram below shows how the processes of <u>photosynthesis</u> and the <u>carbon cycle</u> (CO_2) are related. Refer to it to answer the following question.



In <u>photosynthesis</u>, carbon is taken from the atmosphere by plants. The carbon is later transferred to animals that eat plants. When plants and animals die, much of their carbon is returned to the atmosphere as the organisms decompose, as part of the <u>carbon cycle</u>. Carbon becomes trapped in the earth , instead of returning to the atmosphere, when plants or animals do not decompose right away. Over millions of years, more and more carbon becomes trapped within earth. Humans release more carbon into the atmosphere by burning fossil fuels for energy.

<u>Answer the following</u>: how are humans disrupting the delicate balance of the <u>carbon cycle</u> and <u>photosynthesis</u>?

STOP <u>See your teacher for an answer sheet to check your answers for lesson #4 before moving on.</u>



Lesson #5: Reading Passage – "Cycling of Matter"

Read the passage on the following pages, answering the questions in the middle of the passage, along with questions #1-5 that follow.

SECTION

13.5 Cycling of Matter

Student text pages 412–416

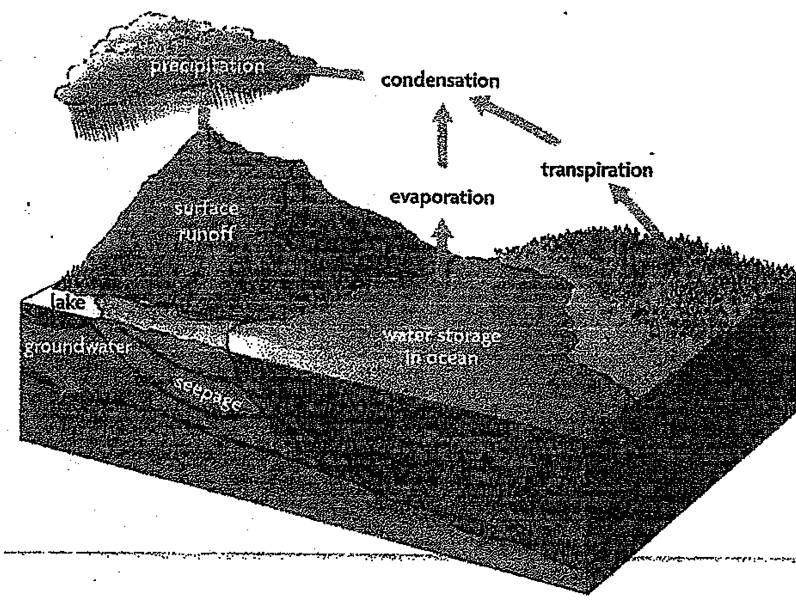
KEY CONCEPT Matter cycles in and out of an ecosystem.

Water cycles through the environment.

Water moves continuously through the water cycle. The water cycle, or the **hydrologic cycle** (HY-druh-LAHJ-ihk), is the circular pathway of water on Earth—from the atmosphere, to the surface, below ground, and back into the atmosphere again. On Earth's surface, living things—including you—are part of the water cycle.

HYDROLOGIC CYCLE

The hydrologic cycle is the circular pathway of water on Earth.



During precipitation, water falls to the ground as rain or snow. Water may trickle through the ground in the process of seepage. Liquid water becomes vapor in the process of evaporation. When water evaporates from plants, it's called transpiration. Water vapor becomes liquid water again during condensation.

INSTANT REPLAY Name two ways that water can enter the atmosphere.

___

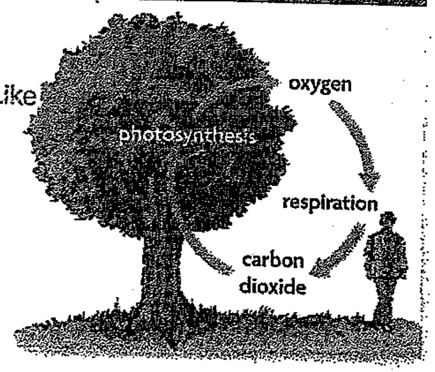
* ACADEMIC VOCABULARY

vapor the gaseous state of a substance

Elements essential* for life also cycle through ecosystems.

Oxygen, carbon, nitrogen, hydrogen, phosphorus, and sulfur are some of the elements necessary to sustain for life. Like water, these elements also cycle through ecosystems. The movement of a particular chemical through the living and nonliving parts of an ecosystem is called a **biogeochemical cycle** (BY-oh-JEE-oh-KHEM-ih-kuhl). Here you will read about four biogeochemical cycles: the oxygen cycle, the carbon cycle, the nitrogen cycle, and the phosphorus cycle.

OXYGEN CYCLE



In the oxygen cycle, oxygen is produced through photosynthesis. Living organisms take in this oxygen and release it as carbon dioxide through respiration.

The Oxygen Cycle

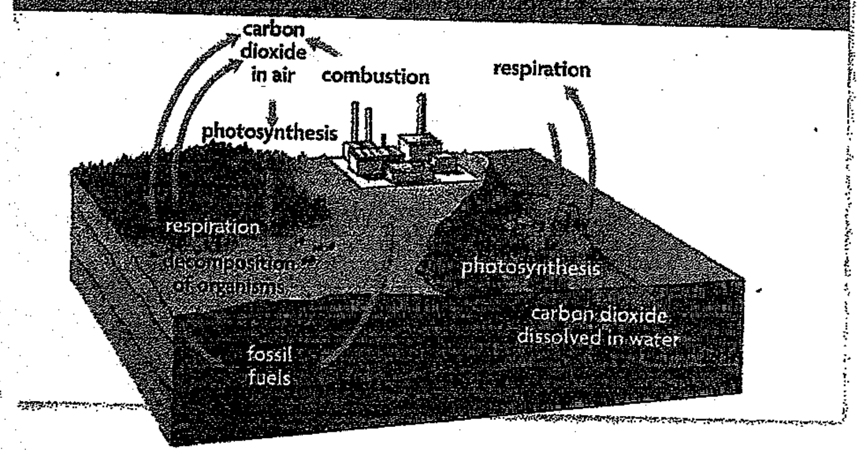
Most organisms use oxygen for cellular respiration. Recall that plants and other photosynthesizing organisms release oxygen as a waste product.

The Carbon Cycle

Carbon is a main component of carbohydrates, proteins, fats, and all of the other molecules that make up living things. Carbon can be inhabited in many different forms—as gas in the atmosphere, dissolved in water, in fossil fuels such as oil and coal, in rocks such as limestone, and in the soil.

Plants convert carbon dioxide from the air into carbohydrates. Carbohydrates get distributed through the living world as one organism eats another. Processes such as respiration and the burning of fossil fuels return carbon to the atmosphere as part of this migratory process.

ARBON CYCLE



Carbon dioxide from the atmosphere is used by plants during photosynthesis. Respiration releases carbon dioxide back into the atmosphere. The burning of fossil fuels, such as oil and gas, releases carbon dioxide into the atmosphere as well. Carbon dioxide is distributed in the atmosphere as dead organisms decompose.

ACADEMIC VOCABULARY

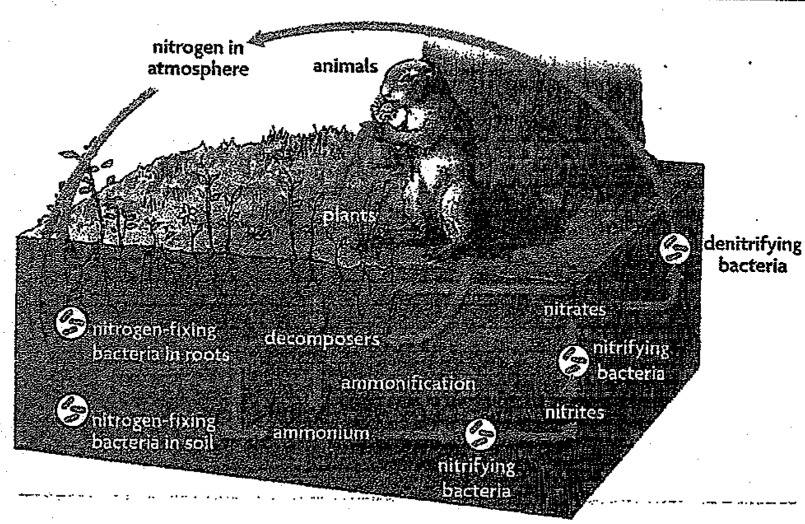
sential necessary, required for

The Nitrogen Cycle

An abundance, or about 78%, of the atmosphere is made of nitrogen gas. Organisms need nitrogen to live, but most organisms cannot use nitrogen in a gas form. Instead, most organisms can only use nitrogen when it is in the form of ions such as ammonium (NH_4^+) or nitrate (NO_3^-). Certain types of bacteria can turn nitrogen gas into ammonia through a process called **nitrogen fixation.**

Much of the nitrogen cycle is regulated underground. After nitrogen fixation, other bacteria turn the product, ammonia, into nitrates. Nitrates are used by plants to make amino acids and proteins. Nitrogen migrates through the living world as one organism eats another. Some types of bacteria also use nitrates, and release nitrogen gas back into the atmosphere.

NITROGEN CYCLE



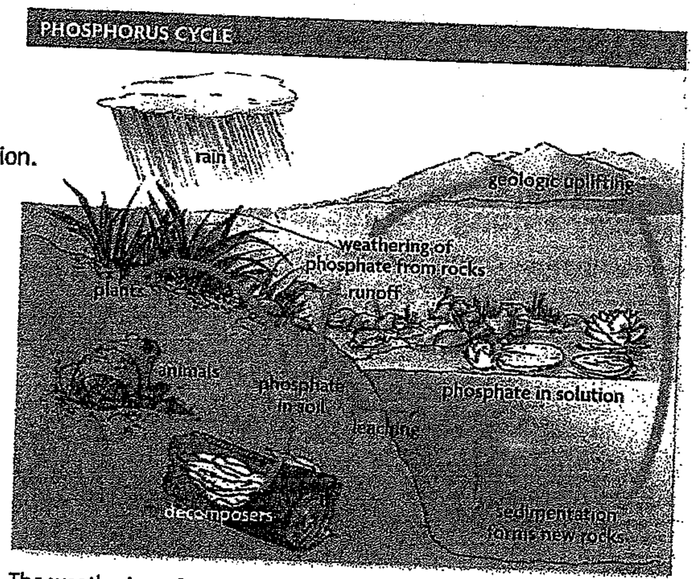
Nitrogen gas in the atmosphere is changed into ammonia by nitrogen-fixing bacteria. Ammonia becomes ammonium, which nitrifying bacteria change into nitrates. Plants use nitrates to make amino acids and proteins. This nitrogen is passed through the food web. Denitrifying bacteria change nitrates back into nitrogen gas, which is released into the atmosphere.

The Phosphorus Cycle

The oxygen, carbon, and nitrogen cycles all have some part that involves atmospheric gases. The phosphorus cycle has some variation. Most of the phosphorus cycle takes place at ground level.

Phosphate is released by the slow breakdown of rocks. Plants take up phosphate through their roots. Phosphorus then moves through the food web. When dead organisms are broken down by decomposers, phosphorus is released back into the environment.

INSTANT REPLAY Underline the main difference between the phosphorus cycle and the other cycles in this section.



The weathering of rocks releases phosphates into soil and water. Plants take up phosphates, which are then passed through the food web. Phophates are released back into the soil when these organisms die. Some phosphates sink to the botttom of water bodies, where they may become rock over thousands of years.

13.5 Vocabulary Check

hydrologic cycle
biogeochemical cycle
nitrogen fixation

Mark It Up

Go back and highlight each sentence that has a vocabulary word in **bold**.

If an area of water becomes so depleted of oxygen that organisms must leave it, the area is considered a dead zone. If there is a dramatic increase in nutrients in a water ecosystem, resulting in increased plant growth, it is a process called eutrophication.

1. List four biogeochemical cycles:

_______ _______ _______ _______

2. Nitrogen fixation changes ____________ into ____________.
3. The hydrologic cycle is the path of what substance? ____________

13.5 The Big Picture

4. What two main biologcal processes are responsible for the cycling of oxygen? ____________________

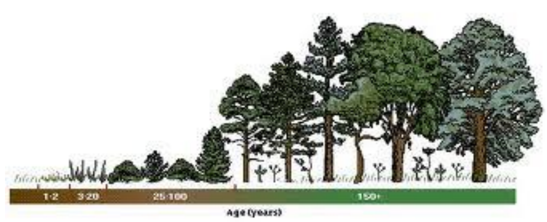
5. What is the difference between a dead zone and eutrophication?

____

____

Lesson #6: Using Graphic Organizers to Learn Word Meanings

Complete the chart below for each of the 15 vocabulary words. Some parts of the chart have been filled in for you as examples.

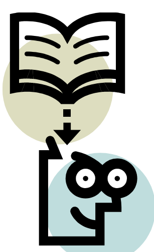
Word	Definition in my own words	A picture, graphic or symbol representing the term & brief explanation of image	Some words related to this term
Disturbance	This is something that really shakes up or changes an ecosystem forever, such as what lives in that space after the disturbance.		
Ecological succession		 This picture shows the gradual process of succession. After a disturbance, life slowly begins to grow and then change that ecosystem. In this picture, at first very little grew, but then after considerable time, large trees flourished in the area.	

Word	Definition in my own words	A picture, graphic or symbol representing the term & brief explanation of image	Some words related to this term
Primary succession			Disturbance Ecological succession Secondary succession
Secondary succession			
Resilience			
Symbiosis			

Word	Definition in my own words	A picture, graphic or symbol representing the term & brief explanation of image	Some words related to this term
Amensalism			
Commensalism			
Parasitism			
Mutualism			

Word	Definition in my own words	A picture, graphic or symbol representing the term & brief explanation of image	Some words related to this term
Cellular respiration			
Photosynthesis			
Carbon cycle			
Eutrophication			

Word	Definition in my own words	A picture, graphic or symbol representing the term & brief explanation of image	Some words related to this term
Dead zone			



Lesson #7: Reading Passage – "Community Interactions"

Read the passage on the following pages, answering the questions in the middle of the passage, along with questions #1-5 that follow.

SECTION

Student text pages 431–434

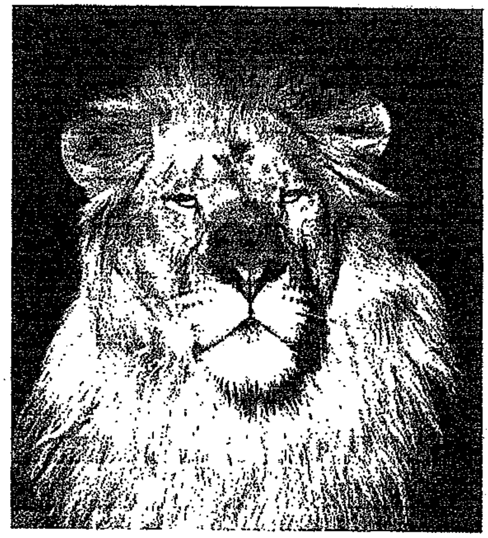
14.2 Community Interactions

KEY CONCEPT Organisms interact as individuals and as populations.

Competition and predation are two important ways in which organisms interact.

There are many different types of interactions between species in an ecosystem. Two important interactions are competition and predation.

- **Competition** occurs when two organisms fight for the same diminished resources. Members of different species may compete for the same resources. Members of the same species may also compete with each other for the same resources.
- **Predation** occurs when one organism captures and feeds upon another organism. Lions and hawks are well known as predators. But herbivores are predators, too. A deer, for example, preys on grass.



Lions are predators, animals that hunt and feed on other organisms.

INSTANT REPLAY Why can a deer be considered a predator?

____

____

Symbiosis is a close relationship between species.

Symbiosis is a close ecological relationship between two or more organisms of different species. One example of symbiosis is the relationship between certain bees and flowering plants. Flowers are often inhabited by bees for short intervals of time. Bees collect pollen or nectar from flowers, and in the process they pollinate the flower. In this case, both species benefit. There are four major types of symbiosis: mutualism, commensalism, parasitism, and amensalism.

- **Mutualism** is an interaction in which both organisms benefit.
- **Commensalism** is a relationship in which one organism benefits and the other organism neither benefits nor is harmed.
- **Parasitism** is a relationship in which one species benefits and the other is harmed. The species that gets harmed is called the host and the species that benefits is called the parasite.
- **Amensalism** is a relationship in which a product of one organism has a negative effect on another organism. One organism is harmed, while the other is neither affected nor benefited.

Predation is also a relationship in which one species benefits and the other is harmed. Parasitism is different from predation because a parasite does not immediately kill its host. Some parasites may lead to the death of the host after days or even years. Other parasites, like fleas or lice, harm the host but do not necessarily kill it.

INSTANT REPLAY Which type of symbiosis benefits one organism and harms the other? ______________________________

14.2 Vocabulary Check

competition
predation
symbiosis
amensalism
mutualism
commensalism
parasitism

Mark It Up

Go back and highlight each sentence that has a vocabulary word in **bold.**

Fill in the blanks with the correct term from the list above.

1. What are four types of symbiosis? ______________________________

____

2. What type of interaction occurs between organisms fighting for the same resources? ______________________________

3. What type of interaction occurs when one organism captures and feeds on another organism? ______________________________

14.2 The Big Picture

4. Your body is currently involved in many different symbiotic relationships. For example, microscopic organisms called mites live at the base of each of your eyelashes. The mites benefit from the relationship by eating dead skin cells and oils released by your skin. You are not harmed, nor does this benefit you. What type of symbiosis is this?

____

5. With both predation and parasitism, one organism benefits and the other is harmed. What is the main difference between parasitism and predation? ______________________________

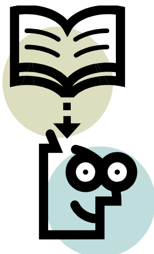
____

____

Lesson #8: Connect Two

Your task in this lesson is to identify relationships between pairs of the vocabulary words. Try to identify as many connections as possible. Words can be paired more than once. Write the two words you are connecting and a brief explanation as to what their relationship is. Refer to the 15 words at the bottom of the page. See the example below.

#	Word #1	Word #2	The connection is…
1.	Disturbance	Resilience	An ecosystem's ability to return to a stable condition after a disturbance is a measure of its resilience.
2.			
3.			
4.			
5.			
6.			
7.			
8.			



Lesson #9: Reading Passage – "Ecological Succession"

Read the passage on the following pages, answering questions #1-3 that follow.

ECTION

Student text pages 445–447

4.5 Ecological Succession

KEY CONCEPT Ecological succession is a process of change in the species that make up a community.

Succession occurs following a disturbance by an ecosystem.

Succession is a sequence of adaptations that recreates a damaged community or facilitates a new community in an area that was not inhabited before. The ability of an ecosystem to recover after a major disturbance is referred to as its resilience.

Connecting CONCEPTS

Symbiosis A lichen is a symbiotic relationship between fungi and algae. The fungi collect water and the algae make food through photosynthesis.

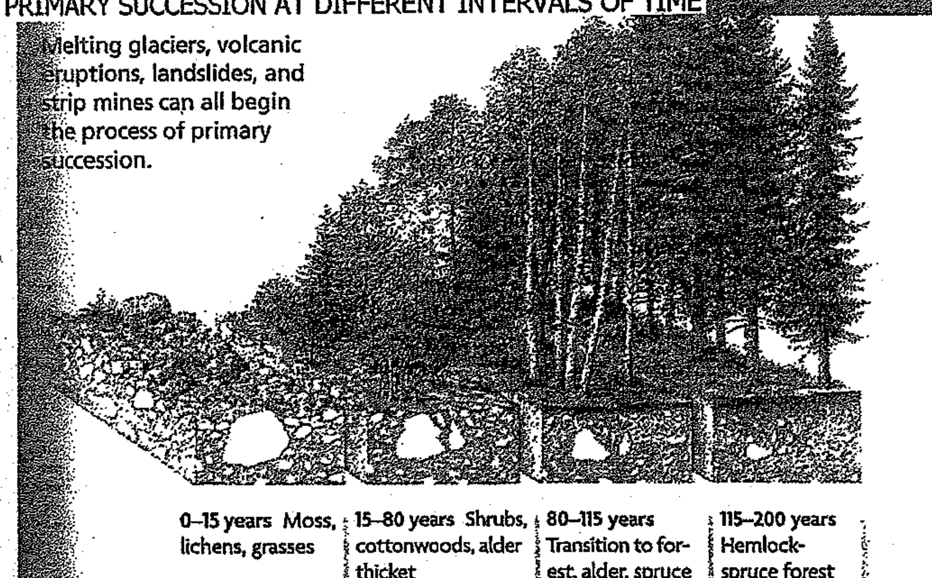
Primary Succession

Primary succession is the development of an ecosystem in an area that was not inhabited before. This type of succession might begin on cooled lava, after a volcano erupts. Or it might begin on bare rock that is exposed when a glacier melts. The first organisms that have immigrated into an area like this are called pioneer species.

Lichens and some mosses are pioneer species. They live on rock, and can minimize rock down into smaller pieces. Dead lichens and mosses mix with rock pieces to form a thin soil. Over time, seeds get blown in and grow in the soil. The soil continues to thicken, and eventually can sustain trees.

PRIMARY SUCCESSION AT DIFFERENT INTERVALS OF TIME

Melting glaciers, volcanic eruptions, landslides, and strip mines can all begin the process of primary succession.



0–15 years Moss, lichens, grasses	15–80 years Shrubs, cottonwoods, alder thicket	80–115 years Transition to forest, alder, spruce	115–200 years Hemlock-spruce forest

ACADEMIC VOCABULARY

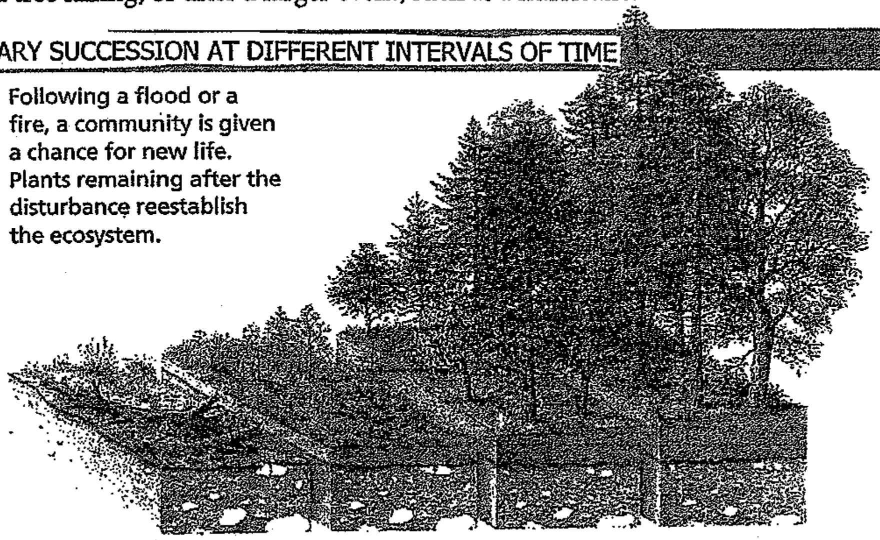
pioneer the first to do a certain thing

Secondary Succession

Secondary succession is the regrowth of a damaged ecosystem in an area that still has healthy soil. This may occur after a small event, such as a tree falling, or after a larger event, such as a hurricane.

SECONDARY SUCCESSION AT DIFFERENT INTERVALS OF TIME

Following a flood or a fire, a community is given a chance for new life. Plants remaining after the disturbance reestablish the ecosystem.



0–2 years Horseweed, crabgrass, asters	2–18 years Grass, shrubs, pine seedlings	18–70 years Pine forest and young hardwood seedlings	70–100 years Oak-hickory forest

INSTANT REPLAY Underline two examples of pioneer species.

14.5 Vocabulary Check

succession	pioneer species
primary succession	secondary succession

Fill in the blanks with the correct term from the list above.

Mark It Up

Go back and highlight each sentence that has a vocabulary word in **bold**.

1. The first species to inhabit an area is a(n) ____________________.
2. Succession in an area that was not previously inhabited is called ____________________.

14.5 The Big Picture

3. What trend do you see in the changes in plant communities over the course of ecological succession? ____________________
____

Lesson #10: Applying Word Knowledge to Writing

Think about the concepts you have been learning during this unit on ecology. Imagine that you needed to teach this unit to a group of 6th grade students in a way that they could understand it. Your task for this lesson is to write several paragraphs explaining the key points from the unit (such as: ecological succession, photosynthesis, carbon cycle, symbiosis) while using as many of the fifteen vocabulary words at the bottom of the page in your description. Underline the vocabulary words when you use them.

amensalism	carbon cycle	cellular respiration	commensalism	dead zone
disturbance	ecological succession	eutrophication	mutualism	parasitism
photosynthesis	primary succession	resilience	secondary succession	symbiosis

APPENDIX J. Group 4 Student Lesson Packet

Subject ID #______________________

Thank you for participating in this study about vocabulary words in biology. Here is some information about the following lesson packet:

- You will work in this packet on your own for about two weeks in class. Do as much as you can each day in the time provided and begin each day where you left off from the day before.

- Included in this packet are short reading passages and questions. Please read the passages and answer the questions that are listed in the middle or at the end of the passage.

- Read the instructions before each lesson.

- Turn this packet and your word list into your teacher at the end of class each day.

- Thank you in advance for trying your best throughout the research study. Your participation and effort are appreciated!

Lesson #1: Reading Passage – "Overview of Cellular Respiration"

Read the passage on the following pages, answering the questions in the middle of the passage, along with questions #1-7 that follow.

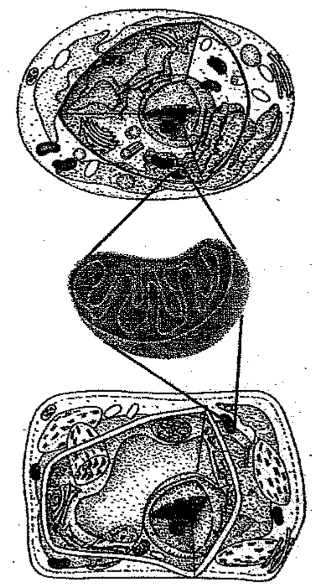
SECTION

Student text pages 113–115

4.4 Overview of Cellular Respiration

KEY CONCEPT The overall process of cellular respiration converts sugar into ATP using oxygen.

By breaking down sugars, cellular respiration makes ATP. **ATP** is a high-energy molecule that has energy that cells can use within its bonds.

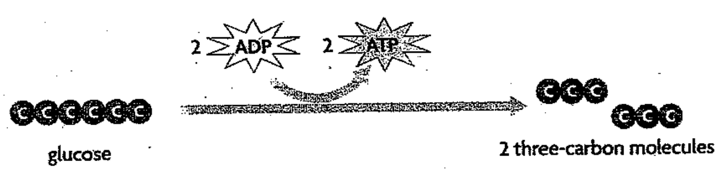


Mitochondria (middle) are found in both animal (top) and plant (bottom) cells. They make ATP through cellular respiration.

You probably know that you need to breathe oxygen to survive. But how does your body use that oxygen? That oxygen helps your body to release chemical energy that is stored in sugars and other carbon-based molecules. The energy isdispersedto produce ATP. This process of using oxygen to produce ATP by breaking down carbon-based molecules is called **cellular respiration.** Cellular respiration makes most of the ATP that a cell needs. Cellular respiration is an aerobic process. **Aerobic** (air-OH-bihk) means that it needs oxygen to function.

Cellular respiration takes place in mitochondria. These organelles are sometimes called the cell's "powerhouses" because this is where most of the cell's ATP is made. Mitochondria do not make ATP directly from food. ATP is made through many chemical reactions.

Before cellular respiration can happen, food has to be broken down into smaller molecules. Food gets broken down into smaller molecules like glucose. Then, glucose gets broken down. Remember that glucose is a six-carbon sugar. **Glycolysis** (gly-KAHL-uh-sihs) breaks glucose into two molecules that each have three carbons.



Glycolysis breaks glucose into 2 three-carbon molecules.

Glycolysis is an anaerobic process. **Anaerobic** means that it does not need oxygen to happen. Glycolysis happens in the cell's cytoplasm. The three-carbon molecules from glycolysis then enter the mitochondria. The products of glycolysis—the three-carbon molecules—enter the mitochondria and are used in cellular respiration.

INSTANT REPLAY Why is cellular respiration called an aerobic process?

____

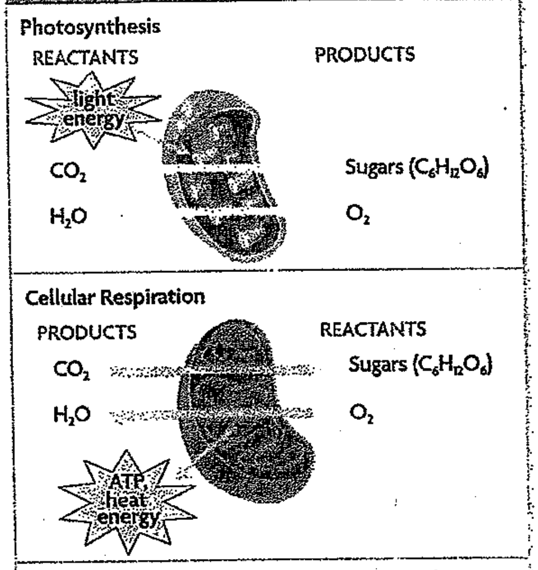
Cellular respiration is like a mirror image of photosynthesis.

A mirror image is like an opposite—the same thing, but in reverse. Cellular respiration and photosynthesis are not really opposites, but it can be helpful to think about them in that way. Photosynthesis makes sugars and cellular respiration breaks down sugars. The chemical equations of the two processes are basically opposites.

The structures of mitochondria and chloroplasts are very similar. Remember that part of photosynthesis happens inside the stroma—the fluid in the chloroplast—and part of photosynthesis happens inside the membrane of the thylakoid. Similarly, part of cellular respiration happens in the fluid inside the mitochondria, called the matrix. The other part of cellular respiration happens in the inner membrane of the mitochondria.

After glycolysis, the three-carbon molecules enter the mitochondria and begin the process of cellular respiration. There are two main parts of cellular respiration:

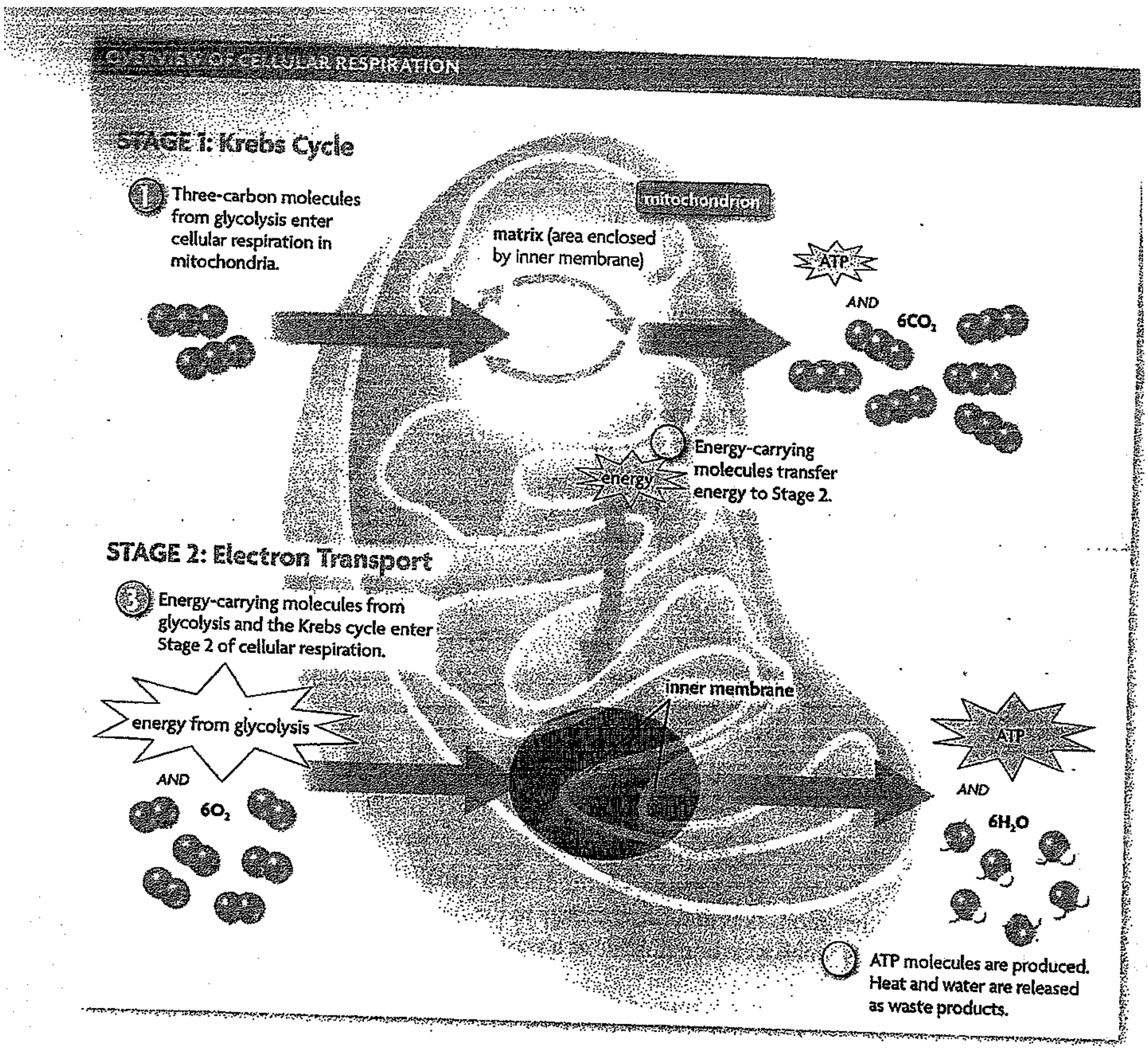
COMPARING PROCESSES



The products of photosynthesis—sugars and O_2—are the reactants in cellular respiration.

Stage 1: Krebs cycle The molecules from glycolysis enter a series of reactions called the Krebs cycle. The **Krebs cycle** produces a small amount of ATP and other molecules that carry energy to the next part of cellular respiration. It also makes carbon dioxide as a waste product.

Stage 2: Electron Transport Energy is moved through a chain of proteins and a large number of ATP molecules are made. Oxygen enters the process here. The oxygen is used to make water molecules, which are waste products.



Up to 38 ATP molecules are made from the breakdown of one glucose molecule. The equation for cellular respiration is shown below. You can see that there are many arrows between the reactants—$C_6H_{12}O_6$ and $6O_2$—and the products—$6CO_2$ and $6H_2O$. These arrows are there to tell you that there are many steps in the process. For example, the equation for cellular respiration includes glycolysis. Many enzymes also play important roles in the production of ATP.

$$\underset{\text{a sugar}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2} \rightarrow \rightarrow \rightarrow \rightarrow \underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O}$$

Follow the steps of cellular respiration shown on in the figure on the previous page.

INSTANT REPLAY Circle the products of cellular respiration in the figure on the previous page.

4.4 Vocabulary Check

cellular respiration

anaerobic

aerobic

Krebs cycle

glycolysis

Mark It Up

Go back and highlight each sentence that has a vocabulary word in **bold.**

1. Which two terms are opposites? ______________________
2. Which term is a process that must happen in the cell's cytoplasm before cellular respiration? ______________________
3. Which term is a process that happens within the mitochondria as part of cellular respiration? ______________________
4. Which term is the name for this chemical equation:

$$\underset{\text{a sugar}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2} \rightarrow \rightarrow \rightarrow \rightarrow \underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O}$$

____

4.4 The Big Picture

5. In which organelle does cellular respiration take place?

____

6. What are the products and the reactants for cellular respiration?

____

7. Where is most of the ATP made during cellular respiration?

____

Lesson #2: Reading Passage – "Cycling of Matter"

Read the passage on the following pages, answering the questions in the middle of the passage, along with questions #1-5 that follow.

SECTION

Student text pages 412–416

13.5 Cycling of Matter

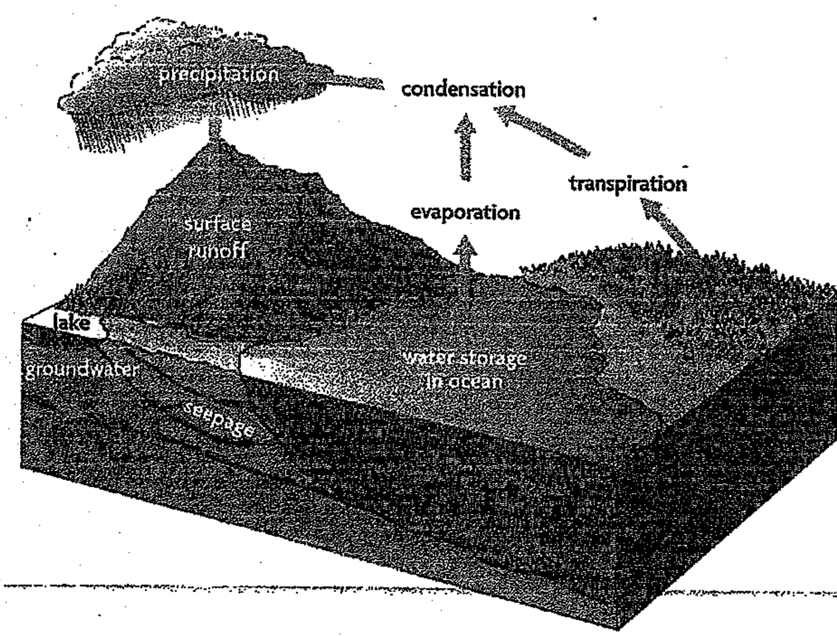
KEY CONCEPT Matter cycles in and out of an ecosystem.

Water cycles through the environment.

Water moves continuously through the water cycle. The water cycle, or the **hydrologic cycle** (HY-druh-LAHJ-ihk), is the circular pathway of water on Earth—from the atmosphere, to the surface, below ground, and back into the atmosphere again. On Earth's surface, living things—including you—are part of the water cycle.

HYDROLOGIC CYCLE

The hydrologic cycle is the circular pathway of water on Earth.



During precipitation, water falls to the ground as rain or snow. Water may trickle through the ground in the process of seepage. Liquid water becomes vapor in the process of evaporation. When water evaporates from plants, it's called transpiration. Water vapor becomes liquid water again during condensation.

INSTANT REPLAY Name two ways that water can enter the atmosphere.

____

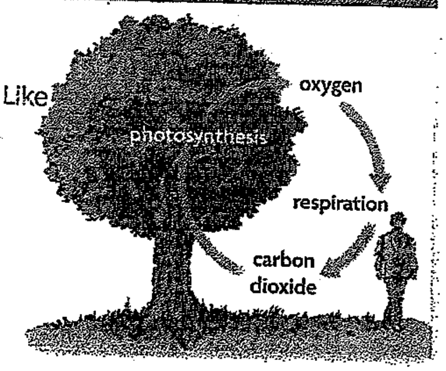
* ACADEMIC VOCABULARY

vapor the gaseous state of a substance

Elements essential* for life also cycle through ecosystems.

Oxygen, carbon, nitrogen, hydrogen, phosphorus, and sulfur are some of the elements necessary to sustain for life. Like water, these elements also cycle through ecosystems. The movement of a particular chemical through the living and nonliving parts of an ecosystem is called a **biogeochemical cycle** (BY-oh-JEE-oh-KHEM-ih-kuhl). Here you will read about four biogeochemical cycles: the oxygen cycle, the carbon cycle, the nitrogen cycle, and the phosphorus cycle.

OXYGEN CYCLE



In the oxygen cycle, oxygen is produced through photosynthesis. Living organisms take in this oxygen and release it as carbon dioxide through respiration.

The Oxygen Cycle

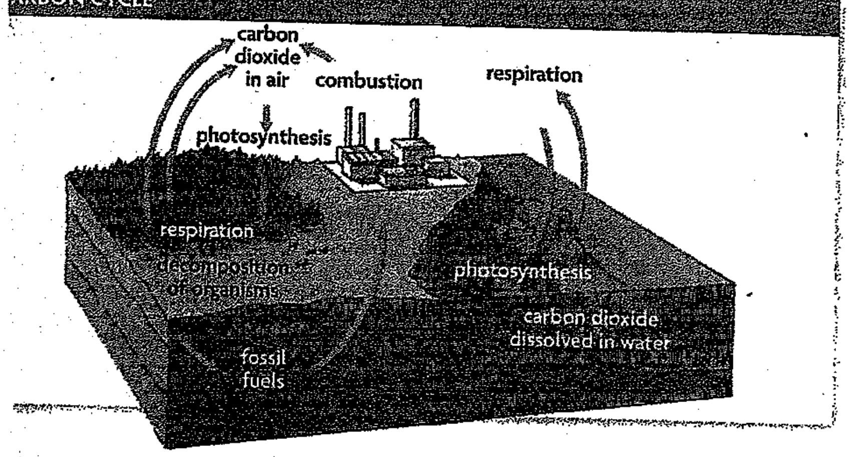
Most organisms use oxygen for cellular respiration. Recall that plants and other photosynthesizing organisms release oxygen as a waste product.

The Carbon Cycle

Carbon is a main component of carbohydrates, proteins, fats, and all of the other molecules that make up living things. Carbon can be inhabited in many different forms—as gas in the atmosphere, dissolved in water, in fossil fuels such as oil and coal, in rocks such as limestone, and in the soil.

Plants convert carbon dioxide from the air into carbohydrates. Carbohydrates get distributed through the living world as one organism eats another. Processes such as respiration and the burning of fossil fuels return carbon to the atmosphere as part of this migratory process.

ARBON CYCLE



Carbon dioxide from the atmosphere is used by plants during photosynthesis. Respiration releases carbon dioxide back into the atmosphere. The burning of fossil fuels, such as oil and gas, releases carbon dioxide into the atmosphere as well. Carbon dioxide is distributed in the atmosphere as dead organisms decompose.

ACADEMIC VOCABULARY

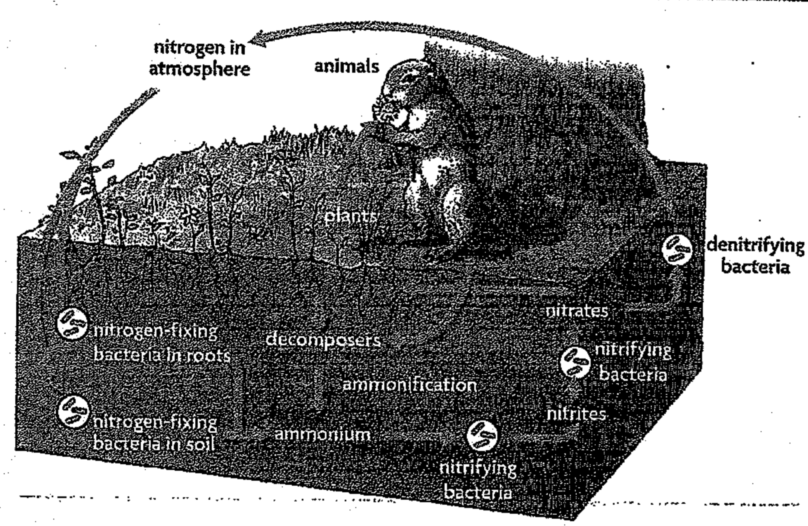
sential necessary, required for

The Nitrogen Cycle

An abundance, or about 78%, of the atmosphere is made of nitrogen gas. Organisms need nitrogen to live, but most organisms cannot use nitrogen in a gas form. Instead, most organisms can only use nitrogen when it is in the form of ions such as ammonium (NH_4^+) or nitrate (NO_3^-). Certain types of bacteria can turn nitrogen gas into ammonia through a process called **nitrogen fixation**.

Much of the nitrogen cycle is regulated underground. After nitrogen fixation, other bacteria turn the product, ammonia, into nitrates. Nitrates are used by plants to make amino acids and proteins. Nitrogen migrates through the living world as one organism eats another. Some types of bacteria also use nitrates, and release nitrogen gas back into the atmosphere.

NITROGEN CYCLE



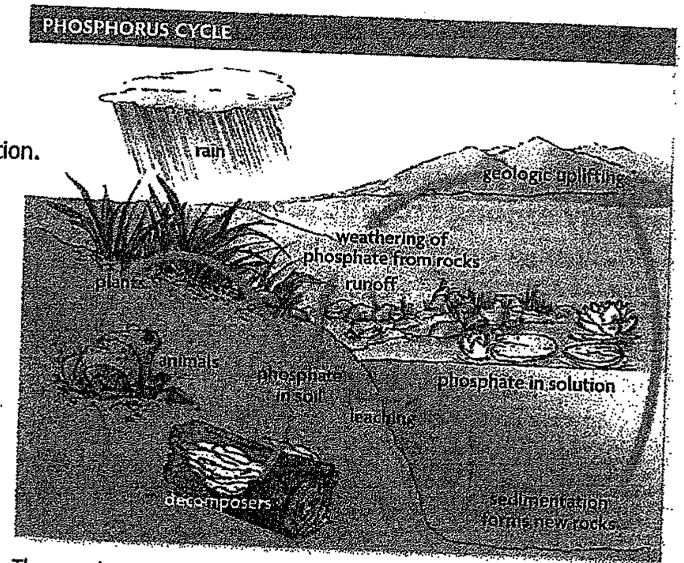
Nitrogen gas in the atmosphere is changed into ammonia by nitrogen-fixing bacteria. Ammonia becomes ammonium, which nitrifying bacteria change into nitrates. Plants use nitrates to make amino acids and proteins. This nitrogen is passed through the food web. Denitrifying bacteria change nitrates back into nitrogen gas, which is released into the atmosphere.

The Phosphorus Cycle

The oxygen, carbon, and nitrogen cycles all have some part that involves atmospheric gases. The phosphorus cycle has some variation. Most of the phosphorus cycle takes place at ground level.

Phosphate is released by the slow breakdown of rocks. Plants take up phosphate through their roots. Phosphorus then moves through the food web. When dead organisms are broken down by decomposers, phosphorus is released back into the environment.

INSTANT REPLAY Underline the main difference between the phosphorus cycle and the other cycles in this section.



The weathering of rocks releases phosphates into soil and water. Plants take up phosphates, which are then passed through the food web. Phophates are released back into the soil when these organisms die. Some phosphates sink to the botttom of water bodies, where they may become rock over thousands of years.

If an area of water becomes so depleted of oxygen that organisms must leave it, the area is considered a dead zone. If there is a dramatic increase in nutrients in a water ecosystem, resulting in increased plant growth, it is a process called eutrophication.

13.5 Vocabulary Check

hydrologic cycle
biogeochemical cycle
nitrogen fixation

Mark It Up

Go back and highlight each sentence that has a vocabulary word in **bold**.

1. List four biogeochemical cycles:

_______ _______ _______ _______

2. Nitrogen fixation changes ____________ into ____________.
3. The hydrologic cycle is the path of what substance? ____________

13.5 The Big Picture

4. What two main biologcal processes are responsible for the cycling of oxygen? ______________________

5. What is the difference between a dead zone and eutrophication?

____

____

Lesson #3: Reading Passage – "Community Interactions"

Read the passage on the following pages, answering the questions in the middle of the passage, along with questions #1-5 that follow.

SECTION

Student text pages 431–434

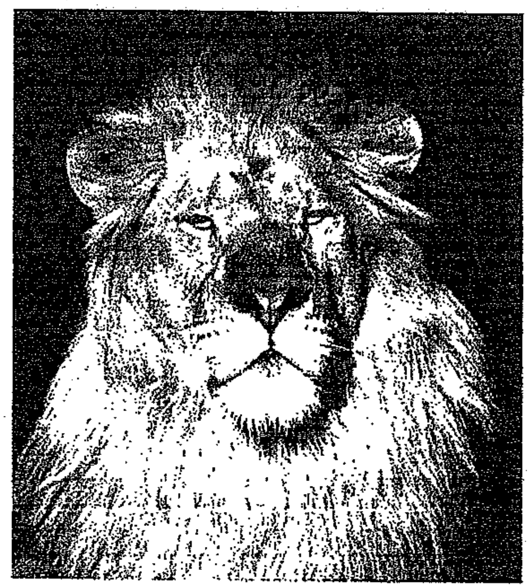
14.2 Community Interactions

KEY CONCEPT Organisms interact as individuals and as populations.

Competition and predation are two important ways in which organisms interact.

There are many different types of interactions between species in an ecosystem. Two important interactions are competition and predation.

- **Competition** occurs when two organisms fight for the same diminished resources. Members of different species may compete for the same resources. Members of the same species may also compete with each other for the same resources.
- **Predation** occurs when one organism captures and feeds upon another organism. Lions and hawks are well known as predators. But herbivores are predators, too. A deer, for example, preys on grass.



Lions are predators, animals that hunt and feed on other organisms.

INSTANT REPLAY Why can a deer be considered a predator?

____

____

Symbiosis is a close relationship between species.

Symbiosis is a close ecological relationship between two or more organisms of different species. One example of symbiosis is the relationship between certain bees and flowering plants. Flowers are often inhabited by bees for short intervals of time. Bees collect pollen or nectar from flowers, and in the process they pollinate the flower. In this case, both species benefit. There are four major types of symbiosis: mutualism, commensalism, parasitism, and amensalism.

- **Mutualism** is an interaction in which both organisms benefit.
- **Commensalism** is a relationship in which one organism benefits and the other organism neither benefits nor is harmed.
- **Parasitism** is a relationship in which one species benefits and the other is harmed. The species that gets harmed is called the host and the species that benefits is called the parasite.
- **Amensalism** is a relationship in which a product of one organism has a negative effect on another organism. One organism is harmed, while the other is neither affected nor benefited.

Predation is also a relationship in which one species benefits and the other is harmed. Parasitism is different from predation because a parasite does not immediately kill its host. Some parasites may lead to the death of the host after days or even years. Other parasites, like fleas or lice, harm the host but do not necessarily kill it.

INSTANT REPLAY Which type of symbiosis benefits one organism and harms the other? ______________________________

14.2 Vocabulary Check

competition	mutualism
predation	commensalism
symbiosis	parasitism
amensalism	

Mark It Up

Go back and highlight each sentence that has a vocabulary word in **bold**.

Fill in the blanks with the correct term from the list above.

1. What are four types of symbiosis? ______________________________

   ____

2. What type of interaction occurs between organisms fighting for the same resources? ______________________

3. What type of interaction occurs when one organism captures and feeds on another organism? ______________________

14.2 The Big Picture

4. Your body is currently involved in many different symbiotic relationships. For example, microscopic organisms called mites live at the base of each of your eyelashes. The mites benefit from the relationship by eating dead skin cells and oils released by your skin. You are not harmed, nor does this benefit you. What type of symbiosis is this?

   ____

5. With both predation and parasitism, one organism benefits and the other is harmed. What is the main difference between parasitism and predation? ______________________________

   ____

   ____

Lesson #4: Reading Passage – "Ecological Succession"

Read the passage on the following pages, answering questions #1-3 that follow.

ECTION

Student text pages 445–447

4.5 Ecological Succession

KEY CONCEPT Ecological succession is a process of change in the species that make up a community.

Succession occurs following a disturbance by an ecosystem.

Succession is a sequence of adaptations that recreates a damaged community or facilitates a new community in an area that was not inhabited before. The ability of an ecosystem to recover after a major disturbance is referred to as its resilience.

Connecting Concepts

Symbiosis A lichen is a symbiotic relationship between fungi and algae. The fungi collect water and the algae make food through photosynthesis.

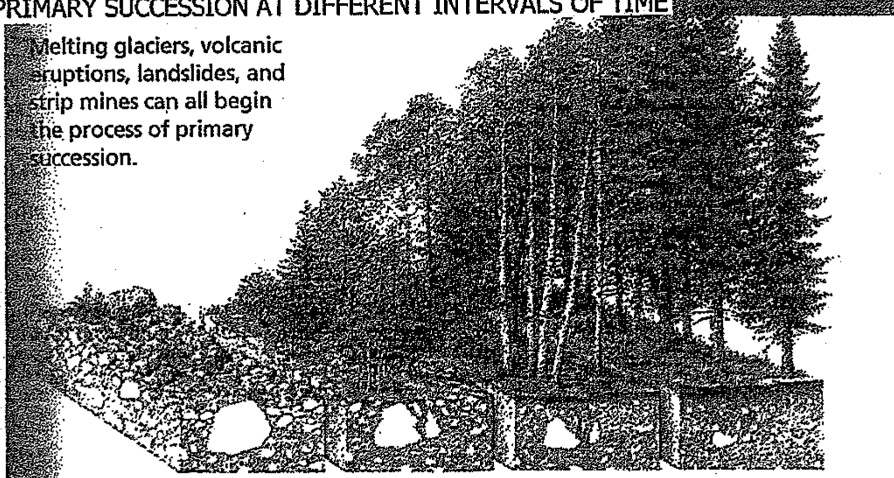
Primary Succession

Primary succession is the development of an ecosystem in an area that was not inhabited before. This type of succession might begin on cooled lava, after a volcano erupts. Or it might begin on bare rock that is exposed when a glacier melts. The first organisms that have immigrated into an area like this are called pioneer species.

Lichens and some mosses are pioneer species. They live on rock, and can minimize rock down into smaller pieces. Dead lichens and mosses mix with rock pieces to form a thin soil. Over time, seeds get blown in and grow in the soil. The soil continues to thicken, and eventually can sustain trees.

PRIMARY SUCCESSION AT DIFFERENT INTERVALS OF TIME

Melting glaciers, volcanic eruptions, landslides, and strip mines can all begin the process of primary succession.



0–15 years Moss, lichens, grasses | 15–80 years Shrubs, cottonwoods, alder thicket | 80–115 years Transition to forest, alder, spruce | 115–200 years Hemlock-spruce forest

ACADEMIC VOCABULARY

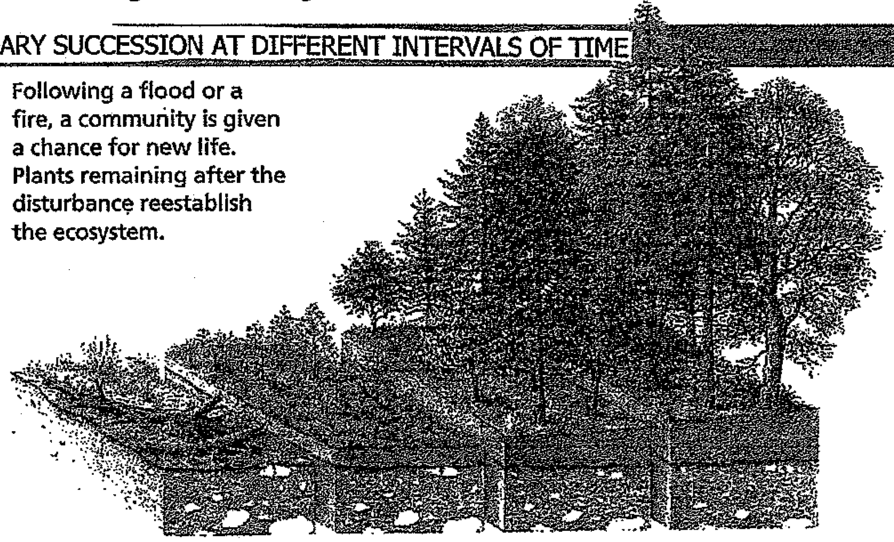
pioneer the first to do a certain thing

Secondary Succession

Secondary succession is the regrowth of a damaged ecosystem in an area that still has healthy soil. This may occur after a small event, such as a tree falling, or after a larger event, such as a hurricane.

SECONDARY SUCCESSION AT DIFFERENT INTERVALS OF TIME

Following a flood or a fire, a community is given a chance for new life. Plants remaining after the disturbance reestablish the ecosystem.



INSTANT REPLAY Underline two examples of pioneer species.

14.5 Vocabulary Check

succession　　pioneer species
primary succession　　secondary succession

Fill in the blanks with the correct term from the list above.

Mark It Up

Go back and highlight each sentence that has a vocabulary word in **bold.**

1. The first species to inhabit an area is a(n) ______________________.
2. Succession in an area that was not previously inhabited is called ______________________.

14.5 The Big Picture

3. What trend do you see in the changes in plant communities over the course of ecological succession? ______________________________
____

<u>Lesson #5: Reading Passage – "Examining the Stages in Ecological Succession"</u>

Read the passage on the following pages, answering questions #1-9 that follow.

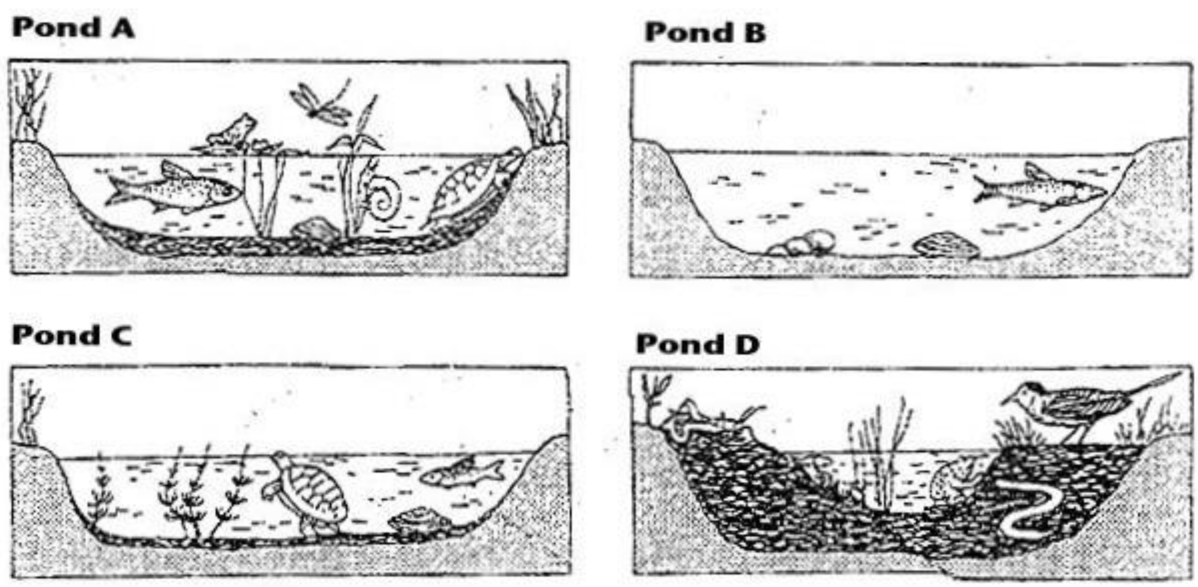
Examining the Stages in Ecological Succession

Succession, a series of environmental changes, occurs in all ecosystems. The stages that any ecosystem passes through are predictable. In this activity, you will place the stages of succession of two ecosystems into sequence. You will also describe changes in an ecosystem and make predictions about changes that will take place from one stage of succession to another.

The evolution of a body of water from a lake to a marsh can last for thousands of years. The process cannot be observed directly. Instead, a method can be used to find the links of stages and then to put them together to develop a complete story.

The water level of Lake Michigan was once 18 meters higher than it is today. As the water level fell, land was exposed. Many small lakes or ponds were left behind where there were depressions in the land.

Below are illustrations and descriptions of four ponds as they exist today. Use the illustrations and descriptions to answer the questions about the ponds.



Pond A: Cattails, bulrishes, and water lilies grow in the pond. These plants have their roots in the bottom of the pond, but they can reach above the surface of the water. This pond is an ideal habitat for the animals that must climb to the surface for oxygen. Aquatic insect larvae are abundant. They serve as food for larger insects, which in turn are food for crafish, frogs, salamanders, and turtles.

Pond B: Plankton growth is rich enough to support animals that entered when the pond was connected to the lake. Fish make nests on the sandy bottom. Mussels crawl over the bottom.

Pond C: Decayed bodies of plants and animals form a layer of humus over the bottom of the pond. Chara, a branching green algae, covers the humus. Fish that build nests on the bare bottom have been replacedby those that lay their eggs on the Chara.

Pond D: The pond is so filled with vegetation that there are no longer any large areas of open water. Instead, the pond is filled with grasses. The water dries up during the summer months.

Questions

1. Write the letters of the ponds in order from the youngest, to the oldest.

____

2. Black bass and bluegill make their nests on sandy bottoms. In which pond would you find them? ______________________

3. What will happen to the black bass and blue gill as the floor of the ponds fills with organic debris? _____________________________________

4. Golden shiner and mud minnows lay their eggs on Chara. In which pond would you find them? _____________________

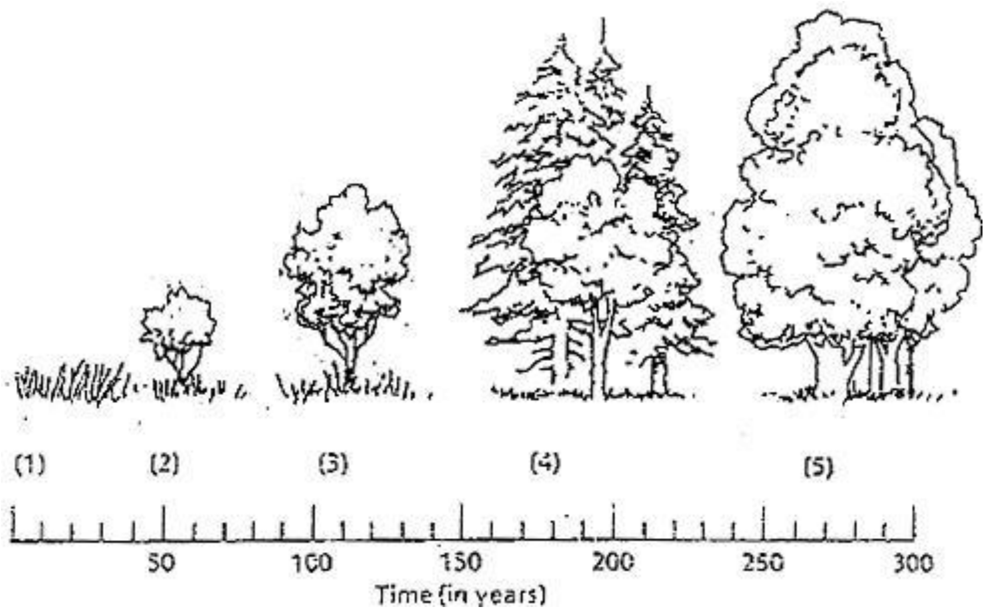
5. Some amphibians and crayfish can withstand periods of dryness by burying themselves in mud. In which pond(s) would they survive? _________

6. Dragonfly nymphs spend their early stages clinging to submerged plants. Then, they climb to the surface, shed their skins and fly away as dragonflies. Which pond is best suited for dragonflies?_____________________________

7. In which pond will gill breathing snails be replaced by lung breathing snails that climb to the surface to breathe? ________________

8. Some mussels require a sandy bottom in order to maintain an upright position. In which ponds will they die out? ______________________

9. The climax community in the area of Michigan is a beech-maple forest. After the ponds are filled in, the area will undergo another series of stages of succession. This is illustrated below.



Briefly explain what is happening in the diagram above.________________________________

____

____

Lesson #6: Reading Passage – "Relationships Within Ecosystems"

Read the passage on the following pages, answering questions #1-2 that follow.

RELATIONSHIPS WITHIN ECOSYSTEMS

Removal of an organisms (or organisms) can cause a food web to collapse or have other unintended results because organisms frequently have close ecological relationship with each other, and these are known as symbiotic relationships. The four main categories of symbiotic relationships are: parasitism, commensalism, amensalism, and mutualism.

An adaptation is a trait (or traits) that helps an organism survive in a habitat. If the conditions in a habitat change sufficiently, or if the organism moves to an entirely different environment, the trait(s) may no longer be useful and the organism might not be as well adapted to the conditions.

Eutrophication is caused when a large increase in particular nutrients in aquatic environments causes an increase in the organic matter available for bacteria, thus increasing the amount of bacteria. Too much bacteria depletes surrounding waters of oxygen, causing other organisms in the ecosystem to migrate or die. The absence of organisms as a result of eutrophication creates areas referred to as dead zones.

Questions:

1) Which adaptations would help a mouse to survive in a desert biome? Name at least 3.

2) Will eutrophication benefit, or harm, an ecosystem? Explain. (See reading above)

Lesson #7: Reading Passage – "Invasive Species"

Read the passage on the following pages, answering questions #1-2 that follow.

INVASIVE SPECIES

Native species are those that are naturally found in an ecosystem. Because it is impossible for humans to know exactly which species are natural to an environment, it is generally considered that a species is native if it is thought to have existed in an environment for thousands of years. An introduced species is one that has been brought in to an environment in which it does not naturally occur. Such species are also referred to as nonnative, exotic, or non-indigenous. If a nonnative species causes harm to the environment, the economy, or human health, it is considered to be invasive.

No two species perform the same role in an environment. If a nonnative species displaces a native species from its role a decrease in biodiversity of the ecosystem might result, which may have an effect on other species in that ecosystem. In such a case, the nonnative species has had a negative effect on the environment, and that species is deemed invasive. Not all introduced species will succeed in a new environment. If an introduced species has traits that are well-suited to the new environment, it is more likely to become established. Changes in the population dynamics of an ecosystem are factors in the success of an invasive species becoming established within an ecosystem.

Questions from reading:

1) In what ways can a non-native species cause harm and then be termed an invasive species?

2) Give ONE example of an invasive species and explain what effect it had upon the ecosystem.

Lesson #8: Reading Passage – "Photosynthesis and Respiration"

Read the passage on the following pages, answering questions #1-5 that follow.

PHOTOSYNTHESIS AND RESPIRATION

Photosynthesis is a cellular process by which an organism captures light from the sun and uses it to store energy. In photosynthesis light energy, carbon dioxide, and water are taken in to produce glucose and oxygen. Only producers perform photosynthesis. Although sunlight is required for photosynthesis to occur, parts of photosynthesis can happen in the absence of light. The stages of photosynthesis that produce oxygen happen in the presence of sunlight. Photosynthesis happens in chloroplasts, which contain chlorophyll. Different variables, such as temperature and amount of light, affect the rate of photosynthesis and cellular respiration. Chemical indicators show chemical changes in a substance, such as the addition of oxygen or carbon dioxide. From changes in chemical indicators, therefore, it can be inferred that a cellular process, such as photosynthesis, is occurring.

Cellular respiration takes in oxygen and glucose and produces carbon dioxide, water and ATP. Most organisms perform cellular respiration, including plants and other producers. Cellular respiration happens in the mitochondria and the area just outside the mitochondria. Plants can perform cellular respiration independently of photosynthesis. Cellular respiration occurs at different rates under different conditions. The substances produced and consumed in photosynthesis and cellular respiration are complementary. For example, aquatic environments depend on a balance of photosynthesis and cellular respiration to prevent dead zones.

The carbon cycle moves carbon between several major reservoirs. Reservoirs in the carbon cycle include rocks and soils, the ocean and other bodies of water, plants/producers, animals/consumers, the atmosphere, and fossil fuels. Although the amount of carbon in the different reservoirs fluctuates, the amount of carbon contained in the carbon cycle is a fixed amount. The carbon in different reservoirs is in different chemical forms, such as carbon dioxide and glucose. The carbon cycle is one of several biogeochemical cycles that move elements through different reservoirs and allow them to be used repeatedly by living organisms.

Questions from reading:

1) What are the reactants involved in photosynthesis? What are the products?

2) What is needed in order for photosynthesis to produce oxygen?

3) What are the reactants involved in cellular respiration? What are the products?

4) In what organelle does cellular respiration take place?

5) How are the compounds produced by photosynthesis and cellular respiration related?

Lesson #9: Reading Passage – "Cellular Respiration"

Read the passage on the following pages, answering questions #1-5 that follow.

Cellular Respiration

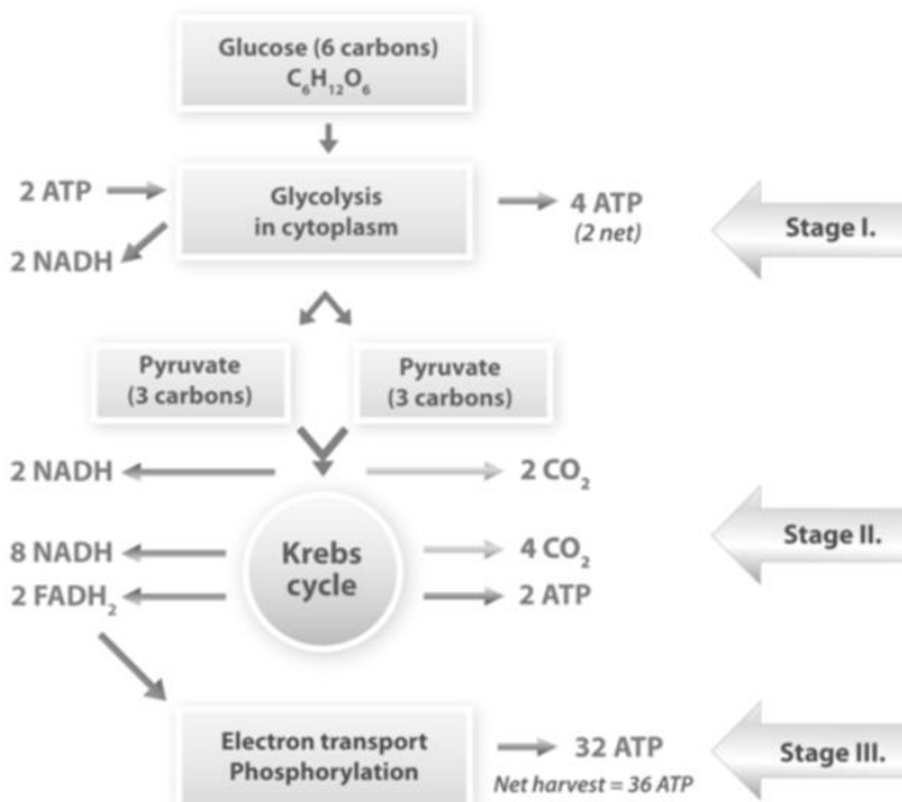
What happens to the energy stored in glucose during photosynthesis? How do living things make use of this stored energy? The answer is **cellular respiration**. This process releases the energy in glucose to make **ATP** (adenosine triphosphate), the molecule that powers all the work of cells.

Stages of Cellular Respiration

Cellular respiration involves many chemical reactions. The reactions can be summed up in this equation:

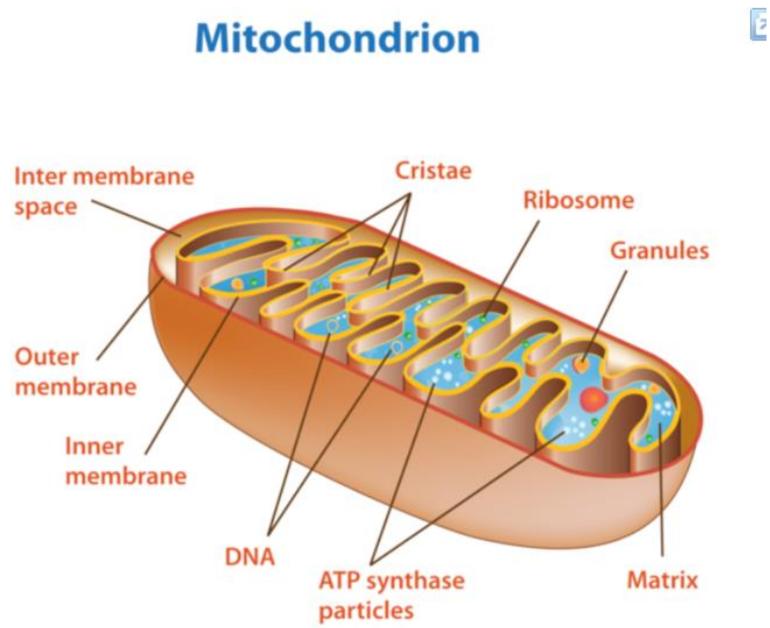
$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + Chemical Energy (in ATP)

The reactions of cellular respiration can be grouped into three stages: **glycolysis** (stage 1), the **Krebs cycle**, also called the **citric acid cycle** (stage 2), and **electron transport** (stage 3). **Figure** below gives an overview of these three stages, which are further discussed in the concepts that follow. Glycolysis occurs in the cytosol of the cell and does not require oxygen, whereas the Krebs cycle and electron transport occur in the mitochondria and do require oxygen.



Structure of the Mitochondrion: Key to Aerobic Respiration

The structure of the mitochondrion is key to the process of **aerobic** (in the presence of oxygen) cellular respiration, especially the Krebs cycle and electron transport. A diagram of a mitochondrion is shown in **Figure** below.



As you can see from **Figure** above, a mitochondrion has an inner and outer membrane. The space between the inner and outer membrane is called the intermembrane space. The space enclosed by the inner membrane is called the matrix. The second stage of cellular respiration, the Krebs cycle, takes place in the matrix. The third stage, electron transport, takes place on the inner membrane.

Summary

- Cellular respiration takes the energy stored in glucose and transfers it to ATP.
- Cellular respiration has three stages: glycolysis: the Krebs cycle and electron transport.
- The inner and outer membranes of the mitochondrion play a important roles in aerobic respiration.

Questions from reading:

1. Describe cellular respiration.

2. Using the chemical equation of cellular respiration and the above figure as a guide, describe what happens to each of the atoms of carbon during this process.

3. Describe the structure of the mitochondrion and discuss the importance of this structure in cellular respiration.

4. Assume that a new species of organism has been discovered. Scientists have observed its cells under a microscope and determined that they lack mitochondria. What type of cellular respiration would you predict that the new species uses? Explain your prediction.

5. When you exhale onto a cold window pane, water vapor in your breath condenses on the glass. Where does the water vapor come from?

Lesson #10: Reading Passage – "Soil and Water Resources"

Read the passage on the following pages, answering questions #1-4 that follow.

Soil and Water Resources

Theoretically, soil and water are renewable resources. However, they may be ruined by careless human actions.

Soil is a mixture of eroded rock, minerals, partly decomposed organic matter, and other materials. It is essential for plant growth, so it is the foundation of terrestrial ecosystems. Soil is important for other reasons as well. For example, it removes toxins from water and breaks down wastes.

Although renewable, soil takes a very long time to form—up to hundreds of millions of years. So, for human purposes, soil is a nonrenewable resource. It is also constantly depleted of nutrients through careless use, and eroded by wind and water. For example, misuse of soil caused a huge amount of it to simply blow away in the 1930s during the Dust Bowl (see **Figure** below). Soil must be used wisely to preserve it for the future. Conservation practices include contour plowing and terracing. Both reduce soil erosion. Soil also must be protected from toxic wastes.

The Dust Bowl occurred between 1933 and 1939 in Oklahoma and other southwestern U.S. states. Plowing had exposed prairie soil. Drought turned the soil to dust. Intense dust storms blew away vast quantities of the soil. Much of the soil blew all the way to the Atlantic Ocean.

Water

Water is essential for all life on Earth. For human use, water must be fresh. Of all the water on Earth, only 1 percent is fresh, liquid water. Most of the rest is either salt water in the ocean or ice in glaciers and ice caps.

Although water is constantly recycled through the **water cycle**, it is in danger. Over-use and pollution of freshwater threaten the limited supply that people depend on. Already, more than 1 billion people worldwide do not have adequate freshwater. With the rapidly growing human population, the water shortage is likely to get worse.

Are We in Danger of Running Out of Water?

California's population is growing by 600,000 people a year, but much of the state receives as much annual rainfall as Morocco. With fish populations crashing, global warming, and the demands of the country's largest agricultural industry, the pressures on our water supply are increasing.

Too Much of a Good Thing

Water pollution comes from many sources. One of the biggest sources is runoff. **Runoff** picks up chemicals such as fertilizer from agricultural fields, lawns, and golf courses. It carries the chemicals to bodies of water. The added nutrients from fertilizer often cause excessive growth of algae, creating **algal blooms** (see **Figure** below). The algae use up oxygen in the water so that other aquatic organisms cannot survive. This has occurred over large areas of the ocean, creating **dead zones**, where low oxygen levels have killed all ocean life. A very large dead zone exists in the Gulf of Mexico. Measures that can help prevent these problems include cutting down on fertilizer use. Preserving wetlands also helps because wetlands filter runoff water.

Summary

- Soil and water are renewable resources but may be ruined by careless human actions. Soil can be depleted of nutrients. It can also be eroded by wind or water.
- Over-use and pollution of freshwater threaten the limited supply that people depend on.

Questions from reading:

1. What happens when fertilizer ends up in waterways?

2. What is soil?

3. Why is soil considered a nonrenewable resource?

4. Why would you expect a dead zone to start near the mouth of a river, where the river flows into a body of water?

APPENDIX K.

UNIVERSITY OF ILLINOIS
AT CHICAGO

Office for the Protection of Research Subjects (OPRS)
Office of the Vice Chancellor for Research (MC 672)
203 Administrative Office Building
1737 West Polk Street
Chicago, Illinois 60612-7227

Exemption Granted

October 12, 2012
Elizabeth Birmingham
Curriculum and Instruction

RE: Research Protocol # 2012-0771
"The Impact of Word Selection in Biology"

Sponsors: None

Dear Ms. Birmingham:

Your Claim of Exemption was reviewed on October 12, 2012 and it was determined that your research meets the criteria for exemption. You may now begin your research.

<u>Exemption Period:</u> **October 12, 2012 – October 12, 2015**

Performance Site: UIC

Number of Subjects: 500

The specific exemption category under 45 CFR 46.101(b) is:

(1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods

You are reminded that investigators whose research involving human subjects is determined to be exempt from the federal regulations for the protection of human subjects still have responsibilities for the ethical conduct of the research under state law and UIC policy. Please be aware of the following UIC policies and responsibilities for investigators:

1. Amendments You are responsible for reporting any amendments to your research protocol that may affect the determination of the exemption and may result in your research no longer being eligible for the exemption that has been granted.

2. Record Keeping You are responsible for maintaining a copy all research related records in a secure location in the event future verification is necessary, at a minimum these documents include: the research protocol, the claim of exemption application, all questionnaires, survey instruments, interview questions and/or data collection instruments associated with this research protocol, recruiting or advertising materials, any consent forms or information sheets given to subjects, or any other pertinent documents.

3. Final Report When you have completed work on your research protocol, you should submit a final report to the Office for Protection of Research Subjects (OPRS).

4. Information for Human Subjects UIC Policy requires investigators to provide information about the research protocol to subjects and to obtain their permission prior to their participating in the research. The information about the research protocol should be presented to subjects in writing or orally from a written script. When appropriate, the following information must be provided to all research subjects participating in exempt studies:
   a. The researchers affiliation; UIC, JBVMAC or other institutions,
   b. The purpose of the research,
   c. The extent of the subject's involvement and an explanation of the procedures to be followed,
   d. Whether the information being collected will be used for any purposes other than the proposed research,
   e. A description of the procedures to protect the privacy of subjects and the confidentiality of the research information and data,
   f. Description of any reasonable foreseeable risks,
   g. Description of anticipated benefit,
   h. A statement that participation is voluntary and subjects can refuse to participate or can stop at any time,
   i. A statement that the researcher is available to answer any questions that the subject may have and which includes the name and phone number of the investigator(s).

j. A statement that the UIC IRB/OPRS or JBVMAC Patient Advocate Office is available if there are questions about subject's rights, which includes the appropriate phone numbers.

Please be sure to:

→ Use your research protocol number (2012-0771) on any documents or correspondence with the IRB concerning your research protocol.

We wish you the best as you conduct your research. If you have any questions or need further help, please contact the OPRS office at (312) 996-1711 or me at (312) 355-2908. Please send any correspondence about this protocol to OPRS at 203 AOB, M/C 672.

Sincerely,

Charles W. Hoehne, B.S., C.I.P.

Assistant Director, IRB # 2

Office for the Protection of Research Subjects

cc: Timothy Shanahan, Curriculum and Instruction, M/C 147

Victoria Chou, Education, M/C 147

APPENDIX L.

VITA

NAME:	Elizabeth A. Birmingham
EDUCATION:	B.A., University of Illinois at Urbana-Champaign, 2003 Ed.M., University of Illinois at Urbana-Champaign, 2006 Ph.D., University of Illinois at Chicago, 2013
PUBLICATIONS:	Dressman, M., & Wolf, S. A. (Eds.), with contributors Batiste, B., Becker, E., (Birmingham) Bruns, A., Fitzgerald, C., Goss, L., Grunloh, C., Hale, G., Keller, S., Kim, A., Kody, L., Mudron, M., Nies, A., Ryder, T., Shouf, C., b Vallicelli, A., Weber, Wolf, L., & Zuhlke, M. (2002). "Young adult bliterature on the cutting edge." *The New Advocate, 15* (3).
GRANTS:	Valley View Educational Enrichment Foundation Mini-Grant Literacy Strategies for All Content Areas ($750, May 2007)
PRESENTATIONS:	Anderson, M., Birmingham, E., Claar, P., Gallman-Witzke, N., Pavlik, S., Rende, M., & Zucker, D. (November, 2006). *That's a Great Idea, but How Will I Ever Have Time for It at My School?: How One School Used Creative Planning to Become a Professional Learning Community*. Conference on English Leadership. Nashville, TN.
PROFESSIONAL MEMBERSHIPS:	National Council of Teachers of English International Reading Association Conference on English Leadership