Photosynthesis, Food, and Populations:

A Squared Away Unit

interact®
Learn Through Experience

About the author

Formerly a fisheries biologist, James Sammons was a successful science classroom teacher for thirty years. He has been recognized by the National Science Teachers Association, the Soil Conservation Service, and the National Association of Geoscience Teachers for his ability to design and manage new and innovative field and laboratory-based investigations for middle and high school students. Today he writes extensively with his wife, Fran, for science and education and is the co-author of *Skateboard Science*.

10200 Jefferson Blvd • P.O. Box 802 Culver City, CA 90232
Phone: (800) 359-0961 • www.teachinteract.com
ISBN# 978-1-56004-595-3

Introduction to *Squared Away* Units

"Squared away" was originally a nautical term used to announce that the sails of a square-rigger sailing ship were correctly set. The navy came to use the phrase to describe sailors who completed a task with competency, as in, "He was right squared away!" We have adopted the term to describe students who demonstrate competency in specific content and skills.

> Developing student competency is the major goal of all *Squared Away* units.

Each *Squared Away* unit allows both teachers and students to concentrate on basic concepts that can be mastered in a relatively short period of time. The basic subconcepts are taught in four instructional blocks. The daily activities are interactive, exploratory, and reflective—all best practices to maximize student learning. By the end of each block, students must demonstrate mastery of the subconcepts. After completing four blocks, students may be considered Squared Away. However, to earn a Golden Square, students must go beyond the basic level indicating that they achieved an exemplary score on a final test/project or mastered a final task requiring higher-level thinking skills.

Levels: The units are designed as complete, stand-alone lessons. Although written for either grades 2–4 or 5–8, the content may be used for instruction, enrichment, or remediation.

Differentiation: Teachers are encouraged to reteach and scaffold the learning so that all students master the concepts. Investigations take place in cooperative group settings that allow for peer teaching and support for students with learning difficulties. An extensive list of optional extra activities follows each Instructional Square and provides opportunities for independent or group investigations. The "Golden Square" activities offer even more challenges for your more talented students.

Student grouping: Students may work in *Squared Away* units as individuals, in pairs, or in heterogeneous teams of three or four. When working in groups, students are responsible for their own learning and for supporting the learning of their team mates. All units provide Cooperative Group Work Rubrics.

Lessons: The lessons begin with a list of concepts to be taught, materials needed, and a lesson-plan schedule. Each lesson is divided into parts that specifically list an objective followed by the teaching plans to achieve the objective.

Assessments and rubrics: All units include a pretest/posttest to be administered before starting and after completing the unit. You also assess students daily to check mastery of content and to determine points of confusion. Part of the assessments requires students to explain orally or in writing what they understand. Students may retake assessments until they achieve mastery. The units provide quizzes, tests, and rubrics. There are many opportunities in the daily lessons, optional activities, and assessments for students to demonstrate Gardner's Multiple Intelligences.

Timeline: The lesson plans address four basic instruction blocks and one block to achieve a Golden Square. These may take five or more days depending on the instructional time available and/or your students' grade level and prior knowledge.

Table of Contents

Table of Contents

Table of Contents

Photosynthesis, Food, and Populations

A Squared Away Unit

Purpose

Although some of your students may be aware of ecosystems and food chains, most are unaware that every ecosystem runs on a tight economy of available resources. They may know that the Sun is the originator of all energy, but they may be unaware of how this energy is transferred among living creatures, specifically in the form of simple sugar molecules. They may also have a perfunctory understanding of photosynthesis and oxidation, but most have not understood these processes at the molecular level where carbon, hydrogen, and oxygen molecules are arranged, broken apart, and rearranged throughout a known process starting with producers, through consumers, and finally ending with decomposers. By the end of this Squared Away unit, your students will have built on all they thought they knew to develop a deep understanding of the life processes that are occurring around them. They will also come to realize that they, as part of a world ecosystem, must pay attention to the importance of not upsetting any one part.

Educational standards

National Science Education Standards

Content Standard B: Physical Science. As a result of their activities in grades 5-8, all students will develop an understanding of transfer of energy

- Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

Content Standard C: Life Science: As a result of their activities in grades 5-8, all students should develop an understanding of Regulation and Behavior

- All organisms must be able to obtain and use resources, grow, reproduce, and maintain stable internal conditions while living in a constantly changing external environment.
- An organism's behavior evolves through adaptation to its environment. How a species moves, obtains food, reproduces and responds to danger is based in the species' evolutionary history.

Content Standard C: Life Science: As a result of their activities in grades 5-8, all students should develop an understanding of Populations and Ecosystems

- A population consists of all individuals of a species that occur together at a given place and time. All populations living together and the physical factors with which they interact compose an ecosystem.

- Populations of organism can be categorized by the function they serve in an ecosystem. Plants and some micro-organisms are producers—they make their own food. All animals, including humans, are consumers, which obtain food by eating other organisms. Decomposers, primarily bacteria and fungi, are consumers that use waste materials and dead organisms for food. Food webs identify the relationships among producers, consumers, and decomposers in an ecosystem.
- For ecosystems, the major source of energy is sunlight. Energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis. That energy then passes from organism to organism in food webs.
- The number of organisms an ecosystem can support depends on the resources available and abiotic factors, such as quantity of light and water, range of temperatures, and soil composition. Given adequate biotic and abiotic resources and no disease or predators, populations (including humans) increase at rapid rates. Lack of resources and other factors, such as predation and climate, limit the growth of populations in specific niches in the ecosystem.

Knowledge, skills, and attitudes

Knowledge*—Your students will understand that:*

- An economy can be based on a direct exchange or indirect exchange that uses a token or coin.
- Living creatures exchange food energy in an energy economy that is very similar to the money economy of people.
- When circumstances change to restrict an economy, all living creatures (including humans) employ different strategies to survive.
- The basic carrier of food energy is simple sugar.
- Glucose is one of several different simple sugars.
- Plants store food energy by concentrating simple sugars as starch in various parts of the plant.
- Simple sugars store energy in their carbon-to-carbon atom links.
- Most of the energy stored in simple sugars can not be released without oxygen.
- When oxygen is available, simple sugars can be broken down completely into carbon dioxide and water.
- Photosynthesis is the process by which green plants use light energy to rearrange the atoms of water and carbon dioxide gas to form simple sugars and oxygen gas.
- During photosynthesis, oxygen gas is released by green plants as a by-product.
- Oxidation is the process by which animals rearrange the atoms of simple sugars and oxygen to form water and carbon dioxide.
- Animals gather simple sugars by eating green plants or other animals.
- Animals gather oxygen by breathing air or drawing oxygen from water (fish with gills).
- Animals release carbon dioxide as gas and water as vapor with their breath.
- In darkness, green plants are metabolically equivalent to animals. They use oxidation to obtain necessary energy.
- Green plants and animals are exchange partners that trade atoms of carbon, hydrogen, and oxygen among each other.
- Energy flow is always one way, from the sun to green plants, and then to the animals.

- The feeding order of green plants and animals is called a food chain.
- An ecosystem is a natural community that is home to multiple populations including producers, consumers, scavengers, and decomposers.
- Food chains begin with a green plant called a producer.
- The first animal in a food chain eats the producer (a plant) and is called the first-order consumer and also an herbivore.
- The second-order consumer eats the first-order consumer (an animal), so the second-order consumer is also called a carnivore.
- The last carnivore in the food chain is an apex predator.
- Animals have developed behaviors to accommodate seasonal changes in food supply such as hibernation, migration, and food storage.
- Food pyramids show food chains with the producers on the bottom and the apex predator at the top.
- The shape of a food pyramid shows that each level contains only one-tenth as much food energy as the level beneath it.
- The Food Pyramids can be used to model and predict the outcome of a food problem.
- That after a food problem has distorted a food pyramid, the pyramid will always return to a smooth-sided shape. The new pyramid may be a different size or have different number of levels.
- Food energy flows from one organism to another through a series of fates (prey, preyed upon, death, decomposition, etc.). Some of these fates are inflexible; others depend entirely on circumstances.

Skills*—Your students will learn how to:*

- Build a simple sugar molecule, the product of photosynthesis.
- Deconstruct a simple sugar molecule into the end products of oxidation.
- Demonstrate the need for oxygen in order to deconstruct a simple sugar molecule.
- Identify carbon, hydrogen, and oxygen in a simple sugar molecule.
- Write the chemical formulae for water, carbon dioxide, oxygen gas, and simple sugars.
- Write the chemical equation for photosynthesis and oxidation.
- Construct a food chain.

- Construct a food web.
- Demonstrate that an ecosystem is a natural community that is home to multiple populations including producers, consumers, scavengers, and decay organisms.
- Represent a food chain with a food pyramid.
- Analyze and suggest viable solutions for a food chain problem using a food pyramid.

Attitudes—*Your students will appreciate that:*

- Food chains are useful study tools and building blocks of food webs.
- Animals spend half their calories just gathering food.
- Animals use only 10% of their calories for growth; the rest is lost as waste heat or used for movement.
- All populations are affected by the amount of available food. Over population on any level of a food pyramid causes an imbalance in the food pyramid with dire consequences.
- Humans are part of a food chain and many human problems can be understood using food pyramids.
- Sunlight comes from space into a meadow where it is used within an ecosystem. In the end, when the energy has passed from life form to life form through the ecosystem, most of the energy ends up as heat which is released again into space.

Content overview

This *Squared Away* science unit is designed to be concept-specific and is, therefore, grade-level independent. It is very effective as a concept introduction/reinforcement unit and can also serve as an efficient remediation unit. Although students may work individually, the lesson plans direct students to work in teams as they complete activities. These investigations will lead students not only to discover science concepts, but also to communicate their understanding to their teammates and classmates.

Square One concepts (blue square)—Students first read about money economies to understand how all economies must have a universal "coin" of exchange. In the primary activity, students actually build a universal energy coin for life on earth that turns out to be a simple sugar.

Square Two concepts (red square)—Students participate in activities that show them how to deconstruct the energy coin and rearrange the pieces into water and carbon dioxide. They learn that they need oxygen to fully take apart the sugar molecule.

Square Three concepts (green square)—Students investigate the chemical equation for oxidation and photosynthesis. Because of what they have learned from building and taking apart their energy coin, this formula will have meaning and not be something they just memorized. This square also introduces food webs and energy flow.

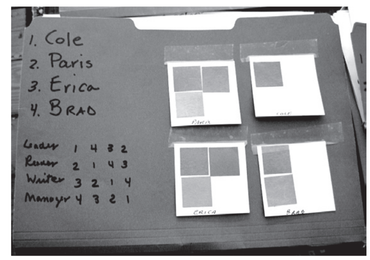
Square Four concepts (purple square)—Students put what they have learned into the context of populations. They learn that food pyramids (a tool that quantifies food chains) are used to study food availability problems. This square also explains why animals adapt when faced with limited food.

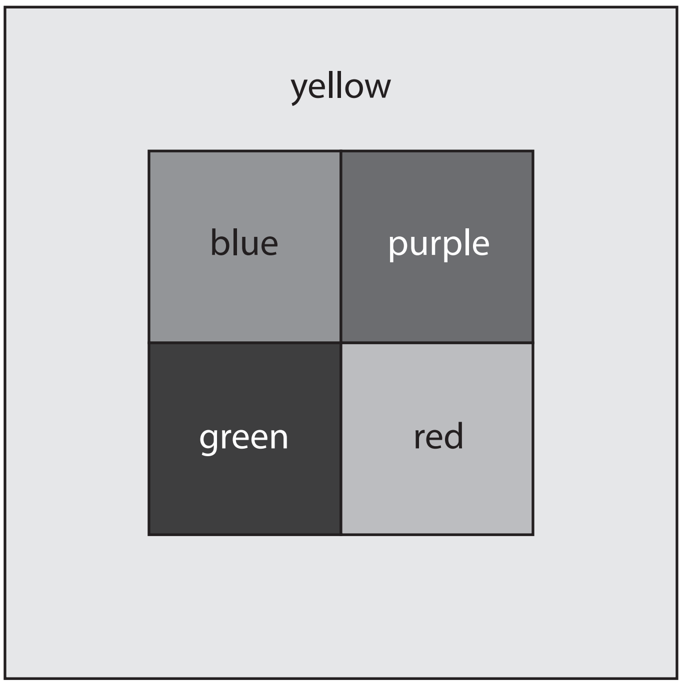
Golden Square concepts—Students first read an essay on the fate of animal food energy and on the role of scavengers and decomposers in the food energy economy. After reading and discussing the essay, students choose between two challenges: The first requires them to determine the primary productivity of a square meter of land in their local area. The second requires them to model a **Food Energy Budget** and prepare a **Food Energy Balance Sheet**.

Making the individual award squares

Award squares can be created from four different colored pieces of construction paper. Cut the paper first into one-inch strips, and then cut those strips into one-inch squares. The four colors are only suggestions; however, use yellow paper only for the Golden Square. Cut a 2¼-inch, plain white square to form the backing. Students will paste their earned squares on the backing as they complete each instruction block. Make a 3½-inch yellow square for each Golden Square. (You may choose to trim the backing before affixing the four-square to the Golden Square.)

Teaching tip
Attach the background squares to the team folders so students do not lose track of them.





Unit Time Chart

Depending on the students' ages, prior knowledge, and the length of your science period, you may complete one group of concepts per instructional block. Block lesson plans are designed for 60 - 90 minutes. If a class is made up of younger students, disabled students, or students that assessments indicate may need more instruction, then the block lessons will take more time. At the end of each instructional block is a list of optional activities.

Instruction Block One

- Pretest
- **Square One concepts** (blue)
- optional activities
- Quick Team Quiz One
- Individual Square One Test

Instruction Block Two

- **Square Two concepts** (red)
- optional activities
- Quick Team Quiz Two
- Individual Square Two Test

Instruction Block Three

- **Square Three concepts** (green)
- optional activities
- Quick Team Quiz Three
- Individual Square Three Test

Instruction Block Four

- **Square Four concepts** (purple)
- optional activities
- Quick Team Quiz Four
- Individual Square Four Test

Instruction Block Five

- **Golden Square concepts** (yellow)
- optional activities
- Golden Square Challenge

Assessment Block

- Final review
- Posttest (one week later)
- Awards ceremony for Four Squares and Golden Squares

General Directions

Photosynthesis, Food, and Populations

Instruction blocks

This unit is divided into four instruction blocks that address specific instructional objectives related to photosynthesis, food, and populations. Each block is sequential and builds on the knowledge and skills learned in the block before it. Always evaluate the tests of one block before going on to the next.

Student grouping

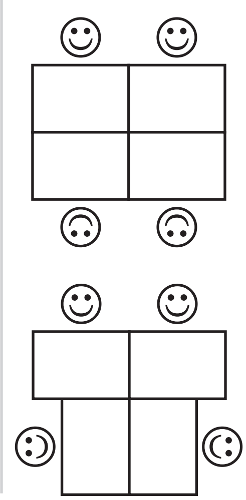
Students will work in this Squared Away in unit teams of four that sometimes break into pairs. Create your teams before the first lesson. Generally, the most successful teams are mixed in terms of gender, science sense, and study skills.

Student roles rotate after each Square test. You may combine roles when necessary. Extra team members rotate in and out of roles. (Combine Leader and Reader for teams of three.) Change roles only after each individual Square Test.

> **Leader**: organizes the team and directs team members as needed. He/she checks that the day's assignments are complete and makes sure teammates submit all assignments. The Leader is the time keeper who also keeps the team motivated and on-task.
>
> **Reader**: reads handouts and/or activity directions, clarifying and repeating as necessary
>
> **Writer**: writes the team's responses and uses the calculator
>
> **Manager**: collects and returns supplies, handouts, and materials needed for the team's daily work. The Manager maintains the team folder and hands it in to the teacher at the end of each day.

Classroom arrangement

Organize students around four desks that will serve as a table for the activities. Allow as much space as possible between groups so that students can converse among their teammates without distractions.



Supplies and duplicated materials

At the beginning of each lesson, the supplies you need to gather and the photocopies you need to prepare are listed. Most supplies can be found in your classroom. Consider photocopying all the handouts ahead of time and storing them in order in a hanging file.

Student folders

Create a folder for each team, listing the names of team members on the front. Inside the folder, attach one copy each of the Cooperative Group Work Rubric and the Content Concept Rubric. On the outside cover, paste blank background squares and make a role assignment chart. Review the duties of each role before beginning an instructional block. Decide where in the classroom you want students to store and retrieve folders each day.

Lesson plans and timeline

Squared Away lesson plans begin with a concepts list and materials list. A lesson schedule matches the headings within the numbered lesson steps. Always read through the day's lesson ahead of time to familiarize yourself with how the lesson should proceed and how the concepts are developed. Specific concepts are introduced in a special order to minimize confusion. The lessons are arranged in instructional blocks that will take about 60 minutes or more, depending on your students' prior knowledge. The five instructional blocks may be broken into ten lessons if students need more time to process the concepts. This arrangement will give you more class time to re-teach students who are having difficulty, while those who are squared away may work on extension activities.

Team competitions

One goal of this unit is for all students to work cooperatively to learn the content. However, awarding points for good teamwork and appropriate student behavior may add some incentive for better effort. Consider grading classwork and teamwork using the rubrics provided and award four, three, or two points. Consider giving points for neatest folder, being on-task first, finishing on time, etc. Keep a daily running tally to encourage students to do their best.

Stop/Think/Draw/Write

In every lesson, students are asked to stop, think, draw, and write about something they have been studying. Research supports enhanced understanding and recall when students are asked to process new information in writing. If your students maintain science notebooks, you may decide to have students add these pages to their notebooks. Otherwise, have students keep their pages in the folder. Ask them to put their individual names and team name on each sheet. They should staple new pages to existing pages so that all their work is together. Check these drawings and writings daily as quick formative assessments. Award team points if you are using team competition as an incentive. There is a blank copy of Stop/Think/Draw/Write without specific prompts on page 70 of this guide.

Assessments

The Pretest and Posttest are identical and are administered at the beginning and the end of the unit. Administer the pretest before Instruction Lesson One. The pretest will reveal students' prior knowledge so you can be more confident about the pace of your lessons. The **Posttest** will let you know how competent your students have become with the content and skills presented in the unit. Give the **Posttest** at least one week after you complete the unit. Both pretests and posttests should be corrected in the same manner. With questions that require students' written and drawn responses, correct each answer using 4-3-2-0 scoring, where four recognizes an answer that demonstrates clear understanding, three recognizes good understanding, two recognizes some understanding, and zero recognizes little or no understanding.

Cooperative group work assessment is ongoing and important to the success of this unit. Students need to work together, taking responsibility for their own learning and helping their team members to succeed. Post the **Cooperative Group Work Rubric** and tape one copy inside each team folder. During the instruction block, occasionally refer to the rubric and comment on how the teams are working. Praise good work and, when necessary, point out where teams could improve. At the end of each block or the end of a teaching day, assess every team member using the **Cooperative Group Work Rubric** as your guide. At the end of the unit, give students a copy of the rubric with an overall assessment of his/her group work.

The Concept Content Rubric is provided for assessing student understanding when they draw their answers or write short essay answers. Tape one copy of this rubric inside the team folders. Use this rubric to provide maximum feedback to the students and to allow you to check off items on the class **Content/Skills Checklist**.

Formative assessments are also ongoing and important. At different times during the lesson, take a moment to ask students individually or as teams to explain what they understand or to demonstrate something they have just learned. You can ask them to respond orally or to quickly write an explanation to share. If you detect confusion in one student, it may indicate a general confusion. Use the available check sheets daily to keep track of skills students have learned or still need to learn.

Quick Team Quizzes take about 5 minutes to administer, but they allow you to make a final check before distributing the individual tests. Each team member gets his or her own paper to complete, but when all the team

Teaching tip
Sometimes some students "hide" during group work, allowing the more vocal students to answer all the questions and make all the comments. Create a seating chart for each day of instruction. When you call on a student, make a checkmark near his/her name. If the student seems confused, circle the checkmark.

members have finished, they compare answers. If there is a discrepancy among the answers, the team discusses the answers and what the team members were thinking. You may also pair teams to compare answers. Always remind students of the **Cooperative Group Work Rubric** and their responsibility to be kind and supportive. After 3–5 minutes, go over the correct answers with the whole class, addressing any questions they may still have.

Individual Square Tests are given at the end of each instruction block. You may administer them at the end of an instructional class period or at a later time. The second, third, and fourth individual Square Tests contain questions from the previous instructional blocks, so the fourth test may be considered a final exam for the four blocks. Separate the desks and require that students work individually on these assessments. Before beginning a new instruction block, evaluate student answers for the individual Square Test to determine the need to re-teach some concepts. Generally only a few students are confused about one or two test questions. Create ad hoc groups, review, and retest. The retest should be a new copy of the same test with those items he/she must redo circled or highlighted. Follow this procedure for each individual **Square Test**.

The Golden Square Challenge takes students beyond the requirements needed to be squared away. It requires students to work with more difficult concepts and procedures. Not all students are expected to earn the fifth, Golden Square. Use the **Concept Content Rubric** to grade students and decide whether they have met the requirements of the Golden Square Challenge. To achieve a Golden Square, students must earn a 3 or 4 on their Golden Challenge work.

Reinforcing and re-teaching concepts

The timeline of this unit depends on your students' prior knowledge and the length of your science period. It is also often difficult to find time to re-teach students who do not grasp concepts on the first round. However, working with struggling students before they are overwhelmed is essential. Consider stopping after Instruction Block Two and again after Instruction Block Three to work with students who still need help. Consider allowing the students who have mastered concepts to work on the optional extra activities while you work with those who need more instruction.

Awarding squares

The lesson plans suggest awarding squares at the beginning of an instructional block, and the most efficient way to award points is to glue the squares or parts of squares onto student folders and announce the names as you distribute them.

If possible, notify students ahead of time why they are not going to earn a square that day. Stress, though, that they will eventually earn their squares, and arrange a time to re-teach and retest them. Consider giving students a portion of a square to indicate that they have mastered some of the content.

Your classes may be too “grown-up” to respond well to collecting squares. In that case, you may choose to acknowledge achievement in other ways. Consider posting a wall chart with check marks, offering class privileges (free time, prizes, etc.) or whatever else will help motivate your students.

Final award celebration

With the successful completion of the individual Square Four Test, students are considered Squared Away. However, consider waiting until you run the Golden Square Challenges to celebrate. This will give you more time to work with those students who are close to finishing the four squares. It would be best if all your students successfully completed the four instructional blocks.

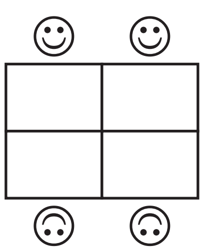
The Golden Square Challenges are just that—challenges, and not essential to being considered “squared away.” Give special recognition and the Golden Square award to all those who do successfully compete the challenges.

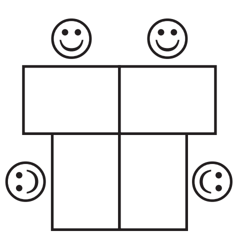
Design a celebration appropriate to your students’ age and your available time and resources. Give one of the two **Special Award Certificates** to acknowledge each student’s achievement.

Special Directions
Before Starting This Unit

1. Read through the teacher's guide to familiarize yourself with the content and materials. Read the **Author's Note** on page 16.
2. Prepare an energy coin.

   The energy coin puzzle is an easy, but unfamiliar task. Most student difficulties will stem from misreading or forgetting part of the instructions. Follow the procedure to make a successful coin beforehand so that you can anticipate where missteps are likely to occur. See page 14 for instructions.
3. Organize the teams and prepare the team folders. See pages 9–10.
4. Unit introduction and **Pretest**.
   a. Photocopy and hand out the unit's introduction. Tell students what they will be learning over the next week or so.
   b. Administer the pretest to all students individually before starting this unit. Remind students not to guess on a pretest. They can just write a "?" next to the question. Correct each answer to the student response questions using the **Concept Content Rubric's** 4-3-2-0 scoring system, where four recognizes an answer that demonstrates clear understanding, three recognizes good understanding, two recognizes some understanding, and zero recognizes little or no understanding. Having a general idea of student pre-knowledge will help you pace your instruction.
5. Photocopy the handouts and collect the materials before beginning Instruction Block One.
6. If you decide to award squares, prepare the awards background square and the colored squares. Attach them to folders. If you decide to use a chart, explain the chart when you explain the unit.
7. On the day you begin the unit, arrange the room. (See left.) Announce the teams. Assign student roles. Review the duties of each role using the **Cooperative Group Work Rubric**.





Pretest/Post Test Answer Key

1. A
2. A
3. B

4. C
5. D
6. C
7. B
8. A
9. B
10. $C_6H_{12}O_6 + 6O_2 \longleftrightarrow 6H_2O + CO_2$ **or** $6H_2O + CO_2 \longleftrightarrow C_6H_{12}O_6 + 6O_2$
11. D
12. C
13. B
14. A
15. C
16. D
17. Answers may vary, but will begin with a green plant and end with an apex predator.
18. C
19. at night
20. A
21. C
22. B
23. Leaf on bottom level, aphid on 2nd level, beetle on 3rd, robin on 4th and hawk on top level
24. C
25. D

Author's Note to the Teacher

Undoubtedly you have seen the photosynthesis-oxidation equation before, usually written like this:

$$6H_2O + CO_2 \longleftrightarrow C_6H_{12}O_6 + 6O_2$$

In this Squared Away unit the equation is reversed and written like this:

$$C_6H_{12}O_6 + 6O_2 \longleftrightarrow 6CO_2 + 6H_2O$$

Because the process is determined by the metabolic activity underway, the choice of direction is arbitrary. However, there are important instructional reasons for the direction used here. Too many students are presented with the photosynthesis equation as something to be memorized. Students will ultimately memorize the equation in this unit, too. But first they will build a simple sugar from individual atoms and then dissemble it. The inductive thinking required in the disassembly process, oxidation, is the key to mastery. In so doing, they will become well-familiar with the composition and number of compounds involved in the processes. They will discover exactly why:

- Animals need oxygen.
- Primitive metabolic systems can beat the no-oxygen condition.
- At the level of the cell, there is no practical difference between starvation and suffocation—energy becomes unavailable either way.

After attaining this deep level of understanding of oxidation, learning the photosynthesis equation becomes a simple translation.

In *Photosynthesis, Food, and Populations*, the equation is described as oxidation-photosynthesis for internal consistency. After Instruction Block Two, you may choose to show students a text or other reference that shows the equation written as photosynthesis-oxidation. Ask students to compare the reference to the equation as they know it. They should easily recognize the two as the same, but reversed, by the location of the simple sugar. You may also find a reference that refers to photosynthesis-respiration. You can have students discover that respiration in this sense is used to mean oxidation using the same comparison technique. Should you present this second comparison, point out that the use of respiration to refer to the *chemical equation* is not appropriate. Photosynthesis and respiration are correctly used as *process* labels.

Instruction Block One

Economies and the Energy Coin

Square One Concepts/Skills*—Students will understand that:*

- An economy can be based on a direct exchange or indirect exchange that uses a token or coin.
- Living creatures exchange food energy in an energy economy that is very similar to the money economy of people.
- When circumstances change, restricting an economy, all living creatures (including humans) employ different strategies to survive.
- The basic carrier of food energy is simple sugar.
- Glucose is one of several different simple sugars.
- Plants store food energy by concentrating simple sugars as starch in various parts of the plant.
- Build a simple sugar molecule, the product of photosynthesis.

Materials

- Blank paper, glue sticks, scissors, pencil with an eraser on the end, highlighter or light colored crayon

Duplicate

- Pre-post tests—*two per student*
- Cooperative Group Work Rubric—*one class copy to post and one per team folder*
- Introduction to the Squared Away unit—*one per student*
- Introduction to Photosynthesis, Food, and Populations (2 pages)—*one per student*
- Stop/Think/Draw/Write 1—*one per student*
- Making an energy coin (2 pages)—*two per team*
- Stop/Think/Draw/Write 2—*one per student*
- Exploring your energy coin—*one per student*
- Where is starch stored?—*(optional) one per student*
- Quick Team Quiz One—*one per student*
- Square One Test—*one per student*

Teaching tip
Use the **Concept Content Rubrics** or **Cooperative Group Work Rubrics** to award points to teams. Keeping track of points sometimes motivates teams to make stronger efforts.

Lesson plan schedule

- Introduction to *Squared Away*
- Introduction to Photosynthesis, Food, and Populations
- Stop/Think/Draw/Write 1
- Making an Energy Coin
- Stop/Think/Draw/Write 2
- Review of team energy coins
- Exploring Your Energy Coin
- Optional Activities
- Quick Team Quiz One
- Square One Test

Lesson Plan

Economies and the Energy Coin

1. Introduction to Squared Away

Whole class

a. Distribute copies of the **Squared Away Introduction**. Read as a whole class.

b. Distribute the folders and review the roles and responsibilities that will change *only* after they take a Squared Away test.

c. Discuss the importance of cooperative work and review briefly the **Cooperative Group Work Rubric** in the folder.

2. Introduction to Photosynthesis, Food, and Populations

a. Write the following focus questions on your board:

   1. Why might you and your classmates trade to get something that you want, instead of simply buying it?

   2. Assuming that you had money, what are the advantages of using money to buy things rather than trading for them?

   3. In colonial America, trading was a very common way of getting the things you needed. What might be the reasons that trading is much less common today?

b. Engage each topic with a brief discussion

   1. Students usually don't have substantial money. Ask,

      Read or say

      What would be the main problem that would stop you from buying a new bicycle?

   2. Money is portable and universally accepted as payment. Begin this discussion by asking,

      Read or say

      "Does anyone know what these words from the face of a one dollar bill mean? 'This note is legal tender for all debts, public and private.'"

   3. Ask, "In what ways were the early colonists like you today?"

c. Give Team Managers enough copies of **Photosynthesis, Food, and Populations** for every member of their team.

d. Read the "Introduction" according to your instructional preference: silent individual, student turns, teacher-read, etc.

e. Use the focus questions to review the reading.

3. Stop/Think/Draw/Write 1

Teaching tip
Remind students that when asked to draw, they should work quickly using simple sketches. Labels should be clear and spelled correctly.

Use words and/or drawings to explain:

1. *What are the advantages of having a coin-based economy?*
2. *In what ways are food energy coins in a living community like coins in a money economy?*

a. This is the students' first **Stop/Think/Draw/Write**. They may be uncertain about getting the "right" answer and therefore reluctant to write. Encourage them to reflect on what they have been learning and try to apply it to the prompts. The only bad answer is "I don't know" or a blank paper. Tell them that sometimes when they start writing, they reveal more than what they thought they knew.

Individual

b. Students should work individually to answer the prompts. While they work, walk around and check that students who have finished early have included all they know. Remind students to work neatly and check their spelling.

Allow teams 2–3 minutes to complete their work

Small group

Whole class

c. Allow teams 2–3 minutes to complete their work. Have students first share what they wrote or drew with their team. Then ask each team to choose one teammate's explanations and drawings to share with the whole class.

d. Use the **Concept Content Rubric** to assess team answers. This is not a grading situation per se. It's an opportunity to clarify thinking and to help students understand how much they need to write to give a complete answer. Reinforce correct explanations and clear up those that are confusing or inaccurate. Summarize the explanations and model the correct drawings on the chalkboard. Ask students to correct their papers if their explanations were incorrect or confusing.

Teaching tip
One of the goals of the unit is to teach students to evaluate their classmates' work to a standard. In this way, students will become more facile evaluating their own work.

4. Making an Energy Coin

Pairs

a. For this activity, ask students to work in pairs, two per team. (Pairs allow students maximum participation and support.) Give Team Managers two copies of **Making an Energy Coin** for their team.

b. Review the instructions with teams.

c. On the board demonstrate the correct way to make a connection with hooks and then simplify the hooks with a single line.

d. Demonstrate setting up the blank puzzle page.

Allow pairs 12–15 minutes to work

e. Allow team pairs 12–15 minutes to work on their puzzles. Walk around the room as they work to give individual attention to pairs that may be off track or to ask students to explain choices they are making as they build the coins.

f. When pairs have completed their puzzles, have them share within their team.

5. Review of team energy coins

a. Reconvene the class and ask how many teams were able to make a 100-point puzzle.

b. Ask a successful team to draw their puzzle on the board and include their names. Ask if any other teams created the same energy coin. If any did, add their names to the drawing.

c. Ask if any team drew a different successful puzzle. If so, have that team add their puzzle to the board and see how many other teams drew this second successful puzzle. Continue until all different puzzles have been added to the board.

6. Exploring Your Energy Coin

a. Have students copy their own or one of the other successful energy coins in the box marked "Figure 3."

b. Have student use a highlighter or light-colored crayon to highlight key words and phrases in the rest of this lesson.

- *The energy coin that you built is really a molecule of simple suga*r.
- *...more than one kind of simple sugar*
- *...glucose...galactose...mannose...*
- *...sugars by their "ose" endings.*

c. Read the paragraph on "Simple sugars and energy coins," highlighting the words "*simple sugar...the food energy compound found in plants and animals.*"

d. Read the paragraphs about food energy storage. Highlight

- *Plants and animals need to store energy for times when they need it...*
- *...they change many simple sugar molecules into a few more concentrated forms.*

Teaching tip
Common errors include making T or circular shapes, drawing a piece with an incorrect hook count, hooking more than two hooks together, and leaving a piece out. Direct team attention to these errors without comment. Remind teams that are badly off-target to start with the special 3-point double link pieces and then add the square pieces in a chain.

Small group

Teaching tip
To save time, draw several five-box chains on chart paper ahead of time. Add circles as teams describe their energy coin. If everyone understands the idea, it is not necessary to draw the triangle shape twelve times for each coin. Instead, just leave a single unhooked line with the understanding that any unhooked line actually is attached to an unseen triangle shape.

Teaching tip
Ask students to use a highlighter or light-colored crayon to highlight the key information in the reading.

- *Starch is the most common form of stored food energy in plants*
- *...fats are primarily an animal food energy storage material.*

7. Stop/Think/Draw/Write 2

Use words and/or drawings to describe how plants and animals store energy.

Individual

a. When teams have finished with the activity, students should work individually to answer the prompt. While they work, walk around and check that students who have finished early have included all they know. Remind students to work neatly and check their spelling.

Allow teams 3–4 minutes to complete their work

Small group

Whole class

b. Allow teams 3–4 minutes to complete their work. Have students first share what they wrote or drew with their team. Then ask each team to choose one teammate's explanations and drawings to share with the whole class.

c. Use the **Concept Content Rubric** to assess team answers. Reinforce correct explanations and clear up those that are confusing or inaccurate. Summarize the explanations and model the correct drawings on the chalkboard. Ask students to correct their papers if their explanations were incorrect or confusing.

8. Quick Team Quiz One

Individual

a. Ask the Managers to come to you for **Quick Team Quiz One**. While students are working individually, walk around the room clarifying and instructing.

Small group

b. When the individuals in each team have finished **Quick Team Quiz One**, the teams should correct the papers. Team members should help other team members who made errors.

c. Present the correct answers on the board and answer any questions.

d. Tell Leaders to tell their teammates to neatly organize all the handouts and the **Quick Team Quiz One** papers and put them under a paperclip in the team folders. When the team folders are organized, the Leader should give the folders to you. The Managers should return all supplies and be certain the work area is cleared.

9. Square One Test

Individual

a. Administer the **Square One Test** to individuals, not teams. Separate desks for privacy. Collect tests when students have finished.

b. While students are taking their tests, use the time to assess the students' cooperative group work. Use the **Cooperative Group Work Rubric** as your guide. Assess each student and assign a score from 1–4 to describe their cooperative behavior. Before beginning the next class, let students know how well they are meeting your expectations and, if necessary, what specifically they can do to improve.

c. Correct the individual tests and evaluate your students' mastery of concepts in Instruction Block One before starting Instruction Block Two. Re-teach and re-test if necessary. Make a list of those students who have earned a square.

Square One Answer Key

Stop/Think/Draw/Write1:

1. Coins are universally acceptable, can be earned one place and used in another, can be stored.
2. Food energy coins can be used by all living things. They can be stored.

Stop/Think/Draw/Write 2:

Plants change simple sugars into starch. Starches are made up of longer box chains. Animals store simple sugars as fats that also use the same box-triangle-circle pieces.

Quick Team Quiz One:

1. B
2. C
3. F
4. simple sugar
5. simple sugars
6. store
7. fat
8. Answers will vary.

Square One Test:

1. A
2. A
3. A
4. B
5. C

Extra credit: Answers will vary.

Optional Activities One

Small group

1. **Science lab**

    - **Where is Starch Stored?** This handout is student-ready. Team members assume their designated roles of Leader, Reader, Recorder, and Manager to follow the directions.

    - ***Important Note:*** The iodine once found in every household medicine cabinet is dark chestnut brown and smells strongly of iodine. Most pharmacy sources today carry a decolorized version that includes ammonium iodide. **This clear iodine solution will not work in this lab**. The traditional iodine/potassium iodine solution needed is available from many science supply houses, but you will find that they will ship it only to your school, or state registered home school address. You need only a few milliliters for each class, so a small bottle will last many years. Here is one source that accepts school or personal orders for delivery to school addresses:

      Science Kit and Boreal Laboratories
      Iodine solution, reagent for starch test
      Science Kit number WW97046, 100 ml bottle, $5.90
      (800) 828-7777

Whole class
or
Small group
or
Individual

2. **Journal writing** is always an excellent way for students to reinforce their own learning. Allow students to write for at least 3 minutes. Direct them to first share what they wrote with their team. Ask for volunteers to share with the whole class. Look for common comments and strategies that students write. Below is a list of prompts you can give individual students, teams, or the whole class.

    - **Prompt 1:** What about a direct economy tends to keep people in a single place?

    - **Prompt 2**: Would you expect to find starch in the bulb of a daffodil or tulip?

Individual
and
Pairs

3. **Research and report.** Ask students to research one of the following topics and make a short written or oral report to share with their classmates:

    - Write for or explore the websites of colonial towns to receive brochures from early American villages. Make a bulletin board display that highlights life in these times. Good examples include: Sturbridge Village in Sturbridge, MA; Plimoth Plantation in Plymouth, MA; Jamestown Settlement and Colonial Williamsburg in Williamsburg, VA.

- In colonial America, some people had skills so valuable that they could always trade for what they needed. Who were these people and what were their skills?
- What kinds of coins were used as money in early America before we minted our own federal coins?
- Most civilizations have a food staple based on a starch—the common form of stored food energy in plants. Choose one or more of the following starch-filled foods to research: **wheat**, **rice**, **corn**, **soybeans**, or **potatoes**. Find the major countries or regions that grow these staple crops and make a world map showing their location.
- Research the word **flour**. Write a short report on the many different foods that are used to make flour.

4. **Real life situations**

   a. People can live about a week without water, but can live months without eating. Explain what the body does to prevent a person from starving to death in a short time.

   b. Look at the nutrition facts labels on cans and boxes of food in your kitchen.

   Make three lists:

   - Foods having more than 30 gm of carbohydrate per serving.
   - Foods having between 11–29 gm of carbohydrate per serving.
   - Foods having less than 10 gm of carbohydrate per serving.

   c. Look at the nutrition facts labels on various foods in your kitchen.

   - Find the one with the highest calorie count. ________________
   - What is the calorie count per serving? ______________________
   - What is the carbohydrate count in grams? __________________
   - What is the fat count in grams? ___________________________
   - This food may be fattening to eat, but it contains the most calories and therefore the most energy per serving.

Instruction Block Two

Exploring and Spending Your Energy Coin

Square Two Concepts/Skills*—Students will:*

- Understand that simple sugars store energy in their carbon-to-carbon atom links
- Understand that most of the energy stored in simple sugars cannot be released without oxygen.
- Understand that when oxygen is available, simple sugars can be broken down completely into carbon dioxide and water.
- Deconstruct a simple sugar molecule into the end products of oxidation.
- Demonstrate the need for oxygen in order to completely deconstruct a simple sugar molecule.
- Identify carbon, hydrogen, and oxygen in a simple sugar molecule.
- Write the chemical formulae for water, carbon dioxide, oxygen gas, and simple sugars.

Materials

- Glue Sticks, highlighter or light-colored crayons

Duplicate

- Spending your energy coin (4 pages)—*one pack per student*
- Stop/Think/Draw/Write 3—*one per student*
- Fermentation (2 pages)—*one per student*
- Quick Team Quiz Two—*one per student*
- Square Two Test—*one per student*

Lesson plan schedule

- Award squares for Instruction Block One
- Taking apart your energy coin
- CBC and TCT shapes
- Stop/Think/Draw/Write 3
- Chemical atoms and molecules
- Quick Team Quiz Two
- Square Two Test
- Optional Activities

Teaching tip
Explain to students who have not yet mastered the first concepts that they will shortly, and you will award them their squares as soon as they do. Consider awarding parts of squares to recognize **content these students have mastered**.

Teaching tip
It is strongly recommended that before teaching this lesson you follow the directions and take apart your own energy coin. You will be better able to anticipate questions students may have with the activity.

Pairs

Whole class

Pairs

Teaching tip
Draw the chart on the board and fill in the information as students report what they discovered.

Lesson Plan

Exploring and Spending Your Energy Coin

Awarding squares

Arrange the room and send students into teams. Students will rotate their roles today. If you have not already done so, announce/award the First Squares (blue) to students who have mastered the first concepts in Instruction Block One.

1. Taking apart your energy coin

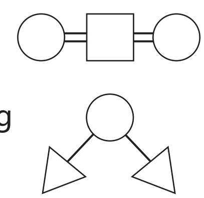
a. Student teams will divide into pairs again today. Keep the same pairs as you had for Block One so that students are working on the same energy coin that they built earlier.

b. Give four packs of **Spending Your Energy Coin** to each team Manager.

c. As a whole class, read "Cashing in your energy coin." Have students highlight the two major points of the paragraphs in this section.

- *Living things use simple sugars to move energy both within themselves and among each other.*
- *To "cash in" a simple sugar molecule to get the energy stored inside, you must take your energy coin apart.*

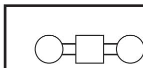
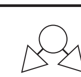
d. Go over the directions so that student pairs understand how to take apart their energy coins. Some students may be confused by the direction #5, making a counting mark. Model how to record each time they make either of the two shapes.



e. Assure them that it is okay if they end up with "left-over" pieces.

f. When all the pairs have finished taking apart their energy coin as far as they can, reconvene the class to compare what all the teams have found. Read "CBC and TCT shapes." Have students fill in the chart.

g. Conclusion: In all cases, **they could not take the whole energy coin apart because they ran out of circles. Energy that is not released cannot be used.** Reinforce this key concept**.**

	
0	6
1	4
2	2
3	0

2. The Circle Source

Pairs

a. Read "The Circle Source" and the directions for taking apart the whole coin. Point out to students that their Circle Source *only* comes in pairs.

b. Before they begin taking apart the rest of the coin, have students copy their counting marks from Table 3 on the first page onto Table 5. If necessary, model how to use and record the circle pairs.

c. Allow students to take apart the rest of their coin using as many circle pairs as they need to make their shapes.

d. Walk around as students work to make sure they have understood the task.

e. If they have completed the task as described, tell them to fill in the formula at the bottom of the page.

(sugar) + 6 (circles) = 6 (box&circles) + 6 (triangles + circle)

3. Counting your energy cash

Whole class

a. Re-copy the formula on the board and ask one of the students to read aloud the first summary statement.

b. Have another student read the rest of the section aloud and add the words (plus a lot of energy) to the formula.

4. Chemical atoms and molecules

a. Read this section as a whole class to reveal that the elements shown as squares, triangles, and circles were in fact: carbon, hydrogen, and oxygen.

b. Have students highlight the following two sentences:

All matter is made of ***atoms****. A group of the same kind of atom makes up an* ***element*****.**

c. Introduce the word molecule by having students highlight the following sentence as you read this section:

Molecules are formed when two or more atoms are linked together.

Whole class

d. Allow students to finish this page as a team by starting with the direction... "Use Table 6 to redraw the TCT shape..." When they finish, reconvene the class and have them report that the three lines were HHO and the rewritten molecule is H_2O. Most students will recognize *water*.

5. Stop/Think/Draw/Write 3

Use words and/or drawings to explain:

1. *Why were you unable to take apart your simple sugar molecule at first?*
2. *What is the "circle source" in real life and where do you find it?*
3. *In what way is being able to completely dismantle a simple sugar an advantage for an animal?*

Individual

a. Have students work individually to complete the three prompts. These will help them to put together the need for oxygen in living processes.

Students share with their team after 2–3 minutes

Small group

b. After 2–3 minutes, have students first share what they wrote or drew with their team. Then ask teams to choose one teammate's explanations and drawings to share with the whole class.

Whole class

c. Together with students, use the **Content Concept Rubric** to evaluate team answers. Ask students to offer ways to improve an answer.

6. Hey, I know that molecule

a. Ask team readers to read this section. Student teams should be able to figure out that the triangle-circle-triangle is CO_2

b. After students have decoded the shapes, they can rename the glucose molecule and the circle source. ($C_6H_{12}O_6$ and O_2)

c. Go over the answers to be sure that all teams understand the conversions.

Teaching tip
Students will notice that this equation does not have an equal sign in the middle, but rather a double pointed arrow. They will learn more about this in Instruction Blocks Three and Four.

Teaching tip
Students do not need to memorize the photosynthesis/oxidation formula until Instruction Block Three.

7. The summary statement as a chemical equation

a. As a whole class, read the summary statement as a chemical equation. Make sure students notice the difference between the whole numbers in front of the molecules and the subscript numbers within a molecule.

b. At this point, it's time to tell students that they need to memorize the following:

- The letter symbols for carbon, hydrogen, and oxygen (C, H, O)
- The chemical formula for carbon dioxide ($CO_{2)}$ and water (H_2O))
- The chemical formula for a simple sugar molecule ($C_6H_{12}O_6$)

c. Have students copy what they need to memorize on a piece of paper that they can take home to study. Give teams a couple of minutes to devise a strategy to help their team to memorize these chemical formulas.

8. Quick Team Quiz Two

Individual

a. Ask the Managers to come to you for the **Quick Team Quiz Two**. While students are working *individually*, walk around the room clarifying and instructing.

Small group

b. When the individuals in each team have finished **Quick Team Quiz Two**, the teams should work together to correct their papers. Team members should help other team members who made errors. Remind students of the **Cooperative Group Work Rubric**.

Whole class

c. As a whole class, present the correct answers on the board and answer any questions. Tell Leaders to put all the **Quick Team Quiz Two** papers neatly in the team folder and give the folders to you.

9. Square Two Test

Individual

a. Before starting Instruction Block Three, administer the **Square Two Test** to individuals, not teams. Separate student desks for privacy. Collect tests when students have finished.

b. While students are taking their tests, consider using the time to assess the students' overall cooperative group work during Instruction Block Two. Use the **Cooperative Group Work Rubric** as your guide, assess each student and assign a number from 1–4 to describe their cooperative behavior. Before beginning the next class, let students know how well they are meeting your expectations and, if necessary, what specifically they can do to improve.

c. Correct the individual tests and evaluate your students' mastery of concepts in Instruction Block Two. Re-teach, if necessary, and re-test. Those who have passed the Squares can do the Optional Activities on page 33.

Square Two Answer Key

Stop/Think/Draw/Write 3:

1. They ran out of circles.

2. The circles represent oxygen, which is found in the air around us.

3. With the additional oxygen, they were able release maximum energy by separating all puzzle pieces to make triangle-circle-triangles and circle-box-circles. This reduces the animal's burden to find food.

Quick Team Quiz Two:

1. simple sugar
2. starch
3. –ose
4. circles (oxygen)
5. C, H, O
6. Students draw shapes for O_2 , H_2O and CO_2.
7. H_2O
8. CO_2
9. glucose or simple sugar
10. carbon—carbon

Square Test Two:

1. A
2. A
3. B
4. D
5. C
6. B
7. A
8. B

Bonus: There are more carbon-to-carbon links in a simple sugar molecule than in propane molecule. The more carbon bonds, the more energy.

Optional Activities Two

Small group

1. **Science activity—Fermentation.** The **Fermentation** handouts are student-ready. Team members assume their designated roles of Leader, Reader, Recorder, and Manager to follow the directions. The steps and procedures are similar to the energy coin activity they just completed. The differences are:

   - to save time, they don't actually assemble a coin but rather just work with the pieces.
   - they are not making water, only alcohol and carbon dioxide—a total of four molecules.

Whole class
or
Small group
or
Individual

2. **Journal writing** is always an excellent way for students to reinforce their own learning. Below is a list of prompts you can give individual students, teams, or the whole class. Allow student to write for at least three minutes. Direct them to first share what they wrote with their team. Ask for volunteers to share with the whole class. Look for common comments and strategies that students write.

   - **Prompt 1:** The simplest form of a carbohydrate is a simple sugar. Look up the word **hydrate**. Now look at the word **carbohydrate** and explain why this name is appropriate.
   - **Prompt 2**: Many of the latest diets claim to be **lo-carb**. Find out what advertisements mean by **lo-carb**. What kinds of foods would be avoided on this type of diet?

Individual

3. **Research and report.** Ask students to research the following topics and make short written or oral reports to their classmates**.** Have students research the following topics:

   a. Dentists advise that their patients to reduce their intake of sweets. How does eating sweet foods often lead to tooth decay?

   b. Foods high in sugars, oils, and fats will burn when dry. What is a bomb calorimeter and how does it measure food energy?

   c. Biofuels are in the news as an alternative energy source. What is a biofuel, what makes it an energy source, and what problems are in the way of more widespread use of biofuels?

4. **Real life situations**

   a. The stems, leaves, and roots of plants are made stiff by cellulose. Both starch and cellulose are made of many simple sugar molecules linked into long carbon-to-carbon chains. The difference is that starch chains are straight and are easily broken to release the simple sugars. But cellulose chains are branching and are hard to break apart.

b. One-celled non-green plants, bacteria, make a chemical that will break up the branched chains of cellulose to release the stored food energy they contain. You can observe this by making a compost pile. Follow the directions below to make one. Use a thermometer to measure the temperature of the pile every day. Be careful when you measure the temperature because once it gets going, the released energy will make the pile hot enough to burn your skin.

1. Make a pile of leaves, grass clippings, and other plant waste at least three feet tall.
2. Add three shovel loads of good soil.
3. Wet the pile with a hose.
4. Thoroughly mix everything.
5. Cover the pile with a loose plastic cover.
6. Remix the pile every three days.

Instruction Block Three

Oxidation and Photosynthesis

Square Three Concepts—*Students will:*

- Understand photosynthesis is the daytime process by which green plants use light energy to rearrange the atoms of water and carbon dioxide gas to form simple sugars and oxygen gas.
- Understand that during photosynthesis, oxygen gas is released by green plants as a by-product.
- Understand oxidation is the process by which animals rearrange the atoms of simple sugars and oxygen to form water and carbon dioxide.
- Understand animals gather simple sugars by eating green plants or other animals.
- Understand animals gather oxygen by breathing air or drawing oxygen from water (fish with gills).
- Understand animals release carbon dioxide as gas and water as vapor with their breath.
- Understand that in darkness, green plants are metabolically equivalent to animals. They perform to oxidation to obtain necessary energy.
- Understand green plants and animals are exchange partners that trade atoms of carbon, hydrogen, and oxygen among each other.
- Understand energy flow is always one way, from the Sun to green plants, and then to the animals.
- Understand the feeding order of green plants and animals is called a food chain.
- Understand food chains begin with a green plant called a producer.
- Understand the first animal in a food chain eats the producer and is called the first-order consumer and also an herbivore.
- Understand the second-order consumer eats the first-order consumer (an animal), so the second-order consumer is also called a carnivore.
- Understand the last carnivore in the food chain is an apex predator.
- Understand animals have developed behaviors to accommodate seasonal changes in food supply such as hibernation, migration, and food storage.
- Write the chemical equation for photosynthesis and oxidation.

- Construct a food chain
- Construct a food web
- Demonstrate that an ecosystem is a natural community that is home to multiple populations including producers, consumers, scavengers, and decay organisms.

Materials

- Highlighters or light-colored crayons, scrap paper, scissors

Duplicate

- Oxidation and Photosynthesis (2 pages)—*one pack per student*
- Food Chains and Food Webs (2 pages)—*one pack per student*
- Stop/Think/Draw/Write 4—*one per student*
- Vocabulary flashcards—*one per student*
- Quick Team Quiz Three—*one per student*
- Square Three Test—*one per student*

Lesson plan schedule

- Award squares for Instruction Block Two
- Oxidation
- Photosynthesis
- Trading partners
- Stop/Think/Draw/Write 4
- Animals and oxygen
- Non-photosynthetic organisms
- Food Chains and Food Webs
- Vocabulary Flashcards (optional)
- Quick Team Quiz Three
- Square Three Test
- Optional Activities

Lesson Plan

Oxidation and Photosynthesis

Awarding squares

Arrange the room and send students into teams. Students will rotate their roles again today. If you have not already done so, announce/award the Second Squares (red) to students who have mastered the concepts in Instruction Block Two. Award partial squares to students who have mastered some of Square Two concepts.

Teaching tip You may decide to move a student along rather than stopping to re-teach. Every new square reinforces previous content and skills. Students will have the opportunity to show they have mastered a skill from Square Two when they take the Square Three Test. Award the squares as soon as you feel that the student has demonstrated his mastery.

1. Oxidation

a. Give four packs of **Oxidation and Photosynthesis** to each team Manager.

b. As a whole class, read the first section stopping at "Reversing the equation." Have students highlight the two major points of the paragraphs in this section.

Whole class

- *You used oxygen to release the energy stored in a simple sugar molecule.*
- *Oxidation is the energy source that powers animal life.*

c. Announce that students must now memorize the formula for oxidation and photosynthesis. They should write it on paper that they can take home to study. Allow teams a minute or two to develop a strategy for learning the formula. (They have already memorized the simple sugar, carbon dioxide, and water formulas.)

Teaching tip Remember as explained in the Author's Note on page 16, in this unit we write the formula with oxidation on the left because we introduced oxidation (the breakdown of simple sugars) first.

2. Photosynthesis

a. Demonstrate how to read the equation in reverse.

b. Have students highlight the first paragraph in this section. Spend a little time stressing this key concept. Refer students to the chemical equation with the double arrows and reinforce that the way this equation, photosynthesis, is read right to left.

The "something" that makes simple sugars are green plants. The process is called photosynthesis and the energy green plants use is sunlight.

c. Read the paragraph under Photosynthesis and have students highlight the following sentences.

...Green plants are called producers. During photosynthesis, green plants take in sunlight, carbon dioxide gas, and water, then make simple sugars, and release oxygen gas.

Teaching tip The equation is a reversible reaction. Sometimes students will see the equation written so that photosynthesis reads from left to right. Whether the equation reads that way or the way shown here is not important. Students will adapt to either presentation because the simple sugar molecule ($C_6H_{12}O_6$) is easily recognized.

3. Trading partners

a. Introduce the term "consumer" and have students highlight:

...animals are called consumers...they use oxygen to release the energy stored in simple sugars. Refer them back to the reversible equation of oxidation and photosynthesis.

b. Read to the end of the section and ask students to highlight the following sentence

- *...the energy flows from the sun to the green plants to chipmunk.*
- *...the pathway from producer to consumer is called a food chain.*

c. Students may think that the water that the chipmunk contributes is its urine. In fact, urine represents a small portion compared to the water that leaves the chipmunk's lungs as water vapor in its breath.

4. Stop/Think/Draw/Write 4

Use words and/or drawings to explain the following experiment.

Scientist conducted an experiment placing a mouse in a closed terrarium with plants and water. Although there was no air available from the outside, the mouse survived. Explain why the mouse was able to live without outside air.

Individual

a. Have students work individually to complete the prompt. Walk around and check that students who have finished "early" have included all they know. Tell students to work neatly and check their spelling.

Small group

Whole class

b. After 2–3 minutes, have students first share what they wrote or drew with their team. Then ask teams to choose one teammate's explanations and drawings to share with the whole class. Use the **Content Concept Rubric** to assess each team's response.

5. Animals and oxygen

Small group

a. Ask students to work as teams to read "Animals need oxygen" and "Oxygen dissolves in water." When they finish, ask students to report on how earthworms and fish get oxygen.

b. Ask students to generalize that all animals need oxygen and have adapted ways to get oxygen from their environment.

6. Green plants and chlorophyll

Whole class

a. As a whole class, read aloud the paragraph about green plants and chlorophyll. Highlight these two sentences:

Chlorophyll is the green pigment that gives green plants their color. This pigment is essential to photosynthesis because it captures light energy in *the first step toward making simple sugars.*

7. Non-photosynthetic organisms

a. As a whole class, read aloud the paragraph about non-green plants. Highlight these two sentences,

Non-photosynthetic organisms do not have chlorophyll, so they can't capture the energy in sunlight. Therefore, many non-photosynthetic organisms use oxidation to get their energy...they eat just like animals!

Whole class

b. Have teams read the rest of the page on their own. As they read, write these questions on the board. When all teams are finished reading, have them work as teams to answer the questions.

- How do mushrooms and bacteria break down food?
- How do bacteria cause our throats to hurt?
- When are green plants like non-green plants?
- What causes a fish kill?

Small group

c. Ask students if they had ever thought about non-photosynthetic organisms before. Will they ever look at a mushroom the same way?

Teaching tip
Remind students of their roles and responsibilities.

8. Food Chains and Food Webs

a. Give four packs of **Food Chains and Food Webs** to each team Manager.

Small group

b. Have students work in teams to complete "Food chains" and "Build your own food chain." Reconvene the class when all the teams have filled in the lines in the second column. Discuss the answers.

Whole class

c. Introduce the difference between food web and food chain. (Food chains are linear → producer, first-order consumer, second-order consumer, etc. Food webs are interlocking food chains.)

Small group

d. Have students complete **My Meadow Food Web** as a team. The Reader should read the directions and the Leader should lead a discussion so that the team agrees by consensus on the order of the web. The Recorder can write the team's choices on scrap paper as they work. When the web is finished, each team member should copy the food web onto their paper.

Teaching tip
Lines may cross in the web, but the direction of the arrows must always go from the source to the consumer. Most teams will arrange their lines flowing from left to right with the apex predators near the right side.

9. Vocabulary Flashcards

a. This is an optional, but recommended activity. Instruction Block Three introduces a lot of vocabulary. Although the actual words are not

Small group

particularly difficult, students may need a more little time working with them to be certain of how they fit into the context of food webs. Ask the Managers to come to you for only one copy of the **Vocabulary Flashcards** for their team.

b. Have students cut out each square and lay the cards in front of them. Teams are going to work through the cards several times. On the first time through, have students individually pick a card and explain what they think it means. If the group agrees, they can put the card to the side. If not, they should look at their papers to get to a definition on which they can agree. Have students continue to work until all the cards are at the side.

c. On the second time through, have student pick 2–4 cards that they feel "go together." (For example, they might choose cards for water and carbon dioxide and say, "Plants use these to make simple sugars in photosynthesis." This time, they replace the cards in the center. A second teammate chooses 2–4 cards and makes a different statement.

d. Walk around the room as teams work to be certain that they are getting the value of the review. Stop by and pick up 2-4 cards and ask students to make a statement that uses the cards.

e. Allow one team member to keep the cards set they used, and ask the team Managers to get vocabulary flashcard pages for the rest of the team. Students may use these to review for **Square Test Three**, **Square Test Four** (which is a cumulative test) or the **Posttest**.

10. Quick Team Quiz Three

Individual

a. Ask the Managers to come to you for the **Quick Team Quiz Three**. While students are working individually, walk around the room clarifying and instructing.

Small group

b. When the individuals in each team have finished **Quick Team Quiz Three**, the teams should correct their papers as a group. Team members should help other team members who have made errors.

c. Present the correct answers on the board and answer any questions. Tell Leaders to put all the **Quick Team Quiz Three** papers neatly in the team folder and give them to you.

11. Square Three Test

Individual

a. Administer the **Square Three Test** to individuals, not teams. Separate student desks for privacy. Collect tests when students have finished.

b. While students are taking their tests, consider using the time to assess the students' overall cooperative group work during Instruction

Block Three. Use the **Cooperative Group Work Rubric** as your guide, assess each student and assign a number from 1–4 to describe their cooperative behavior. Before beginning the next class, let students know how well they are meeting your expectations and, if necessary, what specifically they can do to improve.

c. Correct the individual tests and evaluate your students' mastery of concepts in Instruction Block Three. Re-teach and retest if necessary. Allow those who have earned a square to work on the Optional Activities on page 43.

Square Three Answer Key

Stop/Think/Draw/Write 4:

The plants use water, CO_2, and sunlight to make simple sugars and oxygen. The mouse eats the plants and uses oxygen in the terrarium air to oxidize (take apart) the simple sugars. The mouse gives off CO_2. that the plants use in photosynthesis. It is a trading partners situation.

Quick Team Quiz Three:

1. carbon dioxide and water
2. oxygen and simple sugars
3. oxygen and simple sugar
4. carbon dioxide and water
5. light or sunlight
6. simple sugars
7. chlorophyll
8. oxidation
9. at night
10. a. carbon dioxide and water b.oxygen and simple sugars
11. a. producer b. owl c. snake d. mouse
12. food web
13. H_2O
14. CO_2
15. simple sugar or glucose
16. carbon—carbon

Square Three Test:

1. B
2. A
3. D
4. B
5. $C_6H_{12}O_6 + 6O_2 \longleftrightarrow 6CO_2 + 6H_2O$
6. D
7. C
8. B
9. A
10. C
11. D
12. Answers will vary.
13. C
14. at night
15. A
16. C
17. B
18. Bonus: Food chains present a single food energy pathway. Food webs show multiple pathways.

Optional Activities Three

Whole class
or
Individual

1. **Science lab or activity.** National Science Teachers Association has deemed that chlorophyll extraction and experiments involving middle school students handling mushrooms or other fungi to be too hazardous. Instead try a Google search. "Chlorophyll extraction + video" might present a demonstration or "mushroom + video" might show you parts of a mushroom and how it gets its food energy. These can be viewed on SmartBoards® or individual computers.

Whole class
or
Small group
or
Individual

2. **Journal writing** is always an excellent way for students to reinforce their own learning. Below is a list of prompts you can give individual students, teams, or the whole class. Allow students to write for at least three minutes. Direct them to first share what they wrote with their team. Ask for volunteers to share with the whole class. Look for common comments and strategies that students write.

   - **Prompt 1:** When humans tear down a forest to build malls and parking lots, they are affecting food webs. What can people do to both meet the needs of a growing city and also preserve the ecosystem?
   - **Prompt 2**: The Clean Water Act passed in the 1970s and was amended over the years. This law requires cities to separate their sewers from their storm drains, businesses to monitor any run-off from manufacturing, and requires home owners to have inspected septic systems. Why is this law so important?

Individual

3. **Research and report.** Ask students to research one of the following topics and make a short written or oral report to share with their classmates:

   a. Look up sea creatures such as clams, sponges, coral, jellyfish, or algae. Find out if they are animals or plants. How do they get oxygen? How do they get food?

   b. Look up diatoms. Why are they so important to other sea creatures?

   c. Rabbits are considered one of the most damaging and destructive introduced animals ever brought to Australia. Research the history of rabbits in Australia and how they have affected the ecosystem of the continent.

   d. Look up mushrooms and other fungi. Write a short paragraph with accompanying illustrations to explain how they get their food energy.

   e. Find out why breads made with yeast have large holes in the dough.

4. **Real life situations**

   a. Why do tropical fish tanks always have air pumps that bubble water in the tank?

   b. Trout like to live in fast running streams and are very susceptible to a fish kill. Goldfish, on the other hand, can live in a fish bowl without an air pump. What does this say about the two fish?

   c. People have started fertilizing their lawns to make them very green. This fertilizer runs off into streams and fertilizes the streams. Explain how this can adversely affect the fish that live in the stream.

   d. In your neighborhood, can you identify an apex predator? Draw a food web that ends with this local apex predator.

Instruction Block Four

Food Chains and Pyramids

Square Four Concepts*—Students will:*

- Understand food pyramids, show food chains with the producers on the bottom and the apex predator at the top.
- Understand the shape of a food pyramid shows that each level contains only one-tenth as much food energy as the level beneath it.
- Understand that food pyramids can be used to model and predict the outcome of a food problem.
- Understand that after a food problem has distorted a food pyramid, it will always return to a smooth-sided shape. The new pyramid may be a different size or have different number of levels.
- Represent a food chain with a food pyramid.
- Analyze and suggest viable solutions for a food chain problem using a food pyramid.

Materials

- Highlighters or light-colored crayons

Duplicate

- Food Pyramids, Food Pyramids and People (3 pages)—*one pack per student*
- Food Pyramid Investigations (2 pages)—*one per student*
- Stop/Think/Draw/Write 5—*one per student*
- Stop/Think/Draw/Write 6—*one per student*
- Quick Team Quiz Four—*one per student*
- Square Four Test—*one per student*

Lesson plan schedule

- Award squares for Instruction Block Three
- There's no free lunch
- Stop/Think/Draw/Write 5
- Food pyramids as tools
- Why do birds migrate?
- Stop/Think/Draw/Write 6
- Man at the top of the pyramid
- Food Pyramid Investigations
- Quick Team Quiz Four
- Square Four Test
- Optional Activities

Lesson Plan

Food Chains and Pyramids

Awarding squares

Small group

Arrange the room and send students into teams. Students will rotate their roles again today. If you have not already done so, announce/award the Third Squares (green) to students who have mastered the concepts in Instruction Block three.

1. There's no free lunch

a. Ask Managers to distribute a pack of **Food Pyramids** and **Food Pyramids and People** to each team member.

b. Decide if you are going to run this as a whole class discussion or as a team activity. (Review roles if doing as a team activity.) Have students highlight the following sentences or phrases:

Whole class *or* Small group

- *Food energy is measured in calories...*
- *The green plants of a meadow produce a certain number of food energy calories, and those calories will support a certain body weight of animals, but no more.*
- *The unyielding rule is that pyramid balance is always maintained. If consumer weight rises or producer weight falls, the weight of* individual *consumers must decrease.*

2. Stop/Think/Draw/Write 5

Use words and/or drawings to explain why it is that adding more cows to a certain amount of grazing land results in a herd of skinny cows.

Individual

a. Have students work individually to complete the prompt. Tell them to be specific about why the cows are skinny. They should check their spelling and work neatly.

Have students share their work with their team after 2–3 minutes

Small group

b. After 2–3 minutes, have students first share what they wrote or drew with their team. Then ask teams to choose one teammate's explanations and drawings to share with the whole class. Use the **Content Concept Rubric** to assess each team's response. Give more points to responses that used more precise vocabulary including "producers" and "consumers."

3. Food chains are useful tools

a. Reinforce the difference between a food web and a food chain. Food chains are straight-forward and follow one path, such as grass-mouse-snake-owl. Food webs are formed when food chains interlock. Think about a second food chain of grass, grasshopper, bird, cat, and coyote living in the same meadow as the first food chain. The flow of energy among the creatures might follow more than one path.

b. We use food pyramids to study food chains.

c. Have students highlight the following sentence:

- *In a food chain, the amount of food energy (calories) in each link is ten times lighter than the amount of food energy before it.*

d. Use simple numbers to reinforce the fact that each successive level of a food pyramid is ten times lighter than the level below it. (They will be doing more of this on the next page.)

Write this example on the board:

Food chain of grass-grasshopper-robin, 100 pounds of grass will support ____ (10) pounds of grasshoppers and _____ (1) pound of robins.

e. Using the same example, you can convert the food pyramid level to the population size. If a robin weighs 4 ounces., how many robins could be supported by that 100 pounds of grass? 16 oz ÷ 4oz/robin = 4 robins.

4. Food pyramids show population

a. In this section, students work with the original food chain of grass - mouse - snake -owl. They are working with an owl weight of 1.4 kg. (Using International System weights allows for easy multiplication by 10. For example, 1.4 kg - 14 kg - 140 kg - 1,400 kg.)

b. Have students highlight: *Apex predators are never plentiful*.

c. Have student read "Summer's end." They should highlight these two sentences:

- *Animals have developed various ways to cope with less food in the winter. Migration is just one of those*.

Other possible strategies include hibernation, storing food externally (nuts, seeds) or internally (fat layers), saving energy by reducing movement, and some species simply die off.

d. Have students brainstorm about other animals. What other animals migrate besides birds? (antelope, bison, wildebeest) What do bears and chipmunks do? (hibernate) What do squirrels and bees do? (store food for the winter—nuts, honey)

5. Stop/Think/Draw/Write 6

Below is a food pyramid. Write the following names in the pyramid in the *proper order from producer to apex predator. (grasshopper, bird, grass, hawk)*

Use words and/or drawings to explain what would happen to the pyramid if pesticides killed all the grasshoppers?

Individual

a. Have students work individually to complete the prompt. Walk around to make sure that they understand the two directions to fill in the pyramid and then explain the result of the pesticides.

Small group

Whole class

b. After 2–3 minutes, have students first share what they wrote or drew with their team. Then ask teams to choose one teammate's explanations and drawings to share with the whole class. Use the **Content Concept Rubric** to assess each team's response. Give more points to responses that used more precise vocabulary including "producers" and "consumers" and also refer to the ten-fold difference between levels.

6. Food Pyramid Investigations

Whole class

a. Ask Managers to distribute **Food Pyramids Investigation** pack to each team member.

b. Go over the directions on the top page. On the board, draw two boxes like the ones on the second page. As you read Step 2, draw a temporary food pyramid to the side of the left-hand box (Students will put their temporary pyramid on scrap paper.)

c. For Step 3, model how you modified the temporary pyramid. When it looks the way you want, draw it in the left hand box labeled "Problem Food Pyramid."

d. Entertain a discussion to answer Step 4. Realistic solutions fall into three cases:

   1. If nothing is added to the problem as described, die-offs will occur in any pyramid level that is over-extended. This may eliminate one or more upper levels from the pyramid.

   2. Additions may be made to undercut levels so that levels above are supported. In the case of nations, this might involve trading or receiving food from welfare agencies.

   3. A combination of both strategies.

   Note that the solution must be clearly written.

e. Model Step 5 in the right hand box.

f. Review by double checking the work using the four bulleted questions.

Small group
or
Pairs

g. When students fully understand the process, have them work as teams or in pairs to solve the four problems on the next page. Reconvene the class to share and compare the food problem pyramids, how the problem will be restored to balance and the resolved food pyramids.

7. Quick Team Quiz Four

Individual

a. Ask the Managers to come to you for **Quick Team Quiz Four**. While students are working individually, walk around the room clarifying and instructing.

Small group

b. When the individuals in each team have finished **Quick Team Quiz Four**, the teams should correct their papers as a group. Team members should help other team members who have made errors.

Whole class

c. Present the correct answers on the board and answer any questions. Tell Leaders to put all the **Quick Team Quiz Four** papers neatly in the team folder and give them to you.

8. Square Four Test

Individual

a. This is the last square test that your students will take. It is a cumulative test covering all the four square concepts so it may take a little bit longer to complete. Administer the **Square Four Test** to individuals, not teams. Separate student desks for privacy. Collect tests when students have finished.

b. While students are taking their tests, consider using the time to make a final assessment of the students' overall cooperative group work during Instruction Block Four. Use the **Cooperative Group Work** Rubric as your guide. Consider giving special recognition to teams or individuals who had consistently high scores on their **Cooperative Group Work Rubrics**.

c. Correct the individual tests and evaluate your students' mastery of concepts in Instruction Block Four. Re-teach and retest if necessary.

d. Allow students who have earned the square to work on the Optional Activities on page 53.

9. Are you done yet?

Individual
or
Pairs
or
Small group

a. You may stop at this point having completed the Four Squares of Squared Away for *Photosynthesis, Food, and Populations*. However, Instruction Block Five contains a recommended two-page essay on energy budgets in a food web. Students learn about the role of scavengers and decomposers. You can use this as an extra lesson for all students.

b. If you want to challenge your students further, you may assign them one or both of the two Golden Square Challenge Tasks. These are more difficult and you should expect fifty percent or fewer of your students will be able to successfully complete the activities. You may assign these to individuals, pairs, or teams.

10. Posttest

One week after you finish the unit, give the **Posttest**. Take the time to look at the student answers that were incorrect.

Individual

11. Awards

With the successful completion of the Square Four Test, students are considered "squared away." However, consider waiting until you run the Golden Square Activities to celebrate. This will give you more time to work with those students who are close to finishing the four squares. It would be best if all your students successfully completed the four instructional blocks. The **Golden Square Challenges** are just that—challenges, and not essential to be considered "Squared Away." However, give special recognition to all those who do achieve a Golden Square. Design a celebration appropriate to your students' age, and your available time and resources. Give **Special Award Certificates** on pages 116–117 to acknowledge each students achievement.

Teaching tip
The **Square Four Test** is a cumulative test. If a student completes the **Square Four Tests** with few if any errors, you may award any missing squares.

Square Four Answer Key

Stop/Think/Draw/Write 5:

The grazing land can support a certain amount of cattle. If the farmer puts more cattle on the same land, then the cows will be skinnier and some may die. The amount of grass determines how many cows there are and how much they will weigh.

Stop/Think/Draw/Write 6:

Grass, grasshopper, bird, hawk. The birds need ten times their weight in grasshoppers to survive. If the grasshoppers are killed, then there is no food for the birds. No food for the birds, they will die or migrate. No birds, then no food for the hawk, which will die or migrate.

Quick Team Quiz Four:

1. $C_6H_{12}O_6 + 6O_2 \longleftrightarrow 6CO_2 + 6H_2O$
2. carbon dioxide and water
3. green plants
4. carbon dioxide and water, oxygen and simple sugars
5. oxidation

6. at night
7. a. producer b. sea gull c. starfish
8. The bottom level is diatoms, second level is clam, third level is starfish, top level is seagull.
9. 10,000
10. 2
11. The bottom level is water plants, second level is aquatic insects, third level is trout, top level is stork.
12. The pyramid has only two levels: bottom is water plants, second level is aquatic insects.

Square Test Four:

1. D
2. B
3. $C_6H_{12}O_6 + 6O_2 \longleftrightarrow 6CO_2 + 6H_2O$
4. D
5. B
6. A
7. A
8. B
9. C
10. C
11. C
12. B
13. D
14. at night
15. B
16. D
17. Leaf on bottom level, aphid on second level, beetle on third level, and robin on top level.
18. C
19. C
20. B

Optional Activities Four

1. **Science Activity**

   Contact a scientist from a local university or one working for your state's Department of Environmental Management to come to your class. Send copies of the handouts or give a brief summary of what your students have been doing and ask the scientist to discuss the work that he/she does as it relates to this unit.

   You might also contact a social scientist who works for one of the international food organizations (C.A.R.E., Feed the Children, etc.) and ask how their organizations have worked to relieve hunger in the world.

2. **Journal writing** is always an excellent way for students to reinforce their own learning. Below is a list of prompts you can give individual students, teams, or the whole class. Allow students to write for at least three minutes. Direct them to first share what they wrote with their team. Ask for volunteers to share with the whole class. Look for common comments and strategies that students write.

   - **Prompt 1:** If we all became vegetarians, would there be more or less food available to eat? Explain.
   - **Prompt 2**: From a humanitarian point of view, some people are opposed to hunting. From a food pyramid point of view, what might happen to large wild animals if hunting were totally banned?

Whole class

or

Small group

or

Individual

3. **Research and report.** Ask students to research one of the following topics and make a short written or oral report to share with their classmates:

   - Look up other apex predators such as lions, grizzly bears, killer whales, sharks, wolves, and eagles. Find out what they eat and trace the food chain backwards to the producer level.
   - Blue whales are the largest sea creature. Find out if they are apex predators or something else?
   - Look up an endangered species and try to determine why this species is dying out. What specifically has gone wrong? Can the government do anything to bring balance back into its food pyramid?

4. **Real life situations.** Hungry humans are more likely to go to war than properly fed humans. This pattern can be observed throughout history. Your students can verify this by identifying African nations that have suffered significant food shortages during the past thirty years and comparing them to African nations that have been involved in civil and external wars during the same time period.

Instruction Block Five

Golden Square Challenge

Teacher Options

The Golden Square challenge for *Photosynthesis, Food, and Populations* includes a recommended reading and a choice between two challenge activities. You have four options:

1. End the unit with Instruction Block Four and not have students read the recommended reading.
2. Have students read the recommended reading, but not attempt a Golden Square Challenge.
3. Have students read the recommended reading and complete Challenge A, **Primary Productivity of My Study Area**.
4. Have students read the recommended reading and complete Challenge B, **Modeling a Meadow Ecosystem**.

Before selecting an option, read the introduction to the recommended reading and the two challenge activities.

Option #2—Recommended Reading

Introduction

The recommended reading, **Energy Pathways in a Food Web**, describes why only ten percent of food energy gathered by animals leads to growth. It describes how the flow of food energy in an ecosystem is controlled by a combination of set metabolic requirements and unpredictable conditions and circumstances. The reading also details the role of scavengers and decay organisms and ends with the realization that most of the energy captured by producers ends up as unusable heat.

This recommended reading consists of a series of sequential calculations. Students may be intimidated by the unfamiliar nature of the extended decisions involved. However, each step is straight-forward and involves no more than very simple arithmetic. You can support your students by:

1. Following the instructions and working through the process as your students would.
2. At the board, using an interactive story-telling technique to introduce the first few steps of the process:

So here we have one thousand energy coins entering a meadow, where do they go? Do the instructions give us choices? What do you say Sally, how many go to the green plants?

3. By frequently asking "Do we have any choices?" you will direct student attention to the instructions and instill confidence that they can be trusted as a guide.

Recommended Reading concepts*—Students will understand that:*

- Only a small portion of the food energy gathered by animals leads to growth. The rest is lost as waste and heat.
- By eating dead animals, scavengers return food energy to the food web that otherwise would have been lost as heat.
- Decay is an essential process that recycles critical nutrients for reuse by new living things.

Reproducible handouts

- Energy Pathways in a Food Web (2 pages)—*one per student*

Option #3—Recommended Reading and Challenge Activity 1, Primary Productivity of My Study Area

Introduction

This challenge is recommended for beginning algebra students to model important real-world information. The calculations highlight the connection between math and science and provide reinforcement of basic algebraic operations and handling labels as variables.

The first thing that wildlife managers do when investigating a real-world ecology problem is to determine the primary productivity (the total amount of green plants) of a study area. This provides a baseline—how large should the animal populations be? By comparing this baseline to the observed populations, managers can determine whether a suspected problem is real or a result of inadequate data.

Initial decisions

The lesson plan assumes that you will take your students to a study site where they will determine the scale of the area and collect their own plant samples. If this is impractical for your circumstances, you may find one or more of the following alternatives attractive. Adjust the Concepts, Material List, and Lesson Plan accordingly.

1. **Prepared sample**. After students have weighed and recorded the paper bag, take it home and fill it with lawn clippings or other green plant material. All Golden Square candidates will use the same data from this sample.

2. **Stand-in study area**. Explain to students that it's too difficult to get to and from a study site in a reasonable amount of time, so instead they will be measuring a portion of school grounds as though it were the real study area. This approach can be used even in a paved area.

3. **Artificial data.** Provide students with made-up values for key data. Use this strategy sparingly; overuse will diminish the value of the challenge.

Primary Productivity of My Study Area concepts*—Students will:*

- Collect a quarter square meter plant sample from a study area.
- Determine the area of the study area using on-the-ground reference points and a local map.
- Perform the linked calculations of the page, **Primary Productivity of My Study Area**, to arrive at the total weight of plant material in the study area.

Materials

- Brown paper shopping bags—*one per challenge candidate*
- Meter sticks—*one per challenge candidate*
- Balance or other weighing device accurate to a tenth of a gram—*available to each challenge candidate*
- Map of the study area—*one per challenge candidate*
- Quarter inch graph paper—*one or two sheets, depending on the size of the study area, per challenge candidate*

Reproducible handouts

- Energy Pathways in a Food Web (2 pages)—*one per student*
- Primary Productivity of My Study Area (1 page)—*one per challenge candidate*

Organization

Decide whether you want students to attempt the Golden Square as individuals or as teams of two. Teams and pairs do not need to be the same as those that worked together in the original unit.

Lesson plan: Primary Productivity of My Area of Study

1. **Awarding squares.** Arrange the room and send students into teams. Announce/award the Fourth Squares (purple) to students who have mastered the concepts in Instruction Block Four. Also award squares to the students who have caught up and mastered other block concepts.

2. **Prepare the sample bags.** Have candidates label their sample bags (brown paper shopping bags) <u>in pencil</u> (pencil won't run if the bag

gets wet) with their names, class or any other identifying information that you might add.

Have candidates weigh their bags. Accuracy to the nearest tenth of a gram is desirable, but not essential. Have students record the bag weight on the bag and in their notes.

3. **At the study site; one visit.** Collect a sample. Use meter sticks to measure a square that is 50 centimeters on each side. Cut all plant material within the square to the ground. Place the plant material in the sample bag.

   Determine the scale of the study area. Locate two points in the study area that are also shown on your area map. Measure the distance between these points in meters.

4. **Preparing the sample.** Arrange the samples bags so that they can air dry for a week. A temporary clothesline and pins are ideal for this. After air drying, candidates weigh their sample bags and find their sample weight by subtraction.

   Optional: The validity of the sampling technique is improved if all candidate sample weights are averaged. This reduces the effect of an unusual sample on the final value.

5. **Perform the calculations.** Candidates perform the linked calculations of the page, **Primary Productivity of My Study Area**. Explain that the information in the box at the top of the page must be complete before the calculations can begin. The instructions are numbered one through eight and can be trusted to produce a valid result if followed like a recipe in a cookbook. Check candidate work to ensure that they understand that each calculation is based on the provided formula and the result of previous calculations.

6. **Golden Square Answer Key: Primary Productivity of My Study Area.** It is not necessary to check each step of each candidate's paper. Decide what you wish to evaluate before you begin checking. Some teachers may wish to emphasize algebraic notation while others may be interested in the final result. The easiest way to check calculations is to select three or four submitted papers that have similar grass weights from Step 6. Scan through these pages using estimation to check for errors. You will soon develop a sense of what the primary productivity should be for that starting grass weight. The final result from other correct calculations will be proportional to their starting grass weights. For example, the final result from a paper that started with a grass weight that is double the starting grass weight of your reviewed samples should also show a final result that is double the final result of your reviewed samples.

Options #4—Recommended Reading and Challenge Activity B, Modeling a Meadow Ecosystem.

Introduction

This challenge guides candidates through a series of calculations and decisions that combine the concepts of food webs and food pyramids. The end result is a realistic distribution of food energy among several populations in a small meadow. Students will be amazed at how little food energy is converted into biomass and how much ends up as useless heat! Although the process is intuitive and the calculations are simple arithmetic, candidates can become entangled because the calculations are cumulative—an early error upsets everything after. This is a case where slow and steady is the fastest approach. The Recommended Reading will go a long way toward ensuring success and is essential to this challenge.

Modeling a Meadow Ecosystem concepts*—Students will:*

- Understand that the energy enters an ecosystem as producer growth.
- Understand that only a small portion of the food energy gathered by animals leads to growth. The rest is lost as waste and heat.
- Understand that the final end products of food energy after moving through a food web are biomass (the total weight of living things) and heat.

Materials

- Scrap paper—*one sheet per challenge candidate*
- Calculators are optional—*one per challenge candidate*

Reproducible handouts

- Modeling a Meadow Ecosystem (2 pages)—*one per challenge candidate*
- Meadow Food Energy Balance Sheet (1 page)—*one per challenge candidate*

Organization

Decide whether you want students to attempt the Golden Square as individuals or as teams of two. Assign teams in the latter case.

Lesson plan: Modeling a Meadow Ecosystem

1. **Distribute pages.** Distribute all three reproducible pages plus the sheet of scrap paper.
2. **Recommended reading.** Have students read the recommended reading (see above) if they have not already done so.
3. **Begin the challenge.** Read the first paragraph of **Modeling a**

Meadow Ecosystem out loud.

Call on someone to supply a value for arrow 2.

If acceptable, ask another student where the value should be inserted (on the line on the second page of **Modeling a Meadow Ecosystem**, and on top line of **Meadow Food Energy Balance Sheet**).

Ask:

> Why is the line, "Note that the total of arrows 1, 2, and 3 must equal the primary productivity of 1,000,000 grams," included in the section calculations?

Read or say

(It's a self-check).

Point out that a few arrow calculations may produce a decimal result. But the instructions ask you to record amounts to the nearest whole number. Remind students to round in that case.

4. **Explain the Meadow Food Energy Balance Sheet.** Students will be unfamiliar with the IRS-style balance sheet. Explain that like values are aligned over each other. These values are then added and their sum is written on a line that is shifted to the right. The Energy Balance at the bottom is a subtraction and the final balance is not shifted, it is directly under the subtraction.

   This challenge is not based on understanding IRS-style balance sheets, so feel free to assist candidates if they have problems determining where they should fill in information.

5. **Scoring the challenge.** Candidates who achieve a balance of less than 5 should be considered successful. As always, you are the final determiner of success, but note that small non-zero balances will occur regardless of the care taken due to the rounding specified in the instructions.

Celebration and awards

See the Final Award Celebration information on page 13 of this guide. There are two different awards. Give the first award to students who are "squared away." Give the second award to students who are "squared away" and who also earned the Golden Square.

Posttest

At least one week after you finish the unit, give the **Posttest**. Share with students how much they have learned since beginning the unit.

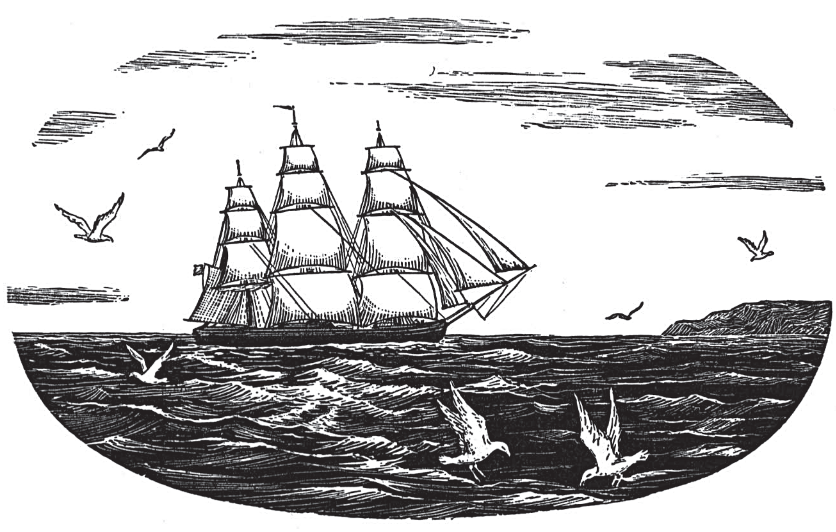
Individual

Introduction

"Squared away" was originally a nautical term used to announce that the sails of a square-rigger sailing ship were correctly set. The Navy came to use it to describe sailors who completed a task with competency, as in, "He was right squared away!" In this unit, you will learn all about how green plants and animals work together to produce food and how that food moves through living communities. When you can demonstrate competency working with these concepts, you will be considered "squared away."

This unit is divided into five instructional blocks. At the end of each block you will be tested on specific content and skills. When you have demonstrated that you have mastered the material, then you will be awarded a colored square. When you have earned four squares, you will be declared Squared Away. Your teacher may decide to assign a fifth square, called the Golden Square. In order to earn a Golden Square, you must go beyond the basic level of understanding and achieve an exemplary score on a challenging test that requires higher level thinking skills.

You will be working in teams of four, sometimes in pairs, on activities designed to teach you about two essential processes of life—photosynthesis and oxidation. You will become familiar with the roles of sunlight, carbon, hydrogen, and oxygen in the building and dismantling of food molecules. You will discover that green plants and animals act like trading partners as food energy moves from plants and grasses to the most humble animals and on through food webs to the apex predators. Finally, you will discover that the size of each animal population (including the human population) is tightly controlled by food availability along each step of their food web. The more thoughtfully you complete these activities, the deeper your understanding will be. Don't miss the opportunity to share what you are learning each day with your parents.



Name: ______________________________ Date: ______________

Pretest / Posttest

Circle the letter in front of your answer. On the pretest, do *not* guess! Just write a "?" next to the question.

1. The "coin" of exchange in nature is....	A. a simple sugar B. a starch	C. a fat D. oxygen
2. Glucose, galactose, and mannose are examples of ______.	A. simple sugars B. starches	C. fats D. gases like oxygen
3. The most commonly found stored food energy in plants are ______.	A. simple sugars B. starches	C. fats D. gases like oxygen
4. The most commonly found stored food energy in animals are ______.	A. simple sugars B. starches	C. fats D. gases like oxygen
5. You can't take apart an energy coin completely unless you add...	A. a simple sugar B. a starch	C. a fat D. oxygen
6. What is CO_2?	A. water B. simple sugar	C. carbon dioxide D. oxygen
7. What is $C_6 H_{12} O_6$?	A. chlorophyll B. simple sugar	C. carbon dioxide D. oxygen
8. What is H_2O?	A. water B. simple sugar	C. carbon dioxide D. oxygen
9. In a molecule, more energy is stored in which link?	A. oxygen to oxygen B. carbon to carbon	C. carbon to oxygen D. carbon to hydrogen
10. Write the formula for oxidation and photosynthesis.		
11. During oxidation, animals release carbon dioxide and ______.	A. oxygen B. simple sugars	C. hydrogen D. water

12. During photosynthesis, plants produce oxygen and _______.	A. hydrogen B. carbon dioxide	C. simple sugars D. water
13. During oxidation, animals take in oxygen and _______.	A. oxygen B. simple sugars	C. hydrogen D. water
14. During photosynthesis, plants take in water and _______.	A. carbon dioxide B. simple sugars	C. hydrogen D. oxygen
15. In a food web, grass is always...	A. a first consumer B. a second consumer	C. a producer D. an apex predator
16. In a food web, an owl is often a/an...	A. producer B. first consumer	C. second consumer D. apex predator
17. Write the names of a four-part food chain that might occur in a meadow.		
18. The energy that green plants capture comes from _______.	A. water B. oxygen	C. sunlight D. a simple sugar
19. When must green plants "act like animals" and use only oxidation instead of oxidation and photosynthesis?		
20. Mushrooms, molds, and bacteria are non-photosynthetic organisms, therefore...	A. they use oxidation to get food energy B. they use photosynthesis to get food energy. C. they use sunlight to get food energy. D. they give off oxygen.	
21. Chlorophyll...	A. is another name for carbon dioxide. B. is used by plants during the night. C. captures light energy from the sun. D. is given off by animals in oxidation.	

22. Fish kills occur at night because...	A. much of the carbon dioxide is used up. B. green plants use up much of the oxygen in the water. C. there is no chlorophyll in the water. D. the fish release too many simple sugars.
23. Draw a food pyramid from this food chain: leaf - aphid - beetle - robin - hawk	
24. In a food pyramid, the amount of stored energy of the second level is _____ the first level.	A. one-half of B. ten times bigger than C. one-tenth of D. the same as
25. After a food problem has distorted a food pyramid...	A. all the producers migrate. B. the food pyramid may lose 1–2 levels. C. nothing further changes. D. the pyramid becomes square-shaped.

Cooperative Group Work Rubric

4 **Exemplary**—You *consistently* and *actively* help your classmates to achieve their goals whether you are working in a team, with a partner, or by yourself. You communicate well with others, encouraging them and helping them to understand the lesson. You *willingly* share materials and responsibilities.

3 **Expected**—You *usually* help your classmates to achieve their goals whether you are working in a team, with a partner, or by yourself. You *generally* communicate well with others, encouraging them and helping them to understand the lesson. You share materials and responsibilities.

2 **Nearly There**—You *sometimes* help your classmates to achieve their goals and help them understand the lesson.

1 **Must Do Better**—You *do very little* to help your classmates to achieve their goals or understand the lesson.

If your evaluation is less than expected, try to use your cooperating skills more consistently.

Cooperative Group Work Rubric

	4 Exceeds Expectations	3 Meets Expectations	2 Nearly There	1 Must Do Better
Contributing	I consistently contribute to the group by sharing my opinions and ideas.	I usually contribute to the group by sharing my opinions and ideas.	I sometimes contribute to the group by sharing my opinions and ideas.	I rarely contribute to the group by sharing my opinions and ideas.
Listening	I actively listen to and support other people's opinions, ideas, and efforts.	I usually listen to and support other people's opinions, ideas, and efforts.	I sometimes listen to and support other people's opinions, ideas, and efforts.	I rarely listen to and support other people's opinions, ideas, and efforts.
Teamwork	I actively encourage all members to participate and work together.	I often encourage all members to participate and work together.	I occasionally encourage all members to participate and work together.	I rarely encourage all members to participate and work together.
Problem solving	I consistently help my team work through problems by actively seeking and suggesting solutions.	I often help my team work through problems by seeking and suggesting solutions.	I sometimes help my team work through problems by seeking and suggesting solutions.	I do not try to help my team to work through problems or to any suggest solutions.
Staying on-task	I consistently stay on the task and complete the work required.	I usually stay on the task and complete the work required.	I stay on the task some of the time and complete some of the work required.	I am often off-task and hardly ever complete the work required .

Concept Content Rubric

4

Exemplary—You demonstrated a clear understanding of the concept. You accurately and completely described/drew the concept in detail using correct labels. You communicated your understanding clearly with few, if any, spelling or grammatical errors.

3

Expected—You demonstrated a good understanding of the concept. You accurately described/drew the concept using some detail and correct labels. You communicated your understanding clearly with few, if any, spelling or grammatical errors.

2

Almost There—You demonstrated some understanding of the concept. However, you did not describe/draw it as accurately or completely as needed and some of your labels were incorrect. Or you did not communicate your understanding clearly because of spelling or grammatical errors. You may need to meet with your team or teacher to learn the concept more completely, or you may need to redo your work, correcting the errors.

1

Incomplete—You demonstrated little or no understanding of the concept, so you could not describe/draw it. You need to meet with your team or teacher to relearn the material.

If your evaluation is 2 or 1, strive to correct your work to at least level 3.

Content/Skills Checksheet **Student names:**																									
Square One Content/Skills—*Students will:*																									
Understand that an economy can be based on a direct exchange or indirect exchange that uses a token or coin.																									
Understand that living creatures exchange food energy in an energy economy that is very similar to the money economy of people.																									
Understand that when circumstances change restricting an economy, all living creatures (including humans) employ different strategies to survive.																									
Understand that the basic carrier of food energy is simple sugar.																									
Understand that glucose is one of several different simple sugars.																									
Understand that plants store food energy by concentrating simple sugars as starch in various parts of the plant.																									
Be able to build a simple sugar molecule, the product of photosynthesis.																									
Square Two Concepts—*Students will:*																									
Understand that simple sugars store energy in their carbon atom-to-carbon atom links.																									
Understand that most of the energy stored in simple sugars cannot be released without oxygen.																									
Understand that when oxygen is available, simple sugars can be broken down into carbon dioxide and water.																									
Deconstruct a simple sugar molecule into the end products of oxidation.																									
Demonstrate the need for oxygen in order to deconstruct a simple sugar molecule.																									
Identify carbon, hydrogen, and oxygen in a simple sugar molecule.																									
Write the chemical equation for photosynthesis and oxidation.																									
Explain the relationship between the members of the photosynthesis and oxidation equation and the compounds used and produced by these processes.																									

Square Three Concepts—*Students will:*																									
Understand that photosynthesis is the daytime process by which green plants use light energy to rearrange the atoms of water and carbon dioxide gas to form simple sugars and oxygen gas.																									
Understand that during photosynthesis, oxygen gas is released by green plants as a by-product.																									
Understand that oxidation is the process by which animals rearrange the atoms of simple sugars and oxygen to form water and carbon dioxide.																									
Understand that animals gather simple sugars by eating green plants or other animals.																									
Understand that animals gather oxygen by breathing air or drawing oxygen from water (fish with gills).																									
Understand that animals release carbon dioxide as gas and water as vapor.																									
Understand that green plants are metabolically equivalent to animals. They oxidize to obtain necessary energy.																									
Understand that green plants draw oxygen from the air or water and use the simple sugars stored in their tissues.																									
Understand that green plants and animals are exchange partners that trade atoms of carbon, hydrogen, and oxygen among each other.																									
Understand that energy flow is always one way, from the Sun to green plants, and then to the animals.																									
Understand that the feeding order of green plants and animals is called a food chain.																									
Understand that food chains begin with a green plant called a producer.																									
Understand that the first animal in a food chain eats the producer and is called the first-order consumer.																									
Understand that because the first-order consumer always eats green plants, it is also called an herbivore.																									
Understand that the second-order consumer eats the first-order consumer (an animal), so the second-order consumer is also called a carnivore.																									
Understand that the last carnivore in the food chain is an apex predator.																									

Animals have developed behaviors to accommodate seasonal changes in food supply such as hibernation, migration, and food storage.																									
Construct a food chain.																									
Construct a food web.																									
Understand that an ecosystem is a natural community that is home to multiple populations including producers, consumers, scavengers, and decay organisms.																									
***Square Four Concepts**—Students will:*																									
Understand that food pyramids show food chains with the producers on the bottom and the apex predator at the top.																									
Understand that the shape of a food pyramid shows that each level contains only one-tenth as much food energy as the level beneath it.																									
Understand that food pyramids can be used to model and predict the outcome of a food problem.																									
Understand that after a food problem has distorted a food pyramid, it will always return to a smooth-sided shape. The new pyramid may be a different size or have different number of levels.																									
Represent a food chain with a food pyramid.																									
Analyze and suggest viable solutions for a food chain problem using a food pyramid.																									

Name: ____________________ Team: ____________

Stop/Think/Draw/Write

(Be sure your labels are spelled correctly.)

Photosynthesis, Food, and Populations

Introduction

Question: What do these characters from literature have in common?

- Karana
  Island of the Blue Dolphins by Scott O'Dell
- Brian Robeson
  Hatchet by Gary Paulsen
- Robinson Crusoe
  Robinson Crusoe by Daniel Defoe

Answer: They were stranded alone in an unfamiliar environment. By their own ingenuity, they had to provide for all of the necessities of life.

At first, this may seem like an exciting challenge, but think about the details for a moment. Every day you must catch or grow your food, prepare it, cook it, and store anything left. You must gather water, maintain some kind of shelter, and make and repair your clothing. Every waking moment of your life would be filled with the countless tasks necessary *just to stay alive*.

Direct exchange

It takes a very special person to survive on his own. Two people have a much better chance because they can share their skills and labor. Survival is even more likely if there is a group of people. Within a group, tasks can be assigned according to member skills. For example, I might be a successful farmer, but you might be a much better wagon-fixer. Therefore, you would repair my wagon, and in exchange, I would grow and stack your hay.

This exchange of skills is good for the individual and for everyone in the group. More hay gets stacked and more wagons get repaired! In small groups, such as the early towns of colonial America, tasks were done this way by direct exchange between specialized group members.

In today's much larger society, having each person perform a specific task for everyone else is still a good system, but direct exchange between two people is not practical. Imagine that you are standing at the supermarket meat counter and you need two pounds of meat for dinner:

You: "I'll wash your car,"

Butcher: "Wash my car and cut my grass."

You: "Too much! Wash your car and walk your dog."

Butcher: "Okay, two pounds of meat for your time. You wash my car tomorrow and walk my dog on Sunday."

What confusion! How long would it take to get through a line of customers, each making a direct exchange? Today we use money to buy things and are paid money for the things we do, but is this method different?

Indirect Exchange and Money

Imagine that you work at a clothing store and each Friday you get paid. On the way home one night, you stop at the supermarket to buy two pounds of meat. If you think about it for a minute, you'll realize that this exchange is just like the work exchange. You are trading some of your job time at the clothing store for the meat. The only difference is that the trade is indirect. Your time at the clothing store is converted to money—your paycheck—and you trade some of your money for the meat. Indirect exchange is efficient because money is universally recognized and accepted. The same coin that buys a pack of gum fits in the soda machine. Indirect exchange—money—allows you to receive the benefit of your skills and labor anywhere and at any time.

Taken together, these money-based trades among the members of a large group are called an economy. Our economy binds Americans together in a cooperative network based on our coin of monetary exchange—the dollar.

Food energy economies

There are other kinds of economies, including economies based on food energy. One of the essential life functions of all living things is gathering energy. Living things need energy to drive countless chemical reactions, perform essential activities, and grow. Only after growing can living things reproduce. But where does this energy come from? For most living things, the source of this life energy is the sun.

And here we have a problem. Only green plants are able to capture energy from the sun, so how are animals and other organisms that are not green (like mushrooms) able to gather energy?

The Coin of Energy Exchange

Humans improved the exchange of services by inventing a token system called money. Living things use a token system that allows energy to be passed among living things, similar to the way we use money. In this *Squared Away* unit, you will discover the coin of energy exchange that is used among living things. You will discover that this energy coin, and the way living things use it, is more like our money than you could ever imagine.

Your spending money

Many young people have summer jobs to earn a little money for various purposes. The classic example is mowing lawns. But this income source is seasonal. Once the ground freezes, the lawn mower goes to the back of the garage until spring. How do you manage the loss of income during winter? You have three choices:

- Save part of your summer earnings for use during winter.
- Switch to a winter job.
- Do without money until springtime.

Adults who work seasonal jobs have a fourth choice; they can move to follow a seasonal job.

Within their food energy economy, living things have different ways to cope with the loss of food energy income during winter. The amazing thing is that these winter food energy strategies are identical to winter money strategies within our money economy!

Name: ______________________________ Team: ______________

Stop/Think/Draw/Write 1

Use words and/or drawings to explain.

(Be sure your labels are spelled correctly.)

1. What are the advantages of having a coin-based economy?

2. In what ways are food energy coins in a living community like coins in a money economy?

Making an Energy Coin

The Energy Coin Puzzle

Here is a fun way to make the coin of the energy token system. You must make an energy coin by linking twenty-four pieces together.

A perfect energy coin has a score of 100 points—no more, no less—that is your goal. Here are the twenty-four pieces:

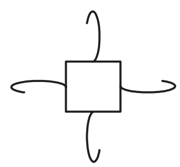
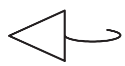
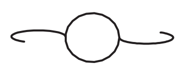
6 Pieces	12 Pieces	6 Pieces
		

Table 1: The puzzle pieces

Notice that each piece has some number of hooks. Squares always have four hooks, triangles always have one hook, and circles always have two hooks. The trick of the puzzle is to join the pieces by linking the hook of one piece into the hook of another piece like this:

Figure 1: Linking hooks

Linking rules

There are two rules to be followed when hooking pieces:

1. One hook must be joined to only one other hook at a linking point.
2. All hooks must be linked to the hook of another piece.

Solve this puzzle with the Energy Coin Pieces Page and a blank sheet of paper. You'll need a glue stick, scissors, and Table 2 on this page for scoring. Note that it's not necessary to draw the hooks once you understand the linking idea. Simply draw a line between two pieces to show the link.

Scoring your energy coin

Your energy coin earns points for each *link* that you make. In other words, the pieces are not counted, just the connections between them. Table 2 shows the point value of each of the six different links you can make. Find your score by counting up the total points of all of your links.

Table 2 also shows the starting pieces of an energy coin. This arrangement makes the energy coin work and must be linked first. Then you can add additional pieces to the single link marked, "Add here."

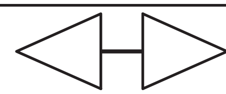
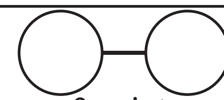
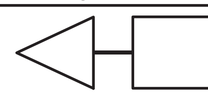
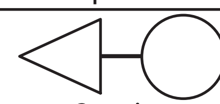
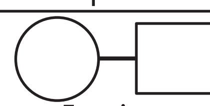
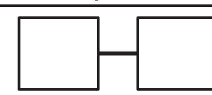
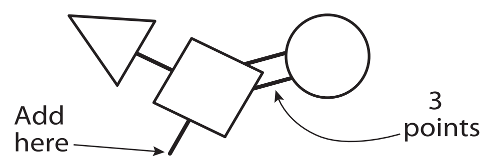
 0 points	 0 points
 1 point	 3 point
 5 points	 10 points
 Starting pieces with special 3-point double link	

Table 2: Links and points

Coin puzzle tips

- Link the starting pieces first.
- Imagine that you are bending the hooks to make the special double link in the starting pieces. This is the only double link in the finished puzzle.
- Add additional pieces starting with the highest value links and working your way down.
- Keep your puzzle in a line and avoid ring shapes.

Remember—your goal is 100 points!

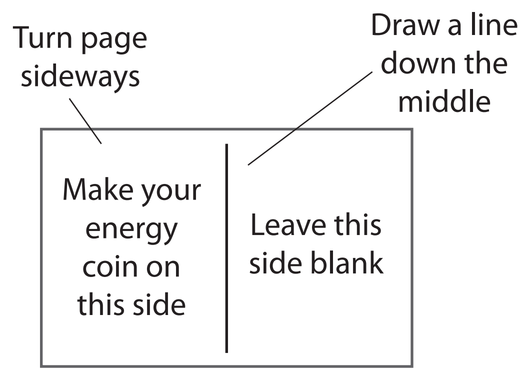
Energy Coin Pieces Page

Below are the energy coin puzzle pieces ready to cut out. Before you start, gather all of the materials and prepare the blank puzzle page. Follow the instructions to make your task easier.

Instructions

1. Prepare the blank puzzle page so that it looks like the illustration.
2. Cut out the coin pieces along the light lines.
3. Review the puzzle linking rules and scoring, then try arranging the pieces to score 100 points.
4. When you are happy with your energy coin, glue each piece by applying a small dab of glue to *one corner* and sticking the piece to the blank puzzle page.
5. Connect the pieces by drawing the link lines between the pieces.

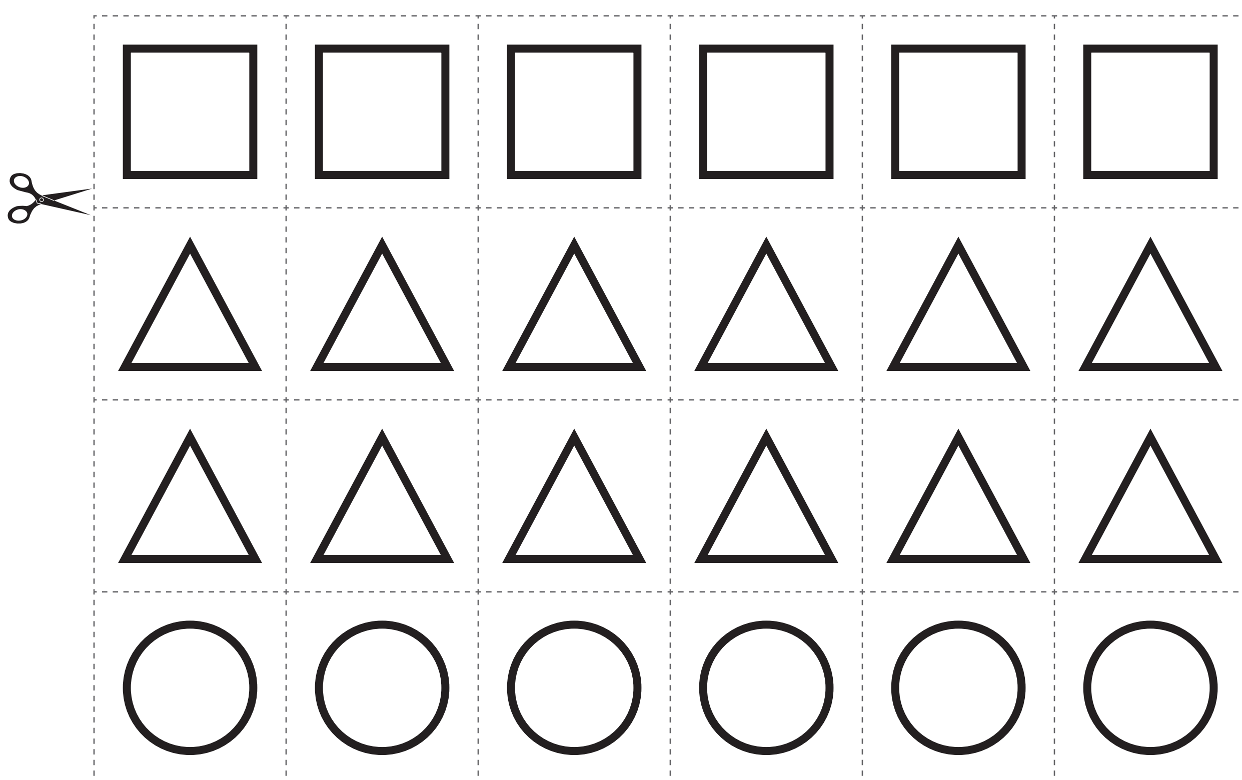
Tip: It's easier to use the eraser end of a pencil than your finger to move the puzzle pieces on the puzzle page.



Blank puzzle page

Materials list

- Scissors
- Glue stick
- Blank sheet of paper
- Pencil with an eraser



Exploring Your Energy Coin

Typical energy coins

If you followed the puzzle rules and scored 100 points, your energy coin will be similar to this typical energy coin.

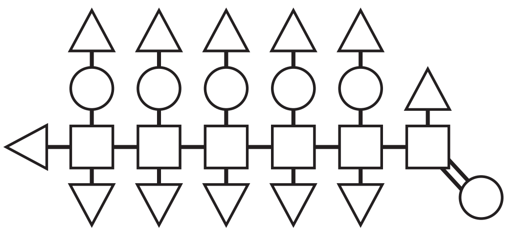


Figure 2: A typical energy coin

Draw your energy coin on the skeleton coin below. Compare your energy coin to the typical energy coin above.

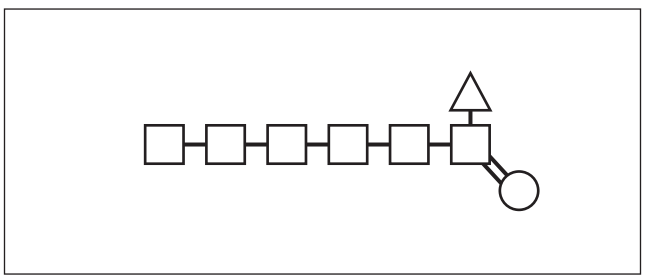


Figure 3: My energy coin

Even if you scored 100 points, your coin may not look like the typical energy coin in Figure 2. That's because there is more than one form of the coin.

Energy coins are simple sugars

The energy coin that you built is really a molecule of simple sugar. There were several correct solutions to the energy coin puzzle because there is more than one kind of simple sugar. The typical energy coin is the simple sugar *glucose*. Other energy coin sugars include galactose and mannose. You can tell that these energy coins are sugars by their "-ose" endings.

Simple sugars and energy coins

From now on, we will use *energy coin* to refer to the puzzle shape that you built. We will use *simple sugar* to refer to the food energy compound found in plants and animals. Your energy coin is a model of a simple sugar.

Where are energy coins stored?

Where is your money? That's easy, it's in your pocket, wallet or purse. Continuing the comparison between money and energy coins, where are simple sugars stored by plants and animals?

Concentrating food energy

We store money for times when we need it. But storing (We call it saving) small coins is a nuisance because they take up a lot of space. We solve that problem by combining many small coins into a few larger coins or bills.

Plants and animals need to store energy for times when they need it, just like we need to save money. They also have the same problem because simple sugars are like small coins—storing them is not efficient. Plants and animals are like our money again in that they solve the storage problem the same way we do, they change many simple sugar molecules into a few more concentrated forms.

Starch, oils, and fat

Starch is the most common form of stored food energy in plants. Starch is made of many simple sugar molecules hooked together to form a much longer box chain.

Storing the food energy of simple sugars as oil or fat is more complicated, but uses the same box-triangle-circle pieces. Oils are found in both plants and animals, but fats are primarily an animal food energy storage material.

Name: ____ Team: _______________

Stop/Think/Draw/Write 2

(Be sure your labels are spelled correctly.)

Use words and/or drawings to describe how plants and animals store energy.

Name: ____ Team: _______________

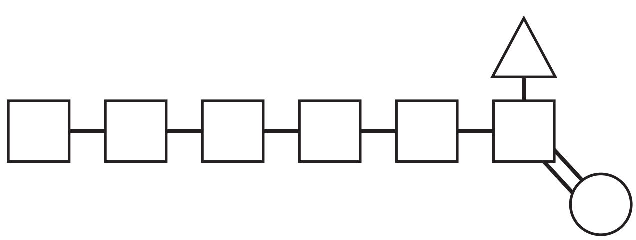
Quick Team Quiz One

Choose the best answer and write the letter on the line.

1. Which is an example of a direct exchange in an economy: _____
   a. You pay the butcher $3.00 for 1 pound meat.
   b. You mow the butcher's lawn for 1 pound of meat.
2. The most important advantage of an indirect exchange economy is ______
   a. that many people can do the same job.
   b. that it is slower than a direct exchange.
   c. that the economy is based on a universal coin used to buy different kinds of things.
   d. that you can bargain for what you want.
3. There is only one way to complete the food energy puzzle because there is only one kind of simple sugar. _____ (T or F)

Fill in the blanks

4. You discovered that your energy "coin" was really a _______________ _________________.
5. Glucose, galactose, and mannose are examples of ________________ _________________.
6. Plants make starches to ______________________ simple sugars.
7. The stored form of food energy in animals is called __________________________________.
8. Draw a simple sugar molecule by adding to the following:



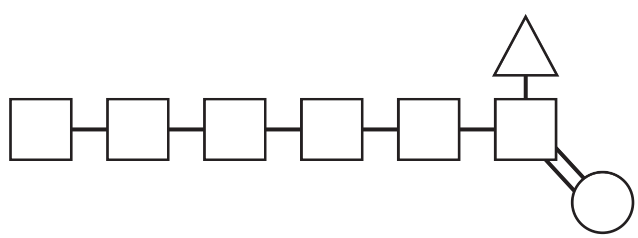
Name: ______________________________ Team: ______________

Square One Test

Circle the letter in front of your answer.

1. Direct exchange.	A. Mike mows the Baker's lawn in exchange for 5 loaves of bread. B. Mike gives the Baker $10 for 5 loaves of bread.	
2. The "coin" of exchange in nature is ______.	A. a simple sugar B. a starch	C. a fat D. oxygen
3. Glucose, galactose, and mannose are examples of ______.	A. simple sugars B. starches	C. fats D. gases like oxygen
4. The most commonly found concentrated food energy in plants are ______.	A. simple sugars B. starches	C. fats D. gases like oxygen
5. The most commonly found concentrated food energy in animals are ______.	A. simple sugars B. starches	C. fats D. gases like oxygen

Extra credit: Draw a sugar molecule by adding circles and triangles:



Where is Starch Stored?

Plants need to store food energy for many purposes. Can you determine what those purposes might be by reviewing your results at the end of the investigation? Before you start, gather all of the materials and prepare the blank puzzle page. Follow the instructions to make your task easier.

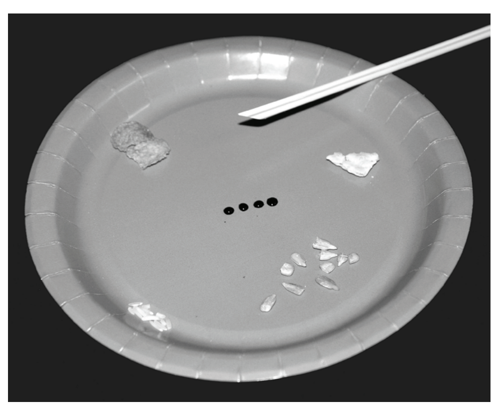
Instructions

1. Team: The starch testing solution will stain clothes and skin. Be careful as you work with it. Cover your work area with several layers of newspaper.
2. Recorder: Prepare a data page with the following columns: *Sample name*, *Plant part source* (e.g., seed, root, etc.), and *Starch test result*.
3. Reader: Flatten the end of a plastic soda straw. Cut the flattened end at an angle so that it looks like the tip of an old-fashioned ink pen.
4. Reader: Review the list of materials available for testing with the team.
5. Leader: Manage a short team discussion to choose four materials to test.
6. Manager: Gather the chosen four materials on a small plastic plate. Place four drops of starch test solution in the middle of the plate. See the example test plate.
7. Team: Each member uses the pointed tip of the soda straw to apply a single drop of starch testing solution to one of the test materials.
8. Recorder: Record all data for samples as each is tested. Use this scale to evaluate results:
    - Color remains chestnut brown. Record as 0, no starch present.
    - Color turns blue-black. Record as +, starch present.
    - Color reaction unclear. Record as ?, not able to determine.
9. Team: After all four samples have been tested and recorded, repeat steps 4 through 9 with new samples.
10. Team: Roll up all used materials in the center of your newspaper and discard.
11. Leader: Submit the completed data page to your teacher.

Materials list

- Newspaper
- Small plastic plate
- Plastic soda straw
- Scissors
- Starch testing solution
- Notebook paper
- Pencil

Danger!
The starch testing solution is poisonous if swallowed. Keep your hands away from your mouth!



Example Test Plate

Spending Your Energy Coin

Cashing in your energy coin

In the introduction, we made the point that money is a token system for labor and skills. Then we compared money to simple sugars among living things. Living things use simple sugars to move energy, both within themselves and among each other. But to "cash in" a simple sugar molecule to get the energy stored inside, you must take your energy coin apart.

Living things can't release the energy of simple sugars by simply pulling them apart. The uncontrolled release of energy would be like a chemical bomb inside a cell. Instead, a very complicated process takes the simple sugar apart in a special order.

Taking apart your energy coin

Fortunately we can skip those steps and easily take your coin apart by producing only the final remaining shapes. These shapes, circle-box-circles, and triangle-circle-triangles are harmless. For convenience, we will shorten the shape names to CBC for the first, and TCT for the second. You can see those shapes and their abbreviations in Table 3, below.

Shapes Built From My Coin	
CBC	TCT

Table 3: Shape counting record.

Here's how to take apart your energy coin. If your coin has a problem, you may rearrange it like the typical energy coin if you prefer.

1. Decide whether you wish to make a CBC or a TCT shape from your coin. Either one is okay.
2. Peel the needed pieces from your finished coin on the left side of your puzzle page.
3. Use a glue stick to stick the pieces in the form of your chosen shape on the right side of your puzzle page.
4. Connect the pieces by drawing the link lines between the pieces
5. Make a counting mark in the space under that shape in Table 3.
6. Repeat steps 1 through 3 until you are unable to make anymore CBC or TCT shapes.
7. Each time you make a new shape, you can choose either one as long as you have the necessary pieces.

Energy that can't be used

You didn't take apart all of your energy coin, did you? Describe in the space below why you were unable to completely dismantle your energy coin.

CBC and TCT shapes

There are four combinations of CBC and TCT shapes that can be formed when you take apart your energy coin. For example, you may have chosen to make only CBC shapes, but your friend may have chosen to make two or more TCT shapes. The number of each shape that can be made depends on how you use the six circles in your energy coin.

Table 4 shows the possible CBC–TCT shape combinations. Find the row that matches your combination and fill in the missing number. To discover the other combinations, start with the first row. Ask yourself: "How many TCTs can I make if I make zero CBCs?" Use this procedure to discover the remaining CBC–TCT shape combinations.

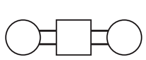
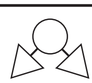
	
0	
	4
	2
3	

Table 4

In spite of your best efforts, a large chunk of your original energy coin is still intact—with most of its energy still locked inside! It's like putting money in the bank and then not being able to get it out. How can we dismantle that remaining chunk?

The Circle Source

The solution is to "invent" the Circle Source. For the moment, this source will remain a mystery. Later you will discover for yourself what this source is and that it is very real. The Circle Source will give you as many circles as you want, but there's a catch. The Circle Source will only give you circles in *pairs of circles*. You can take the pairs apart and use them separately, but you must use both circles.

Circle pairs can be split into separate circles.

Taking apart the whole coin

Now you can take apart that remaining big chunk and release all of the energy stored in your energy coin.

In the next section we will need an accurate count of the total CBC and TCT shapes made from your energy coin, plus the number of circle pairs that you used from the Circle Source. So before you start making more CBC–TCT shapes, copy your counting marks from Table 3 to Table 5 below.

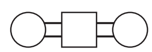
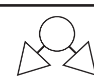
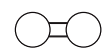
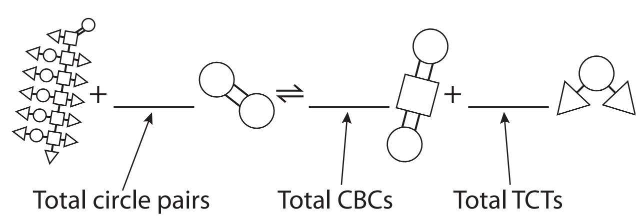
Shapes Built		Pairs Used
		

Table 5: Total shapes from my energy coin

Finish taking apart your energy coin by peeling pieces from the remaining chunk. Paste each CBC or TCT shape on the right side of your puzzle page as before. When you need circles, make a counting mark in Table 5 under *Pairs used* and simply draw the circles into place on your puzzle page.

Finally, add up all of each of the three shapes. Write each total on the line before that shape in the summary statement below. There is no line before the energy coin because we took apart only one of them.



Counting your energy cash

If your shape counts are correct, and you read the summary statement as a sentence, it should sound like this:

"We took apart one energy coin,
using six circle pairs,
and made six circle-square-circles,
plus six triangle-circle-triangles."

This summary statement is incomplete however. You took your coin apart to release its stored energy. We can account for that energy by adding an additional sentence. Here is the complete summary statement:

"We took apart one energy coin,
using six circle pairs,
and made six circle-square-circles,
plus six triangle-circle-triangles,
plus a lot of energy."

Puzzle pieces are chemical atoms

Working with the puzzle pieces was an interesting challenge, but drawing all those shapes and links was a pain. Fortunately chemists, scientists who study atoms, have a much easier system.

All matter is made of atoms. A group of the same kind of atom makes up an element. The square, triangle, and circle puzzle pieces that you have been working with are really atoms of three common elements. Table 6 shows the names and symbols of those elements.

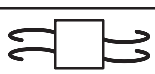
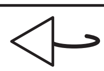
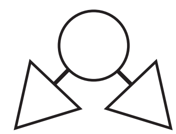
Piece	Element	Symbol
	carbon	C
	hydrogen	H
	oxygen	O

Table 6: Puzzle piece element names.

Molecules are groups of atoms

Molecules are formed when two or more atoms are linked together. You were actually forming molecules when you linked puzzle pieces—atoms—together to form shapes.

Use Table 6 to redraw the TCT shape by substituting chemical symbols for its puzzle pieces.



=

Shape with pieces Shape with symbols

To make writing molecules easier, the symbols are written in a straight line, like the letters of a word. Also, there is an order of atoms. C (carbon) comes before H (hydrogen) which comes before O (oxygen). Now write the three-letter group that identifies the triangle-circle-triangle shape. Remember the order of atoms and place the letters for the two triangles one after the other.

______ ______ ______

If there is more than one of the same atom in a molecule, its symbol is written once and a small subscript number is written after the atom to show how many there are. Rewrite your three-letter group, but this time replace HH with H_2.

______$_2$ ______

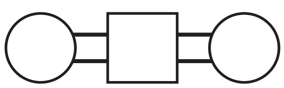
Do you recognize this well-known molecule?

Hey—I know that molecule!

Now that we have converted the TCT shape to its chemical name H_2O, you will realize that half of what comes from releasing energy from simple sugar is plain water!

What about the CBC shape, can you convert the other half of what comes from releasing energy from simple sugar? Follow the same steps to write its chemical identity on the lines below. The subscript number is already in place.

1. Convert the pieces to their atomic symbols.
2. Group same symbols.
3. Write the symbols in the C-H-O order.
4. Add subscripts if there is more than one of the same kind of atom (done for you).

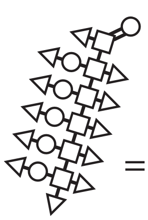


= ____ ____2

You probably know this molecule, CO_2, is carbon dioxide. Its the gas that is in our breath, that makes bread rise, and makes soda fizzy.

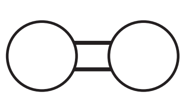
Converting the remaining shapes

There are only two shapes left to convert, the simple sugar, glucose, and the circle pairs. Use the same four steps to make these last conversions.



= ____6 ____12 ____6

Glucose with pieces Glucose with symbols



= ____2

This molecule, O_2, is oxygen gas. Oxygen gas makes up 19% of our atmosphere.

The summary statement as a chemical equation

With all of the shapes converted to chemical symbols, we can write the summary statement as a chemical equation:

$$C_6H_{12}O_6 + 6O_2 \rightleftharpoons 6CO_2 + 6H_2O +$$

Take a moment to compare this chemical equation to your summary statement. The full-sized numbers in front of the molecules show the number of shapes that you used or made. The lightning bolt represents the fifth line in your statement, the energy that was released.

"We took apart a simple sugar molecule,
using six oxygen molecules,
and made six carbon dioxide molecules,
plus six water molecules
plus a lot of energy."

Where is energy stored in a simple sugar molecule?

The energy is stored in the carbon-to carbon links. A simple sugar molecule is like a spring. It takes energy to stretch a spring, and you get that energy back when you release it. In the same way, it takes a lot of energy to link two atoms of carbon together and you get a lot of energy back when you break that link. That's why the square-to-square connection was worth ten points; it stores more energy than any of the other connections!

The more carbon-to-carbon links in a molecule, the more energy it contains. Ethane is a gas that has one carbon-to-carbon link. Propane, the gas used in some stoves, has two links, and butane has three. Compared to those molecules, our simple sugar molecule, with five carbon-to-carbon links, contains a lot more energy!

Where does this energy come from and how does it get into simple sugars? You will find out in Instruction Block Three.

Fermentation

Storing Food

Among the most important developments in modern times are canning and refrigeration. Before these techniques, storing food was an essential but difficult task. Only a good supply of stored food stood between life and starvation during winter.

We introduced simple sugars as energy coins, because like money among humans, they are accepted by virtually all living things. Unfortunately, that universal acceptance means that our stored foods are good energy sources for just about any animal—big or small. And not just animals; non-green plants use simple sugars too. Unprotected, stored foods are likely to be lost to uninvited consumers. How were foods stored before canning and refrigeration?

The trick is to make stored foods less attractive to those would-be thieves while remaining edible for humans. Meat and fish were dried or salted. Fruits were protected by adding sugar—jams and jellys. These are examples of techniques that stop non-green plants from attacking foods. Fermentation is another food preserving techique that makes food less likely to spoil.

Fermentation converts simple sugars to ethanol and carbon dioxide. Ethanol is also called grain alcohol and is the same alcohol found in beer and wine. Ethanol has a single carbon-to-carbon link at its center, so it has stored food energy, but much less than the original simple sugar. The decision to ferment food is a trade-off, less food energy for the ability to store food for a longer time.

Small Farms

Most small farms raise field crops and a few animals. Every drawing of one of these farms includes a barn with a silo—the tall cylinder attached on one side. It's purpose is to store food for the animals. This stored food is protected from spoilage by fermentation.

Silage

Here's how it works: After the fall harvest, the farmer chops the stalks of corn and other field crops into small pieces and loads them into the top of the silo. The weight of the chopped material presses out any air from the stalks, making it an anaerobic (oxygen-free) environment.

This is ideal for natural fermentation and within two weeks, the simple sugars in the chopped stalks begin to ferment. As the simple sugars break down, energy is released and the temperature inside the silo begins to rise. After fermentation, the material, now called silage, can be fed to ruminant animals, like sheep and cows, all winter. And yes, the animals get drunk if they eat too much silage!

Hard cider

Apples were a staple crop in early New England because the trees grow well on slopes that were hard to till for other crops. Their fruit is tasty, but hard to keep. Every New England village had a cider mill where apples were squeezed for their juice. Then the juice was fermented to make hard cider. Everyone drank hard cider as part of their diet, including children. This was simply a fact of life; a valuable source of food energy.

Fermentation and carbon dioxide

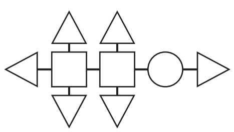
The other product of fermentation is carbon dioxide gas. Carbon dioxide gas combines with water to make a weak acid. It's the carbon dioxide gas dissolved in water that gives soda its tangy taste.

The original root beer was just that—fermented sassafras root juice! The flavor came from the sassafras, the tang came from the carbon dioxide, and amount of alcohol was small so that intoxication usually was not a problem. Benjamin Franklin had his own special recipe, described in his autobiography.

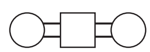
You have seen that to take apart an energy coin completely, you need extra circles—oxygen. But if anything, living things are resourceful. Fermentation is a way to partly take apart an energy coin without any extra oxygen.

Instructions

1. Cut out the puzzle pieces and prepare a blank puzzle page as you did in the activity, *Energy Coin Pieces Page*. Write "Fermentation" at the top of the page.
2. You know that these 24 pieces make a simple sugar, so it is not necessary to glue them down. Simply spread them on the left side of the blank puzzle page.
3. Take apart the imaginary energy coin (the spread out pieces) as before. You will make carbon dioxide again, but this time you will make ethanol (grain alcohol) <u>instead of water</u>. Here are their shapes:



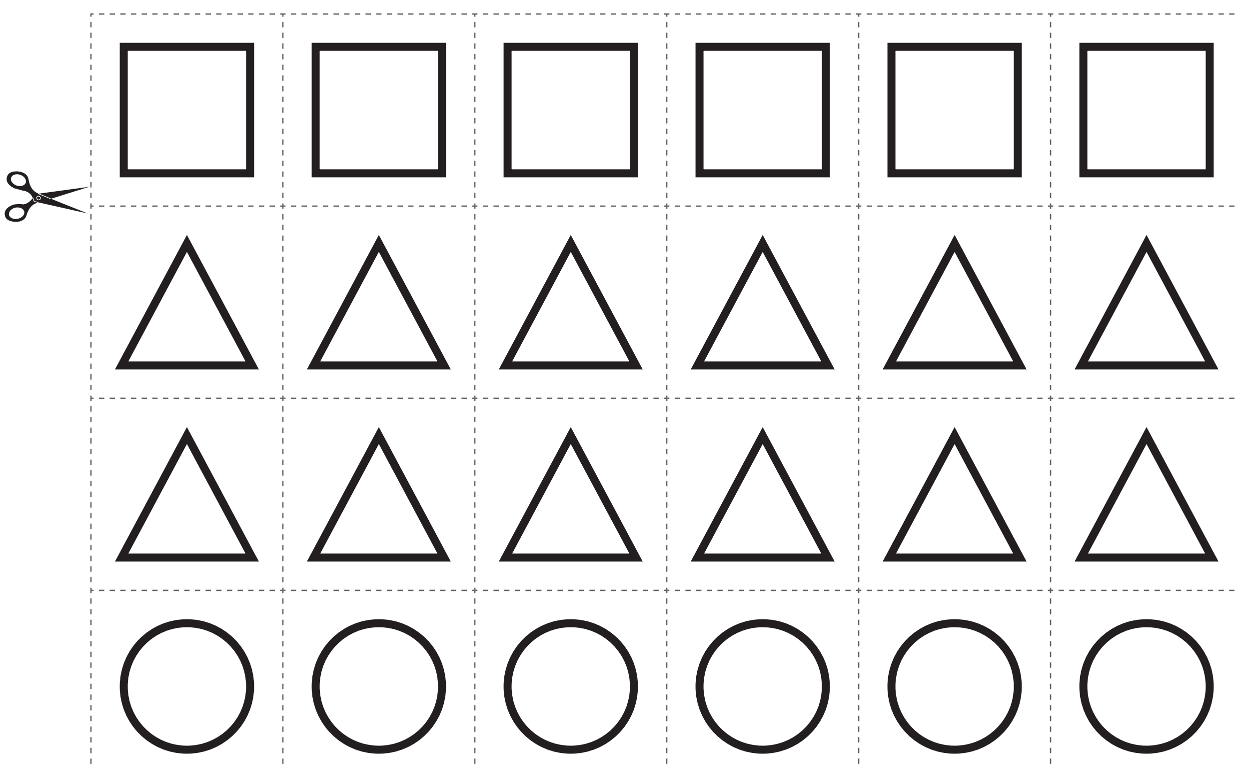
ethanol



carbon dioxide

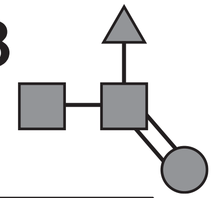
4. Follow the puzzle piece linking rules and use all 24 pieces.
5. When you are happy with your shapes, use a glue stick to stick the pieces to the right side of your puzzle page.
6. Connect the pieces by drawing the linking lines between the pieces.
7. Record the following in complete sentenses on the left side of your page:
   - Total number of ethanol shapes that you made from a simple sugar.
   - Total number of carbon dioxide shapes that you made from a simple sugar.
   - Were you able to release any energy by making ethanol and carbon dioxide?
   - Which releases more energy, taking apart a simple sugar with oxygen or without oxygen? Explain your answer.

Tip: Remember that energy is released from simple sugars by breaking carbon-to-carbon links. Ask yourself, "How many carbon links were broken?"



Name: ____ Team: _______________

Stop/Think/Draw/Write 3



Use words and/or drawings to explain.

(Be sure your labels are spelled correctly.)

1. Why were you originally unable to take apart all of your simple sugar molecule?

2. What is the "circle source" in real life and where do you find it?

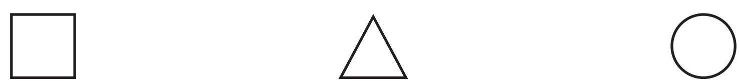
3. How does the "circle source" help living creatures to take apart simple sugar molecules?

Name: ____ Team: _______________

Quick Team Quiz Two

Fill in the blanks

1. You discovered that your Energy "coin" was really a ______________ ________________.
2. The most common form of stored food energy in plants is ___________________________.
3. You can often tell a simple sugar because it ends with "-______."
4. When you were taking apart your energy coin, what piece (triangle, circle, or box) did you run out of? _____________
5. What letters are used to describe carbon ______, hydrogen ______, and oxygen ______?
6. For the Energy Coin activity, you used three pieces for the elements. Use the pieces to draw the molecules below:



carbon hydrogen oxygen

What did your oxygen molecule look like?	What did your water molecule look like?	What did your carbon dioxide molecule look like?

7. What letters and numbers do you write to describe a molecule made up of hydrogen + hydrogen + oxygen? _____________
8. What letters and numbers do you write to describe a molecule made up of carbon + oxygen + oxygen? _____________
9. What molecule does $C_6H_{12}O_6$ describe? ____________________ ____________________
10. Most of the energy of a simple sugar molecule are in the _____________ to _____________ links.

Name: ______________________________ Team: ______________

Square Two Test

Circle the correct answer.

1. The "coin" of exchange in nature is ______.	A. a simple sugar B. a starch	C. a fat D. oxygen
2. The ending -ose often identifies ______.	A. a simple sugar B. a starch	C. a fat D. oxygen
3. Plants store energy in the form of ______.	A. a simple sugar B. a starch	C. a fat D. oxygen
4. You can't take apart an energy coin completely unless you add...	A. a simple sugar B. a starch	C. a fat D. oxygen
5. What is CO_2?	A. water B. simple sugar	C. carbon dioxide D. oxygen
6. What is $C_6H_{12}O_6$?	A. water B. simple sugar	C. carbon dioxide D. oxygen
7. What is H_2O?	A. water B. simple sugar	C. carbon dioxide D. oxygen
8. In a molecule, more energy is stored in which link?	A. oxygen to oxygen B. carbon to carbon	C. carbon to oxygen D. carbon to hydrogen

Bonus: Explain why a sugar molecule has more energy than a propane gas molecule.

Oxidation and Photosynthesis

In the chemical equation below, the arrows in the middle are pointing both right and left. This means that the energy coin reaction can run both ways.

$$C_6H_{12}O_6 + 6O_2 \rightleftharpoons 6CO_2 + 6H_2O + ⚡$$

Oxidation

As you took apart your energy coin, you were working from left to right. You used oxygen to release the energy stored in a simple sugar molecule. Along the way, you produced carbon dioxide and water. This process is called **oxidation** and it is the energy source that powers animal life.

As animals, we eat food that contains simple sugars, we take in oxygen with the air we breathe, and we breathe out carbon dioxide gas and water vapor. As you have seen, the mysterious Circle Bank is simply the oxygen in the air we breathe.

Reversing the equation

Now read the equation using the lower arrow—from right to left.

> "Using energy, something combines six water molecules and six carbon dioxide gas molecules to make six oxygen molecules plus a molecule of simple sugar."

What is this sugar-making something?

Photosynthesis

The "something" that makes simple sugars are green plants. The process is called **photosynthesis** and the energy green plants use is sunlight!

Think about that for a moment. Although tremendous light energy pours over Earth every second, as an animal, you can't use it! Only green plants can convert sunlight energy into a form that we, and other animal life, can use. For this reason, green plants are called **producers**. During photosynthesis, green plants take in sunlight, carbon dioxide gas, and water, then make simple sugars, and release oxygen gas.

Trading partners

Animals get simple sugars directly, or stored as starch, from green plants by eating their stems, roots, leaves, and seeds. This is why animals are called **consumers**. Then they use oxygen to release the energy stored in simple sugars. During oxidation, animals release the same carbon dioxide gas and water that green plants take in during photosynthesis.

In Figure 4 below, note that the oak tree and the chipmunks are trading the same atoms back and forth, but the energy flows from sun to green plant to chipmunk. This energy coin pathway from producer to consumer is called a **food chain**. In this way, plants and animals are part of an energy economy that exchanges food energy—your energy coin.

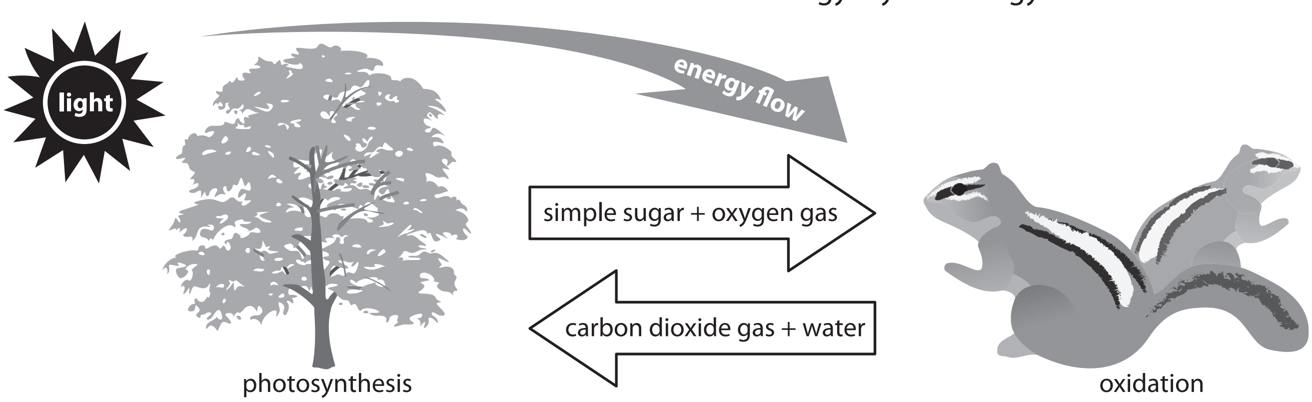


Figure 4: Trading partners

Animals need oxygen

If animals use oxidation to release the energy of simple sugars, then it seems reasonable that animals must need oxygen to do that. Most animals that we see everyday—dogs, cats, birds, for example—clearly breathe air. But some animals don't seem to breathe, so how do they get oxygen?

Some animals take in oxygen through their skin. Earthworms take in oxygen from the small amount of air found in the tiny spaces between soil particles. When it rains, these soil air spaces are flooded—that's why you see so many earthworms on top of the soil after a soaking rain. They are literally drowning!

Oxygen dissolves in water

Fish live underwater, away from the oxygen in the air. How can they get oxygen? Oxygen dissolves in water, but only a little bit. Oxygen gas makes up about one-fifth of the air we breathe. But oxygen in water only makes up a few parts in one million! Fortunately, this tiny amount is enough for fish to take from water with their gills.

Green plants and chlorophyll

Chlorophyll is the green pigment that gives green plants their color. This pigment is essential to photosynthesis because it captures light energy in the first step toward making simple sugars. Although chlorophyll may be masked by other colors, it is present in all green plants.

Non-photosynthetic organisms

Non-photosynthetic organisms do not have chlorophyll, so they can't capture the energy in sunlight. Therefore, many non-photosynthetic organisms use oxidation to get their energy, and yes, they eat just like animals! Mushrooms and bacteria are examples of non-photosynthetic organisms that use oxidation. Yet you have never seen a mouth on a bacterium or a mushroom, so how do they eat?

Non-photosynthetic organisms and decay

After we eat, chemicals digest the food in our stomachs. Mushrooms and bacteria also secrete chemicals that break down their food, but this happens outside their bodies. Then they absorb the digested food as a liquid. This is extremely helpful for other life because it's the only way to release the nutrients trapped in dead things so that living things can reuse them. This is why gardeners add grass clippings to the soil. Bacteria break down the clippings and release trapped nutrients so that new plants can grow well.

On the other hand, when bacteria use chemicals to dissolve the back of our throats, we call that a sore throat and take medicine to stop them from trying to eat us alive.

When are green plants like non-green plants?

In order to introduce key ideas, we have presented photosynthesis as a green plant process and oxidation as an animal process. In fact, green plants also use oxidation around the clock to release needed cell energy from some of their simple sugar. The difference between green plants and animals is that in daylight, photosynthesis produces much more simple sugar and oxygen than green plants use, so they build a surplus of simple sugar and release the extra oxygen. But at night, photosynthesis is not possible and only oxidation continues. At night green plants are like non-green plants because they must take in oxygen to supply needed cell energy through oxidation.

Water pollution and fish kills

Some forms of water pollution encourage the growth of green plants in lakes or streams. The problem comes at night when these green plants may use up most of the tiny amount of oxygen in the water. On a particularly bad night, the oxygen may drop too low for fish to survive. When this happens, the shore will be littered with dead fish in the morning!

These are just a few of the many ways that the opposite energy reactions, oxidation and photosynthesis, affect our living world.

Food Chains and Food Webs

Food chains

Earlier, we learned that the feeding relationship between an oak tree and a chipmunk is called a food chain. Now imagine a meadow by a stand of trees—perhaps there's a small stream nearby and it's late spring. In this meadow are grasses, mice, snakes, and owls in the trees.

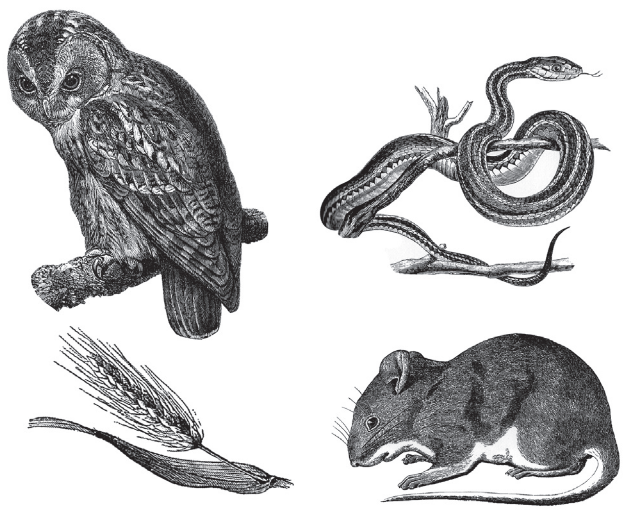


Figure 5: Meadow life

As you have learned, all food chains must begin with a green plant. Green plants are called **producers** because they are the only food chain member that can convert the sun's light energy into food energy by making simple sugars.

The next member of the food chain is the **first-order consumer.** This is always a plant-eating animal, so the first-order consumer is also called an **herbivore**.

The **second-order consumer** is an animal that eats the first-order consumer. Because the first-order consumer is an animal, the second-order consumer is also called a **carnivore**, or meat-eater.

Other consumers follow in number order after the second-order consumer, depending on the animals present. The final consumer, eaten by no other animal is the **apex predator**. There can be more than one apex predator.

Build you own food chain

Using the animals shown in Figure 5, build your own food chain by writing the names of each life form on the lines below.

- Third-order consumer ________________
- Second-order consumer ______________
- First-order consumer _________________
- Producer ____________________________

Now see if you can name each animal by its food source name.

- Who is the apex predator in your food chain?

  ____

- Who is the herbivore in your food chain?

  ____

- Who is one of the carnivores in your food chain?

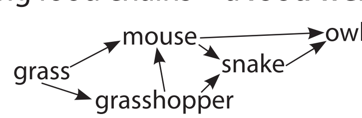
  ____

Food webs

Assume this feeding order for a moment:

grass – mouse – snake – owl

That's a perfectly reasonable food chain, but how would it change if one day the owl ate a snake and the next day it ate a mouse? Or what if we added a grasshopper? This is much more like the real world and creates a web of interlocking food chains—a **food web.**



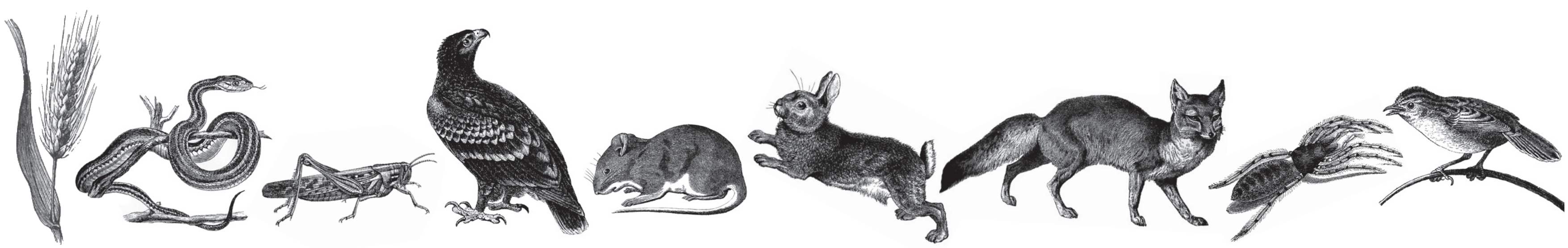
The arrows show the direction of food energy flow. How many separate food chains can you trace in this food web by following the arrows? In a food web, many animals have more than one consumer order number. Trace your food chains to find how the owl can be a second-, third-, or fourth-order consumer.

Name: ______________________ Class: ____________

My Meadow Food Web

grasshopper

grasses



<u>Grasses</u>	<u>Snake</u>	<u>Grasshopper</u>	<u>Hawk</u>	<u>Mouse</u>	<u>Rabbit</u>	<u>Fox</u>	<u>Spider</u>	<u>Bird</u>
	grasshopper mouse spider	grasses	snake mouse rabbit bird	grasses	grasses	snake mouse rabbit bird	grasshopper	grasses grasshopper spider

Try your hand at building a realistic meadow food web using these life forms. Each image represents several closely related species. Begin by noting what each animal eats. Use scrap paper to lay out your food web with the producer on the left and the apex predators on the right. Use the food lists to place each animal in the food web. When you have the layout completed, draw boxes on this page containing the name of each animal. Then show the flow of food energy by drawing arrows away from the producer. The grasses (producer) and grasshopper have been done to get you started.

Name: ______________________________ Team: ______________

Stop/Think/Draw/Write 4

Use words and/or drawings to explain the following experiment.

(Be sure your labels are spelled correctly.)

Scientists conducted an experiment placing a mouse in a closed terrarium with plants and water. Although there was no air available from the outside, the mouse survived. Explain why the mouse was able to live without outside air.

Vocabulary Flashcards

carbon dioxide	oxygen	water
simple sugar	producer	first consumer
second consumer	third consumer	apex predator
herbivore	carnivore	sunlight
oxidation	photosynthesis	chlorophyl
food web	food chain	energy flow

Name: ______________________________ Team: ______________

Quick Team Quiz Three

Write the formula for oxidation and photosynthesis:

The formula above may help you to fill in the blanks:

1. During oxidation, animals release molecules of ______________ and ____________.
2. During photosynthesis, plants produce molecules of ____________ and ____________.
3. During oxidation, animals take in molecules of ______________ and ____________.
4. During photosynthesis, plants take in molecules of ____________ and ____________.
5. ____________________ is the energy plants capture to complete photosynthesis.
6. Green plants use the energy they capture to make ______________________________.
7. ____________________ is the pigment that allows green plants to capture energy.
8. Non-green plants are like animals because they get their energy from the process called

   ___________________ .
9. When do green plants use oxidation only? _________________________________
10. Chipmunks and oak trees are life trading partners.
    a. Chipmunks provide _______________ and _______________ for the oak tree.
    b. The oak tree provides ______________ and _______________ for the chipmunk.
11. In the feeding relationship represented by grass → mouse → snake → owl:
    a. The grass is known as a ____________________ .
    b. The apex predator is the ___________________ .
    c. The second consumer is the _________________ .
    d. The herbivore is the ______________________ .
12. When two or more food chains are interlocking, the food chain becomes a ____________.
13. What letters and numbers do you write to describe a molecule made up of hydrogen + hydrogen + oxygen? ___________
14. What letters and numbers do you write to describe a molecule made up of carbon + oxygen + oxygen? ___________
15. What molecule does $C_6H_{12}O_6$ describe? __________________ __________________
16. Most of the energy of a simple sugar molecule are in the ________ to ________ links.

Name: ______________________________ Team: ______________

Square Three Test

Circle the correct answer.

1. Plants store energy in the form of _______.	A. oxygen B. a starch	C. a fat D. a simple sugar
2. You can't take apart an energy coin completely unless you add _______.	A. oxygen B. a starch	C. a fat D. a simple sugar
3. What is $C_6 H_{12} O_6$?	A. water B. oxgen	C. carbon dioxide D. simple sugars
4. In a simple sugar, more energy is stored in which link?	A. oxygen to oxygen B. carbon to carbon	C. carbon to oxygen D. carbon to hydrogen
5. Write the formula for oxidation and photosynthesis.		
6. During oxidation, animals release carbon dioxide and _______.	A. oxygen B. simple sugars	C. hydrogen D. water
7. During photosynthesis, plants produce oxygen and _______.	A. hydrogen B. carbon dioxide	C. simple sugars D. water
8. During oxidation, animals take in oxygen and _______.	A. oxygen B. simple sugars	C. hydrogen D. water
9. During photosynthesis, plants take in water and _______.	A. carbon dioxide B. simple sugars	C. hydrogen D. oxygen
10. In a food web, grass is always...	A. a first order consumer B. a second order consumer	C. a producer D. an apex predator
11. In a food web, an owl is often a/an...	A. producer B. first order consumer	C. second order consumer D. apex predator
12. Write the names of a four-part food chain that might occur in a meadow.	☐ → ☐ → ☐ → ☐	

13. The energy that green plants capture comes from	A. water B. oxygen C. sunlight D. a simple sugar
14. When must green plants "act like animals" and use oxidation only instead of oxidation and photosynthesis?	
15. Mushrooms, molds, and bacteria are non-photosynthetic organisms and therefore....	A. they use oxidation. B. they use photosynthesis. C. they use sunlight. D. they give off oxygen.
16. Chlorophyll...	A. is another name for carbon dioxide. B. is used by plants during the night. C. captures light energy from the sun. D. is given off by animals in oxidation.
17. Fish kills occur at night because...	A. all the carbon dioxide is used up. B. green plants use up all the oxygen in the water. C. there is no chlorophyll in the water. D. the fish release too many simple sugars.
Bonus: How is a food chain different from a food web?	

Food Pyramids

There's no free lunch

At the end of each day, bank tellers must add up all of the money they took in, then subtract the money they gave out. The difference must match the money in their cash drawers—to the penny! This procedure allows close control of the money in the bank.

Food energy in a living community is just as strictly counted, not by tellers, but by life itself. Food energy is measured in calories, the same calories that you hear about with diets. The green plants of a meadow produce a certain number of food energy calories as simple sugars each day, and those calories will support a certain body weight of animals, but no more! If one more mouse should come into the meadow, all mice will have a little bit less to eat. They will all lose a little bit of weight, so although there is one more mouse in the meadow, the *total weight* of their bodies will remain the same.

There are countless examples of this strict relationship between producers and consumers:

- Cattle ranches are limited by the amount of grazing land they have, not the number of cows. Adding more cows only produces skinnier cows.
- Fisheries managers stock fresh-water streams with hatchery-raised trout to replace the fish taken by fishermen. This keeps fishermen catching fish and buying licenses. But adding too many hatchery fish stunts their growth.
- Famine is a reoccurring problem for many African nations. The food supply is reduced when long dry spells cause cropland to turn to desert sand, causing widespread hunger.

In each case, the total weight of cattle, fish, or people is limited by the weight of producers. Underfed cows, fish, and people are not just underweight, they are more likely to die from diseases and metabolic problems.

The unyielding rule is that pyramid balance is always maintained. If consumer weight rises or producer weight falls, the weight of *individual* consumers must decrease.

Food chains are useful tools

We have seen that real world ecosystems are made of food webs. However, food chains are very useful for studying parts of a food web. Here is the simple meadow food chain that we used before. It shows the order of consumers beginning with the producer.

grass – mouse – snake – owl

Here is the same food chain shown as a food pyramid. The food pyramid is built on the producers because they support the consumers.

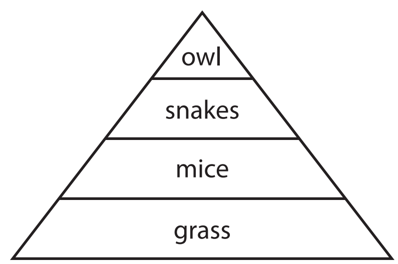


Figure 6: A balanced food pyramid

The members of the food chain are stacked in order, with the owl at the top—the apex predator.

Food pyramids show populations

It takes about ten times as much weight of food to grow one weight of animal body. Some animals require a bit less, others a bit more, but a ten-to-one ratio of food to growth is a good average value. That means that the amount of food energy each food chain link is ten times lighter than the amount of food energy before it. The pyramid shape reminds us of this ten-to-one ratio.

To convert a food pyramid level to the population size (the number of members of the group), you must divide the weight of the level by the average weight of one group member.

Balancing food pyramids

Food pyramids show whether animal populations are balanced or not. If not, they allow us to predict changes that will occur. Food pyramid predictions are based on two assumptions:

1. If any level weighs *more* than 1/10th of the level under it, the excess will be lost until the ten-to-one ratio is restored.
2. All animals produce excess offspring. If any level weighs less than 1/10th of the level under it, that level will increase until the ten-to-one ratio is restored.

Why do birds migrate?

We can answer this question with a pyramid. Take a look at Figure 6 again. It's summer and green plants are growing well. The smooth sides of this pyramid tell us that the ten-to-one steps are in order for all three consumers.

Let's assume that the owl weighs 1,400 grams, or 1.4 kilograms. It would need to eat ten times its weight in snakes. Those snakes would have to eat ten times their weight in mice. And finally, the mice would have to eat ten times their weight in grass. Fill in the weight of each level in the empty food pyramid below to find the weight of meadow grass needed to support just one owl.

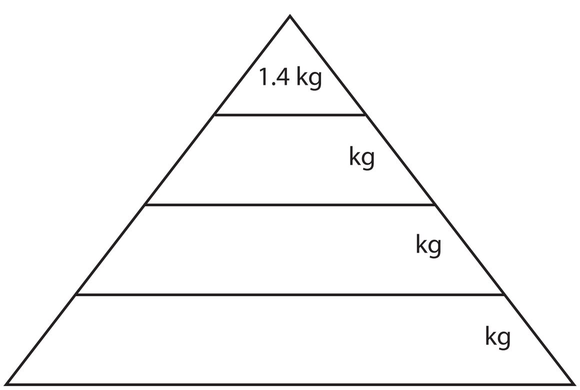


Figure 7: Weights for each level

Were you surprised by the weight of grass necessary to support one owl in the meadow? As a third order consumer, the owl requires that the meadow produce 1,400 kilograms of grass! That's about a ton and a half of grass!

Right away this food pyramid shows us an important concept:

Apex predators are never plentiful!

No wonder mice are much more common than owls!

Summer's end

As summer comes to an end, the days grow shorter and the nights get colder. Photosynthesis slows and green plants begin to die. How will this affect our food pyramid?

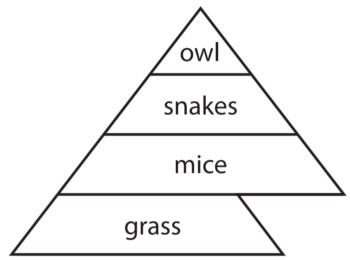


Figure 8: Late fall food pyramid

First to feel the loss of food will be the mice. With less food, the mouse population will decline. Next, the snakes will decline because there will be fewer mice to catch. Finally, the owls will be hard pressed to find a meal, but they have an out: *they can migrate to another place*.

One of the characteristics of temperate climates, like the United States', is that food availability changes with the seasons. Animals have developed various ways to cope with less food in winter. Migration is just one of those; can you name some others?

How does this affect the winter food pyramid? Whether the owl dies of hunger or flies away, its place at the top of the pyramid will be gone. But note that although the winter populations are smaller, they are in balance.

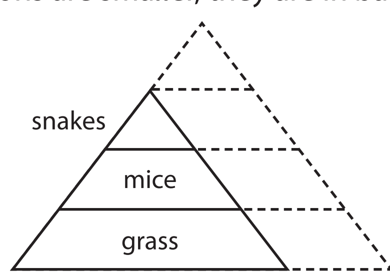


Figure 9: Winter food pyramid.

Food Pyramids and People

Man at the top of the pyramid

Humans are part of food chains too. Food pyramids can be used to investigate problems with our food supply in the same way that they are used with wild animals.

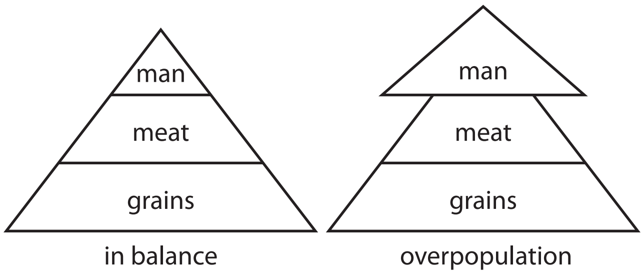


Figure 10: Human food pyramids

The left pyramid shows a human population as second order consumers. They eat meat from domestic animals like cows, pigs, or chickens. Because the human population is small, their food pyramid is in balance.

The right pyramid shows the same food pyramid, but the human population has grown too large for the producer base. You can see that this is not stable and that the human population is in trouble. Unless something changes, people will die of starvation and related sickness. The suffering will continue until the pyramid assumes a balanced shape again. Can this problem be solved?

Balancing a food pyramid

There are only two options to restore a food pyramid to balance—reduce overhanging levels, or increase undercut levels. In this case, we are trying to prevent human suffering, so have only one option, to increase the undercut levels.

Eating meat is not an option for many people

The first line of defense when food is scarce is to remove animals from the human food chain. This moves people from second-order to first-order consumers. You recall that each level of a food pyramid holds ten times as much food energy as the level above it. By eating producers directly, rather than feeding producers to animals and eating the animals, the human food supply increases ten times.

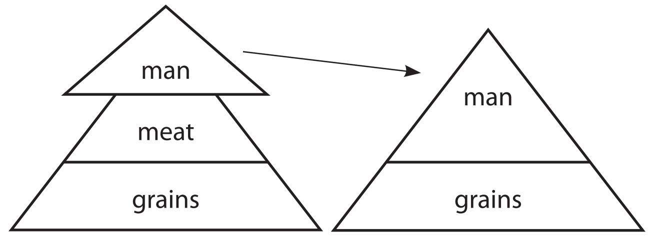


Figure 11: Man as first-order consumer

Boosting agricultural yields

It's reasonable to think that modern agriculture should be able to increase the amount of producers grown. Unfortunately, that doesn't work in many cases.

In the late1960s, severe drought hit West Africa. Crops dried up in the fields, but worse, the soil turned to sand and blew away. One well-intentioned effort to help the West Africans was to bring in modern farm machinery. But mechanical tilling exposed the soil to even more damage! Improved seed varieties helped some people, but not enough. Changing age-old livestock practices also helped, but this kind of change is difficult to make.

Bringing in food from other countries

Bringing in outside food has the effect of increasing the undercut sides of the pyramid. This solves the balance problem as long as the food continues to arrive and the human population doesn't grow even bigger.

World hunger today

Unfortunately, hunger is a fact of life for families in many parts of the world today. Other families eat only rice or other grains because that's all they have. You can see that the way that food energy moves through a food chain is brutal, unyielding, and makes no exceptions!

Food Pyramid Investigations

Solving a food problem with a food pyramid

The first step in solving a food problem is to identify the food chain within the problem that you are investigating. Do this by reading the problem description carefully. You are looking for three elements:

1. What is the producer?
2. What are the consumers?
3. What is the order of consumers?

Step 2, drawing a temporary food pyramid

In the next step, you will draw an unbalanced food pyramid that illustrates the food problem. To prepare for that, you need to draw a temporary food pyramid that simply shows the producer and consumers in the order that you determined in the first step. Draw this as a balanced food pyramid on scrap paper. Think ahead before you draw—how big should it be so that you'll be able to read the names on the lines? The producer name will go on the bottom of the pyramid, so you'll have to add as many level lines as you have consumers.

Step 3, drawing the Problem Food Pyramid

In this step, you will modify the size of some levels of your temporary food pyramid so that it matches the food problem. If any food chain member's population has been reduced, you must cut away part of that level on one side or both. Here's what the pyramid would look like if a rodent virus killed half of the mice:

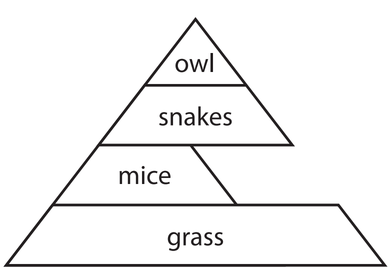


Figure 12: Half of the mice die

If any food chain member's population has increased, you must add to that member's level. Do this on one or both sides so that it sticks out farther than it did before.

You may be concerned about the awkward shape of your modified temporary food pyramid. But this is as the pyramid should be because it represents a food problem. Now redraw this pyramid in the left box of the work space labeled *Problem Food Pyramid*.

Step 4, finding a solution

Now you must decide how the Problem Food Pyramid will be restored to balance. This requires that you combine your knowledge of food and populations with your imagination. There is no best answer as long as the principles of food pyramids are followed. Record your solution on the lines at the bottom of the work space.

Step 5, drawing the Restored Food Pyramid

Finally, redraw the food pyramid after your solution has been applied in the right box of the work space labeled *Restored Food Pyramid*. This new pyramid will be in balance, but it may be a different size or have a different number of levels.

Double check your work

Make sure your ideas are logical and clear to the reader:

- Does the *Problem Food Pyramid* match the description?
- Does your solution follow food pyramid principles?
- Does your written solution clearly describe your idea?
- Does your *Restored Food Pyramid* match your written description?

Name: ______________________________ Team: ______________

Food Pyramid Investigations

Food Pyramid Problems

Instructions:

Here are four food problems for you to solve. Follow the instructions detailed in Food Pyramid Investigations. Each problem is described to the left of its work space.

Problem Food Pyramid	Resolved Food Pyramid

1 **New England.** Chipmunks are small, quick, rodents that live in burrows and natural cavities. They eat seeds and nuts. Although chipmunks are wary, falcons like the Merlin catch them from the air.

An outbreak of rabies reduces the chipmunk population to a third of its normal size.

____

____

____

____

2 **Idaho.** Big Horn Sheep live in the northern Rocky Mountains where they are able to escape from predators. They feed on grasses and low-growing plants among the rocky outcrops.

A forest fire burns away the tree canopy allowing more sunlight to reach the ground. The grasses and low-growing plants grow vigorously.

____

____

____

____

Problem Food Pyramid	Resolved Food Pyramid

3 **Kentucky.** Blind cave fish live in totally dark pools in deep caves. They eat insects that grow among the droppings of bats that roost from the cave ceiling. At night, the bats leave the cave to eat flying insects. The insects eat various green plants that grow outside of the cave.

Vandals kill the bats.

4 **Australia.** Rabbits were introduced to Australia in the 1800s. With few predators, the rabbit population exploded. Rabbits ate so many plants that the exposed soil became damaged by erosion. Half of the other plant-eating animals died from lack of food.

Hint: Rabbits share level two with other herbivores in a two-level pyramid.

Name: ______________________________ Team: ______________

Stop/Think/Draw/Write 5

(Be sure your labels are spelled correctly.)

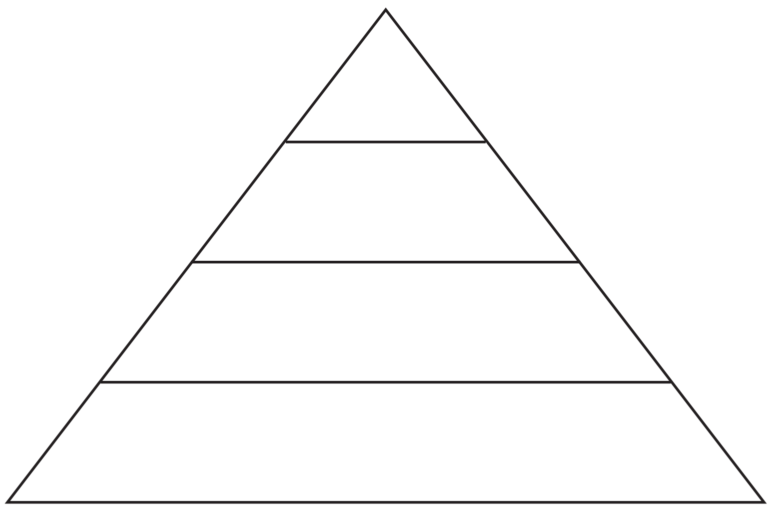
Use words and/or drawings to explain why it is that adding more cows to a certain amount of grazing land produces a herd of skinny cows.

Name: ______________________________ Team: ______________

Stop/Think/Draw/Write 6

(Be sure your labels are spelled correctly.)

Below is a food pyramid. Write the following names in the pyramid in the proper order from producer to apex predator: grasshopper, bird, grass, hawk



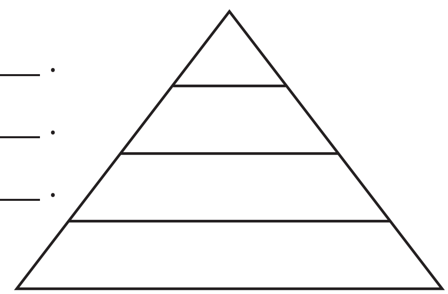
Use words and/or drawings to explain what would happen to the pyramid if pesticides killed all the grasshoppers?

Name: ______________________________ Team: ____________

Quick Team Quiz Four

1. Write the formula for oxidation and photosynthesis:

2. During oxidation animals release ________________ and ________________.
3. During photosynthesis, ____________ ____________ produce simple sugars and O_2.
4. As life trading partners, chipmunks give trees ____________ and ____________, while trees give the chipmunks ____________ and ________________ .
5. Non-photosynthetic organisms are like animals because they get their energy from the process called ____________________ .
6. When do green plants get take in oxygen like animals? ______________________
7. In the food chain: diatoms → clam → starfish → seagull
   a. The diatoms is known as a __________________ .
   b. The apex predator is the ____________________ .
   c. The second-order consumer is the ______________ .
8. Use the food chain in #7 to make a food pyramid. →



9. How many pounds of diatoms are needed to support 1,000 pounds of clams? ________
10. If seagulls weigh 5 pounds, how many seagulls could support this pyramid? ________
11. Draw a balanced food pyramid with a food chain of waterplants – aquatic insect – small trout – stork.

12. Imagine that a fish kill removes all fish from the pyramid described in question 11. Redraw that pyramid as it would look several months later.

Name: ______________________________ Team: ______________

Square Four Test

Circle the letter next to the correct answer.

1. You can't take apart an energy coin completely unless you add _______.	A. a simple sugar B. a starch	C. a fat D. oxygen
2. What is $C_6 H_{12} O_6$?	A. water B. simple sugar	C. carbon dioxide D. oxygen
3. Write the formula for oxidation and photosynthesis.		
4. During oxidation, animals release carbon dioxide and _______.	A. oxygen B. simple sugars	C. hydrogen D. water
5. During photosynthesis, plants produce simple sugars and _______.	A. hydrogen B. oxygen	C. carbon dioxide D. water
6. During oxidation, animals take in simple sugars and _______.	A. oxygen B. carbon dioxide	C. hydrogen D. water
7. During photosynthesis, plants take in carbon dioxide and _______.	A. water B. simple sugars	C. hydrogen D. oxygen
8. The most commonly found stored food energy in plants are _______.	A. simple sugars B. starches	C. fats D. gases like oxygen
9. The most commonly found stored food energy in animals are _______.	A. simple sugars B. starches	C. fats D. gases like oxygen
10. In a food web, a green plant is always _______.	A. a first order consumer B. a second order consumer	C. a producer D. an apex predator
11. In a food web, the first consumer is always _______.	A. a producer B. a plant	C. an herbivore D. an apex predator
12. The energy that green plants capture comes from _______.	A. water B. sunlight	C. oxygen D. a simple sugar

13. Chlorophyll...	A. is another name for carbon dioxide. B. is used by plants during the night. C. is given off by animals in oxidation. D. captures light energy from the sun.
14. When must green plants "act like animals" and use oxidation only instead of oxidation and photosynthesis?	
15. Mushrooms, molds, and bacteria are non-photosynthetic organisms, and therefore...	A. they use photosynthesis. B. they use oxidation. C. they use sunlight. D. they give off oxygen.
16. Fish kills occur at night because...	A. all the carbon dioxide is used up. B. there is no chlorophyll in the water. C. the fish release too many simple sugars. D. green plants use up much of the oxygen in the water.
17. Draw a food pyramid from this food chain: leaf – aphid – beetle – robin	
18. In a food pyramid, the weight of the second level is _______ the first level.	A. one-half of C. one-tenth of B. ten times bigger than D. the same as
19. If a farmer adds more cows to his grazing land with no other changes...	A. the herd will be bigger and the cows will weigh the same. B. the farmer will definitely have more meat to sell. C. the herd will be bigger but the cows will lose weight. D. some cows may migrate to another farm.
20. After a food problem has distorted a food pyramid...	A. all the producers migrate. B. the food pyramid may lose one or two levels. C. nothing further changes. D. the pyramid becomes square-shaped.

Energy Pathways in a Food Web

Food energy in food chains

So far you have learned several key ideas about photosynthesis, food, and populations:

- Food energy is captured by green plants and stored as simple sugars.
- These simple sugars can be thought of as energy coins and counted just like money.
- Food energy moves through food chains with strict budgeting of who gets which food and how much they get.

Food energy in food webs

You also know that real ecosystems are made of many interlocking food chains that form a food web. How can food energy be followed in a food web? There are so many pathways, is it even possible?

In fact, that's just what professional ecologists do. In this final challenge, you will apply your new knowledge to a meadow food web. Like a financial accountant, you will count the energy coins as they enter the meadow food web and follow them to their ends.

The fate of animal food energy

What happens to the food energy that an animal gains when it eats a plant or another animal? Imagine that a snake eats a 200 calorie mouse. What happens to those calories?

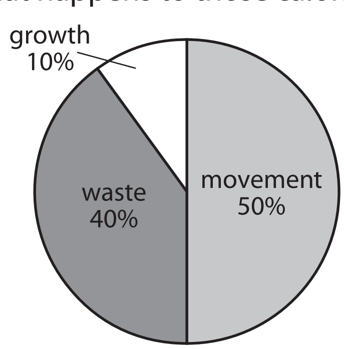


Figure 13: How animals use food energy.

Only ten percent (20 calories) actually add to the weight of the animal! The other calories are lost as waste or used to move the animal around. In other words, it cost the snake half of its dinner just to catch it! This ten percent value is an average for all animals; some are more efficient, others less.

The fate of all life forms

Wow—what a loss! Only ten percent of the food eaten grows more animal. But wait—you've seen this before! Remember that each level of a food pyramid is ten times smaller than the level beneath it. Now you know why.

Okay, now that we've grown some animal, what happens to the food energy of its body? That depends on what happens to the animal. In the meadow, all life forms, including plants, will meet one of three fates:

- Some will live.
- Some will be eaten alive.
- Some will die.

There is no way to predict how many plants or animals will live, be eaten, or die. When conditions are good, many will live. On the other hand, a hard freeze could kill most plants in one night!

Plants and animals that live

The plants and animals that live make up the life that you see in the meadow. Imagine that somehow you gathered up all of them in a huge heap and weighed the heap. The result would be the weight of food energy contained in the bodies of all living things. This weight is called the **biomass** of the meadow.

Plants and animals that get eaten

This fate includes only those plants or animals that are eaten alive. Plants or animals that die, then are found and eaten, belong to the *Some will die* fate.

When a plant or animal gets eaten alive, the food energy of its body passes to an animal on the next higher level in the food pyramid. We must now leave the plant or animal that was eaten and shift our attention to the animal that did the eating. The eaten body is incoming food energy for the animal doing the eating. This starts the food energy counting process all over again for this new animal, beginning with the food energy losses described in the section "The fate of animal food energy."

Plants and animals that die

Clearly any life form that gets eaten alive also dies. This fate is different because it describes what happens to animals that die from other causes. The difference is that there is no body left after it is eaten alive. But plants and animals that die from other causes leave a body behind. What happens to these dead bodies? All dead life forms face two ends:

- Some dead life forms will be found and eaten by scavengers.
- Some dead life forms will decay.

Scavengers

Scavengers are animals that eat dead things. They can range in size from tiny insects to large birds like vultures. Scavengers have the same losses and fates as animals that eat live bodies because they use dead body food energy just like other animals use live body food energy.

Why are scavengers separate from animals that eat live bodies? The key difference is when a plant or animal is eaten alive, the food energy of its body moves in a specific direction—up to the next level on its food pyramid. But a scavenger may return the same body food energy to the food pyramid at any of several levels, depending on the nature and size of the scavenger.

For example, a shrew, a frog, or a bird might feed on scavenger insects. But none of these smaller predators could take on a vulture. It would require a larger animal higher on the food pyramid to prey on a vulture.

Decay

Decay organisms attack the dead bodies of any life form that is not found by a scavenger. Decay organisms include organisms like mushrooms and bacteria. These organisms will also decay all waste produced by animals. You have seen and smelled the decay process, but you probably called it rot.

The end of food energy—heat

Decay is the end of the journey for food energy, because decay takes apart any remaining energy coins, just like you did earlier. The result is water, carbon dioxide, and energy in the form of heat. This kind of heat energy is not usable by living things and so it is eventually lost to space.

There's an irony here. Food energy started in the form of sunlight passing through space until it arrived at Earth's surface. Green plants stored that energy in energy coins—simple sugars—that were passed from life form to life form. But in the end, those life forms decay and the energy coins are released as heat energy, to continue their journey through space.

Decay is an essential process

Gathering materials and energy is an essential life process. This *Squared Away* unit focuses on the energy side of the gathering process. But just as important is the gathering of key materials needed by young bodies to grow. Earth is big, but it is not without limit. If every green plant that ever lived kept the magnesium that it gathered while it was alive, green plant growth would slow and eventually stop as the supply of magnesium was used up.

Fortunately that will never happen. As the decay process breaks down once-living tissue, trapped nutrients, including magnesium, are released and returned to the ground. In this way, decay ensures a continuing supply of nutrients for new green plants.

Name: ______________________________ Class: ______________

Primary Productivity of My Study Area

To determine the primary productivity of a study area, you need to find and record the three pieces of information listed below. Work the calculations in pencil one step at a time. Label all numbers and circle your answers with their labels.

Tasks to do and information to record

A. Write your name and class on a paper shopping bag in pencil, then weigh the bag in grams.

B. Select an average place in your study area and cut all green plants to the ground within a quarter square meter (50cm by 50cm). Carefully place all of the cut plants in the shopping bag. Allow the plants to dry for a week. Then weigh the bag with the plants inside, in grams.

C. Find a map of your study area. Locate two points on the map that you can also find on the ground. Go to the points *in your study area* and measure the distance between them in meters.

1 Locate the study area on your map. Place a piece of graph paper over the map and trace your study area onto the map. Count and record all of the graph squares covered by your study area.

Squares =

2 Draw a line on your *map* between the two points that you measured for information C. Find the length of this line in graph square sides. Do this by turning the graph paper so that its edge lies along the line. Count the length of the line in graph square sides.

Sides =

3 Find the outdoors length of one side of a graph square in meters by dividing the length of the line in meters (Information C) by the length of the line in graph square sides (Step 2).

$$\frac{\text{(Info C) meters}}{\text{(Step 2) sides}} = \frac{\text{meters}}{\text{side}}$$

4 Find the area of one graph square in outdoors square meters by multiplying one graph square side in meters (Step 3) by itself.

$$\left(\frac{\text{(Step 3) meters}}{\text{side}}\right)\left(\frac{\text{(Step 3) meters}}{\text{side}}\right) = \frac{\text{meters}^2}{\text{square}}$$

5 Find the area of your study area in square meters by multiplying the total number of graph squares (Step 1) by the area of one graph square in outdoors square meters (Step 4).

$$\frac{\text{(Step 4) meters}^2}{\text{square}} \cdot \text{(Step 1) squares} = \text{meters}^2$$

6 Find the weight of dry grass in a quarter square meter sample by subtracting the empty bag weight (Info A) from the filled bag weight (Info B).

(Info B) grams – (Info A) grams = (plants) grams

7 Find the weight of dry grass in a one square meter sample by multiplying the quarter square meter sample weight (Step 6) by 4.

$$\frac{\text{(Step 6) grams} \div \text{meter}^2}{4} \cdot 4 = \frac{\text{grams}}{\text{meter}^2}$$

8 Find primary productivity by multiplying your study area in square meters (Step 5) by the weight of dry grass in a one square meter sample (Step 7).

$$\frac{\text{(Step 7) grams}}{\text{meter}^2} \cdot \text{meters}^2 = \text{grams}$$

Modeling a Meadow Ecosystem

In this final challenge, you will model a simplified meadow ecosystem by making a food energy budget that assumes a primary productivity of 1,000,000 grams of green plants. The meadow food web has been drawn for you in *My Meadow Food Energy Budget*. To guide you, each food energy arrow has a brief description and a number that matches a step in the next section, *Calculations*. As you decide each step, record the amount to the nearest whole number on its arrow line and also on the *Meadow Food Energy Balance Sheet*.

Calculations

Arrows 1, 2, and 3

Green plants can live, be eaten, or die. Note that the total of 1▶, 2▶, and 3▶ must equal the primary productivity of 1,000,000 grams. Choose amounts for:

1▶ Plants that are eaten by the first consumer, the mice. Make this at least 500,000 grams or later you will not be able to support the second consumer.

2▶ Green plants that live.

3▶ Green plants that die and decay.

Arrow 4

4▶ Find the food energy cost of mouse movement by multiplying 1▶ by 50%.

Arrow 5

5▶ Find the food energy lost as mouse waste by multiplying 1▶ by 40%.

Arrow 6

6▶ Find the food energy stored as new mouse growth by multiplying 1▶ by 10%. Check that 4▶ + 5▶ + 6▶ = 1▶.

Arrows 7, 8, and 9

Mice can live, be eaten, or die. Note that the total of 7▶, 8▶, and 9▶ must equal 6▶, mouse growth. Choose amounts for:

7▶ Mice that are eaten by the second consumer, the fox. Make this are least 30,000 grams.

8▶ Mice that live.

9▶ Mice that die.

Arrow 10

10▶ Find the food energy cost of fox movement by multiplying 7▶ by 50%.

Arrow 11

11▶ Find the food energy lost as fox waste by multiplying 7▶ by 40%.

Arrow 12

12▶ Find the food energy stored as new fox growth by multiplying 7▶ by 10%. Check that 10▶ + 11▶ + 12▶ = 7▶.

Arrows 13 and 14

Foxes can live or die, but because they are the apex predator, they cannot be eaten. Note that the total of 13▶ and 14▶ must equal 12▶, fox growth. Chose amounts for:

13▶ Foxes that live.

14▶ Foxes that die.

Arrows 15 and 16

Dead bodies can be eaten by scavengers or decay. Note that the total of 15▶ and 16▶ must equal 9▶ + 14▶. Choose amounts for:

15▶ Bodies that decay.

16▶ Bodies that are eaten by scavengers.

Arrow 17

17▶ Find the food energy cost of scavenger movement by multiplying 16▶ by 50%.

Arrow 18

18▶ Find the food energy lost as scavenger waste by multiplying 16▶ by 40%.

Arrow 19

19▶ Find new scavenger growth by multiplying 16▶ by 10%. Check that 17▶ + 18▶ + 19▶ = 16▶.

Arrows 20 and 21

Find the food energy that passes to the decay organisms. Add 3▶ + 5▶ + 11▶ + 15▶ + 18▶.

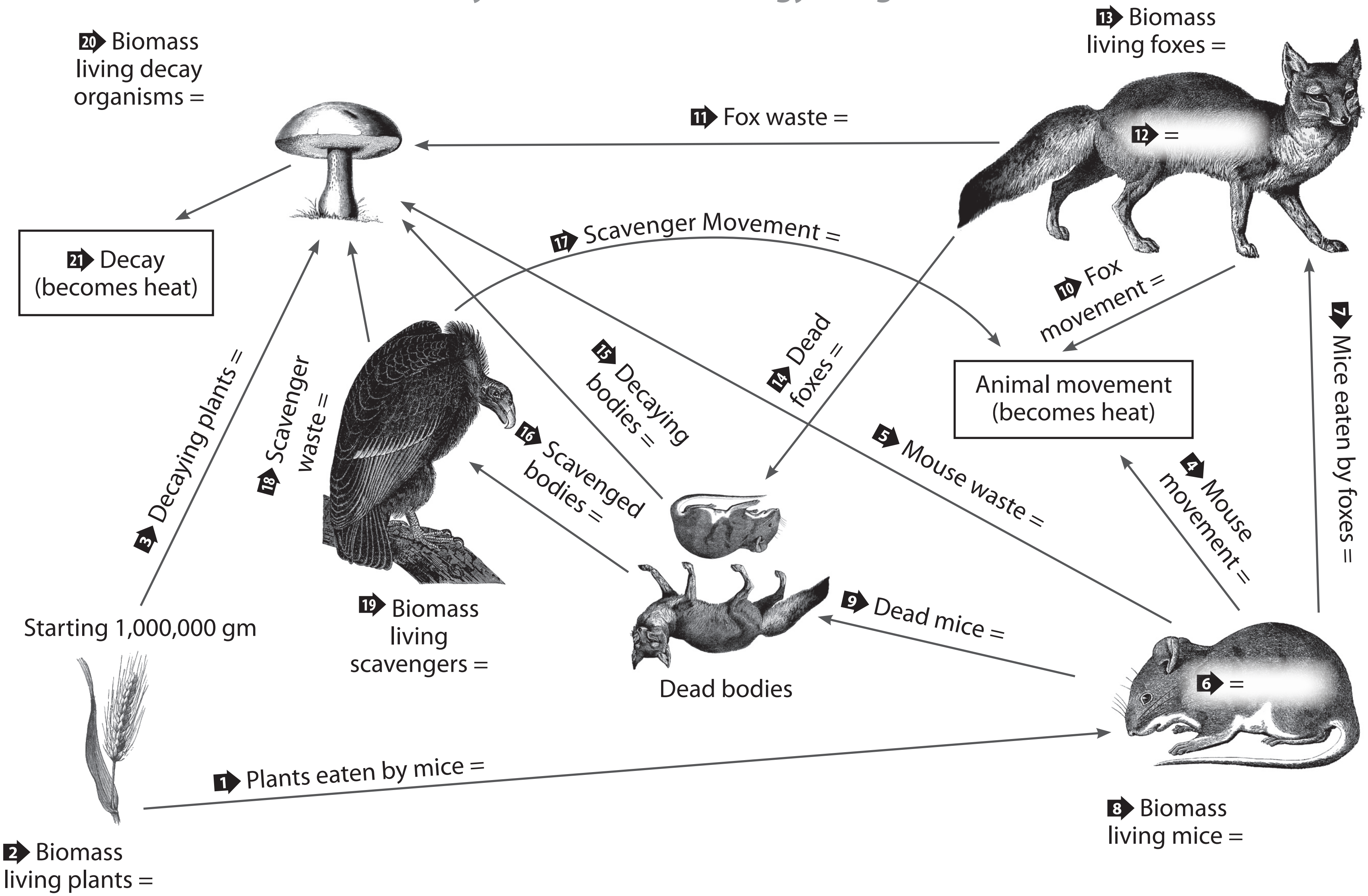
20▶ Find the food energy stored as living decay organisms by multiplying the total food energy that passes to them by 2%.

21▶ Find the food energy that decays to heat energy by subtracting 20▶ from the total food energy that passes to the decay organisms.

Name: ______________________ Class: ____________

Modeling a Meadow Ecosystem

My Meadow Food Energy Budget



Name: ______________________________ Class: ____________

Meadow Food Energy Balance Sheet

The basic idea in business accounting is that the company income should exactly equal all of the costs of doing business plus the money on hand. We will use this same idea to check your meadow food energy budget. We will assume that primary productivity (company income) should exactly equal energy lost as heat (the cost of doing business) plus the biomass (money on hand). As you work on *My Meadow Food Energy Budge*t, transfer the arrow amounts to the table on the right.

The last row of the first four groups is the total for the group. Add the group member amounts and write the total in the box set to the right. The last group, "Energy balance," is the difference between primary productivity and all of the energy in the meadow. This a subtraction and if you worked carefully, it will show a balance within a few grams of zero.

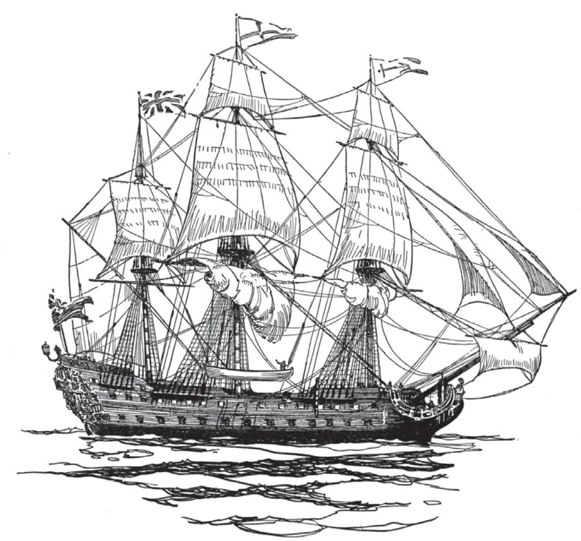
Biomass	
Living plants 2	gm
Living mice 6	gm
Living foxes 12	gm
Living scavengers 19	gm
Living decay organisms 20	gm
Total biomass	gm
Movement	
Mouse movement 4	gm
Fox movement 10	gm
Scavenger movement 17	gm
Total movement	gm
Decay	
Decaying plants 3	gm
Decaying mouse waste 5	gm
Decaying fox waste 11	gm
Decaying scavenger waste 18	gm
Decaying bodies 15	gm
Total decay	gm
Total heat produced	
Total movement	gm
Total decay	gm
Total heat produced	gm
Total energy expended in the meadow	
Total biomass	gm
Total heat produced	gm
Total energy expended in the meadow	gm
Energy balance	
Primary productivity	1,000,000 gm
Total energy expended in the meadow	gm
Balance	gm

Special Award

Recently we have been working on a special science unit called *Squared Away*. “Squared away” was originally a nautical term used to announce that the sails of a square-rigger sailing ship were correctly set. The navy came to use it to describe sailors who completed a task with competency, as in, “He was right squared away!” We have adopted the term to describe students who demonstrate competency in specific content and skills.

Students could only master the concepts and skills of this *Squared Away* unit by learning a great deal about photosynthesis. They have learned that it is not just a formula, but a molecular process where carbon, hydrogen, and oxygen molecules are arranged, broken apart, and rearranged. They have investigated the roles of producers, consumers, and decomposers in a food web and predicted the population size supported by the producers in an ecosystem. They have also learned how to account for energy from the Sun as it passes through a natural community.

Congratulations to



____

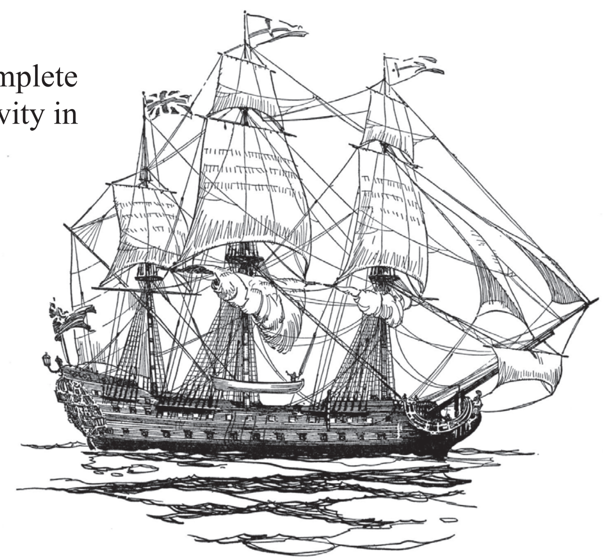
For Being Squared Away in
Photosynthesis, Food, and Populations

Special Award

Recently we have been working on a special science unit called *Squared Away*. “Squared away” was originally a nautical term used to announce that the sails of a square-rigger sailing ship were correctly set. The navy came to use it to describe sailors who completed a task with competency, as in, “He was right squared away!” We have adopted the term to describe students who demonstrate competency in specific content and skills.

Students could only master the concepts and skills of this *Squared Away* unit by learning a great deal about photosynthesis. They have learned that it is not just a formula, but a molecular process where carbon, hydrogen, and oxygen molecules are arranged, broken apart, and rearranged. They have investigated the roles of producers, consumers, and decomposers in a food web and predicted the population size supported by the producers in an ecosystem. They have also learned how to account for energy from the Sun as it passes through a natural community.

Only some students also earned a “Golden Square.” These students had to complete one of two difficult Golden Square Challenges: Determining Primary Productivity in a study area or Modeling a Meadow Ecosystem.



Congratulations to

____

For Being Squared Away in
Photosynthesis, Food, and Populations
and Earning a Golden Square!

Teacher Feedback Form

At Interact, we constantly strive to make our units the best they can be. We always appreciate feedback from you—our customer—to facilitate this process. With your input, we can continue to provide high-quality, interactive, and meaningful instructional materials to enhance your curriculum and engage your students. Please take a few moments to complete this feedback form and drop it in the mail. Address it to:

Interact • Attn: Editorial
10200 Jefferson Blvd. • P.O. Box 802
Culver City, CA 90232-0802

or fax it to us at **(800) 944-5432**
or e-mail it to us at **access@teachinteract.com**

We enjoy receiving photos or videotapes of our units in action!
Please use the release form on the following page.

Your Name: ______________________________

Address: ______________________________

____

E-mail: ______________________________

Interact Unit: ______________________________

Comments: ______________________________

____

____

____

____

____

____

____

____

Release Form for Photographic Images

To Teachers:

To help illustrate to others the experiential activities involved and to promote the use of simulations, we like to get photographs and videos of classes participating in the simulation. Please send photos of students actively engaged so we can publish them in our promotional material. Be aware that we can only use images of students for whom a release form has been submitted.

To Parents:

I give permission for photographs or videos of my child to appear in catalogs of educational materials published by Interact.

Name of Student: ______________________________ (print)

Age of Student: ______________________________ (print)

Parent or Guardian: ______________________________ (print)

Signature: ______________________________ Date: ____________

Address:

____

____

____

____

Phone: ______________________________

Interact
10200 Jefferson Blvd.
Culver City, CA 90232-0802
310-839-2436