Teacher's Edition

FOOD PACKAGING

MODULE

Materials World Modules
An Inquiry-based Science & Technology Educational Program

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How can the Materials World Modules help you . . .

relate your teaching to your students' everyday world? The question of relevance is one your students may frequently raise. And the Materials World Modules can help you flesh out your answer, whatever science, math, or technical education subject you teach. Each module explores a topic of current interest in materials science, combining clear instruction with innovative activities and design-centered projects. With these modules, students make a direct connection between what they are learning in class and their everyday lives. The Materials World Modules will capture your students' interest and inspire their creativity.

How the Materials World Modules Work

The Materials World Modules are built around a common structure. Four or more related Activities introduce an important topic in contemporary materials science. Through these Activities, students learn about the topic, investigating key features of the materials that are the focus of the module. Then they use what they have learned from doing the Activities to participate in a Design Project. This project inspires students to design, build, test, and redesign a product that incorporates the materials that are the focus of the module.

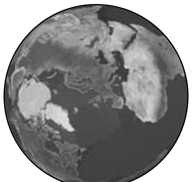
Enrich Your Teaching with the Materials World Modules

The Materials World Modules are easy to organize, inexpensive to run, and adaptable for use, in whole or in part, with any science, math, or technical education curriculum. The modules will help you enrich your teaching by:

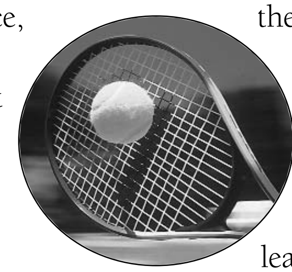
- supplying new and exciting hands-on activities to supplement existing classroom and lab experiences
- incorporating science, math, writing, and thinking skills students need to develop
- promoting an awareness of the roles science and technology play in society, down to the details of our everyday lives
- introducing students to issues that materials scientists face at the forefront of technological research
- reinforcing students' abilities to work creatively and collaboratively
- motivating students to develop and communicate clear, logical explanations of phenomena they observe
- guiding students to take increased control of their work, so they can successfully complete independent, design-centered projects
- simulating the work processes of scientists and engineers, to give students a sense of what careers in these fields can be like

Materials World Modules?

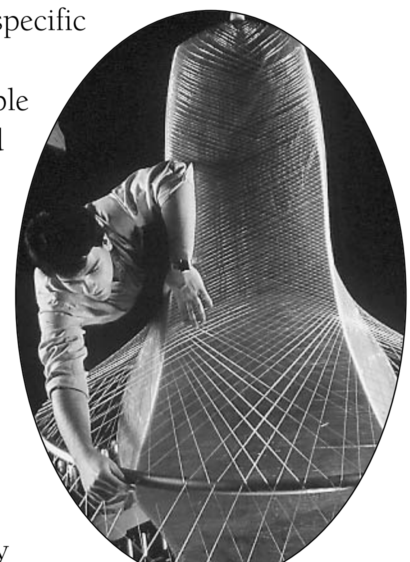
Learning About the World Through Materials Science



Most people have never heard of materials science. But it is materials science that makes our modern world possible. Without materials science, there would be no optical fibers to transmit phone calls. We wouldn't have computers, VCRs, and many modern sports materials. The glass towers that rise above our cities would exist only in the imagination, and space exploration would be an ever-distant dream.



Materials science is an interdisciplinary field that employs the tools of science, technology, and mathematics in developing new materials to meet specific needs. In a quest to uncover nature's design secrets, materials scientists have analyzed cross sections of dragonfly wings, examined the microstructure of corals, and experimented with the "superglue" mussels use to attach themselves to rocks. They then bring what they have learned to the design and manufacture of different materials. Each material has unique properties, which are engineered into the material's physical and chemical structure. These properties allow the material to serve specific functions—the smooth, hard, cleanable ceramic tiles designed for a bathroom are very different from the lightweight, heat-shielding tiles designed for the Space Shuttle.



With the Materials World Modules, students gain an in-depth view of many different kinds of materials and deal directly with issues of materials design. By introducing students to materials science through the Materials World Modules, you will give students an opportunity to understand the world around them in a way they've never experienced before.

How can you use the Materials World Modules to meet education standards?

State and national standards for teaching science and mathematics mandate that students not only learn facts and theories but that they also gain the ability to apply what they learn to real-world situations. The Materials World Modules can give you a clear-cut and direct way to meet these standards. Both in their general pedagogical approach, featuring inquiry through design, and in their specific presentation of science content, the Materials World Modules meet current education standards at the local, state, and national levels.

The Materials World Modules were designed with the following science education goals in mind. These goals are consistent with recent National Science Education Standards* and include:

• **Developing the abilities necessary to do scientific inquiry.** These include the ability to generate questions, design and conduct scientific investigations, formulate models, analyze alternative models, and communicate and defend explanations.

• **Understanding scientific inquiry.** Understanding that scientific inquiry is focused on logically consistent explanations, grounded in current knowledge and augmented by mathematics and technology.

• **Becoming familiar with materials science.** Developing an understanding of materials science by applying knowledge from physical, life, and earth sciences to create materials for specific purposes.

• **Taking part in iterative design.** Providing opportunities to identify technological problems, propose designs, choose between alternative solutions, implement and evaluate a solution, redesign the product, and communicate the problem, process, and solution.

• **Understanding the relationship between science and technology**. Understanding the differences between the purposes and nature of scientific and technological studies and the interrelationship between these fields.

• **Understanding contemporary problems.** Appreciating the use of science and technology to meet local, national, and global challenges, including problems of personal and community health, natural resources, environmental quality, and human-induced hazards.

• **Presenting a historical perspective.** Viewing the history and nature of science as a human endeavor, producing new knowledge, supported by developing technology.

*National Research Council. *National Science Education Standards*. Washington, D.C.: National Academy Press, 1996.

Inquiry Through Design

The pedagogical base of the Materials World Modules can be captured in a phrase: *inquiry through design*. This approach unites the abstract, quantitative methods of scientific inquiry with the concrete methods of technological design, helping students develop and integrate these interlinked skills in a unique way. The charts below, adapted from the National Science Education Standards*, outline steps in the complementary processes of scientific inquiry and technological design.

Scientific Inquiry

- Develop researchable questions to guide scientific investigations
- Design and conduct scientific investigations using appropriate tools and mathematical analysis
- State scientific explanations and devise models following rules of logic and evidence
- Recognize and analyze alternative explanations and models
- Communicate and defend the conclusions of scientific investigations

Technological Design

- Identify new or replacement uses for a material or technological device
- Propose designs to meet a specific need and select the most promising alternative
- Create a prototype and develop appropriate testing procedures following rules of logic and evidence
- Evaluate tests, redesign prototypes, and identify constraints in designs and testing procedures
- Communicate about the design and the processes of its development and evaluation

In guiding students through the processes involved in scientific inquiry and technological design, the Materials World Modules reinforce essential thinking, reasoning, and laboratory skills with unparalleled effectiveness. With the Activities and Design Projects, the Materials World Modules inspire students to increase their skills, integrate quality work habits, and enjoy learning in the process.

What would you say if . . .

Teachers' wish list

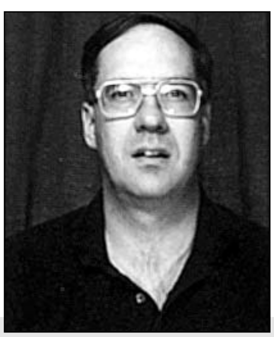
We would like to be able to:

- Offer students stimulating activities that relate science to their everyday lives
- Use projects to motivate students and help them apply their real-world experiences to scientific problems
- Find practical ways to promote collaborative learning in the classroom
- Close the gap between classroom science and science on the frontiers of research
- Hook into Northwestern's resources on science and science education through computer linkages
- Develop collegial support among science teachers across the nation and scientists and science educators at Northwestern and other universities

a group of university professors called you up and asked, "What can we do to improve science education in your high school?" Northwestern's Professor Robert Chang and materials-science researcher Matthew Hsu tried it. Based on their initial phone calls, they held meetings with more than 20 science teachers and curriculum supervisors from northern Illinois and southeastern Wisconsin. At the meetings, teachers drew up a wish list of ways scientists and educators at Northwestern could help them meet their goals.

The Materials World Modules were developed with this wish list in mind. Teachers have participated in the design and development of all of the modules. In fact, teachers co-wrote many of the modules together with scientists and educators at Northwestern. The modules have undergone extensive field-testing at a number of high schools with hundreds of students participating.

The Authors



Brad Goral has taught chemistry for 15 years at New Trier High School in Winnetka, Illinois. He focuses on interdisciplinary content and problem-based learning. In addition to working on the Food Packaging module, Brad has participated in computational science programs at Northwestern and the National Center for Supercomputing Applications at Champaign/Urbana.

Kate Heroux earned her Master of Education degree from the University of Manchester in Manchester, England, in 1993. She has taught chemistry at Lake Forest High School for two years. One of Kate's interests is science articulation and integration. Kate helped write and field test the Food Packaging module.

Cindy Quinn has been a science teacher for five years. In addition to working with the Materials World Modules team, she has been a Department of Energy research assistant and has worked with members of Northwestern's BGuILE (Biology Guided Inquiry Learning Environments) Project to develop curriculum and software for science classrooms.

Teachers have reported that students are very excited about the modules. They especially enjoy the Design Projects, in which they get to design, build, and test their very own materials or products.

The initial development of the Materials World Modules has been funded by a grant from the National Science Foundation. The project continues to expand, with the development of new modules and additional support materials. You can get involved in the design or field-testing of upcoming modules by contacting:

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The Director

Professor Robert P. H. Chang A veteran of materials research, Professor Chang worked at Bell Laboratories in New Jersey for 15 years before coming to Northwestern in 1986. As director of the Materials Research Institute and also of the Materials World Modules program, he admits, "With my research in materials science, the results come only slowly. But I get immediate rewards from directing the development of these modules: I see young people's interest in science sparked. It is among the most exciting work I have ever done."

Other Materials World Modules

Biodegradable Materials
Students make, test, and evaluate biodegradable films and gels. They use their knowledge to design devices that release a dye in a controlled manner as they degrade.

Biosensors
Students investigate the use of biological molecules as materials and use enzymes as chemical sensors in the design of diagnostic tests for peroxide, cholesterol, and glucose.

Ceramics
Students study the microstructure of ceramics and simulate high-temperature synthesis of ceramics. They then use ceramics to make a voltage-protecting device.

Composites
Students discover what composite materials are and test them to learn their advantages over pure materials. They design a new composite material to make a strong, lightweight fishing pole.

Concrete: An Infrastructure Material
Students learn how the components of concrete can be modified to alter the properties of concrete. They use their knowledge to make concrete roofing tiles that meet specific design and performance criteria.

Environmental Catalysis
Students examine different types of catalytic systems, including heterogeneous catalysis, thermocatalysis, and photocatalysis, which they can adopt in their own designs to catalytically eliminate water pollutants.

Introduction to the Nanoscale: Inquiry into Surface Area and Volume
Students explore how changes in the shape or size of an object affect the surface area to volume ratio, which can change dramatically in the nanoscale. They apply this knowledge to design an "exploding" liquid geyser.

Manipulation of Light in the Nanoworld
Students learn about how light waves interact with matter. They then apply their knowledge of diffraction and interference to fabricate, test, and evaluate their own photonic crystals.

Nanotechnology
Students investigate size-dependent properties of nanoscale materials, how they are made and characterized. They are challenged to design a prototype nanoscale imaging apparatus.

Polymers
Students examine properties of polymers. They design and test a humidity sensor made of a polymer film.

Smart Sensors
Students investigate the behavior of piezoelectric films. They use these materials to make a coin-counting device.

Sports Materials
Students test and analyze a wide variety of materials used in athletic equipment. Then they design a suitable material for use in a newly invented game.

MWM

What wonders can you find on the Web?

The World Wide Web has a wealth of information to enhance science and math curricula. Specifically, the Materials World Modules program has a Web site that can enrich your experience as you use the modules. Students can also use our Web site as a starting point for current research on different materials and their applications. The Materials World Modules Web site offers these features:

For Students

- inspiration for their own design projects, based on ideas other students have had
- links to international resources that have information about materials and materials science
- pointers to relevant educational programs on the Internet

For Teachers

- an overview of the MWM project as a whole
- an overview of each of the many modules
- contact with teachers who have used the modules
- links to other resources on the Internet that reinforce or extend concepts stressed in the Materials World Modules
- assessment rubrics to help you tailor the modules to your classes
- samples of students' work
- announcements of upcoming MWM conferences and workshops in your area
- many publications put out by the MWM team

Helping Your Students Use the Internet for Research

Information abounds on the Internet, but it's easy to get lost on the electronic superhighway. One sure place you can send students is to the Materials World Modules Web site. Here, students can find a well-maintained list of addresses (URLs) to many interesting Web sites related to module topics and to materials science. We keep this list up-to-date so you can avoid the frustration of collecting URLs for a particular topic only to find the sites have moved or are no longer in existence (a common problem).

Another way to help students use the Web is by doing some trail-blazing before you send them to the computer. The Planning Guide pages of this module all include a feature called Using the Internet. This feature suggests key words you can use to locate Web sites with information about polymers. After you log on to the Internet, select a search engine, such as Webcrawler, Yahoo, or Alta Vista, to find Web sites that have information on the key word topic. Check out some of the different Web sites and give the URLs of the best sites to your students. This will help students find the most current information quickly.

If you have questions about the Materials World Modules Web site or about ways to use the Internet for research related to the modules, contact us at mwm@nwu.edu. See you on the Net.

Visit us at http://mwm.ms.nwu.edu/

Using Your Food Packaging Module

The following section provides a variety of information to help you use the Food Packaging module with ease.

Background The Background section gives you general information about food packaging, which you can share, if you wish, with interested students.

Connecting to Your Curriculum This section can help you decide how to fit the Food Packaging module into your curriculum, whatever subject you teach. Connections (brief teaching tips in the margin notes) are also listed for various subjects.

Module Overview The brief summaries of the Activities and Design Projects provided in the Module Overview are a further aid to planning.

Module At-a-Glance This chart lists learning objectives, materials, and estimated time for each of the Activities and Design Projects.

Using the Activities and Design Projects This section points out the features in the Student Edition of the module and highlights how you can use the different features to help students further their learning.

Flexibility of Use Addressing the issues of time, teaching style, and teaching students of varying abilities, this section gives tips to help you use the modules whatever your goals or constraints.

Adapting the Modules This section gives further tips on different ways you can adapt the module for particular classes or for particular pedagogical goals.

Inquiry and Design in the Classroom This section gives tips on incorporating elements of scientific inquiry in the module and on running successful Design Projects.

Assessment Options A variety of assessment options is outlined for the module, including inquiry-based assessments, traditional assessments, self-assessments, and portfolio assessments.

A Note About Safety Specific safety tips help you run the module successfully and safely.

Resources on Food Packaging An annotated list of books, articles and Web sites related to the module topic can help you and your students learn more. Additional Internet resources can be found by visiting the Materials World Modules Web site, http://mwm.ms.nwu.edu/

Contents

Background on Food Packaging

A hiker stops to rest beside a trail and takes a box out of her backpack. Inside the box is a tray of food—the hiker's dinner. Instead of building a fire or lighting a camp stove to heat her meal, however, she simply removes another tray from the box. This meal comes with its own "stove"—a specially designed heating tray that produces heat through a chemical reaction. The hungry hiker simply opens a packet of water (included in the package) and pours it on the heating tray. Inside the tray is a plastic pad, which contains magnesium, an iron alloy, and salt. When water is added, salt water forms. The salt water rusts the metal in the pad, and heat is produced. Fifteen minutes later, the hiker sits down to a steaming, hot meal.

Meals heated by chemical "stoves" were first developed for use by the U.S. military in the early 1990s.

Food packaging has come a long way from the woven baskets and clay pots that our early ancestors used to store and carry their provisions. Although the basic purpose of food packaging remains the same—to contain and protect food until it's eaten—today's packaging often does much more, as the example of the "heater meal" shows.

Food packaging plays many roles. It keeps food safe to eat and protects it from damage. It makes food easy to handle for shipping, storage, and display. It provides information and offers convenience to consumers. It also offers many benefits, including less food wasted due to spoilage or damage and fewer food-related illnesses, because of the reduced spread of disease-causing microorganisms.

Food packaging technology responds to society's changing needs. In the U.S. and other countries, for example, an increase in the number of smaller families and single-person households has led to new developments in packaging for convenience foods, carry-out items, and single-serving meals. An increased demand for health foods has led to innovations in packaging fresh fruits and vegetables. New technologies for preparing foods, such as the microwave oven, have led to new types of packaging as well. Increased concerns about the environment and the ecological impact of packaging and legislation, such as "bottle bills," have also put pressure on manufacturers to produce packaging that can be recycled or that is biodegradable.

Designing Food Packaging

Food packaging designers begin by looking at the physical and chemical properties of the food to be packaged. They must consider what kind of protection the food needs and how the package will be manufactured, shipped, stored, displayed, used, and disposed of. In addition, they must meet the food manufacturer's production, marketing, and cost specifications.

Packaging designers then choose from a number of materials, including paper, cardboard, glass, metal, plastic, and composites, from which to construct the packaging. To design new packaging, packaging designers often use computer-aided design (CAD) systems. Using CAD, a designer can draw a design on-screen or scan in images from other sources, such as sketches, photos, or video. The computer then produces a wireframe model—a three-dimensional diagram of the

Over the past few decades, Americans have dramatically increased their use of convenience foods, such as frozen microwaveable meals. Since many of these foods are packaged in nonrecyclable and nonbiodegradable materials, their use has contributed to an increase in food packaging waste.

packaging that can be viewed from different angles, overlaid with graphics and text, and redesigned with the touch of a few buttons. The computer can even be set up to provide information about the physical characteristics of a package, such as its capacity, weight, and strength. Using such a program, a designer can quickly see how design changes will affect these characteristics.

New materials and new applications of existing materials have led to exciting innovations in food packaging design. For instance, fresh vegetables need to "breathe" to stay fresh and flavorful. As they ripen, these foods take in oxygen and give off carbon dioxide. If they don't get sufficient oxygen or if too much carbon dioxide builds up in the package, the vegetables can mold or rot. To package fresh vegetables, materials engineers have developed plastic film packaging with tiny holes that allow oxygen to enter and carbon dioxide to escape, while also retaining needed moisture. They've even designed packaging that will breathe at different rates, matched to the specific needs of the food.

Food Packaging and the Environment

But we pay a price for all this packaging—waste. About 35% of municipal solid waste—waste from homes, businesses, and institutions, such as schools, and hospitals—is packaging waste. That's 72 million tons a year, and about half of that is food packaging waste. Much of that waste ends up in landfills, many of which are rapidly filling up.

Food packaging waste was not always such a problem. As one environmental advocate puts it, "For centuries, the business of eating did not contribute all that much to the waste stream—what was added was generally decomposable or compostable materials like corn husks and pea pods."

Today, though, with hundreds of convenience foods and single-serving packages made of nonbiodegradable and nonrecyclable materials, we produce a lot of packaging waste. How can we reduce the impact of food packaging on the environment? One way is to use less packaging—a concept known as source reduction. Using less packaging means that fewer materials and energy resources are used to manufacture

The majority of food packaging waste ends up in landfills.

Unloading cans at an aluminum recycling center. Currently in the U.S., more than 60 percent of aluminum beverage cans are recycled.

packaging and less waste is produced when the packaging is disposed of.

A number of packaging manufacturers have turned to lightweighting—reducing the amount of material used in a container—as a way to reduce packaging and cut their costs. For example, they've developed new plastics that can be made into ultra-thin-walled containers. Such containers use less plastic and thus cost less, without sacrificing important properties, such as stiffness and strength. Aluminum beverage cans have also gotten thinner and lighter, and as a result take less aluminum to manufacture. In 1972, 1 kg of aluminum produced only 48 cans. Today 1 kg of aluminum yields 70 cans.

Such changes in packaging can mean substantial savings for manufacturers. A pasta company, for instance, switched from polystyrene trays inside shrinkwrapped, plastic-coated paperboard cartons to polyethylene bags for its frozen pasta. This resulted in a 475-ton-per-year waste reduction and a 50% cost savings. The change in packaging also meant that more bags could be shipped in each corrugated shipping box, reducing the use of corrugated cardboard by 33%.

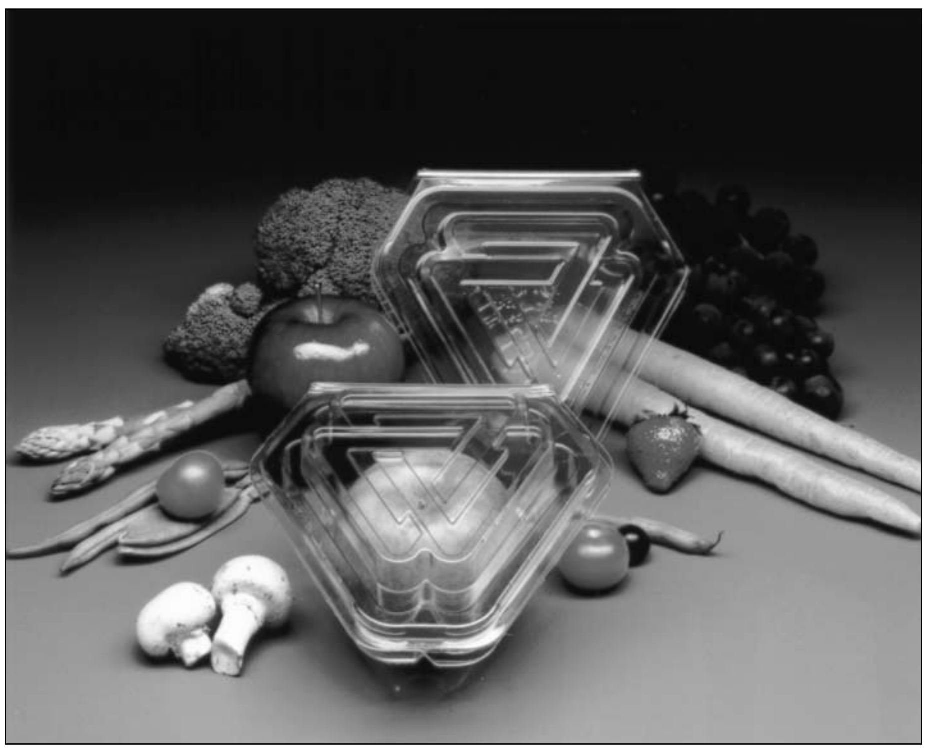
Using recycled or recyclable materials also helps reduce waste. Paper, cardboard, glass, and aluminum are all widely recycled and used as materials in new food packaging. Plastic recycling, however, is more limited. Although some plastics are currently being recycled into products with non-food uses, recycling plastic for food use presents some problems. One obstacle to "closing the loop" on plastic recycling—using recycled plastic food packaging to make new plastic food packaging—has been FDA concerns about food safety. Plastics may be contaminated by a number of substances, such as adhesives, pigments, dirt, paper, metal, and food waste. These contaminants may remain in the recycled plastic and potentially migrate into food packaged in recycled plastic. New techniques are being developed, however, that allow the use of more post-consumer recycled materials without compromising safety or quality. For example, one company has come up with a method of using 100% post-consumer recycled polyethylene terephthalate (PET) for fresh produce packaging. Because single materials are easiest to recycle, engineers are also working on new techniques for making single-material containers, such as imprinting information directly on plastic containers rather than on paper labels.

Reusable containers can also help keep waste in check. In many European countries there are strict waste management guidelines, and as a result, reusable packaging has become a popular option. For instance, in Germany, about 75% of Coca-Cola's glass and plastic bottles are refilled.

Another way to reduce waste from food packaging is through composting. According to a 1992 study by the National Audubon Society/Procter and Gamble Co., 70 percent of household trash could be removed from landfills by composting and recycling. Since materials contaminated by food wastes cannot currently be recycled, composting is a promising option for biodegradable food packaging. One British company has developed a biodegradable polymer through the fermentation of glucose. This material could be used instead of plastic as a waterproof coating for paper and cardboard. Once used, the entire container could be composted.

Reducing food packaging waste has a number of environmental benefits. It reduces waste overall and conserves resources, including energy and land that would be needed for new landfills.

A number of new developments in food packaging clearly take these environmental concerns into account. Biodegradable polymers made of corn, wheat, or potato starch mixed with cellulose hold promise as replacements for some types of plastic packaging. And someday we may even be able to eat the packaging that protects our food. One company is using collagen, a fibrous protein, to produce a packaging film. When food wrapped in the film is cooked, the film melts right in.



Some companies are working on methods for using post-consumer recycled plastics to produce new plastic food packaging like this.

Connecting to Your Curriculum

The Food Packaging module can enhance your curriculum and increase your students' understanding of science and technology. The charts below list subjects that dovetail well with the Activities and Design Projects in this module. Connections (specific teaching tips) for the subjects are listed along with page references.

Chemistry

- Acids and Bases
- Bonding
- Changing States of Matter
- Heat and Temperature
- Kinetic Energy of Molecules
- Polymers
- Properties of Matter

Chemistry Connections pp. 8, 15

Biology and Life Science

- Biodegradation
- Decomposers
- Environmental Issues
- Microorganisms
- Plant Hormones
- Thermoregulatory Adaptations

Biology Connections pp. 12, 13, 18, 22, 43

Mathematics

- Computer Modeling
- Formulas
- Graphing
- Percentages
- Rates
- Ratios
- Volume
- Weights and Measurement

Mathematics Connections pp. 3, 11, 16, 17, 22, 25, 44, 45

Physics and Physical Science

- Acceleration
- Forces
- Gravity
- Heat and Heat Transfer
- Insulation
- Mass
- Microwaves
- Newton's Second Law of Motion
- Potential and Kinetic Energy
- Thermal Energy
- Volume and Capacity

Physics Connections pp. 31, 34, 47

Geology and Earth Science

- Mining

Earth Science Connection p. 7

Technical Education

- Insulating Materials
- Microwave Ovens

Social Studies

- History of Food Preservation and Packaging Technology

Social Studies Connection p. 10

Language Arts

- Describing a Sequence

Language Arts Connection p. 29

Food Packaging Module Overview

Through the following Activities, students learn about the functions of food packaging and the properties of food packaging materials as well as the impact of these materials on the environment. Each Activity prepares students for the Design Projects, in which they are challenged to design and build a package for a hot potato and new type of food packaging.

Activities

1 Investigating Food Packaging

Students take apart a package of microwave popcorn, identify the purposes of each part of the package, examine the materials from which they are made, and draw conclusions about the package's design and the reasons for the choice of materials used.

2 Analyzing Food Packaging Materials

Students look for different kinds of food packaging, identify the materials used in the packaging, list the purposes of these materials, analyze the properties of the materials, and form hypotheses about why each material was chosen for its use.

3 Evaluating the Impact of Food Packaging on the Environment

Students examine several different types of packaging for the same food product. They compare the mass of each package with the amount of food packaged to determine which packaging alternatives produce the least amount of waste.

4 Researching Food Packaging Materials

Students try to come up with an environmentally friendly response to the question "Paper or plastic?" Students research the manufacture, use, and disposal of paper and plastic grocery bags and draw conclusions about the overall environmental impact of each material. Students write a research report summarizing their findings.

5 Designing a Protective Package

In Part A, students test and compare the ability of different packaging materials to protect package contents—in this case, a tomato—from a fall. In Part B, students use what they have learned to design, construct, and test a package that protects a tomato, while not exceeding certain mass specifications.

6 Comparing the Insulating Properties of Packaging Materials

In Part A, students test and compare the insulating properties of different packaging materials. In Part B, students use what they have learned to design, construct, and test an insulating package, while not exceeding certain size specifications.

Design Projects

1 Designing a Hot Potato Package

Students design prototypes of a package for a baked potato that will keep the potato above a specified temperature for a specified period of time, protect the potato from physical damage, and meet weight, size, and cost specifications. Students test and evaluate their prototypes and then improve their best package design for another round of prototype testing.

2 Designing New Food Packaging

Students design a new type of environmentally friendly food packaging. They can improve existing food packaging or design packaging for a new food product. Students construct, test, evaluate, and redesign prototypes of their packaging to determine the best design.

Analyzing Food Packaging Materials

Purpose
To identify and analyze materials used in food packaging in terms of their purposes and properties.

Summary of the Activity
Students look for different kinds of food packaging, identify the materials used in the packaging, list the purposes of these materials, analyze the properties of the materials, and form hypotheses about why each material was chosen for its use.

Advance Preparation
You may wish to bring students on a field trip to a large, well-stocked supermarket where they can do Part A of the activity. If so, arrange your trip in advance, informing the store management of the visit and its purpose and getting the manager's permission. Some stores may be willing to give the class a behind-the-scenes tour to show students the kinds of packaging food is in when it arrives off the truck.

LINKS

TO THE PREVIOUS ACTIVITY In Activity 1, students made a detailed examination of a microwave popcorn package to determine the materials of which it was made and the purpose of each material. They build on that experience in this activity by analyzing the materials used in a variety of food packages.

TO THE NEXT ACTIVITY In this activity, students identify properties of food packaging materials and how they are used. In Activity 3, students will investigate the environmental impact of food packaging materials by looking at the amount of waste produced when they are discarded.

TO THE DESIGN PROJECTS The Design Projects challenge students to design new food packaging, and this activity familiarizes them with the properties of common food packaging materials that they may choose to use in their prototypes.

Safety
Discuss safety issues students should be aware of, including:

- getting a parent or guardian's permission to visit a grocery store to gather data for the activity
- letting the grocery store manager know students' purpose in visiting the store so as not to arouse suspicion as they examine different food packages
- safety issues that may be of concern in your classroom or in stores in students' neighborhoods

Curriculum Connections

Connecting to Your Curriculum on page T16 suggests ways you can fit the Food Packaging module into your general curriculum. The chart at right gives ideas for connecting concepts introduced in this activity with different disciplines. The page numbers in the chart refer to teaching tips that you can use to make connections to the subjects listed.

Background Information

Packaging materials — primarily paper, cardboard, glass, plastic, steel, and aluminum — are made into boxes, cans, jars, bottles, bags, and other containers and used to package foods during shipment, storage, display, and consumer use. As students will observe in this activity, food packages have many different purposes, including protecting the food until use, preventing spoilage, providing convenience, complying with government regulations, communicating information, and attracting consumers.

One issue that arises with food packaging is the question of overpackaging. You've probably seen dozens of examples of food packaging that seems excessive, for instance, slices of cheese individually wrapped in plastic or individual servings of lunch meat, cheese, and crackers in a plastic tray covered with shrink wrap and packaged in a cardboard box. Some packaging that appears unnecessary may help reduce waste overall because it keeps food fresh and safe to eat longer. But some packaging is designed simply to convince consumers that they are getting something of value or convenience, so that they will buy the product. In general, overpackaging is considered to be packaging that is not necessary for storing a product, protecting its shelf life, or communicating essential information.

Cross-Curricular Teaching

Invite an art teacher to visit the class and discuss how text and artwork are produced and printed on food packages. With the art teacher, students can compare the graphic design of several common food packages, for instance cereal boxes, juice containers, or canned tomatoes. They might analyze the art and type that appear on the packages and describe how the graphic design may influence consumers.

Using the Internet

To learn about food packaging materials, go to an Internet search engine and use the key words ***food packaging.***

Portfolio Project

At the completion of this activity, have each student select a favorite food and design a better package for it. Have students draw or even construct the improved package and include the drawing or prototype in their portfolios.

Art
Graphic design

Biology
Microorganisms p. 12
Plant hormones p. 13

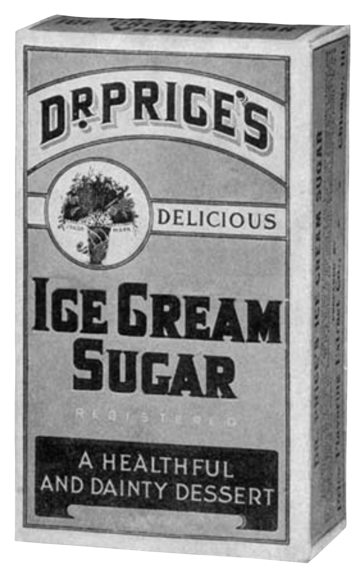
Chemistry
Acids and bases p. 15
Polymers p. 8

Mathematics
Percentages p. 16
Graphing p. 11

Earth Sciences
Mining p. 7

Home Economics
Food storage

Social Studies
History of food preservation and packaging technology p.10



Multicultural Links

Around the first century A.D., Syrian glassworkers made an important discovery. They developed a technique for blowing glass into hollow shapes. This innovation allowed artisans to create a wide variety of glass containers for all types of food storage.

2
INTRODUCTION

In Activity 1, you examined the materials used in one type of food packaging—a microwave popcorn bag. In this activity, you'll analyze the materials used in a number of different types of food packaging.

Food Packaging Materials

Natural food packaging—a coconut

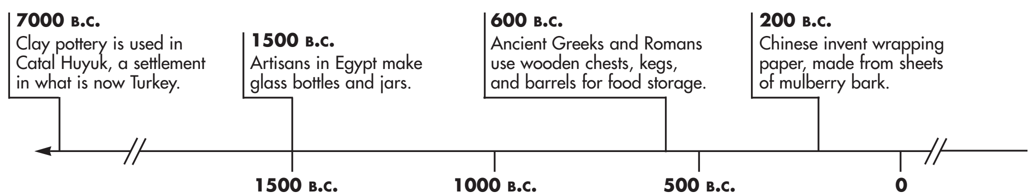
When you think of food packaging, you might picture a canister full of potato chips or a plastic jug of milk. But not all food packaging is manufactured. Consider the coconut, for example. This fruit of the coconut palm is actually a beautifully designed, natural package. The hard shell protects the delicate contents inside: a seed and the food needed to nourish it as it begins to grow. Like the coconut, most fresh foods come in their own protective packages. Egg shells, nut shells, and the skins of fruits and vegetables all preserve and protect what's inside them.

Early humans probably took their cue from the world around them and began using natural containers, such as seashells, gourds, and animal skins, to carry and store foods. Later, people put other natural materials to work, carving wood into bowls and weaving plant fibers into baskets—probably the first examples of human-made food packaging.

Pottery from 3500 B.C.

CONCEPTS behind FOOD PACKAGING

Many types of materials are used in food packaging. The choice of materials depends on the purpose of the packaging and the properties of the materials.



To Inspire Questioning and Learning

Ask several students what they had for breakfast today or for an evening meal last night, and write each food on the board. Then ask students to name the kind of package each food came in, be it a "natural" package such as a nutshell or banana peel or a manufactured package such as a pasta or cereal box. Have students briefly discuss the possible purposes of each kind of packaging.

Focusing on Study Skills

Concepts Behind Food Packaging summarizes the main point of the activity. Write this summary on the board for students to refer to as they read the introduction and do the activity.

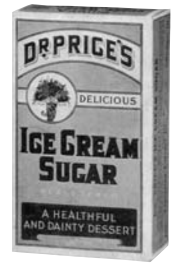
To sharpen students' research skills, have them learn about other developments in the history of food packaging and add these to a poster-sized illustrated timeline.

Over time people developed other materials, with other properties, for food packaging, as the timeline below shows. Pottery, glass, cloth, wood, and paper were among the materials most commonly used.

Metals, too, were used for food storage for thousands of years. But it wasn't until the early 1800s that the technology for making tin cans was developed. In 1809, the French general Napoleon Bonaparte offered a reward to anyone who could discover a way to preserve food for his army to eat on long campaigns away from home. A French chef came up with the winning idea: he packed the food in glass jars, using heat to sterilize the contents. The following year a British inventor patented the use of tin cans instead of glass jars. These all-purpose containers, actually made of tin-coated steel, quickly became popular. Food preserved in tin cans remained safe to eat for years, without refrigeration.

Tin can from 1853

The Industrial Revolution, which began in England in the late 18th century and then spread around the world, also brought changes in food packaging. As economies shifted from agriculture to manufacturing, people left the farms and moved to cities to work in factories. With fewer people living near food-producing areas, food had to be shipped farther and stored longer. Manufacturers began using paper and cardboard cartons to package foods. These containers were lightweight and easy to ship and store. In addition, advertising



Cardboard packaging from the early 1900s

- **A.D. 1810** First tin cans.
- **A.D. 1890s** First printed cardboard cartons.
- **A.D. 1933–35** Polyethylene and polystyrene developed.
- **A.D. 1949** First plastic bag.
- **A.D. 1959** First aluminum can.

A.D. 1800 **A.D. 1850** **A.D. 1900** **A.D. 1950** **A.D. 2000**

Note on Food Preservation

The invention of canning in 1809 is credited to the Frenchman Nicholas Appert. Appert's process included heating glass jars of food in boiling water and sealing them airtight with corks and wire. While Appert's processing and packaging methods were generally successful, spoilage still occurred. Appert attributed food spoilage to air rather than to bacteria. Fifty years later the work of fellow Frenchman Louis Pasteur would correctly link food spoilage to the growth of microorganisms. Apparently Appert's canning process did not always kill the microorganisms that were in the food.

Note on the History of Food Packaging

One of the most common food packages is the cardboard box. It first appeared on most grocers' shelves in 1899. In that year, the National Biscuit Company, now known as Nabisco, introduced a new product—a soda cracker called Uneeda Biscuit. Crackers, like many other food products of that time, were usually sold in bulk from barrels or large boxes. Unfortunately, crackers sold in bulk would often break or absorb moisture and become stale. The manufacturers of Uneeda Biscuit wanted a package that would protect their product from these problems. They designed a machine that would fold a piece of paperboard into a six-sided carton. The carton was lined with wax paper for added protection against moisture and breakage. The printed paper outer wrap of the carton contained this message:

> *To protect, preserve and deliver to the consumer our new and splendid Uneeda Biscuit, as fresh and crisp as when just from the oven, we have devised this moisture proof package. Carefully remove the wrapper and after the biscuits are eaten, you have a school children's lunch box. Keep the box closed. This preserves the crispness.*

The product was an overnight success, due in no small part to its unique and resourceful packaging. Soon other products such as butter, flour, and tea moved from the barrel to the paperboard carton.

Connection to Earth Science

Aluminum is the most abundant metallic element in the earth's crust. Because of its chemical nature it is found only as a compound, not in its pure metallic form. Bauxite, which is a mixture of hydrated aluminum oxides, is the principal source of aluminum. Have students find out where bauxite is found and how it is mined.

Multicultural Links

Different cultures have developed ingenious, multipurpose food packages using materials readily at hand. For instance, in Japan, dried fish is traditionally wrapped in a length of straw rope. This wrapping protects the fish and allows just the right amount of air to circulate to keep the fish safe to eat for six months or longer. Another advantage to this packaging: the fish can be unwrapped a little at a time as it is used and the package can be resealed by simply rewinding the rope.

Connection to Chemistry

Plastics are polymers, made up of smaller units called monomers. Different plastics have different properties. For example, polyvinyl chloride (PVC) begins to soften at about 70–80°C, while polypropylene (PP) remains solid up to about 145–150°C. PVC is also a good oxygen barrier, while PP lets oxygen pass through it. These properties are determined by the types of monomers that make up the plastic, the bonds between monomers, and other chemicals, such as plasticizers, that are added to the plastic. (Plasticizers are substances that prevent the formation of some of the bonds between polymer molecules, which makes the resulting plastic more flexible.) Common monomers used in plastic production include ethylene, propylene, benzene, and styrene. Have students investigate one of the plastics commonly used in food packaging and diagram its chemical structure.

could be easily printed on paper packages — an advantage for food manufacturers trying to win new customers.

Supermarkets, which first appeared in the U.S. in the 1930s, led to further innovations in food packaging. Before this time, most people shopped at general stores where foods, such as flour, sugar, and crackers, were kept in barrels and scooped up by the shopkeeper into containers that customers brought from home. With the arrival of self-service supermarkets came the need for new types of packaging. One material in particular began to fill this need—plastic. Plastic packaging was lightweight, relatively cheap, and virtually unbreakable.

In the last 30 years, other changes in society and technology have created a number of new packaging needs. An increased demand for convenience foods, for instance, has led to ready-made meals and snacks in packages designed to go from the freezer to the microwave to the table. These packages are often made of composites — a combination of materials, which are bonded together.

Today food packaging is big business — a $110 billion-a-year industry in the U.S. alone. In this activity, you'll take a closer look at some of today's food packaging materials and how they're used.

In a general store (left), many foods were sold in bulk — the shopkeeper scooped them up from big barrels into customers' reusable containers. Today (right) most foods are packaged in individual packages, so shoppers can serve themselves.

Tips from the Trenches

To focus students' attention on the advertising on food packages, I bring in brand-name goods and matching generic items and do a blind taste test. With many foods, students think that the generic item is one of the brand-name goods. They are often quite surprised. They usually realize that generic products are more economical, but without tasting them assume that they are not as palatable as brand-name products. The taste test alerts them to the subtle powers of advertising on food packaging labels.

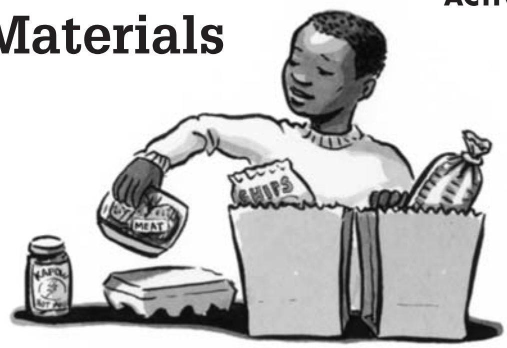
Cindy Quinn
Science teacher
Oak Park and River Forest High School

Note on the History of Packaging Materials

Plastic was first made in 1868 by John Wesley Hyatt, an inventor who was trying to create a material that could be used instead of ivory to manufacture billiard balls. Hyatt mixed pyroxylin (made from cotton and nitric acid) with camphor to get celluloid, the first plastic.

Analyzing Food Packaging Materials

2
ACTIVITY



Take a close look at what's inside your grocery bag. You might find a loaf of bread wrapped in cellophane, a dozen eggs in a cardboard carton, potato chips in a bag made of plastic and foil, hot sauce in a glass jar, or a package of meat on a polystyrene foam tray shrink-wrapped in plastic film. Why are different foods packaged in such different ways? You'll try to answer that question in this activity.

Think about these questions as you do the activity:
- ? What are the purposes of food packaging?
- ? Why are certain materials used in certain types of food packaging?
- ? What are the properties of different food packaging materials?

Design Connection How does the type of food packaged affect the choice of materials used in its packaging?

Part A

In this part of the activity, you'll look at different types of food packaging, determine what purposes the packaging serves, and identify the types of materials used in the packaging. In Part B, you'll consider the properties of those materials and form hypotheses about why certain materials are chosen for certain types of packaging.

▶ **Make a data table with room to record:**
- the type of food packaged
- a description of the packaging
- the purposes of the packaging
- the materials used in the packaging
- the purposes of each material

Estimated Time
- Part A, hunt done as homework over one or two days; 20 minutes to make group list of packaging purposes
- Part B, 20 minutes to make group data table and graph; 20 minutes for discussion

Suggested Grouping
Groups of three or four

Homework assignment may be done individually.

Activity Objectives
Students will:
- examine a variety of different types of food packaging
- identify the materials used in food packaging
- determine the purposes of the materials used in specific food packages
- analyze the properties of different food packaging materials

Part A

Leading In to the Activity
Bring in several examples of food packages. As a student reads the introductory paragraph on this page aloud, display the packages on a table or desk. As a class, discuss reasons why packaging engineers might have designed the packaging for each food.

Recording Data and Observations
Activity-Log Sheet 2 contains space for students to list and describe foods and their packages, as well as list packaging materials and their purposes. You may photocopy this log sheet and distribute it to students, make an overhead transparency of the log sheet for students to copy, or have student devise their own data tables.

Materials (per student)
- data tables in notebooks or on clipboards
- pens or pencils
- graph paper

Connection to SOCIAL STUDIES

Archaeologists often find food containers amidst the other artifacts of ancient cultures they uncover. Have students choose an ancient culture and find out what types of food containers they used. Encourage students to use photos, drawings, and text to make a visual display of the food packaging technology of the culture they have studied.

Procedure, Data, and Observations

1. In your data table, list three foods in each of the following categories:
   - fresh foods, such as fresh fruits, vegetables, and breads
   - staples, such as flour, dried pasta, rice, cereal, and beans
   - prepared foods, such as frozen foods, canned foods, and mixes for baked goods
   - take-out foods, such as fried chicken, burgers, and fries
   - beverages, such as milk, juice, and soft drinks
2. Hunt for the foods on your list—at home, in the supermarket, or elsewhere. Take your data table with you so you can record your observations about the packaging materials. For each food on your list, write down a description of the packaging. (If there are several different types of packaging available for the food, describe the one you or your family usually buys.)
3. Describe the purposes of the packaging. Consider how the packaging meets needs in each of the categories listed in the chart below.

Sample Purposes for Food Packaging

Protection	Manufacturing, Shipping, and Storage	Use	Disposal	Marketing
• to keep food from spoiling • to keep food from breaking • to keep air or moisture in or out	• inexpensive • lightweight • easy to stack	• to keep food hot or cold • to cook in	• to be recyclable • to be reusable • to be biodegradable	• to provide room for printed information • to appeal to consumers

Procedure, Data, and Observations

1. Be ready to offer suggestions to students who cannot think of three examples in each food category. Other fresh foods might include meats, fish, and shellfish. Other staples could include sugar, honey, crackers, popcorn, and coffee or tea. Prepared foods might include microwave-ready meals and snacks, frozen desserts, and toaster foods. Other take-out foods include submarine sandwiches, pizza, falafel, tacos, burritos, ice cream, and frozen yogurt. Beverages might include coffee, tea, lemonade, powdered drink mixes, sports drinks, and milkshakes.
2. Students should perform steps 2 through 4 for each package in turn. Encourage students to start with foods that they already have at home. If possible, students should open packages so that they can identify all the materials used. Suggest that if they open any packages, they carefully store the food, so that it will not be wasted.

   If students go to a supermarket, suggest that when students first enter the store, they go to see the store manager and ask for permission to conduct their hunt in the store. That way, students are less likely to be questioned by store personnel as they handle and discuss various packages. Remind students to record all the packaging materials they can observe, without opening or damaging any of the packages. Students should collect all the data for one package and then move on to the next package.

   If students go to a supermarket, suggest they work in pairs in the store so that one person can examine a package and the other person can record all observations.
3. Remind students that most packaging meets a number of different purposes. Refer them back to Activity 1 and the many purposes they identified for the microwave popcorn package.

4. Determine the materials that are used in the packaging and the purpose of each material. Record this information in your data table.
5. Share your results with other group members. Make a group list of all the purposes food packaging can serve.

Interpretations of the Data

1. How many packages listed in your data table were made of paper (including cardboard)? Glass? Steel? Aluminum? Plastic? A composite of several materials?
2. How many packages were made of materials that can be easily recycled? How many packages could be reused?

Reflections

3. Were you surprised by any of the purposes of the packaging you examined or the materials used in the packaging? Explain.

Part B

Why are certain materials chosen for certain types of food packaging? In this part of the activity, you will discuss your results from Part A with other group members. Based on your data and group discussions, you will form hypotheses about the uses of different food packaging materials.

▶ **Make a group data table with room to record:**
- the materials used in the food packaging you examined
- the properties of those materials

Packaging is crucial. It's the silent salesman.

Observation from an American packaging design firm

DISCUSSING THE QUOTE

Have students consider how packaging can sell a product (convenience, appealing appearance, advertising printed on it). For discussion, you might bring in three examples of packaging for one product, such as cereal or potato chips, and ask students which one they would buy and why.

Connection to MATHEMATICS

Suggest that students count the different materials used for each category of food listed on page 10 (fast food, prepared food, and so on) and determine which material is most commonly used in that category. Ask students to decide the best way to present their information graphically and to use their graphs to explain their results to the class.

4. Once students have identified the materials that make up each package, they should look over the purposes they have listed for the packaging and try to infer from the construction of the package and from their knowledge of materials which material serves which purpose. Some materials may serve the same purpose. For example, a plastic cap and an aluminum foil seal under the cap both help keep food fresh and help secure food in the package.
5. Ask students to refer to their data table entries from step 3.

Interpretations of the Data

1. Answers will depend on students' food choices. You might suggest that students create a tally chart in which they list each material. They should then look back at their data tables and count the number of packages in which each material was used. In general, paper (including cardboard) will probably be the most common packaging material with plastic a close second. Glass and metals (primarily steel and aluminum) will probably be less widely used.
2. Discuss the materials that can be recycled in your community. Most communities have recycling programs for aluminum. Some also have recycling programs for glass, tin cans, some plastics, and paper and cardboard that are not contaminated by food wastes. Have students calculate the percentage of the packages they examined that can be recycled by dividing the number of recyclable packages by the total number of packages.

Reflections

3. Students may have been surprised by less-obvious purposes, such as protecting food during shipping or being easy to display on a store shelf. Students may have been surprised to find how many different materials may be used in one package.

Connection to Biology

Two main categories of food preservatives are used today: antimicrobials (which prevent the growth of microorganisms) and antioxidants (which prevent oxidation and therefore discoloration and spoiling). Have students find out how microorganisms and oxidation harm foods and how each of these preservatives works to prevent this damage. By law, package labels must say not only what preservatives have been used but also what they do. Have students check package labels for preservative information and categorize each preservative as either an antimicrobial or an antioxidant.

Procedure, Data, and Observations

1. In a group data table, list all the materials used in the food packaging that group members analyzed. Through group discussion, identify the properties of each material and list these in the group data table. A list of some of the properties of packaging materials appears below. Be sure to consider properties that might be advantageous as well as disadvantageous in food packaging. For example, paper is lightweight, but tears easily when wet. Glass is watertight, but shatters when dropped. To help you determine the properties of different materials, look back at your data table from Part A in which you listed the purposes of the materials used in the packaging you examined.

Sample Properties of Packaging Materials

- strong
- breakable
- lightweight
- watertight
- airtight
- transparent
- opaque (keeps light out)
- can withstand high temperatures
- can be printed on
- good insulator (keeps hot things hot and cold things cold)
- microwaveable
- recyclable
- reusable
- biodegradable
- inexpensive

2. Compile all the information from group members' responses to question 1 on page 11. Make a bar graph in which you compare the frequency of use of the different materials.

Part B

Recording Data and Observations

Activity-Log Sheet 3 includes a group data table for students to record the materials they found in food packaging and the properties of those materials. It also provides a graph grid for students to graph their data in step 2 of the procedure. Photocopy the log sheet for students, or have them devise their own tables for compiling this information.

Materials (per group)

- data tables from Part A
- Activity Log-Sheet 3 or graph paper
- pens or pencils

Procedure, Data, and Observations

1. Suggest that each group select one member to record the observations of the group and one member to be discussion leader.
2. In this step, students pool their data from Part A, Interpretations question 1 on page 11. Students should first collect data in a table and then graph it. Suggest that they make the x-axis of their graphs the type of packaging material (glass, aluminum, steel, plastic, paper, and composite) and the y-axis the total number of packages made of each material. For packages that are not composites, but are made of more than one material, students should identify the primary packaging material and count the package in that category.

Interpretations of the Data

1. Students will pool their data from Part A, Interpretations question 1. Answers will depend on the foods that students examine. They will probably find that paper and plastic are the most common materials and that glass and metals are less common. Students' explanations should relate the most commonly used material to the properties that make it so suitable for food packaging.

Reflections

2. Students may have been surprised by which materials are most widely used in food packaging.

Putting It All Together

1. Students will combine information from Part A (purposes of

Interpretations of the Data

1. Which material was used most often in the packaging your group examined? Why do you think this material is so widely used in food packaging?

Reflections

2. Were you surprised by any of the results? Explain.

Putting It All Together

1. Choose one of the foods from the data table you made in Part A and use what you learned in Part B to explain why it might be packaged the way it is.
2. What generalizations can you make about the types of materials used to package fresh foods? staples? prepared foods? take-out foods? beverages?
3. What are some of the advantages and disadvantages of using each of the following materials in food packaging: paper, plastic, steel, aluminum, glass, and composites?
4. How would you define overpackaging? Would you consider any of the foods you examined to be overpackaged?

Design Connection What factors do you think food packaging designers take into account in designing packages?

I Wonder

Now that you've had a chance to look at some examples of food packaging, what new questions do you have about food packaging materials? Write down at least three questions and tell how you could find answers to them.

Connection to BIOLOGY

Some fruits release a hormone, ethylene (ethene), that helps them ripen. Ask students to set up an experiment in which two unripe tomatoes are placed together in a plastic or paper bag and two other unripe tomatoes are left unwrapped to ripen. The tomatoes in the bag should ripen sooner because of the ethylene that becomes trapped in the "package." Have students use their results to design packages in which tomatoes would ripen as they are being shipped from grower to grocer.

packaging) and Part B (properties of packaging materials) to deduce why a particular material or combination of materials is used in packaging a food.

2. Sample generalizations: Fresh foods are often packaged in plastic or paper. Transparent packaging, such as plastic and cellophane, lets consumers check the condition of the food. Insulated plastic containers are often used to keep fresh foods hot or cold. Paper and breathable plastics let fresh foods "breathe." Staples are usually packaged in moisture-resistant and light-blocking materials, such as coated paper and cardboard or plastic bags, to allow for long-term storage. Prepared foods are packaged similarly or in glass jars or tin cans, depending on the type of food. Take-out foods are usually packaged in paper or plastic, which are lightweight materials and which are often made into containers for heating or eating the food. Beverages are usually packaged in glass, aluminum, plastic, or composites. Such materials are watertight and in some cases recyclable. Accept other generalizations that students can support with evidence or logical reasoning.

3. Suggest that students organize their data in a chart. A portion of a sample chart appears below.

Material	Advantages	Disadvantages
Paper	lightweight biodegradable can be printed on	tears easily not waterproof burns easily
Plastic	lightweight easily made into different shapes may be microwaveable	may not be recyclable not biodegradable
Steel	strong airtight watertight opaque recyclable	not microwaveable heavy

4. Students might define overpackaging as packaging not necessary to protect or contain contents or provide necessary information. Have students give examples of any overpackaged foods they found and explain how the packaging could be reduced.

Design Connection Answers will probably include the nature of the food to be packaged, properties and cost of available packaging materials, the need to attract consumers, the need to carry nutritional information, weight of package, ease of manufacturing and shipping, convenience, how the package will be disposed of, and so on.

I Wonder

Have students work in groups to brainstorm questions.

Expanding on the Concepts This article compares the properties of paper and cardboard, glass, metals, plastics, and composites used as food packaging materials. Note that Municipal Solid Waste refers to wastes from residential, commercial, and institutional (schools, hospitals, etc.) sources.

How to Use These Pages

Assign this article for general reading after students have completed the activity. You might also divide the class into five groups, assign each group a type of material, and ask groups to read about their material and compare the information to their observations from the activity. Have students discuss how their own observations confirmed or contradicted information in the article.

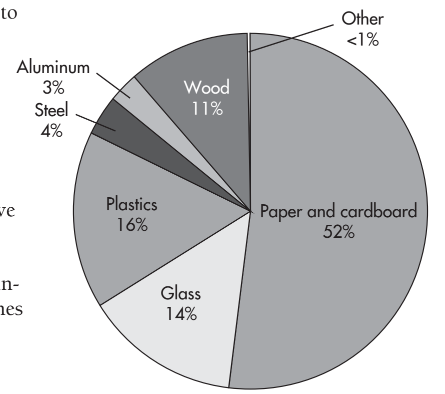
Expanding on the Concepts On your hunt, you probably found food packaging made of paper, glass, steel, aluminum, and plastic, or composites of those materials. What properties did you identify for each material? Compare the information below with your own ideas about these materials and their use in food packaging.

Glass packaging is often used for beverages.

How do food packaging designers make decisions about which materials to use? First, they think about the characteristics of the food to be packaged and the type of protection it needs. Other considerations include how the packaging will be manufactured, used, and disposed of; the cost and availability of different packaging materials; information that must appear on the package; and government packaging regulations. Depending on these design goals and constraints, a designer will choose from a number of basic materials.

Paper and cardboard are two of the materials most widely used in food packaging. Paper is made from wood fibers, and cardboard is made of pressed paper pulp or pieces of paper glued together. Paper has a number of properties that make it useful in food packaging. It is lightweight, relatively inexpensive, not airtight (good for foods that need to "breathe"), and can be easily printed on. It's not, however, water- or grease-proof, although it can be coated with wax or plastic to give it those properties. Paper has some environmental advantages as well. It comes from a renewable resource—trees—and, under the right conditions, paper is biodegradable. Most paper is also recyclable.

Another common food packaging material is glass, which is made of sand and other compounds melted together at high temperatures. Among the properties that make glass useful for food packaging: it's transparent, airtight, watertight, microwaveable, and non-toxic. It can also be molded into many different shapes. Although glass is brittle and can shatter when dropped, it makes a strong container, even for con-



Materials Used in Containers and Packaging
% by weight in Municipal Solid Waste (MSW), 2003

Note on Paper Recycling

Paper that has come into direct contact with food cannot currently be recycled because the food residues interfere with the paper pulping process. Some food-contaminated paper, however, can be used as fuel in certain types of furnaces.

such as carbonated drinks. In addition, glass doesn't react with most substances, so it can be used with acidic foods, such as those containing vinegar. Because glass melts only at very high temperatures, it can also be used for foods that are packaged while hot. Many glass containers can be sterilized and reused as well as recycled.

Metals used in food packaging include steel and aluminum. "Tin" cans are actually made of steel coated with a thin layer of tin. The steel makes the can strong, and the layer of tin keeps the iron in the steel from rusting. Properly sealed, tin cans keep out moisture and air and preserve foods for years without refrigeration. Tin cans can also be recycled. One disadvantage of tin cans, however, is their weight, which increases transportation costs.

Aluminum is not as strong as steel, but it is much lighter—about one-third as heavy. That means that food packaged in aluminum cans weighs less and costs less to transport than food packed in tin cans. Aluminum foil is also used in food packaging. Foil is opaque and thus protects foods from light. It can also keep out moisture and air. In addition, foil can withstand high temperatures, so it can be used in packaging designed to be heated in an oven. Since thin foil tears easily, however, it is often combined with paper or plastic for added strength.

Aluminum cans are widely recycled.

One disadvantage of aluminum is that it reacts with certain chemicals. So, for example, to keep the acids in carbonated drinks from attacking the aluminum, beverage cans are coated with a thin layer of plastic. Aluminum is also very expensive to produce because the process requires a tremendous amount of energy. Fortunately, though, aluminum can be recycled. Using recycled aluminum reduces the amount of energy needed to make new aluminum products by 95%.

An increasingly popular food packaging material is plastic. Plastic has many properties that make it useful for food packaging. It's lightweight, waterproof, resistant to breaking, and microwaveable. In addition, plastic can be made into rigid containers, flexible pouches, or film.

Different plastics have different properties. For example, some plastics are strong enough to withstand the high pressure of carbonated drinks. Some hold up under the high temperatures required for cooking and baking. Others melt at low temperatures and can be used to shrink-wrap foods.

Plastics have disadvantages as well. For the most part, plastic containers are not biodegradable or easily recycled, so they quickly end up in landfills. In addition, plastics are made from petroleum, a nonrenewable resource.

Connection to Chemistry

Ask student volunteers to research the pH of common foods and identify examples of acidic foods and basic foods for the class. If possible, ask students to demonstrate the effect of an acidic liquid (vinegar, tomato juice, lemon juice) on an uncoated piece of metal and on a piece of glass. After the demonstration, have the class discuss how the pH of a food could affect a packaging designer's choice of material.

Note on Recycling

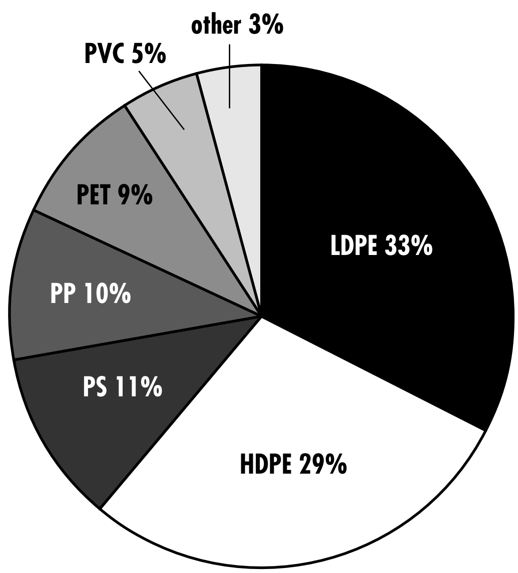
Recycling often conserves the use of other resources as well as the material being recycled. For instance, recycling one ton of glass saves one ton of oil used in manufacturing new glass. Recycling glass also reduces water use by 50%.

Note on Packaging Materials

Another wood pulp product commonly used in food packaging is cellophane. Although it looks like a plastic film, cellophane is actually made from regenerated cellulose. This transparent packaging film is greaseproof and holds its form when twisted or creased. Cellulose packaging is easy to tear and open, can be printed on, and is easily sealed with heat.

Note on Plastics Used in Packaging

According to recent statistics, the percentages of different plastics used in all types of packaging are as follows:



Activity 2 Analyzing Food Packaging Materials 15

Extending Thinking

Have a student read the final paragraph about composite materials aloud. Ask the class to try to explain the specific purpose of each material—paper, metal foil, and plastic—used in the juice box composite. Then ask students to consider questions such as these:

What materials would you use if you were designing a package that needed to be both waterproof and lightweight? opaque and waterproof? recyclable and resistant to acids? microwaveable and lightweight?

Connection to Mathematics

Encourage students to record the kinds of plastics they found in the food packaging they examined for this activity. They can refer to the recycling codes on the bottoms of the containers or use the chart on page 16 to help them identify different kinds of plastics. Ask them to calculate the percentage of different plastics used in the packaging they examined.

Plastic	Recycling Code	Common Uses
polyethylene terephthalate (PET or PETE)	1	rigid: bottles for carbonated drinks and juices, oven-ready trays
high-density polyethylene (HDPE)	2	rigid: containers for milk and other dairy products, bottled water film: shopping bags, liners for food boxes
polyvinyl chloride (PVC)	3	rigid: containers for cooking oil, bottled water film: wrapping for meat, fish, poultry, and other foods
low-density polyethylene (LDPE)	4	rigid: squeezable bottles film: wrapping for baked goods, candy, dairy foods, meat, and produce; shopping bags; shrink wrap
polypropylene (PP)	5	rigid: bottles and tubs film: wrapping for candies, snacks
polystyrene (PS)	6	rigid: produce baskets, containers for dairy foods foam: clamshell containers for fast foods; hot-drink cups; disposable dishes; egg cartons; meat trays

are made from petroleum, a nonrenewable resource.

Some of the plastics commonly used in food packaging are listed on the left. You can identify these by the recycling code printed on containers made of each material. Although all these plastics have recycling codes, so far only PET and HDPE are widely recycled.

Along with other materials, packaging designers today use composites—packaging made from several different materials, such as paper, metal, and plastic, bonded together. Composites take advantage of the different properties of the different materials from which they're made. Juice boxes, for example, are made from a composite of paper, metal foil, and plastic bonded together. They are lightweight and can keep juice fresh for six months without refrigeration. One disadvantage of composites, however, is that they are hard to recycle. Most recycling processes cannot handle mixed materials.

Plastic recycling center

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Enriching Science Experiences

Students can investigate the paper recycling process by making paper out of old newspapers or other uncoated scrap paper. First, have students tear the newspaper into small pieces. Add the pieces to a pan of water and heat on medium heat for several minutes, stirring frequently. The mixture should resemble oatmeal. Let the mixture cool, then process it in batches in a blender until pulpy. Mix the pulp with more water in a large plastic tub. Use a papermaking screen (available at art supply stores) or fine plastic needlepoint mesh to form the paper. Put the screen or a large piece of mesh into the tub and lift it up through the pulp. Let it drain for a minute or two, then flip it over onto a clean sheet of newspaper. Lay another layer of newspaper over the screen or mesh and use it to blot up the excess liquid. Then carefully lift the screen or mesh and let the new paper dry.