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ABSTRACT

The ability to utilize and change energy is one of the most fundamental characteristics of living things. Plants have the unique ability to change light energy into the chemical energy on which human beings depend for such things as fuel and food. Through the activities in this book students examine how plants and other living things use and transform energy. By gaining a basic understanding of energy, students begin to develop the background for knowing how to use the Earth's energy resources more efficiently. The activities included follow an inquiry-based approach that aims at teaching basic science concepts and science process skills. Each activity follows a multi-step teaching and learning cycle and includes the following parts: overview, time, materials, background, laying the groundwork, exploration, objective, making connections, and branching out. (JRH)

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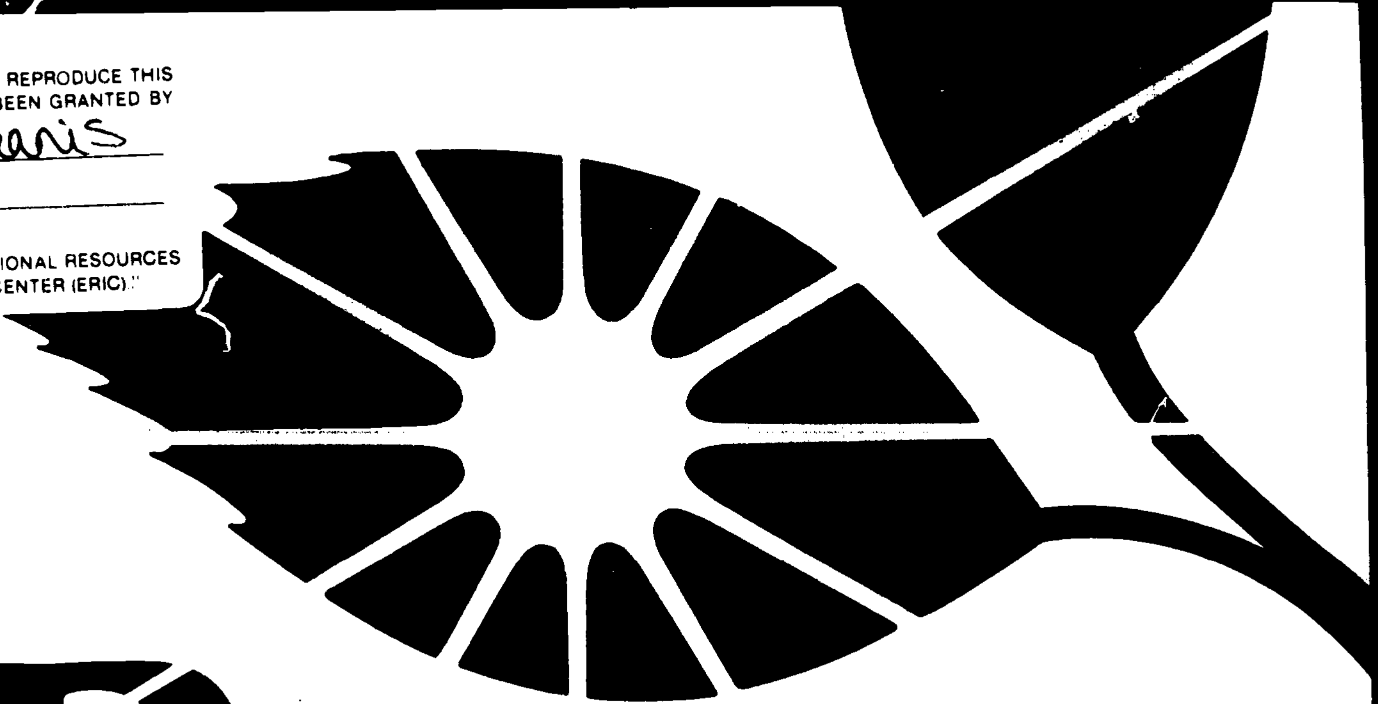

Power Plants

A plant-based energy curriculum for grades 5 through 8

National Gardening Association
with support from the Burlington Electric Department
and the Vermont Department of Education

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A plant-based energy curriculum for grades 5 through 8

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Preface

Linking plants and a simple flick of the light switch may at first seem a stretch. Once we realize that fossil fuels and biomass provide the bulk of our energy resources, the intimate connection between plants that harness the sun's energy through photosynthesis and plants that generate our electricity is apparent.

Wisely using the Earth's energy resources depends on the actions of informed consumers and voters. Studies show that tomorrow's active, informed citizens are today's intensely involved children. Through National Gardening Association's (NGA) GrowLab Program, we at NGA have learned that young people become deeply engaged by opportunities to nurture and examine plant life and to inquire and wonder about plants' roles in our world. *Power Plants* extends the hands-on format of GrowLab to involve students in examining topics of energy and energy conservation.

As in the GrowLab Program, *Power Plants* activities are a springboard for teachers and students interested in creating original plant investigations. We would like to hear from you as you try out, adapt and alter these activities. Through the *Growing Ideas* newsletter, we share ideas developed by teachers across the U.S. and Canada. If you haven't already, join with others in the GrowLab Program who are using plants as a vehicle for exciting investigations.

Tim Parsons

Tim Parsons
Director of Education Programs
National Gardening Association

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Acknowledgements

Many people offered their time and energy in the development of this curriculum.

Special thanks to the Burlington Electric Department and the Vermont Department of Education for realizing that there is a pressing need to educate our children about energy and energy conservation. They responded with their full support and funding of the development of *Power Plants.*

Karen Villanti of the Burlington Electric Department and Alan Kousen of the Vermont Department of Education were particularly helpful in championing the development of *Power Plants.*

Central Vermont Public Service's and Green Mountain Power's initiative in awarding GrowLab grant awards to Vermont and New Hampshire schools enabled us to recognize the link between energy, energy conservation and plants.

With the help of Monica Nelson, Director of Curriculum, Burlington Schools, a core group of Burlington, Vermont teachers were identified to help design the framework of *Power Plants* and field-test the curriculum. Special thanks to Joan Donath, Edmunds Elementary School; Lois D'Arcangelo, Lawrence Barnes Elementary School; Pat Majercik, Mater Christi School; Karen Paquette, John J. Flynn Elementary School; Chip Porter, Edmunds Elementary School; Jean Rocheleau, H.O. Wheeler Elementary School.

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Finally, great appreciation to Dylana and Ezra Dillon, whose boundless energy serve as a source of inspiration and a reminder that Earth's future lies in the minds, attitudes and actions of our children.

Introduction

The ability to utilize and change energy is one of the most fundamental characteristics of living things. Plants have the unique ability to change light energy into the chemical energy on which we depend for such things as fuel and food. Throughout the *Power Plants* curriculum, you and your students will examine how plants and other living things use and transform energy. You will approach the topic of energy by focusing on how energy is changed throughout food systems. By gaining this basic understanding of energy, students will begin to develop the background for knowing how to use the Earth's energy resources more efficiently. After all, the power is in their hands.

How to Use this Book

Power Plants was developed to complement another hands-on, plant-based science curriculum, *GrowLab: Activities for Growing Minds*. The GrowLab Program offers a curriculum for grades kindergarten through eight that uses an indoor classroom garden to teach key life-science concepts and science-process skills. Activities in *Power Plants* follow the inquiry-based approach of *GrowLab: Activities for Growing Minds*; we recommend using it as a reference for effective science teaching. *Power Plants* may be used alone or in conjunction with the GrowLab Program.

For basic information about growing plants, refer to *GrowLab: A Complete Guide to Gardening in the Classroom*. Additional resources from the GrowLab Program and other organizations are listed on page 50.

Activities

Activity Format

Each activity follows a multi-step teaching and learning cycle. The activity format is described in detail on page 2.

Activity Format

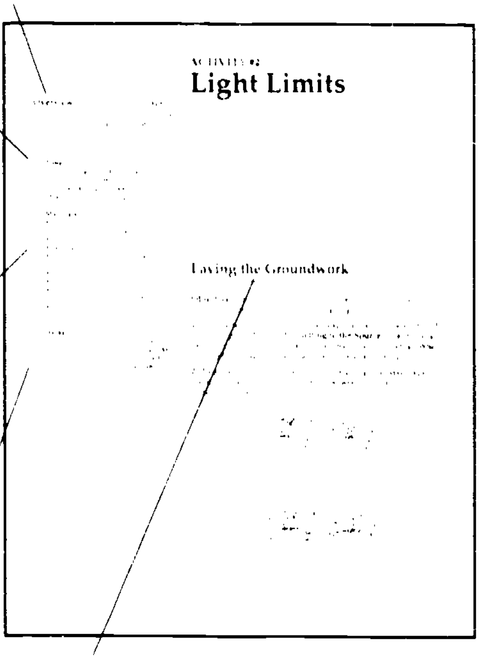
Overview
This statement summarizes what students will do during the activity.

Time
The time allotments suggested are based on experiences in field-test classrooms. Adapt them to your own classroom needs. Making Connections is always indicated as "ongoing," for it is an ongoing process that will vary with your approach to the activity.

Materials
This lists recommended materials and reproducible worksheets. For open-ended investigations with student-generated ideas, materials will vary.

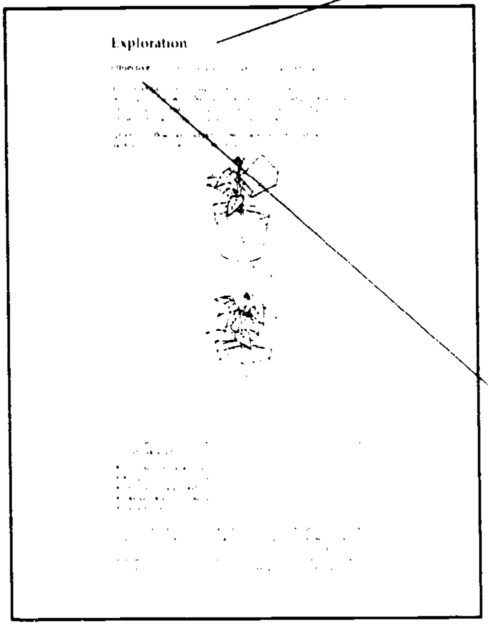
Background
This section lists where to find background information that supports the activity.

Laying the Groundwork
This section engages students in the concept. The Groundwork helps tie the Exploration to familiar concepts/experiences in students' lives. It includes questions and creative activities to help identify students' current understanding and ideas on the topic or concept. This allows you to structure the exploration to guide students effectively as they examine new ideas.



Light Limits

Laying the Groundwork

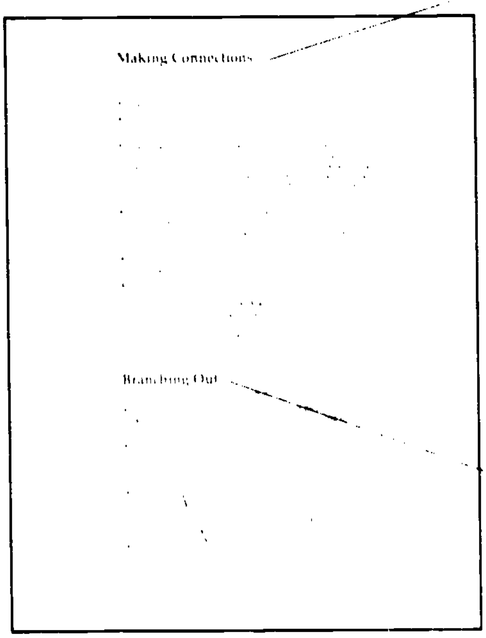


Exploration

This section provides opportunities for students to explore phenomena actively. It includes explicit yet flexible suggestions for facilitating hands-on explorations. It has procedural hints, suggests classroom management strategies and recording and reporting techniques, and includes results to expect, when appropriate.

Objective

This states the purpose of the different sections of the activity.



Making Connections

This section offers ideas for helping students process the Exploration for meaning. This includes interpreting data, reflecting on experiments, identifying patterns, clarifying concepts, seeing "the big picture," communicating results with others, applying understanding to other contexts, and raising new questions. This is also an important opportunity for you to assess what students have learned.

Branching Out

This section suggests optional activities in different subject areas that extend the concepts covered or processes used.

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Activity Sequence

The six activities in *Power Plants* are designed to be conducted in sequence—the concepts build on each other. If your students have already explored topics that meet any of the objectives, feel free to adapt the sequence to your needs.

Background Information

Each activity begins with a teacher background section and references to relevant background information from *GrowLab: Activities for Growing Minds*. Key terms and vocabulary are in bold type. Share information from these sections with your students as you see fit. We recommend, however, that students use scientific terms only after they've had an opportunity to experience and understand phenomena or principles.

Key Concepts

The key concepts developed in the activities in *Power Plants* are:

- Living things require energy for everything from breathing to making food.

- The original source of energy for living things is sunlight.

- Plants convert solar energy to the food (chemical) energy they use to grow and reproduce. They also convert some energy into structures such as leaves and roots. Animals that eat plants use part of the plants' stored energy for their own growth and maintenance.

- Plants harness solar energy through the process of photosynthesis.

- Energy is transferred from one member to another in an ecosystem through a sequence called a food chain. Food chains consist of producers (mainly green plants which make their own food), consumers, and decomposers.

- Every time energy is converted from one form to another (for example, light energy to chemical energy), some of the energy is changed to heat, a less useable form of energy.

- Eating closer to the source of a food chain is more energy-efficient.

- Humans are different than other animals in their uses of energy. People not only utilize food energy for their bodies, they use sources of energy outside themselves, for example electricity to process food and fuel oil to heat homes.

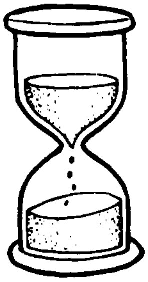
- Good energy conservation practices can preserve energy sources.

Energized Science Teaching

Science should be fun and full of wonder. Some of the instructional techniques proven to enhance students' conceptual understanding and delight in science include:

- Accept students' current understanding of how our world "works" without correcting them. Conceptions usually only change after students participate in hands-on activities and classroom discussions.
- Provide hands-on activities that give students concrete experiences.
- Demonstrate scientific phenomena, then ask students to communicate—tell, draw, write about—what they observed.
- Encourage students to make predictions based on their current ideas and past experiences.
- Ask open-ended questions that stimulate students' thinking, for example: *"What will happen if...?"*. Follow up with related questions to encourage students' inquiry.
- Facilitate discussions to help students share their ideas and questions.
- After completing an exploration, encourage students to reexamine their original predictions. Ask them how their ideas have been modified.
- Have students work in small groups to promote cooperation and communication skills.

For more ideas for effective, energized science teaching, refer to *GrowLab: Activities for Growing Minds*, pages 12–21.



Wait Time
Provide "wait time" of at least a few seconds after asking a question so students can think about the question and develop answers and/or more questions.

Problem Solving for Growing Minds

In many science classrooms, students are often asked to follow a fairly rigid "scientific method." But the actual process of discovery occurs when scientists—and your students—explore in an atmosphere that promotes "messing about," where students watch for the unexpected while following careful procedures. Whether your students use our Problem Solving for Growing Minds process on page 6 or another variant of the scientific method, encourage your students to use a problem-solving process that more accurately reflects what scientists do.

Problem Solving for Growing Minds uses garden metaphors in place of the traditional steps of the scientific method. Records can be kept on the reproducibles provided on page 44.

Partners in Learning
Many people can help you teach your students about energy. Contact your local utility's energy educator. Teachers at the secondary level or local college instructors in physics, biology, botany or other subjects will often share their expertise. For help with growing plants, contact your local Cooperative Extension Service, botanical garden, garden club or nursery. Encourage your students and their families to recommend helpful local gardeners and to help arrange for guest visitors or field trips.

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Problem Solving for Growing Minds

Plant a Question

Many questions can become the basis for a scientific exploration. Asking and encouraging open-ended questions is central to learning more about the world. Facilitate a brainstorm of questions on a particular topic (for example, light and plant—I wonder what would happen if...). Then identify, as a class, those you'd like to explore further. Consider making a class chart with the following headings: "What I Believe About _____"; "Questions I Have About_____." Encourage each student to keep an ongoing list of questions on different topics.

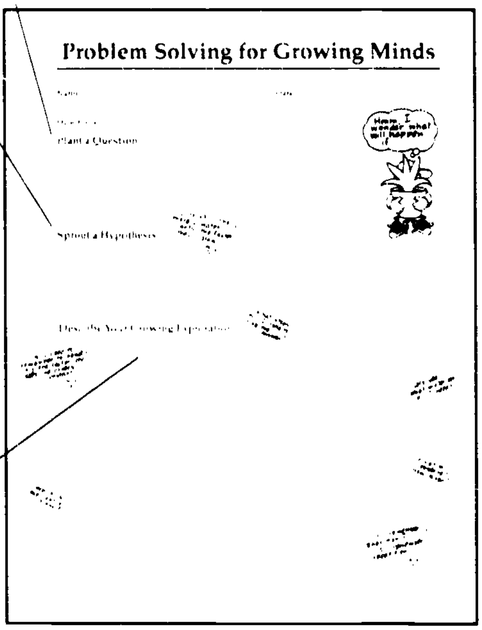
Sprout a Hypothesis

Encourage students to draw on their experiences, to reflect on what they already know (or think they know), and to speculate on answers to their questions. Students may choose to do preliminary research to gather information to help them frame a hypothesis.

Describe Your Growing Exploration

Students should consider how they'll systematically explore their ideas. Explorations could entail open-ended observations, or setting up a controlled "fair test." Important elements to consider when designing a fair test are:

- **Choose one experimental variable.** *What one factor or variable (for example, amount of light) will you look at or change during the investigation? How will it vary from group to group? Why?*
- **Keep all other variables constant.** *Other than the experimental variable, what factors (for example, fertilizer, water, or temperature) can influence the answer to your question? How will you keep these constant for each group?*
- **Is there a need for a control group?** *Which group will be the "normal" condition (for example, the group that receives the recommended amount of light) to which we can compare the other groups?*
- **Repeat experiment.** *How can we be sure our results were due to the experimental treatment and not to another factor (for example, a bad seed)?* To have more confidence in the validity of your results, have at least two pots/plants/seeds in each group or repeat the experiment at least twice.
- **Decide what to observe.** *What observations will you make? How often will you record observations/measurements? Why do you want to gather that data?* When doing experiments with plants, consider looking at changes in size, shape, color, weight, smell, growth rate, etc. of different parts of the plants. Remind students that, although they may choose certain criteria, it is important to keep an open mind and look for the unexpected. Many important discoveries (such as penicillin) have been "accidental."



Problem Solving for Growing Minds

(see page 45)

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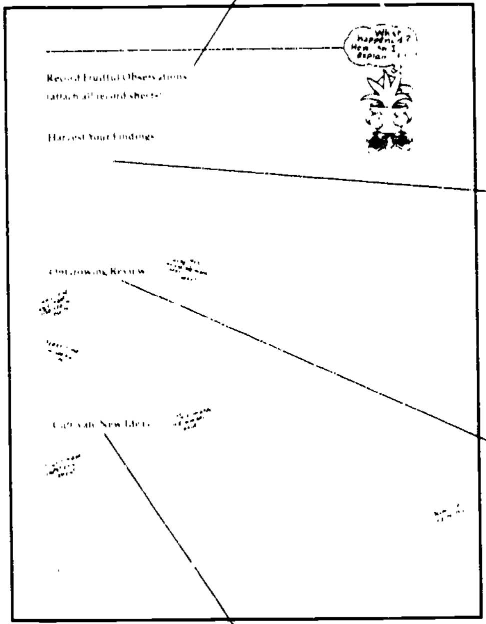

Record Fruitful Observations

Help students decide how to keep track of their observations, ideas, and newly generated questions. Charts, graphs, and journals all offer different ways of organizing data. Students should record raw data and not what they believe they should be finding. Records of these observations and data will be important as students try to derive meaning from their explorations. Always attach separate record-keeping sheets to this worksheet.

Harvest Your Findings

Help students organize the data and describe connections that exist. Ask: *Based on what you've observed, what's your explanation of what happened? After drawing your conclusion, what other questions do you have?*

Remind students not to overgeneralize their conclusions. Ask: *Based on your findings, can we assume that all plants will respond the same way?* Encourage small group discussion as students try to make sense of their exploration. Sharing between groups will also enhance communication skills and reinforce the fact that there are always multiple ways of looking at the same thing.

OnGrowing Review

An important element of true scientific exploration is reflection on and healthy skepticism of our process. *How effective were the procedures we used to answer the question?* Throughout investigations, encourage students to reflect on their process, either individually or with a peer review. They will hopefully learn to view feedback as an important part of the learning process.

Ask: *How do the results compare to your predictions? Why do you think they do or do not compare?* If you have conflicting data, or results that contradict conventional scientific knowledge, brainstorm a list of other factors that might have affected your results. Also consider questions such as: *What were some of the weaknesses of the experiment? How might other factors have influenced the results* (e.g., human error—They really didn't all get the same amount of water because when Ezra had the flu we forgot to water his pot)? *How and why might you design the experiment differently if you were to repeat it?*

Cultivate New Ideas

Exploring the natural world inevitably leads students to extend their thinking into other related areas. Encourage students to continue to ask more questions and to transfer the classroom experience to a broader setting. Let students know that these new ideas and questions are integral to the science process. Questions might dig deeper into relevant science topics or extend into other disciplines. Ask: *What else would you like to know about...? How do you think you could find out?* Allow students to brainstorm "I wonder what would happen if...." and the cycle continues.

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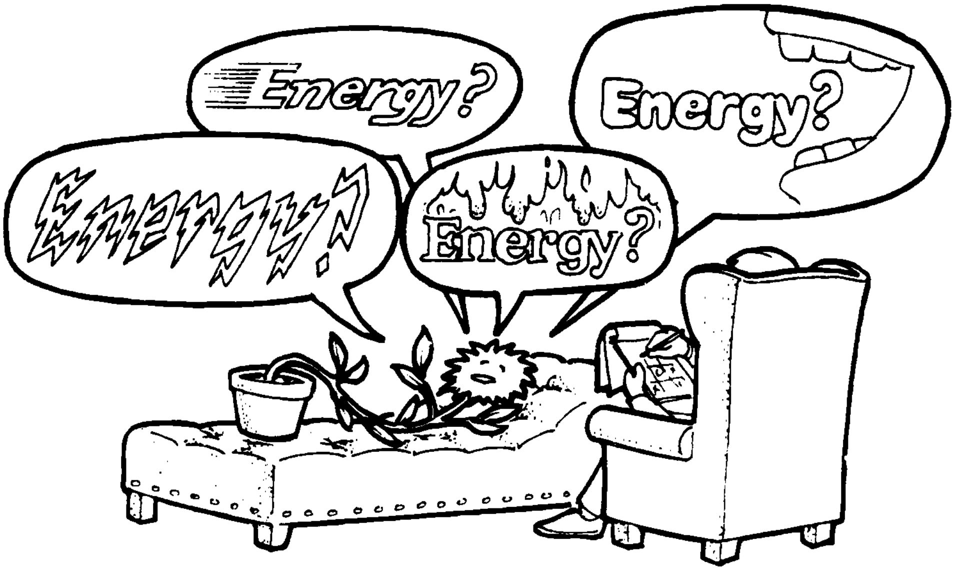
BACKGROUND: ACTIVITY #1

An Energy Primer



ENERGY IDENTITY CRISIS

We need it to run our cars and light up our homes. Without it your students start to lose their spunk as lunch break gets closer. If plants didn't get it from light, we'd be without our primary sources of food and fuel. "It" is energy, and it's what helps our world go 'round.

What is energy?

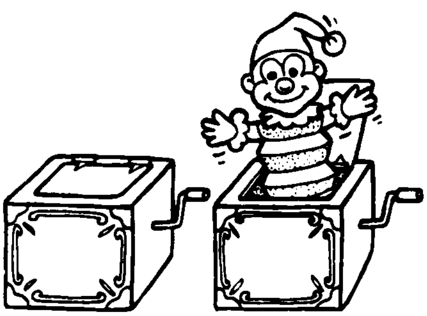
What is "energy" anyway? Isn't energy both a thing and a process? People talk about energy in terms of everything from electrical power plants to candy bars. We can look at energy in many ways. Ask a physicist, a biologist, or a homeowner to discuss the topic, and you'll hear a different perspective from each.

The traditional scientific definition of energy is the capacity to do work. But "work" can mean many things. Energy is involved whenever something moves or changes. When a flower blooms, a car engine runs and when a rock rolls down a mountainside, energy is involved. While the type of work in each example is very different, in each case energy is being converted from one form to another.

Three main forms of energy are potential energy, kinetic energy and light energy, also known as electromagnetic or radiant energy. **Potential energy** is stored energy that's not yet being utilized; for example, energy in a stretched bowstring that hasn't yet been released; food energy in a potato that has yet to be eaten; energy in a tank of gasoline that has yet to be burned. The potential energy in food and fuel are also known as chemical energy.

bow is released and the arrow flies through the air, the energy associated with that movement is called kinetic energy. The mechanical energy in the moving pistons of a car engine is kinetic energy. The sound energy of your vibrating eardrums is kinetic energy. And the heat energy of moving molecules is kinetic energy. Electricity moving through a wire is both kinetic and potential energy because of its potential to light a lamp at the end of a wire.

When plants make sugars and store starch, another kind of energy is involved. **Light energy** is the primary energy source for plants. Light energy is converted to potential energy when it is stored as food.



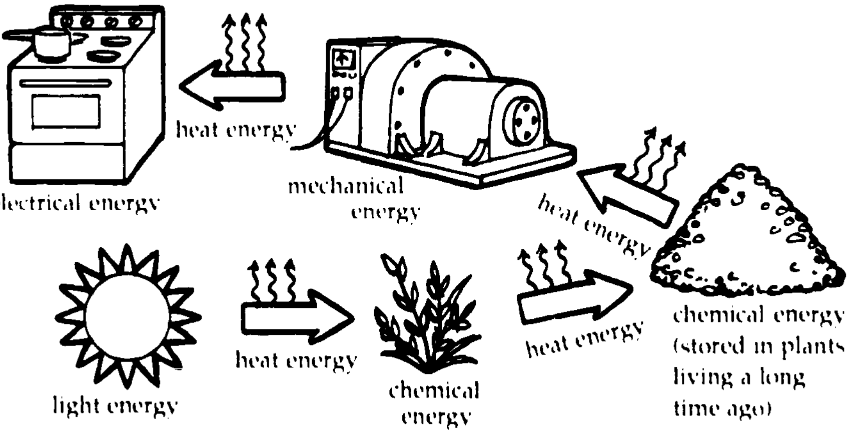
The Energy Switch

Energy is always changing from one form to another. For example, when you toast a marshmallow, stored food energy in the marshmallow is changed to heat energy. When a teapot whistles, some of the energy of heated water (the movement of the kinetic energy of water molecules) is changed to sound energy. Most of the energy, however, remains as heat energy associated with the molecular motion of the steam as those molecules move faster and faster as the water heats up.

When you rub your hands together, the kinetic energy (motion) of your hands changes to heat energy as the molecules of the hand move more quickly. When light energy from the sun changes to heat energy, water evaporates. Have your students play with a compressed spring (a Slinky), a jack-in-the-box, a water wheel, or even just a rock they can drop, to see how potential energy can change to kinetic energy.

Tracking energy as it converts from form to form produces what we'll call an "energy chain." Most energy chains start with the sun. Solar energy is converted and stored in many things; for example, a tree's wood, garden vegetables, fossil fuels, wind, clouds (evaporated water). The sun, therefore, is the original source of food energy and most fuel and electrical energy on Earth.

An Energy Chain



Thinking About Thinking
"If we value teaching for conceptual growth, then it stands to reason that we strive to uncover as much as we can. Accepting students' ideas without correcting those ideas is just the beginning. Indeed, we should revel in the students' conceptions... perhaps some of these will be the same as what Aristotle, for example, thought 3000 years ago! So if it took 3000 years to alter some of these conceptions, how can we expect young people to change their 'gut dynamics' after only a few activities or discussions (or, traditionally, from a single page or two from a textbook)....We need to find out as much as possible about what students are thinking (or think they understand) prior to, during and after engaging in science investigations."—Gregg Humphrey, Vermont Elementary Science Project

When energy changes form, no energy is gained or lost. This is the **first law of thermodynamics**—the amount of energy in the universe (or any closed system) is constant. Energy may change from one form to another or pass from one place to another, but there is no gain or loss in the total energy involved. For example, when a plant converts light energy to chemical energy, energy is being transformed, not produced.

Before you and your students conduct the other *Power Plants* activities, it is a good idea to start to uncover students' conceptions about the topic of energy. Activity #1, **Getting to the Source,** departs from the standard activity format to offer a series of exercises to help students explore their ideas about the topic. You can find out what students already know (or think they know) about energy. As students continue to investigate, many more preconceptions will emerge (see sidebar "Thinking About Thinking," page 9). Your understanding of students' thinking will be very helpful as you join with them to develop, through hands-on activities, new understanding of the world.

ACTIVITY #1

Getting to the Source

Overview: Students conduct projects to develop their own ideas about the topic of energy. They also consider the source of peoples' food energy.

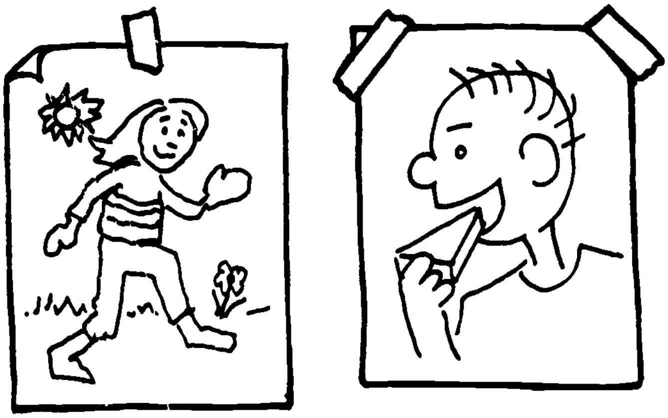
Time:
variable

Materials:
- drawing paper
- pencils, crayons, or markers
- assorted classroom materials

Background: Page 8

1. Facilitate a class brainstorm session about the topic of energy. Ask questions such as: *What is energy? What do you know about energy?* and record their ideas on the chalkboard.

2. Have students draw pictures of some of the things they do in the course of a day, such as walk, eat, drive. Display the pictures around the room.



Ask: *Which of these activities require energy? How can you tell when energy is being used* (something moves, something lights, a living thing grows, etc.)? *Where do you get the energy to do those things? When have you ever felt low energy? What might happen if you use more energy than you take in?*

Try acting out a few low-energy scenarios.

3. Focus students' attention on food (chemical) energy. Ask students where they think the energy they received from their lunch came from. As a class, write a list of the foods in the school lunch for the day. Remind students to pay attention to each detail, like the ketchup served with the french fries.

Next have small groups of students take one of the items on the class list and trace the food energy back to its source. Have students share their ideas, for instance, by illustrating a

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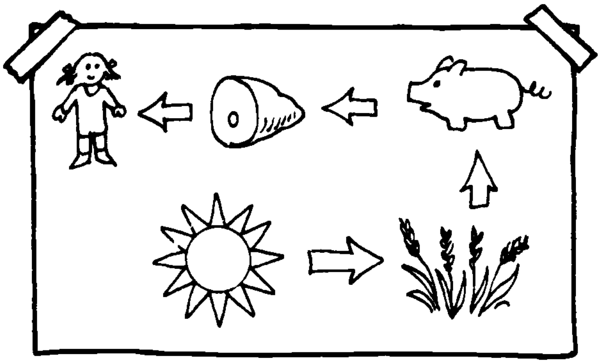
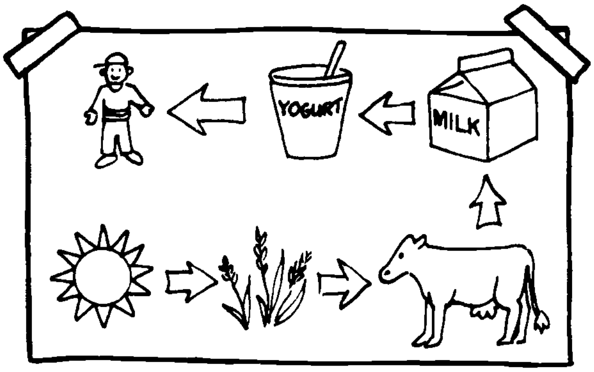
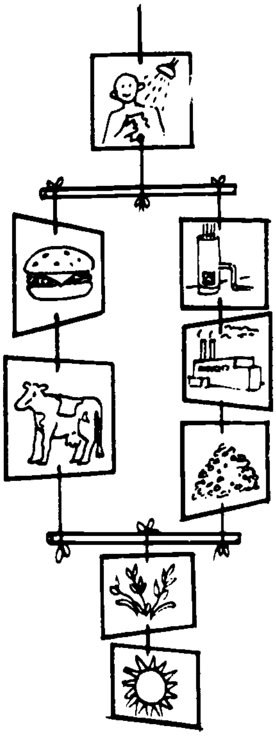
poster or telling a story (along the lines of "this is the house that Jack built...").

Some examples:





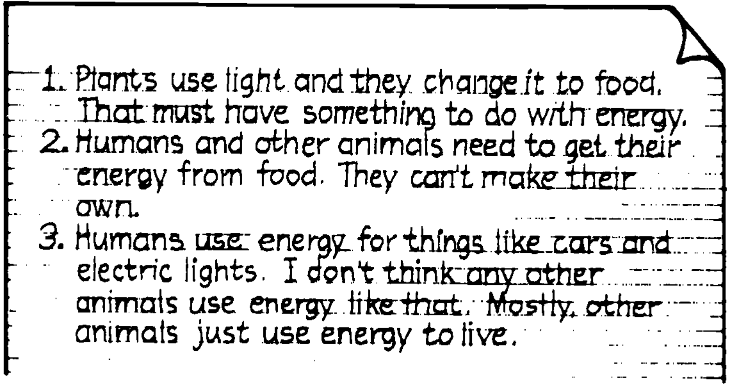
Ask: *What do you think our food energy is used for?* (Some is used for growth, some for work, e.g., play, reading, etc., and some is used to keep the body warm.) *As you look at the food energy you received, what role do plants play? What role does the sun play?* Challenge your students to find a food energy source that doesn't depend on plants. Challenge them to find one that doesn't ultimately depend on the sun.



4. As a class, choose one of the energy-requiring activities (from #2 above), and trace it back to its primary energy source. At each step in the energy chain, ask your students: *Where do you think that energy comes from?*

Try to present creatively the energy chain, for example by role-playing the parts of the chain, by making posters, or by making energy chain mobiles using magazine pictures.

5. In small groups, have students compare the way(s) humans use energy with the ways other living things use energy. Have them record their observations. For example,



1. Plants use light and they change it to food. That must have something to do with energy.
2. Humans and other animals need to get their energy from food. They can't make their own.
3. Humans use energy for things like cars and electric lights. I don't think any other animals use energy like that. Mostly, other animals just use energy to live.

6. With the brainstormed list (from #1) as a backdrop, ask the students to develop a list of questions they have about energy. Post these questions around the room and use them to fuel more discussions and explorations as the *Power Plants* unit progresses.

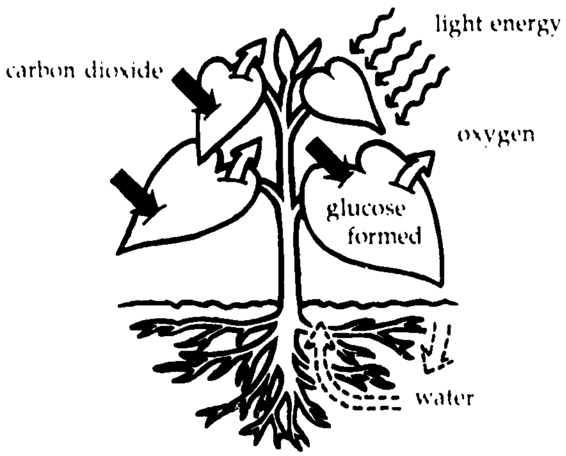
BACKGROUND: ACTIVITY #2 and ACTIVITY #3

Sun and Plants—The Ultimate Energizers

The planet Pluto receives so little of the sun's energy that it's cold and icy. Life—as we know it—just can't survive in such an environment. Parts of Mercury receive too much solar energy. Excessive heat does not allow life to flourish. Here on Earth, plants and most other living things thrive on the sun's energy. But that energy needs to change form before it is useful to most living things. Plants harness light energy and change it into food energy through a process called **photosynthesis**.

During photosynthesis, plants trap light energy and use it to change carbon dioxide and water into food, a sugar called glucose. Oxygen is given off as a byproduct. If plants don't use all the glucose right away, they change it to starches, lipids and protein and store them for later use. In the activity **The Energizers**, your students will test for stored food energy in plants. Starch is relatively easy to test for, and that is why we test for starch rather than other food energy such as simple sugars or fats.

Puzzled by Photosynthesis?
If you and your students would like to learn more about how plants make their own food, refer to pages 74 to 86 in *GrowLab: Activities for Growing Minds.*



$$\text{carbon dioxide} + \text{water} \xrightarrow[\text{of light energy}]{\text{in the presence}} \text{glucose} + \text{oxygen}$$

Plants store energy in all parts, including leaves, stems, roots and seeds. For example, we eat sugar cane stems, potato stem tubers and carrot and beet roots. A seed has a high proportion of its total mass in stored potential energy that helps it absorb water, break through its seed coat and start to grow. While the seed's roots spread down in search of water, and its shoot bores up in search of light, it taps into the stored energy resources. What happens if the seed's energy resources are depleted before the young seedling has a chance to break through the surface and receive supplementary light energy?

Lighten Up
Although you won't depend directly on the energy from sunlight if you use your indoor garden under lights, investigations with the fluorescent lights in your GrowLab enable your students to explore aspects of the relationship between plants and light energy. For more information about light in the GrowLab, see pages 44 to 46 in *GrowLab: A Complete Guide to Gardening in the Classroom* and pages 74 to 96 in *GrowLab: Activities for Growing Minds*.

If you and your students split a seed (try using a larger seed like a bean or peanut that has been soaked in water for 24 hours), you'll see a tiny plant inside. The bulk of the seed is actually the stored food required to provide the energy the plant will use until it's large enough and in the correct environment to produce its own food through photosynthesis. If the seedling can't get to the light, and the seed's food resources are used up, the plant just won't survive.

In the activity **Light Limits**, students will explore the relationship between light energy and plants. The activity **The Energizers** challenges students to examine photosynthesis and infer that light energy changes to food energy. You may choose to conduct one or both of these activities, depending on how familiar your class is with plants, light and photosynthesis.

ACTIVITY #2

Light Limits

Overview: Students conduct experiments to investigate the relationship between light energy and plant growth and development.

Time:
Groundwork: 30 to 40 minutes
Exploration: 40 to 60 minutes setup: 1–2 weeks ongoing observations
Making Connections: ongoing

Materials:
- fast-germinating seeds, such as radishes, peas, mung beans or beans
- any mature plants
- potting mix
- small containers, such as milk cartons or plastic bags
- plastic wrap
- tape
- "Problem Solving for Growing Minds" reproducible, page 45
- "Observation Journal" reproducible, page 49

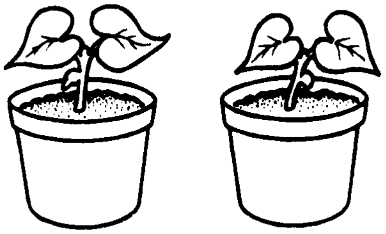
Background: Page 13
If you need more information about light and plant growth, see pages 44 to 46 in *GrowLab: A Complete Guide to Gardening in the Classroom* and pages 74 to 96 in *GrowLab: Activities for Growing Minds*.

Laying the Groundwork

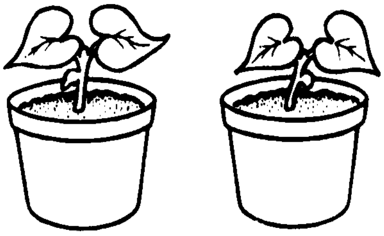
Objective: To consider that the sun is the ultimate source of energy on earth and to practice designing a "fair test."

1. Review with students what they explored about the source of food energy in Activity #1, **Getting to the Source**. Ask: *For any food source, what do you think is the ultimate source of energy? What role do plants play? How do you think plants depend on light?*

2. As a class, help students practice designing one basic experiment that explores the relationship between light and plant growth. For example,

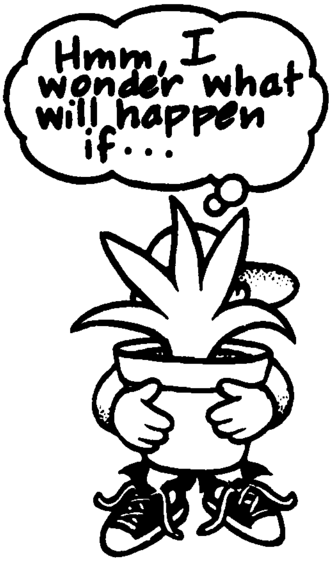


Group A
No light



Group B (Control)
14 hours of light

ERIC



3. Follow the Problem Solving for Growing Minds process, page 6, and ask students to:

- Choose one experimental variable.
- Keep all other variables constant.
- Decide if they need a control group.
- Decide what to observe.
- Repeat the experiment.

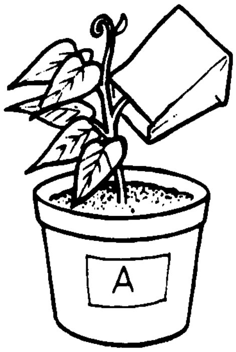
Help students think about the experimental design. Ask: *Did you remember to control* (keep unchanged) *all variables* (water, fertilizer, temperature, etc.) *other than the experimental variable? Do you have enough plants in each group to trust your findings? Do you need a control group? Which one is it? Why do you think you need one?*

Exploration

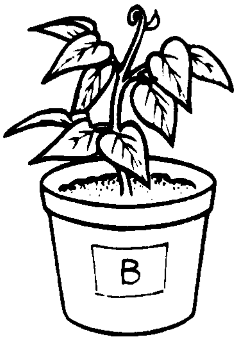
Objective: To infer that plants depend on light energy.

1. Challenge small groups of students to follow the Problem Solving for Growing Minds process and to conduct experiments exploring the relationship between light energy and plant growth. Some sample investigations follow:

Question: *What will happen if some leaves of a plant are kept in the dark while other leaves receive light?*

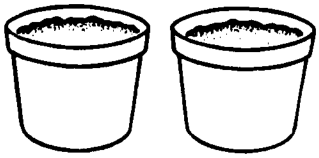


Group A
Some leaves in dark

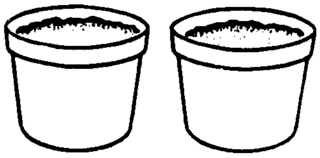


Group B
All leaves in light

Question: *What will happen if seeds are planted more deeply than recommended?*

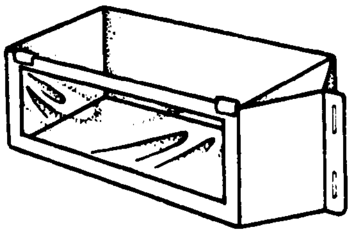


Group A
Recommended depth



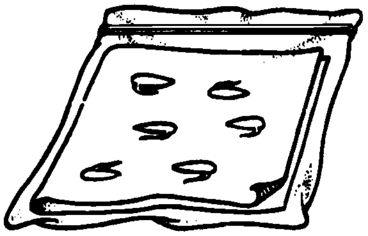
Group B
4X recommended depth

Just budding in: Use quickly germinating seeds such as radishes, beans or peas. If possible use a root view box to aid observations, but keep the root view box in the dark.

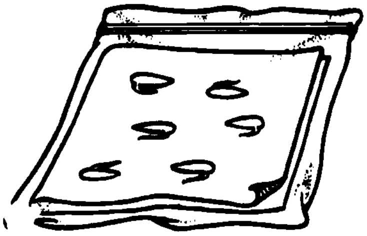


Root view box

Question: *How will edible sprouts respond if they are grown in different light conditions?*



Group A
Seeds in light



Group B
Seeds in dark

2. Ask: *What do you think will happen to the plants or seeds in each group (experimental and control groups)?* Have students record their predictions.

3. Have students compare and record—in words and sketches—the changes in plants.

4. Discuss findings as a class. Ask: *In general, how does light—or absence of light—seem to affect plants?*

What to expect: Plants (or parts of plants) that do not receive light energy will not photosynthesize. Without photosynthesis, plants will not convert light energy into the food energy they need to grow and develop. Plants that receive only partial light may continue to grow for a while, but they will not develop as well as those receiving optimum light energy. Often, plants grown without adequate light will be taller, but this "legginess" is a sign of weak growth.

Seeds contain stored food energy. A seed planted too deeply will not have enough stored food energy to reach the surface to become a "solar collector," where it would convert light to food. It is also possible that seeds planted too deeply would not receive enough oxygen and would fail to germinate. Remind your students that there might be more than one logical conclusion for their findings.

Although sprouts will germinate well in darkness, students will find that once sprouts are exposed to light, they will turn green due to the appearance of chlorophyll. This green pigment will enable sprouts to photosynthesize, make their own food, and grow. Sprouts that don't receive light after three to four days may look "taller," but spindly growth due to inadequate light is not healthy. Eventually, sprouts grown in darkness will fail to develop.

Making Connections

1. Possible discussion questions:

- *How did your findings compare with your predictions?*
- *What can you infer about plants' light requirements for growth? What did you observe that led you to your conclusions?*
- *How can you explain what happened to the seeds in the various experimental groups (for instance, those planted at different depths)? Can you be sure that the seeds or seedlings did not survive because they didn't have enough stored energy? What other possible explanations can you give for their lack of success?* (Perhaps seeds planted too deeply didn't receive enough oxygen.)
- *Can you be sure of your conclusions? Why or why not?* (If the experiment was not conducted as a fair test, for instance, seeds planted at different depths received unequal amounts of water, students might question whether they can trust their conclusions.)
- *What might you do differently if you were to conduct this experiment again? Why.*
- *How do humans and other animals use light energy?*
- *How do plants grown under artificial (fluorescent or incandescent bulbs) ultimately depend on sunlight energy?* (Except for nuclear energy, most other sources of electrical energy, such as coal, gas,

and hydroelectric, originate from sunlight.)

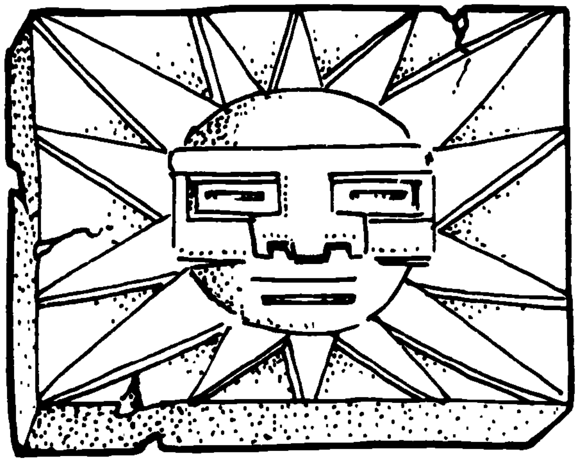
- *What else about light energy would you like to find out? How do you think we could find out more?*

2. Discuss the concepts of limits. Ask: *Just as plants are limited if they don't have sunlight energy, how are we limited if our energy sources run out? How are you affected personally? What might be the global impacts of depeleted energy resources?* Consider using a Futures Wheel, page 47, to explore this concept.

Branching Out

- In the center of a large poster board, draw a picture of the sun. Make a collage branching out from the picture showing how living and nonliving things relate to the sun.

- Write a series of newspaper articles reflecting how different cultures (ancient Egyptians, Incas of Peru, Native Americans) view the sun's role as a life and energy source. Consider how our reliance on the sun has changed throughout history.



- Find out how the sun's energy can be an energy source in your school or homes (solar heating and hot water, etc.).

- Research different types of lights that are marketed for growing plants. Find out how different lights approximate sunlight.

- Measure the growth of plants grown under different types of lights (incandescent, fluorescent tubes, compact fluorescent). Make a chart of comparative growth and discuss differences.

ACTIVITY #3

The Energizers

Overview: To understand that photosynthesis can change light energy to food (chemical) energy, students test plants for the presence of stored energy (starch).

Time:
Groundwork: 40 minutes
Exploration: 40 minutes setup; 4-6 days later, 40 to 60 minutes
Making Connections: ongoing

Materials:

- corn starch
- iodine solution (see Advance Preparation below)
- assorted foods and/or GrowLab edibles (see Laying the Groundwork below)
- potting mix
- growing containers
- various mature plants (see Exploration below)
- ethyl alcohol (Ethyl alcohol and isopropyl alcohol are both sold as rubbing alcohol; make sure you use ethyl, not isopropyl alcohol.)
- hot plate
- tweezers
- shallow container
- "Problem Solving for Growing Minds" reproducible, page 45
- "Observation Journal" reproducible, page 49

Background: Page 13

Advance Preparation:
Make an iodine solution for starch test by adding approximately 40 drops of iodine to 1/2 cup (approximately 125 ml) of water.

Caution: Iodine is toxic. Store away from heat and direct light. For long term storage, place bottle in a plastic bag, close with a twist tie, and place in an empty, covered can. Fill can with cat litter. Follow proper disposal procedures. Iodine will stain skin and clothing.

Laying the Groundwork

Objective: To discover that plants store starch.

1. Ask students: *Where do you think plants get their food? How do they make their food?* Discuss the process of photosynthesis with your students. (See sidebar "Food Making at a Glance," page 22)

2. Demonstrate that several drops of iodine solution (see Advance Preparation) reacts when dropped onto some corn starch dissolved in water. The brownish-yellow iodine solution will turn blue-black when it touches starch. Drop some plain water on the corn starch as a control. Explain that the iodine is used to test for the stored starch in plants.

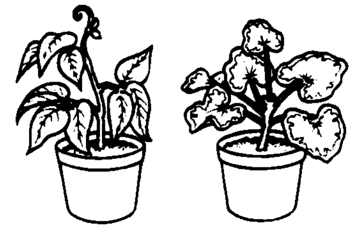
3. Now try several other foods of plant origins: potatoes, table sugar, crackers, cooked pasta, and raw and cooked edibles grown in your classroom. Have students predict which foods might contain starch. Ask: *How do you think the starch got into these foods?*

Exploration

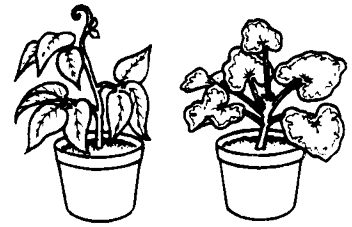
Objective: To discover that light energy is necessary for starch production in leaves and to infer that starch stored by plants is a major source of food energy for plants, humans, and other animals.

1. Ask: *If we eat plants (or if we eat animals that eat plants) to get our food energy, where do you think plants get their food energy (the stored starch) from?*

2. Following the Problem Solving for Growing Minds process, page 6, have students set up the following investigation to compare starch production in plants grown in the dark with that of plants grown in light.

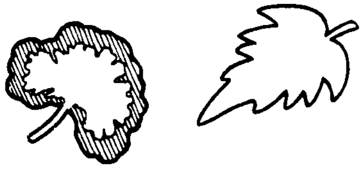


Group A
Plants in closet

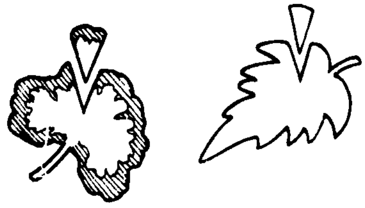


Group B
Plants in light

After four days, remove several leaves from each plant. Make sure to cut a notch in or tie string through the stems of the leaves from one group to distinguish them from those in the other group after they're tested for starch.



Leaves from Group A (closet) plants



Leaves from Group B (light) plants

Just budding in: We recommend using leaves from plants such as: geraniums, tomatoes, beans, Swedish ivy and/or peas.

3. Ask: *What do you think we'll find in the leaves from each experimental group? What explanation can you give for your prediction?* Help students test for starch in leaves, carefully following the directions on the next page.

Test for Starch in Leaves

Pour approximately 200 ml of water into a small pot (or beaker or metal cup) and add the leaves. Boil for approximately 15 minutes. When the leaves become pale and flimsy, remove them and place them in approximately 200 ml of alcohol (ethyl alcohol or ethyl rubbing alcohol, NOT isopropyl). Work with the alcohol in a well-ventilated area. Caution: Keep alcohol away from heat. Let the leaves sit in the ethyl alcohol for a few minutes. Remove them with tweezers, rinse them with water, and place them in a shallow container, such as a Petri dish. Cover with iodine solution (see Advance Preparation).

Just budding in: The iodine test for starch in leaves is more complicated than the simple process used with corn starch because plant leaves have rigid cell walls and contain chlorophyll. It is necessary to first boil them to weaken the cell walls and remove the chlorophyll. Only then will the iodine test for starch work in leaves.

What to expect: Leaves from plants that have received light energy will have turned blue-black from the iodine. Starch was produced in these leaves. Plants grown in darkness will have used up any starch they had originally stored.

Food Making at a Glance
All living things need food to give them energy and help them grow. Lacking legs, wings, or fins to carry them in pursuit of food, plants make their own food from raw materials in their immediate environment. Leaves are the main food-making factories in plants. They have a special ability to trap light energy and use it to change carbon dioxide (taken in through the leaves) and water (taken in through the roots) to food, a sugar called glucose. During this process, called photosynthesis, plants give off oxygen, which humans and other animals need to live.

If appropriate, explain or review the process of photosynthesis with students. (See **Teacher Background**, page 13, or sidebar, "Food Making at a Glance.")

Making Connections

Possible discussion questions:

- *How can you account for the presence and absence of starch among the different experimental groups?*

- *Which plant parts do you think might be good sources of energy for humans and other animals? Why might there be differences in the plant parts?* (Roots are good for storing starch and seeds can contain starch, fats and oils.)

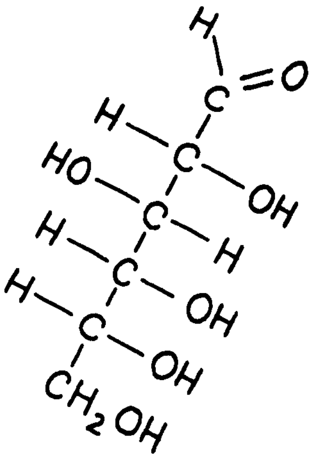
- *Plants store energy that humans and other animals can use for food. Can you think of other ways humans rely on the stored energy in plants?* (Most of the major fuel sources—oil, coal, natural gas—come from stored chemical energy in plants.)

Branching Out

- Test for the presence of sugar—another source of energy—in plants:

  Use Clinitest papers and follow directions, or use

Benedict's solution (both available in drug stores or from chemical supply companies). For Benedict's solution finely chop or grind up leaves. Put in test tube and fill halfway with Benedict's solution. Heat (boil gently) for approximately five minutes. The solution will start blue. If it changes to a deep red color, sugar is present.



- Test for the presence of stored oils in plant seeds. Rub seeds against a brown paper bag. If a greasy, wet spot remains that looks translucent when held up to light, this is evidence that the seed contains fats or oils. Find out how plants and animals use fats and oils as energy sources.

- The products of photosynthesis are all made up of carbon, hydrogen and oxygen. Find out more about the chemical bonds between carbon, hydrogen and oxygen. Build models of the compounds and demonstrate how energy is stored in the bonds.

- Make posters advertising plants' abilities to convert light energy into the food energy needed by living things (including humans).

- Write and perform photosynthesis plays, acting out the various "characters" involved in this process.

- Make dioramas representing the different fuel sources that originate with plants (coal, wood, oil) or the sun (solar, wind, waves). Ask: *Which of these resources are easiest to use up? How long might it take to replace these resources once they are gone?*

BACKGROUND: ACTIVITY #4

The Energy Flow

In an ecosystem, somebody or something is always eating somebody or some other thing. The successive levels of who is eating whom is called a **food chain**. Food chains consist of **producers, consumers** and **decomposers**. Green plants are usually the producers and form the base of the food chain. Any animal that consumes the plants (and/or other consumers) is known as a consumer. Ultimately, all living things are consumed by the decomposers, mostly consisting of fungi and bacteria that use dead plants and animals as food. They release nutrients that are used again by plants. When many food chains are interconnected, they form a more complex **food web**.

Energy in Food Chains

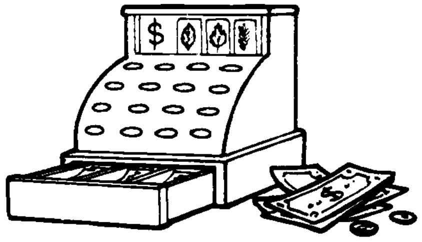
There are a limited number of links in any food chain (typically not more than four or five). Each time energy is transferred in a food chain (when something gets eaten by something else), there is less useable energy available. The **second law of thermodynamics** says, basically, that anytime energy is transformed or transferred, there is some reduction in quality of the energy. The energy available becomes less useable for many reasons.

A main reason that the quality of energy is reduced at each link in a food chain is that much of the food (chemical) energy is converted to heat energy. All living things produce heat, but heat energy cannot be used as a primary energy source. Heat is kinetic energy—molecules in random motion. "Hot molecules" are less ordered and, therefore, harder to harness and pass on to another link in the chain.

Another reason a large portion of useable energy becomes unavailable as it is transferred along a food chain is because it is utilized for living processes such as growth and reproduction. Let's think of a living thing as a business. Plants and animals utilize much of their energy for day to day operations such as waste removal and maintenance. These are the "costs" of maintaining and building a living thing. Only the food energy that is left over can be "invested" in the growth of the "business" (for example, the production of new leaves). As more energy goes into keeping a living thing alive, less is available to the next animal in the chain.

Photosynthesis uses less than one tenth of one percent of the solar energy reaching the Earth's surface. When plants photosynthesize, only about one to three percent of the energy they receive ends up being available to animals eating the plants. A key reason for this loss is that during photosynthesis plants utilize a great deal of energy splitting water molecules into hydrogen and oxygen.

Then only 10 percent of that energy is available to the animals who ate the animals who consumed the plants. The other 90 percent is used for life processes like circulation of fluids and respiration. The amount of food energy available to any consumers farther along the food chain is so small that rarely are more than four or five links possible. Because nothing can be supported beyond this level, more energy from the sun is needed. Thus, most living things are continually dependent on the sun for energy. For example,



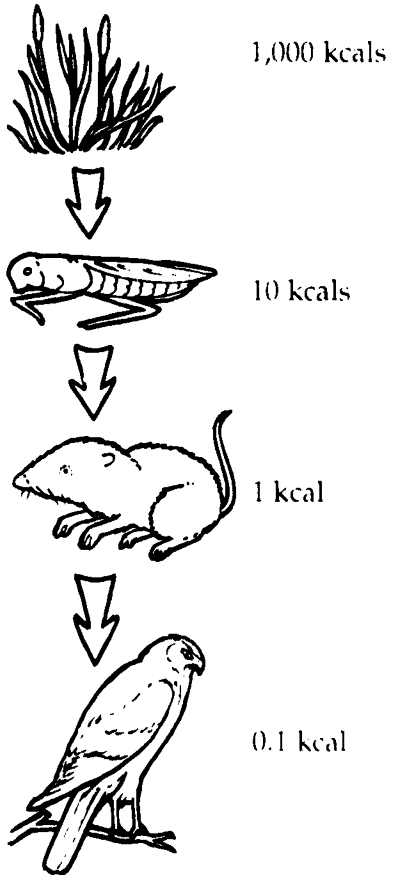
Bones for Brunch?
Some food energy becomes less available at each link in a food chain simply because the food is inedible or indigestible to the consumer. While cows can digest grasses to unlock the energy and nutrients, humans cannot. And when was the last time you enjoyed cartilage au gratin?

If one square meter of plants used about 1,000 kcals* of light energy in photosynthesis per day,

about 10 kcals of energy would be available for this consumer, and

1 kcal would be available for this consumer,

leaving only approximately 0.1 kcal available to this consumer!



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* One kcal is equal to the amount of heat energy needed to raise the temperature of 1,000 grams of water one degree Celsius.

In the activity **Let it Flow,** students consider how energy is transferred along food chains. They're asked to compare the costs of running a business to the "costs" of building and maintaining a living thing. Students are challenged to simulate how less energy becomes available to the next link each time energy is transferred. Finally, students will be asked to consider why eating lower on a food chain, that is, closer to the sun's energy, is more energy-efficient.

ACTIVITY #4

Let it Flow

Overview: Students play a simple business game to simulate how energy becomes less available at each level in a food chain.

Time:
Groundwork: 40–60 minutes
Exploration: 40–60 minutes
Making Connections: ongoing

Materials:
- paper
- markers, crayons or pencils
- empty 2-liter soda bottle
- water
- miscellaneous classroom materials such as paper clips
- optional: popcorn or peanuts (see Exploration on page 28)

Background: Page 24

Laying the Groundwork

Objective: To understand the basics of the energy costs throughout a food chain.

1. Divide the class into small groups. Ask each group to set up a business and decide:

- the name of their business
- a product they want to make
- how much the product will cost to make
- how much the product should sell for
- how much money they will make

Ask: *What will your profit be? What will be available to put back into the business?*

For example,

- BeauTEEfuls, Inc.
- hand-painted tee shirts
- cost $12 to make
- will sell for $20
- profit = $8

Or does it?

Most students will probably calculate their profits in this very simple way. Ask: *Besides the actual costs of materials, etc. (that it took to make the shirts), what about all the costs that go into the day-to-day running of the business, like phone calls, packaging, postage, electric bills, transportation, etc.?* Discuss that in any business you have to consider those costs before you can figure out what your real (net) profit is. The cost of running the tee-shirt business might really be about $6 per shirt. So, you need to figure the real profit as:

$20 (gross earnings)
- $18 ($12 to make shirts plus $6 for other costs of running the business)
$2 (net profit)

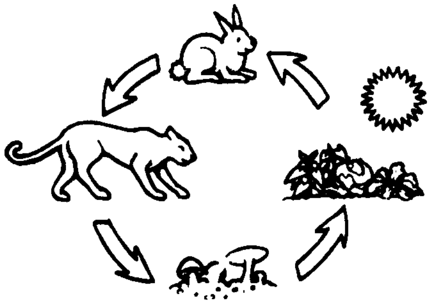
Your net profit is really $2, or 10 percent. This $2 is the amount of money that is available to do other things. You might choose to invest this money in purchasing more materials (How about some special glow-in-the-dark paint?), or to increase your advertising.

2. Ask students how plants and animals use their energy resources for day-to-day operations. Discuss that, just like running a business, living things use a lot of their energy for activities such as waste removal. These are the "costs" of maintaining and building a living thing. Only the food energy that is left over can be "invested," for example, in the production of new leaves (growth). Therefore, only a fraction of the original energy will be available to consumers at other links in the food chain.

Generally, there is about a 90 percent decrease in the amount of energy available at each link due to much energy being changed to the less useable form of heat energy. The rest of the energy is used for living processes such as growth and movement. Share **Teacher Background** information about **Energy in Food Chains,** as appropriate.

Exploration

Objective: To demonstrate how useable energy becomes less and less available at each link in a food chain.



1. If necessary, review with students that when one living thing consumes another, passing along food energy, the path is known as a food chain. Ask: *Where does a plant get its food energy from? What do you think the energy it gets from the sun is used for?* (Some is used for growth, work, e.g., play, reading, etc., and some is used to keep the body warm.) *If a caterpillar comes along and eats the plant, do you think it will get all of the energy the plant got from the sun?*

2. Facilitate a class discussion about whether students think they can, in a classroom setting, explore how energy becomes less and less available at each link in a food chain. It's important that students realize that not all scientific concepts can be "proven" without sophisticated technology beyond the reach of your classroom. Ask: *Since we can't actually see the changes in available energy, are there any ways we can use our limited resources and unlimited imaginations to simulate or model what is happening?*

3. Choose several students to role-play the various links of a food chain. For example,

marsh grass → grasshopper → shrew → marsh hawk

Fill a 2-liter soda bottle with water. Have a student represent the plant. He or she inverts the jar and pours out 90 percent of it. Now, you will have only about 200 ml available for the grasshopper.

Ask: *What does the reduced water level in the jar represent?* (The water poured out represents the energy that becomes unavailable at each link in the food chain. The remaining water represents the energy that is still available for the next consumer.)

At each link, pour out 90 percent of the water remaining in the bottle. Out of the 200 ml from the grasshopper, only 20 ml will be available to the shrew. Only 2 ml (a few drops) will be available to the hawk. Ask: *How much "energy" (represented by the water) would be available to something hunting the hawk?*

4. Challenge small groups of students to create their own methods to illustrate energy losses at links in food chains. For example,

- Start with 1,000 popcorn kernels or peanuts, representing the total energy available. Have students at each link eat ninety percent before passing the remaining, available "energy" on to the next link.

- Have the students representing the first link hold 100 paper clips. Each time energy is passed from one link to the next, only 10 percent of the paper clips get transferred.

Making Connections

1. Possible discussion questions:

- *Were you surprised by the amount of energy that becomes unavailable at each link in the food chain? Why or why not?*

- *Why did your group choose the simulation you did? How did it help you illustrate the ecological principle?*

- *What other types of scientific investigation require the use of models and simulations?* Encourage students to think about things that are too far away (such as space exploration), too dangerous (such as nuclear explosions), or without the necessary technology (before the invention of microscopes) to explore directly.

- *How is eating closer to the source of the food chain more energy-efficient?* (The amount of useable energy is reduced as it passes through a food chain. For example, a cow needs to eat a lot of plants to get enough food energy to live and produce milk.) *Why do you think it's more energy-efficient to be an herbivore rather than a carnivore?*

- *How can humans most directly obtain food energy from the sun?*

2. Discuss: The further we are from a food source in time, distance and processing (refrigeration, transport, etc.), the greater the indirect energy costs.

Branching Out

- Grow and eat sprouts. *Why are these such energy-efficient food sources?* (There's more direct use of energy when you eat producers, and there's less waste due to transport, packaging, etc.)

- Find out if there are local farmers' markets in your area. Interview a farmer and a grocer to find out the paths the same foods make to get to your table from each source.

- Discuss this quote: "When you pick a flower, you shake a star." —John Muir, naturalist.

- Create food webs illustrating how complex the energy flow is through a system of interdependent food chains.

- Have students bring in photographs of themselves at different stages in their life (baby, toddler, present age) and draw and/or discuss what they might look like as a 30-year old and as an elderly person. Ask students how energy is used differently throughout life cycles.

BACKGROUND: ACTIVITY #5

Energy in Food

Most living things are made up of cells. These cells are like little furnaces that run on the materials and energy from food. While some food energy is used to keep the "furnaces" operating, some of it is transformed to heat. Some of this heat energy is needed to help maintain the optimum temperature for the cells to function.

The **energy value** of each food differs. One way to figure out how much energy is stored in food—its energy value—is to burn the food and measure the kilocalories. A **kilocalorie** is the amount of heat needed to raise 1,000 grams of water one degree Celsius. A kilocalorie (kcal) is equal to 1,000 calories. The caloric value of foods is usually given in kilocalories; the more commonly used term "**Calories**" is actually kilocalories. You and your students can measure the amount of food energy of different foods by building and using a special device called a **calorimeter**.

In the activity **Burn It!**, students will conduct basic physics experiments and use a simple calorimeter. They'll measure and compare how much energy is stored in different types of plant-based foods.

Some powerful conversions

A British Thermal Unit (BTU) is the amount of heat energy needed to raise the temperature of one pound of water one degree Fahrenheit. There are 252 calories in one BTU. One pound of coal releases about 13,000 BTU's of heat, and one pound of wood releases about 11,000 BTU's. 100 cubic feet of natural gas releases about 100,000 BTU's and one gallon of home heating oil releases about 138,000 BTU's of heat. Have your students calculate the amount of heat energy generated by the different fuels. Pound for pound, how do they compare?

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ACTIVITY #5

Burn it!

Overview: Students build and use a simple calorimeter to explore that food energy may be measured in the form of heat energy.

Time:
Groundwork: 40–60 minutes
Exploration: 45 minutes setup;
40–60 minutes observations
Making Connections: ongoing

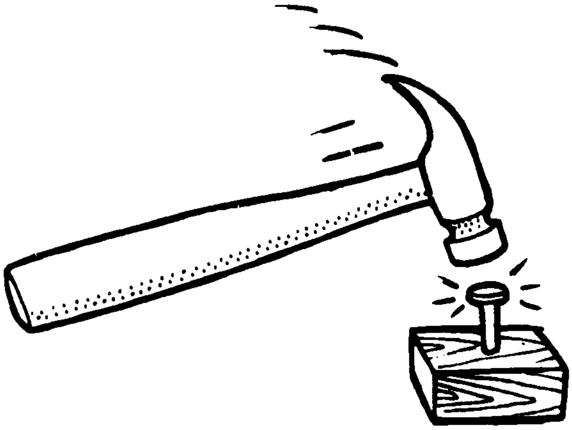
Materials:
- iron nails
- hammer
- block of wood
- ice cubes
- small (6–8 ounce) juice or soup can
- large (1–1 1/2 quart) can
- scrap wire
- small clump of clay
- long pin (like a hat pin)
- matches
- water
- thermometer
- safety glasses
- assorted foods: peanuts, chunk of coconut, popcorn potato chips, meat trimmings, home grown edibles (beans, carrots, radishes)

Background: Page 31

Laying the Groundwork

Objective: To consider that heat is produced when energy is changed from one form to another.

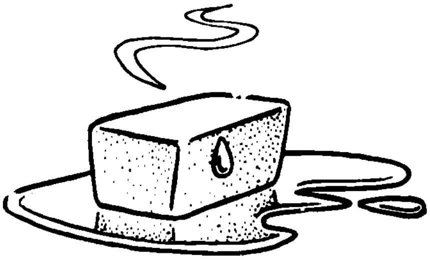
1. Pass around an iron nail and let students feel it and observe it closely. Next hit the nail powerfully with a hammer into a block of wood. Quickly let students touch it and observe it. Ask: *Use all your senses and describe what changes you notice in the nail. Why do you think these changes occurred?*



The moving hammer has kinetic energy—the energy of motion. When it hits the nail, some of this energy strikes, flattens and moves the nail. Some of the energy is converted to sound energy (we hear the striking), some of the energy is converted to heat (the nail feels warm), and some of the energy goes into driving the nail into the wood.

2. Ask: *If we observe something happening, how can we tell if energy is involved?* (something moves, lights, cools, warms, a living thing grows, etc.) Conduct several simple physics experiments/demonstrations to show that heat is produced when energy changes form.

For example:



- Have students vigorously rub their hands together and note the changes in temperature.
- Have students melt ice cubes with their hands, with incandescent lights, with GrowLab lights and/or with sunlight.
- Have students do hard exercise for several minutes and notice changes in themselves.
- Vigorously pump a bicycle pump and feel the temperature of the pump change.
- Take the temperature in a closet or small room. Crowd as many students in as possible. After a few minutes, take the temperature again.

Just budding in: Have students compare ice cubes left in the dark with those left under the GrowLab lights. Remind them to keep all variables the same (for example, the ice cubes inside and out of the GrowLab should be the same height, be on the same surface, etc.) They will find that ice cubes will melt in either case. Ambient classroom temperature is also providing the heat to melt the ice. However, the additional heat provided when light energy is converted to heat energy will cause the ice cubes to melt more quickly in the GrowLab.

3. Ask: *What is happening in each of these activities? How do the results in each case compare?* Discuss that, in each case, some form of energy is given off as heat energy. Discuss with students that almost any time energy is being changed from one form to another, some is changed to heat energy. Ask: *Can you think of some examples?* (I get hot. My car engine gets warm. My refrigerator gives off heat. My dog pants....)

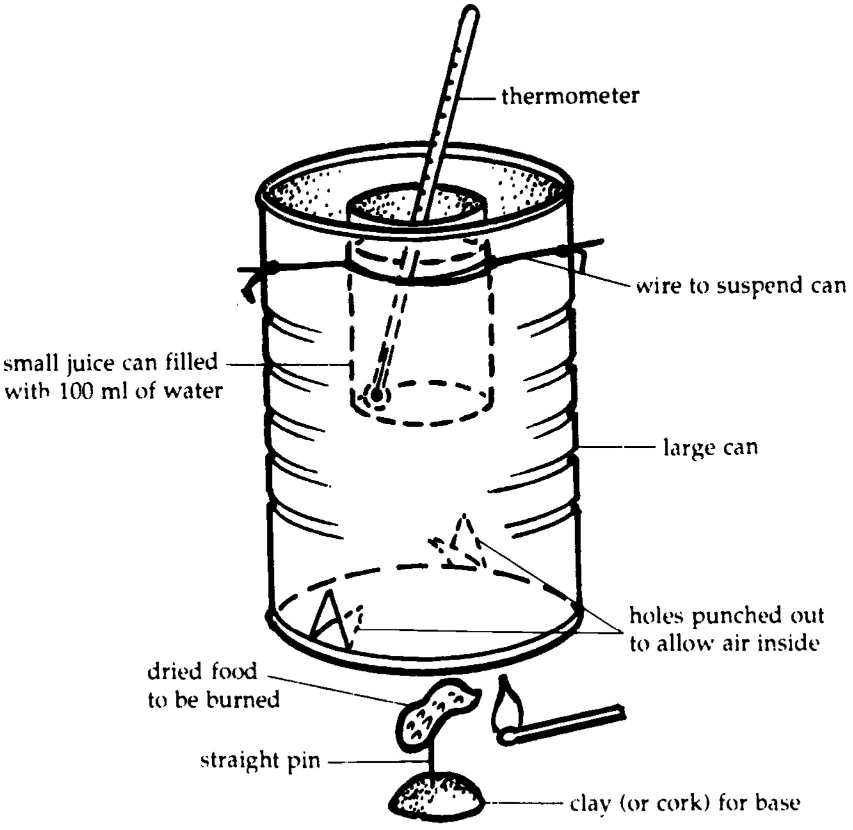
Exploration

Objective: To demonstrate that foods store chemical energy. To infer that some food energy is changed to heat energy.

1. Discuss with students that the food energy is measured in heat units called kilocalories. A kilocalorie (kcal) is the amount of energy required to raise the temperature of 1,000 grams of water by one degree Celsius. When people talk about "counting Calories" for weight loss, they are actually talking about kilocalories.

2. Ask students to predict which types of foods will contain more energy value. Ask: *Why do you think they will?*

3. Have students set up a simple calorimeter, as illustrated below, and measure the energy values of different foods.



A simple, homemade calorimeter

Caution: Wear safety goggles when using the calorimeter.

Calorimeter Directions:

- Measure approximately the same amount of grams of several different foods: peanuts, chunk of coconut, potato chips, plants grown in class, fat trimmed from meat.
- Fill the small can with 100 ml of water at or slightly below room temperature. Record the temperature of the water.
- Place one food at the end of the pin and stick the pin in the clay.
- With a match, light the food and quickly—and carefully—place the double-can setup over the burning food.
- Immediately place the thermometer in the water and measure the temperature change.
- With this simple setup, some extraneous heat loss will occur, but you can still compare the heat energy generated by different foods.

Just budding in: If you are measuring the energy in fresh fruits or vegetables, you must first dry them out completely before you can burn them.

- Calculate the heat produced as follows:

Since you'll be using 100 ml of water (which is the same as 100 grams of water), simply divide the temperature change of the water by 10 to find out the food's heat energy value.

(Remember, one kcal is the amount of energy required to raise the temperature of 1,000 grams of water by one degree Celsius.)

Making Connections

1. Possible discussion questions:

- *Which types of foods gave off more heat?*
- *How do your findings compare with what you know about the various functions of plant parts?* (Seeds and some roots are energy storehouses.)
- *Why do you think you need to drink water after being very active?* (Vigorous activity produces a lot of heat energy. Your body has several ways to dissipate excess heat—circulating blood, exhaling breath, sweating. Drinking water also helps cool your core body temperature.)
- *What might happen to a living thing if it didn't produce enough of its own heat energy?*
- *Not only do different foods have different energy values, but living things differ in their energy needs. How do different plants and animals, for example, sloths and hummingbirds, differ in their energy requirements?*

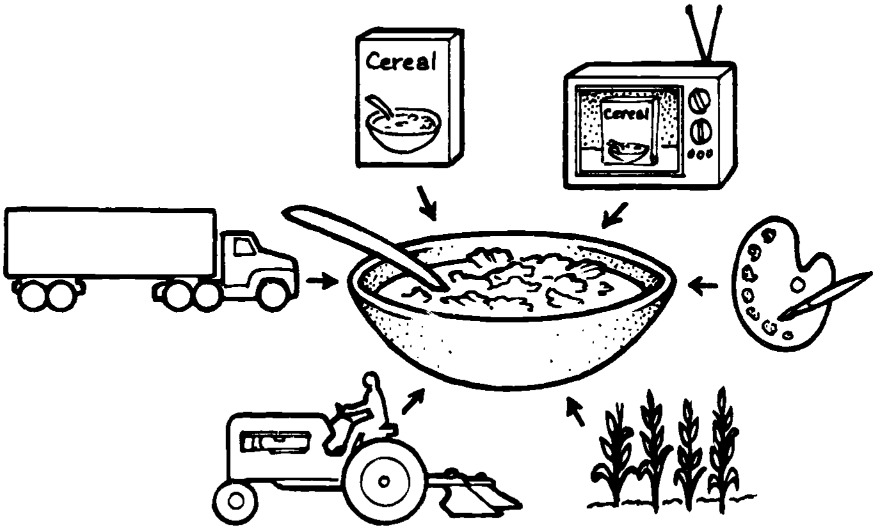
2. Examine this chart of the amount of kilocalories expended in some common activities.

Activities	Average Kilocalories Used Per Hour
playing piano	150
gardening	450
reading quietly	75
making beds	230
running fast	1000
bowling	250
sleeping	60

Use nutrition charts and/or food labels to find out the caloric values of certain foods. Compare the amount of kilocalories received from certain foods with the amount of kilocalories expended from specific activities. Ask: *How difficult is it to obtain an "energy balance" (kcals taken in vs. kcals used)?*

Branching Out

- Compare the energy it takes to produce a box of cereal (growing, production, packaging, transport, etc.) with the energy your body will receive when you eat the food. Repeat for other foods. *How energy-efficient does the cereal seem compared to other foods?*



- Rank the caloric values of different foods. Make graphs to illustrate.

- Convert nutritional energy (kilocalories) to thermal energy (BTU's).

- Use nutrition charts and/or food labels to analyze the kilocalories and nutritional content of GrowLab food (or fresh garden food) as compared with processed foods.

- Compare the energy efficiency of incandescent and fluorescent light bulbs.

BACKGROUND: ACTIVITY #6

Conserving Energy Resources

"Energy is Conserved"
When physicists talk about conservation of energy, they don't mean that we should remember to turn off the lights. They mean that, while energy constantly changes form, the overall amount in the universe never changes.

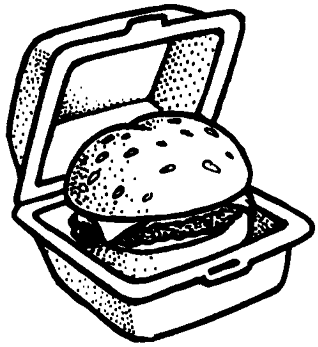
Humans, like all other living things, require energy for natural processes such as growth, digestion and motion. But we also have found many other uses for energy resources. For activities such as heating our homes, running our refrigerators and driving our cars, we depend on fuels such as coal, natural gas, oil and uranium. Supplies of energy sources such as these are limited and considered "**nonrenewable**" because they require millions of years to replace. In contrast, resources such as wind, solar and hydroelectric power are considered **renewable**. Over 90 percent of the energy resources used in the United States today are nonrenewable.

How'd the Fossil Get in Fossil Fuels?
When living things die, the remains are generally consumed by decomposers and scavengers. Sometimes plants and animals (including microorganisms) die and are buried by landslides or sink to the bottom of an ocean or swamp where their remains can't immediately be used by other living things. Over millions of years, pressure turns the fossilized remains of dead plants and animals into coal, oil and natural gas. These fossil fuels are quickly being depleted by modern society.

Energy Resources and Food Systems

People in the United States use significantly more energy resources per capita than people in other countries. The *Atlas of the Environment* (Prentice Hall Press, 1990) reports that the United States burns more than a quarter of the world's fossil fuels, even though it has only six percent of the world's population. Comparing fuel oil alone, approximately 2,900 gallons of fuel oil (almost 70 barrels) is consumed each year by each North American, according to Peter Tompkins and Christopher Bird, authors of *Secrets of the Soil* (Harper & Row, 1989). An average of only about 450 gallons (11 barrels) is the per capita consumption worldwide.

The food system in the United States has an extensive dependence on nonrenewable energy resources. Overall, 17 percent of fuel oil burned is used for food production. Crops are grown, animals are raised, food is processed, packaged, transported, marketed, purchased and eaten—all with highly energy-intensive methods. For every food item consumed, there are many direct and indirect energy costs.



The cattle industry is just one illustration of the energy-intensive process. According to Tompkins and Bird, each American steer eats some 21 pounds of plant protein to produce one pound of protein in steak. About 25,000 kilocalories of energy is expended for every 1,000 kilocalories of beef produced. And people in the United States consume about 140 pounds of red meat per capita. Growing your own food, eating foods that are less processed and less packaged and eating less meat are some possible ways to save energy in the food system. Decisions we make about how we produce and consume food can greatly affect the efficient use of energy resources.

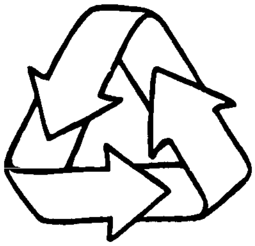
Biomass Energy
Plant or animal matter that can be converted into fuel is called "biomass." Almost half the world's population rely on biomass, with wood the most common form of biomass fuel. It is estimated that 80 percent of people in developing countries rely on wood as their primary fuel. But other biomass sources, such as blue-green algae, charcoal, dung, corn and oil palms are viable alternatives to burning fossil fuels, according to the U.S. Department of Agriculture.

Why Not Waste Energy Resources?

Nonrenewable resources are nearly irreplaceable. There are also some serious social and environmental problems associated with the burning of fossil fuels. The greenhouse effect, air pollution and oil spills are a few of the environmental issues surrounding the use of energy resources. The potential hazards of nuclear power and political and military tensions due to our dependence on foreign oil are other concerns.

The best ways to make the most of our energy resources and lessen the environmental, economic and political impacts include conservation and energy efficiency. Conserving our energy resources is promoted by the following:

- Reduce overall uses of energy resources.
- Substitute renewable resources for nonrenewable resources whenever possible.
- Reuse or recycle products.



In the activity **Conservation Quest**, students are asked to analyze their personal uses of energy resources. They are challenged to figure out ways they can become more efficient energy users, specifically regarding their role in food systems.

ACTIVITY #6

Conservation Quest*

Overview: Students analyze their own energy conservation practices. They explore how energy resources are used in producing food. They then try to figure out ways to be more efficient energy users.

Time:
Groundwork: 30 to 40 minutes
Exploration: 1 week
Making Connections: ongoing

Materials:
- paper
- pencils
- scrap paper, twigs or blocks
- "Futures Wheel" reproducible, page 47

Background: Page 37

Laying the Groundwork

Objective: To uncover ideas about the concept of energy conservation. To understand that any energy source can be exhausted when the rate of use exceeds the rate of supply.

1. Without defining "energy conservation," ask each student to write down one example of a way to conserve energy. Compile all responses in a class list on the chalk board. After reviewing the list, have the class come up with a definition for "energy conservation."

2. Ask students if they think that they are energy conservers. Have students give some examples of ways in which they conserve energy. Ask: *How can we conserve even more?* There are many ways to conserve energy resources, such as not using resources faster than they can be replaced, using fewer resources, and not wasting resources.

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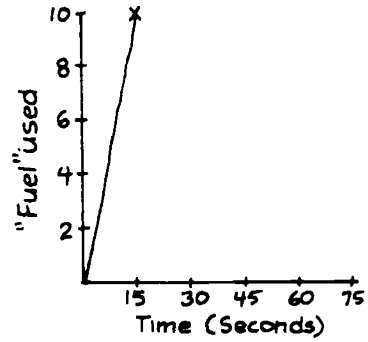
*Parts of this activity are adapted from *[illegible]* copyright National Energy Foundation, used with permission.

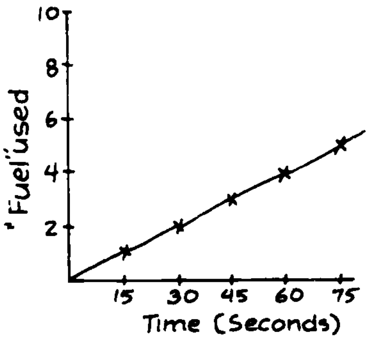
3. To illustrate the effect of controlling how fast they use energy resources, have your students play the game, All Gone! as follows:

All Gone!

- Give each student about 10 small strips of paper and have them roll or crumple them up to represent logs or chunks of coal. (Students can also use blocks or twigs.) Have students place all the "fuel" in the middle of their desks.
- When the signal is given, students should begin removing the "logs" one-by-one from their desks until all the logs have been "used up."
- Have each student stand when he or she has finished removing the "logs" (and remain standing until all students have finished).
- Have one person be the recordkeeper, recording how many students have removed all of their "logs" in 15-second intervals.
- The class makes a line graph showing time vs. log use.
- Repeat, but this time students can only use one piece of fuel when the timekeeper tells them so—every 15 seconds.
- Construct a second graph of these results.



First trial



Second trial

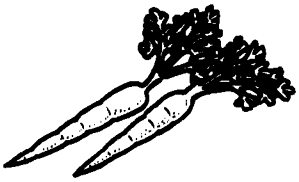
Ask: *How do the two graphs compare? What is the major difference when you "control your rate of consumption?" How did the game illustrate one type of conservation?*

Exploration—Part 1

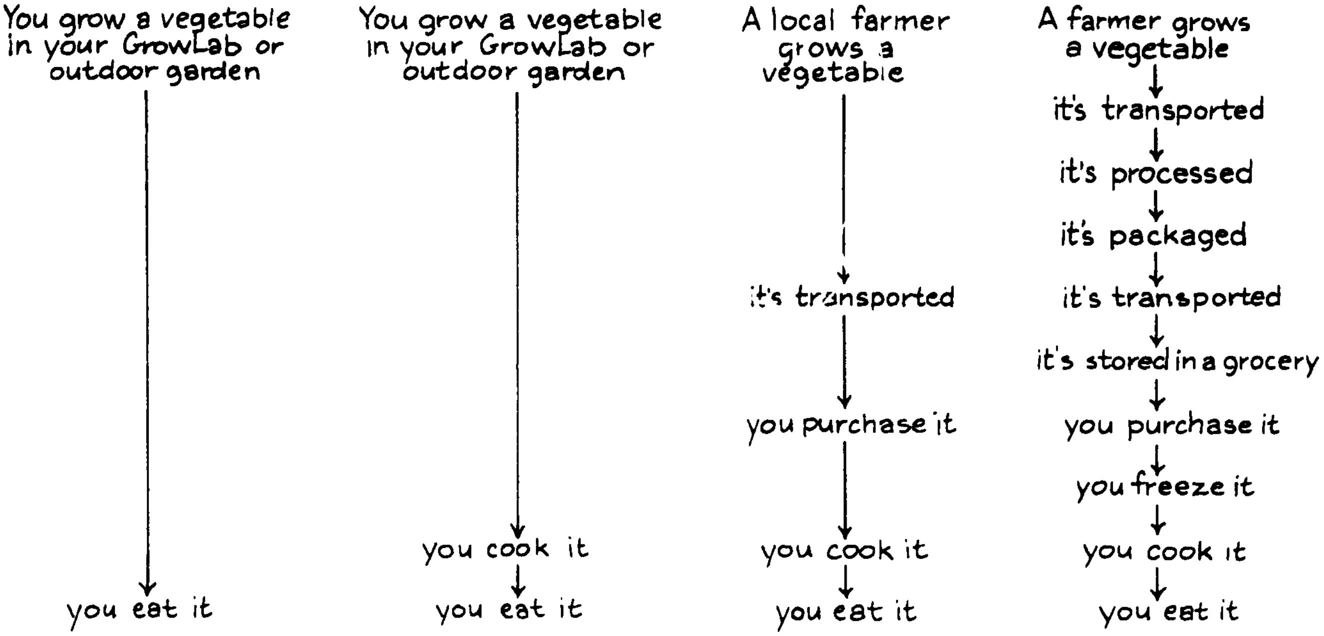
Objective: To explore how the food system depends on energy resources.

1. Ask: *What energy resources do you think it takes to produce your food?* Facilitate a class brainstorm in which students consider the direct and indirect "energy costs" for farming, processing, packaging, transporting, storing, cooling, cooking, etc. Ask: *How do you think a change in your eating habits can help you use less energy resources?*

2. Break the class into small groups of students. Have each group choose a different food product and develop different kinds of



"food system chains" for the same product, illustrating ways to produce a food and conserve energy at the same time.
For example:



3. Have each group creatively present its "chain" to the rest of the class. Encourage students to use visual aids, charts, video, role-playing, etc. to relay the information.

Exploration—Part 2

Objective: To evaluate personal uses of energy resources.

1. Each day for one week, have students record one specific electrical energy-requiring activity such as how long they leave the lights on in their bedroom or how long they leave the television on.

Ask: *How much electric energy do you think you use for this activity in the course of one week? How much energy do you think you could save if you change your habits?*

2. Explain to students that electricity is often measured in units called kilowatt-hours. A kilowatt-hour (kWh) is the number of kilowatts (1 kilowatt = 1,000 watts) used per hour. For example, a 100-watt light bulb consumes 100 watts per hour or 0.1 kWh.

3. Have students examine the labels on appliances or contact your local utility to find out the wattage used by varying activities. The chart on page 42 gives typical watts per hour used by some common activities.

Watts Up?

$$\frac{100 \text{ watts} \times 1 \text{ hour}}{1{,}000} = 0.1 \text{ kWh}$$

OR

$$\frac{100 \text{ watts} \times 10 \text{ hours}}{1{,}000} = 1 \text{ kWh}$$

Activity	Watts used
color TV	350
black and white TV	240
electric range	4,000
25-watt fluorescent tubes	25
60-watt incandescent bulbs	60
GrowLab lights	160
personal computer	50
electric clothes dryer	5,000
radio	70
air conditioner	1,560

4. Have students calculate the total amount of electricity they used each day and graph their findings.

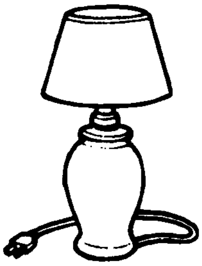
5. Have students repeat steps 1-5, but this time, make a conscious effort to reduce the amount of electricity they use.

6. Discuss your findings: *Did the amount of time spent or the amount of electricity you consumed surprise you? Why or why not? How were you personally affected by your conservation efforts? How did it feel to change your habits?*

Making Connections

1. Possible discussion questions:

- *How can food and consumer choices impact energy resources?*
- *In what simple ways can you save energy by your food choices?* (Grow your own foods, eat less highly-processed foods, buy local foods or foods in season, avoid excess packaging, recycle containers, and/or reduce the amount of meat you eat.)
- *How do you think saving electricity (and other energy resources) helps the environment? Why?*



2. Consider using the "Futures Wheel," page 47. Ask: *Imagine you are in a power blackout –how much do you rely on energy resources?* or *How would your lifestyle change if your energy resources were limited?* Examine the environmental and economic tradeoffs of different lifestyle practices such as using VCR's, using more efficient light bulbs, etc.

3. Ask the class to "take a stand" on the following statement, with students lining themselves up across the room according to where they feel they belong on the continuum. Ask students to

elaborate on why they chose to stand where they did.

I feel that my personal use of energy and/or conservation practices...

(does)--(does not)

...make a difference in the world's energy resources.

Branching Out

- Survey your local groceries to find out what kinds of foods are imported. Discuss how purchasing these foods affects energy resources.
- Find out the rate your local electric utility charges. Calculate the costs of your electric usage and the possible savings you could make.
- Find out how your local utility bases its rates (time of use, peak periods, seasonal costs, sources of power).
- Debate whether and how governments should mandate limits on energy consumption (building construction, types and use of vehicles, types of and timers on street lights).
- Videotape a message to other students and community members about how they can save energy.
- Tour your school building and document where and how energy is being used. Figure out ways energy could be used more efficiently.
- Write an advertisement—Help Wanted: Energy Conserver. What are the skills, background, attitudes, etc. necessary for such a role?
- Create and present conservation awards to deserving school, home and community recipients.
- Develop a conservation survey. Ask: *Are you an energy conserver or an energy waster?*
- Design ways to make your GrowLab more energy efficient.
- Compare different ways humans have use(d) energy over time and in different cultures/societies. Challenge students to find examples that might help them be more energy-efficient at home.

Saving Energy Through Recycling
Have your students compare the energy investments in waste disposal with the energy costs of recycling. They should find some staggering facts. For example, the energy required to produce one ton of aluminum from scrap uses only five percent of the energy required to extract and process new aluminum from ore!

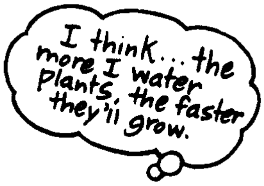
Appendix A: Record-Keeping Reproducibles

Problem Solving for Growing Minds

Name: ______________________________ Date: ______________________

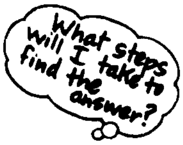
Directions: Use this sheet to guide you through the stages of problem solving.

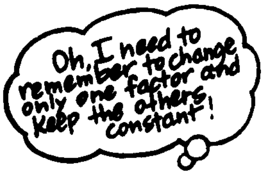
Plant a Question:

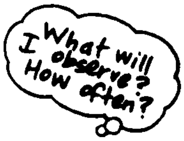


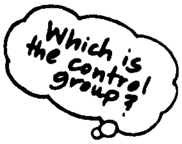
Sprout a Hypothesis:

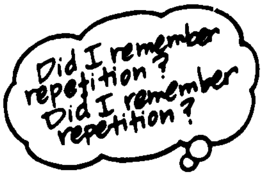
Describe Your Growing Exploration:











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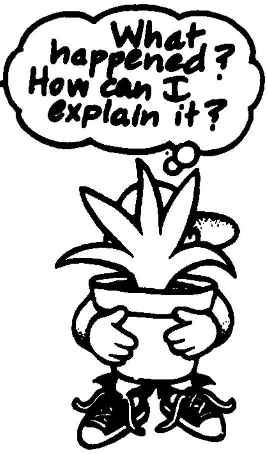
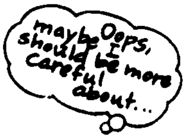


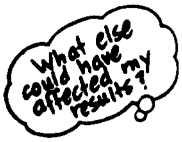
Record Fruitful Observations:

(attach all record sheets)

Harvest Your Findings:

OnGrowing Review:





Cultivate New Ideas:

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Using a Futures Wheel*

A Futures Wheel can help your students use their imaginations to respond to "What would happen if..." questions. It will illustrate that every action or change has endless implications, both positive and negative. Many "Making Connections" sections suggest using this process to enable students to consider some of the implications of environmental change.

Directions for using a Futures Wheel:

1. As a class or in small groups, choose a "What would happen if...?" question. To practice the basic process, have students choose a topic that's relevant to their daily lives. For instance: *What would happen if kids brought their dogs to school?* Have a recorder write the question in the center of a piece of paper or on the board. This will be the "hub" of the Futures Wheel.

2. After reviewing the question for the class, ask for three to five quick responses. Tell students that they can think of both positive and negative consequences, and may want to label some as good (+), bad (-), or neither (o). Write down the responses in the space around the central question, circle them, and draw a single line or "spoke" connecting each of the responses to the central question. These are the first-level responses.

3. Then ask: "What would happen if..." to discover the consequences of each of the first level responses. Write the new answers around each first-level response, circle them, and connect each new answer to the first-level response with a double line. These are now the second level of responses.

4. Continue in this manner, asking "What would happen if..." regarding each of the second-level responses, connecting new answers with triple lines. You're limited only by your writing space and your students' imaginations.

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* Adapted from the Acid Rain Foundation, Raleigh, North Carolina

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Futures Wheel

I wonder what. . . ? What might happen. . . ? What if. . . ?

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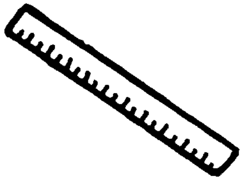

Observation Journal

Name:________________________ Activity:________________________

Experimental Groups				
Time (Day/Date/Week)	General Observations and Sketches			

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Appendix B: Resources

This appendix highlights selected resources useful for teaching about the topic of energy. See *GrowLab: A Complete Guide to Gardening in the Classroom* and *GrowLab: Activities for Growing Minds* for additional resource listings for plant-based teaching.

Contact your state energy office, state office of environmental education, or:

Conservation and Renewable Energy Inquiry and Referral Service (CAREIRS)
PO Box 8900
Silver Spring, MD 20907 (800) 523-2929

- A service of the U.S. Department of Energy, providing bibliographies and activities which promote awareness of energy conservation and renewable energy.

National Appropriate Technology Assistance Service (NATAS)
US Department of Energy
PO Box 2525
Butte, MT 59702-2525 (800) 428-2525

- NATAS conducts computer searches to locate educational or technical projects about renewable energy and energy efficiency.

National Energy Foundation (NEF)
5160 Wiley Post Way, Suite 200
Salt Lake City, UT 84116 (801) 539-1406

- A nonprofit organization offering a wide variety of training programs and curriculum services and products about energy, technology, science, natural resources and other related topics. A free catalog of NEF materials is available upon request.

National Energy Information Center
EI-231
Forrestal Building, Room 1F-048
Washington, DC 20585 (202) 586-8800

- Another U.S. Department of Energy service that specializes in technical information and provides a booklet, *Energy Education Resources*, and statistical information sheets.

Contact your local utility for educational materials or resources. Some utilities have worked with schools in support of classroom gardening programs. Contact National Gardening Association for more information about utility company sponsorship of GrowLab classroom gardening programs. There are also national associations that link the local utilities and promote energy education related to their industries, for example:

Edison Electric Institute
701 Pennsylvania Avenue NW
Washington, DC 20004-2696 (202) 508-5589

- Provides short activity booklets to teachers.

GrowLab Program Resources

The *Power Plants* curriculum guide is an outgrowth of National Gardening Association's GrowLab program. Funded in part by the National Science Foundation, GrowLab is an indoor, hands-on science program designed to spark curiosity and investigations as young people explore plants.

GrowLab provides teachers with a familiar teaching medium—an indoor garden laboratory—to engage students in exploring science and a range of other subjects. In thousands of classrooms nationwide, we have watched students' curiosity, confidence, and problem-solving skills grow as they tend plants and unravel the mysteries of the natural world in their GrowLabs.

Partnerships between schools and community organizations help classroom gardening programs thrive. We work with an extensive network of people and organizations across the country who provide training and technical assistance to indoor-gardening classrooms. We are available as a resource to connect GrowLab users with these organizations and to provide technical assistance and advice.

The GrowLab Program includes:

- *Growing Ideas* teachers' newsletter
- *GrowLab: Activities for Growing Minds* K-8 curriculum
- *GrowLab: A Complete Guide to Gardening in the Classroom* horticultural guide
- GrowLab Indoor Garden units, mobile stands and starter kits
- *GrowLab Partners' Guide: Building Community/School Partnerships Through Indoor Gardening*
- GrowLab teacher training videos
- GrowLab training network
- GrowLab database network
- GrowLab instructional classroom posters

For more information about GrowLab educational materials and programs, write: National Gardening Association, Dept EN, 180 Flynn Avenue, Burlington, Vermont 05401, (802) 863-1308; FAX (802) 863-5962.

> The National Gardening Association is a nonprofit, member-supported organization dedicated to helping people garden successfully at home, in community groups, and in schools. We believe gardening adds joys and health to living, improves the environment, and encourages the proper stewardship of the Earth.

Linking plants and a simple flick of the light switch may at first seem a stretch. Once we realize that fossil fuels and biomass provide the bulk of our energy resources, the intimate connection between plants that harness the sun's energy through photosynthesis and plants that generate our electricity are apparent. *Power Plants* provides students with activities that make that powerful connection.

"My students loved the hands-on participation of *Power Plants*. They even took many of the activities home to involve their parents. This is a good curriculum to use as a springboard for interdisciplinary studies—we did so many things including journal writing, math, social studies and art."

—Joan Donath, Classroom teacher, Burlington, Vermont

"*Power Plants* provides a growing awareness of the importance of energy. It is an innovative tool in helping us realize energy efficiency as a way of life."

—Dale Pohlman, General Manager, Burlington Electric Department

"*Power Plants* combines good content with real inquiry. I'd be thrilled if my own children were in a class in which *Power Plants* was being taught."

—Bob Prigo, Professor of Physics, Middlebury College, Vermont

Power Plants is an outgrowth of National Gardening Association's GrowLab Program. GrowLab provides teachers with a familiar teaching medium—an indoor garden laboratory—to engage students in exploring science and a range of other subjects. For information on GrowLab Indoor Gardening Program resources and the network of GrowLab users and support partners throughout the country, contact: National Gardening Association, Department EN, 180 Flynn Avenue, Burlington, VT 05401.
Phone: (802) 863-1308; FAX (802) 863-5962