Part A How Much Is Needed?

Materials

For each student

1 calculator

Procedure

1. Use the information in Table 1 to calculate the total number of Calories needed each year for one person.
2. Use the information in Table 1 to calculate the total number of Calories needed to supply the world's population in 2004.
3. Calculate the total number of Calories needed to supply a population of 8.5 billion people.

Table 1 Human Calorie Requirements

Human Energy Requirement* (Cal/day/person)	2004 World Population	Energy Available From World's 2004 Food Harvest (Cal)
2,500	6.4 billion (6.4×10^9)	7,000,000 billion (7×10^{15})

*Energy expended by an average human at a moderate activity level

Analysis

Group Analysis

1. Were enough Calories harvested in 2004 to supply the world's population?
2. By what percent would the world's food harvest have to increase (from the 2004 level) to provide enough Calories for a population of 8.5 billion?

12.4 Mineral Mania

Purpose

Identify foods that contribute to the minimum daily requirements for specific nutrients. Use this information to plan a healthy menu of snacks for a class party.

Introduction

You have explored how plants obtain essential nutrients from the soil. All organisms, including humans, must consume minimum amounts of many types of nutrients to survive. Most ecosystems and organisms have evolved so that sufficient quantities of necessary nutrients can be obtained from the ecosystem. Technology has not only made many different foods available, but has also allowed human populations to survive in ecosystems that would not otherwise support so many people. Humans today have many options when deciding how to obtain nutrients.

Proteins, carbohydrates, and fats are essential components of the diets of humans and other animals. Vitamins and minerals are also essential. In this activity, you will focus primarily on **minerals**, which when referring to foods are nutrients made of a single element. (The word "mineral" has different meanings in different contexts.) You will identify which minerals are supplied by different foods and select an assortment of foods that not only make good party snacks, but also provide half of the recommended daily allowance (RDA) of several important minerals. (Assume that your guests will obtain the other half of their RDA during other meals on the day of your party.)

Fruits and vegetables supply many needed nutrients.

Materials

For each team of two students

at least 8 nutritional labels from various party foods

Table 1 A Quick Mineral Guide

Mineral	Role in Body	Source	Adult RDA**
Calcium	Maintains healthy bones and teeth; especially important during growth. Also involved in blood clotting and muscle contraction. Osteoporosis is a disease associated with too little calcium in the diet.	milk and dairy products, whole grains, dark green vegetables, kelp & other sea vegetables, some fish	1,000 mg
Chromium	Assists in regulating blood sugar. Important for diabetics and those with Turner's syndrome, because it is necessary for the conversion of carbohydrates to energy.	brewer's yeast, broccoli, cottage cheese, chicken, corn oil, grapes, milk, rice, wheat germ	male: 35 µg* female: 25 µg*
Copper	Required for the production of hemoglobin, ATP, and many hormones. Helps sustain healthy nerves and blood vessels.	almonds, beans, cocoa, mushrooms, potatoes, seafoods	900 µg
Iodine	Fundamental to the structure of thyroid hormones, which regulate metabolism and stimulate immune functions.	iodized salt, kelp, milk, shellfish, other seafoods	150 µg
Iron	Essential to the structural integrity of hemoglobin. Enhances overall resistance to disease and assists in production of ATP.	asparagus, beans, fruits, grains, meats, molasses, nuts, potatoes	male: 8 mg female: 18 mg
Magnesium	Needed for proper nerve and muscle action. Assists in the production of new cells, bone, protein, and fatty acids.	grains, grapefruit, almonds, oysters, shrimp, nuts, beans	male: 400 mg female: 310 mg
Manganese	Assists in the production of large organic molecules in the body. Necessary for nervous system function.	beet tops, beans, cocoa, milk, egg yolks, shellfish, tea, pineapple	male: 2.3 mg* female: 1.8 mg*
Phosphorus	Integral to the structure of DNA, therefore necessary for cell reproduction and repair. Also plays a role in nervous system functions.	milk products, grains, meat, fish, poultry, nuts	700 mg
Potassium	Essential for fluid balance, blood pressure, and muscle tone in the body, so plays a role in kidney, blood, and brain function.	bananas, yogurt, grains, apricots, sweet potatoes, beans, citrus fruits, green vegetables	4.7 g*
Selenium	Aids in some metabolic processes and in normal body growth and fertility by stimulating thyroid hormones. A well studied antioxidant that reduces cancer risk.	Brazil nuts, celery, cucumbers, broccoli, onions, tomatoes	55 µg
Zinc	Fundamental to immune function, repair mechanisms, and protein synthesis.	meat, eggs, yogurt, brewer's yeast, beans, nuts	male: 11 mg female: 8 mg

*Note that for these minerals there is not enough information to establish an RDA. Figures given are the AI (adequate intake).

**µg = microgram = 1×10^{-6} gram

Safety Note

A science lab is not a recommended area for food consumption. If you use the lab area for this activity, cover all surfaces with tablecloths.

Procedure

1. Use Table 1, "A Quick Mineral Guide," to select three minerals you want to make sure your party food will supply to your guests.

2. Prepare a data table with headings similar to those shown below. Title it "Data Table 1: Minerals in Foods" and enter the name and RDA of each of your three chosen minerals.

Data Table 1: Minerals in Foods

Mineral	RDA	Food Item(s) Providing This Mineral	Servings Needed to Obtain 1/2 RDA

3. Obtain eight food labels and record in Data Table 1 which foods provide each of your 3 target minerals.

Note: One food item may provide several of your target minerals.

4. Determine how many servings of each food item are needed to provide half of the RDA for that mineral. Record this information in Data Table 1.

5. Prepare a data table with headings similar to those shown below. Title it "Data Table 2: Party Menu." Compare your foods to those selected by the other team in your group. Using all the minerals and foods investigated by both teams, prepare a group menu for a party which will provide half the RDA for three minerals. Include the number of servings (you may use fractions) of each food item that each of your friends at the party must consume in order to obtain half the RDA for each of your three target minerals. Record your answers in Data Table 2.

Data Table 2: Party Menu

Food Item	Amount of Mineral Per Serving	RDA	Servings Needed to Obtain 1/2 RDA

6. At the direction of your teacher, share your ideas with the entire class. Help the class plan the party, and volunteer to bring one of the snacks. Make sure that you volunteer for something you can actually bring. (If you have specific food allergies, make sure that your teacher knows about them and that the party menu includes foods that you will be able to consume and that will provide the minerals for half of your RDA.)

Analysis

Group Analysis

1. How did you select your three target minerals?

2. Which mineral or minerals do you think are the most important to the diet of humans? Explain.

3. Do you think the nutrient requirements of people and plants are similar? Explain.

4. What effect, if any, will a continuing increase in human population have on the nutrients available to other organisms? Explain.

5. Should world leaders attempt to provide the RDA of every nutrient to every person on Earth? Discuss the trade-offs involved. Include in your answer what you think is the solution that best balances the benefits and costs of providing adequate nutrients to the world's population.

Extension

Include other nutrients—such as vitamins, fats, and protein—or calorie content in your party menu planning.

The Basics of Genetics

Gregor Mendel was a 19th-century monk who set out to explore this question scientifically. He chose to work with pea plants, which were relatively easy to use for his experiments. He studied how certain traits were passed from one generation of pea plants to the next. The traits he analyzed included seed color (yellow vs. green) and stem length (long vs. short). Over several years, he conducted carefully controlled experiments that involved selecting parent plants and keeping detailed records of the traits inherited by their offspring. Mendel found that there appeared to be units of information that were passed from parent to offspring. He also noticed that these units behaved as though each one was made up of two parts.

Since the time of Mendel, many scientific studies have provided huge amounts of evidence that support and expand upon his basic ideas about inheritance. Today, Mendel's "units" are called **genes**, and each gene is present in an individual in two copies, called **alleles**. We now know that each parent provides one allele for every gene of every offspring. In any organism, some traits are determined by the alleles of only one gene, while others are determined by many genes. Some traits are determined by a combination of genes and environmental conditions.

In the simplest cases, a gene has only two possible traits, one of which is dominant over the other. An example of this is a gene that determines whether corn kernels are smooth or wrinkled. The scientific evidence tells us that a corn plant having two smooth alleles will always have smooth kernels and a plant with two wrinkled alleles will always have wrinkled kernels. However, the evidence also shows that a plant with one smooth and one wrinkled allele will always have smooth kernels. This evidence leads to the conclusion that the smooth trait is **dominant** and the wrinkled trait is **recessive**. The dominant trait is defined as the trait that is seen in an organism with one of each type of allele. The observed feature, such as smooth or wrinkled corn kernels, is known as the organism's **phenotype**.

An organism has many genes, or allele pairs. Biologists use an uppercase letter to represent the dominant allele and a lowercase letter to represent the recessive allele. (To make it easier to distinguish between uppercase and lowercase letters, we underline the uppercase letters.) For the corn kernel alleles, we can use **S** for smooth and **s** for wrinkled. Any allele pair, such as **SS**, **Ss,** or **ss**, is known as the organism's **genotype**. Genotypes that have two identical alleles, such as **SS** or **ss**, are called **homozygous**. The prefix *homo-* means "same." Genotypes with two different alleles, such as **Ss**, are referred to as **heterozygous**. The prefix *hetero-* means "different." Organisms with homozygous recessive alleles will express the recessive phenotype (e.g., wrinkled kernels), organisms with homozygous dominant alleles will express the dominant phenotype (e.g., smooth kernels), and organisms with heterozygous alleles will also express the dominant phenotype (e.g., smooth kernels).

Analysis

1. Explain the difference between genotype and phenotype.

2. A plant with red flowers is bred with a plant with white flowers.

a. If all offspring have red flowers, what does this tell you?

b. If all offspring have pink flowers, what does this tell you?

3. Organisms that reproduce asexually have only one parent. How would you expect the genotype and phenotype of asexually produced offspring to compare to the genotype and phenotype of the parent?

17.3 Rearranging Rice Genes

Purpose **Explore the patterns of genetic inheritance.**

Introduction

In Activity 17.1, "Modeling Inheritance," you created your own model to describe how one trait is passed from parents to offspring. In the simplest situations, a trait is determined by one gene. In organisms that reproduce sexually, each parent contributes one allele for each gene. Organisms that reproduce asexually have only one parent; both alleles for each gene come from that one parent.

One trait that is very important for the production of high-yield rice is plant height. This is determined by a single gene, called the "semi-dwarf" gene. Semi-dwarf rice plants are shorter and sturdier than tall rice plants, so they survive better and thus produce more rice. The semi-dwarf trait is recessive, and the tall trait is dominant; plant breeders use the symbols sd1 and <u>SD1</u> for the alleles associated with the semi-dwarf and tall traits, respectively. (For this activity, an uppercase <u>T</u> will represent <u>SD1</u> and a lowercase t will represent sd1.) In this activity you will use a model to investigate what happens when a homozygous, tall rice plant (genotype <u>TT</u>) is crossed with a homozygous, semi-dwarf rice plant (genotype tt).

This picture shows twelve different types of rice, all with different genetic traits.

17.4 Generation Next: Crossing the Offspring

Purpose

Simulate a cross between heterozygous plants.

Introduction

Do the kernels on these ears of corn exhibit the same phenotype?

In Part A of this activity you will investigate the genetics of corn plants. Each ear of corn has hundreds of kernels; each kernel is a really an embryo, an offspring of two adult plants. One gene determines the color of the corn kernels, which may be yellow or purple, depending on the alleles contributed by the parents. You will examine and compare pictures of offspring produced by two different sets of parents and use evidence from these pictures to extend your investigations on the inheritance of dominant and recessive traits.

In Part B, you will model the inheritance of the semi-dwarf gene in a rice plant. As you learned in the last activity, this gene determines the plant's height. The tall trait is dominant, and the tall allele is represented by T. The semi-dwarf trait is recessive, and the semi-dwarf allele is represented by t. What type of offspring are possible when you breed a heterozygous rice plant (Tt) with another heterozygous rice plant (Tt)?

Part A Counting Corn

Materials

For each group of four students

1 Corn Ear A

1 Corn Ear B

Procedure

1. Count the number of purple kernels and the number of yellow kernels on each of your two corn ears. Record your results in a data table.

Analysis

Group Analysis

1. When a corn plant with all purple kernels is crossed with a plant with all yellow kernels, the offspring are all purple kernels. For this species of corn, which kernel color is dominant? Explain your evidence.

2. Given this information, determine

   a. the genotype of each parent of Corn Ear A.

   b. the genotype of each parent of Corn Ear B.

   Explain how you reached your conclusions.

Part B Rice Ratios

Materials

For each team of two students

2 blue semi-dwarf rice allele cards (t)

2 blue tall rice allele cards (T)

Procedure

1. Working with your partner, place the four rice allele cards face up on the desk or table. This time, each person will represent a heterozygous tall plant and should take one tall allele card (T) and one semi-dwarf allele card (t).
2. Each partner should close their eyes, shuffle their two cards, place one of the cards on the desk, and then open their eyes.
3. The two cards on the desk (one from you and one from your partner) represent the pair of alleles inherited by the offspring of a cross between two heterozygous tall plants. Record the genotype of the offspring.
4. Repeat Steps 1–3 nine more times.
5. Make a data table to record the genotype and the phenotype of each of your 10 offspring.
6. Report your data to your teacher. Data from all groups will be used to determine the total number of each genotype and phenotype in the first-generation offspring.

Analysis

Group Analysis

Use the class data to answer these questions.

1. For this rice breeding simulation,
   a. list all the possible genotypes in the offspring.
   b. determine what percent of the offspring possessed each genotype.
   c. list the possible phenotypes for the offspring.
   d. determine what percent of the offspring displayed each phenotype.
   e. calculate which ratio best expresses the ratio of the tall to the semi-dwarf phenotype: 1:1, 2:1, 3:1, or 4:1.
2. Do you see any pattern or relationship between the parent genotypes and the frequency of certain genotypes in the offspring? Explain.

Analysis

Individual Analysis

3. Imagine that you have two corn plants, and one of them (Parent 1) produces offspring with only brown corn kernels; the other (Parent 2) produces offspring with only white corn kernels. You breed the two plants and find that all of the first-generation offspring have brown kernels. You then breed two first-generation offspring and discover that the second-generation plants produce both brown and white kernels.

a. Which trait is dominant—white or brown? How do you know?

b. List the genotypes and phenotypes you would predict to be present in

- Parent 1.
- Parent 2.
- the first-generation offspring.
- the second-generation offspring.

c. For a second-generation corn ear with 800 kernels, what is the approximate number of kernels likely to have each phenotype? Explain and show your work.

Part B Second Generation

Materials

For each team of two students

- 2 green flood-tolerant allele cards (F)
- 2 green flood-intolerant allele cards (f)
- 2 yellow non-aromatic allele cards (A)
- 2 yellow aromatic allele cards (a)

Procedure

Now that you have determined that the genotype of all the first-generation offspring is AaFf, you will use cards to represent the different alleles for the flood-tolerant and aromatic genes to simulate a cross that produces second-generation offspring.

1. You and your partner should each take one green card with an uppercase F, one green card with a lowercase f, one yellow card with an uppercase A and one yellow card with a lowercase a. Both you and your partner now have a set of four alleles for a first-generation plant.

2. To simulate a cross between two first-generation plants, place your four cards face down on the table and mix them up while your partner does the same with his or her cards. Turn one of your partner's green cards and one of your partner's yellow cards face up while your partner does the same with your cards.

3. The four cards that are face up represent the genotype of a second-generation plant. Record the genotype.

4. Repeat Steps 1–3 until you have genotypes for 16 second-generation plants. Report your 16 genotypes to your teacher.

5. Prepare a table to record the following data on the second generation:

- number of each genotype your team produced
- total number of each genotype produced by the class
- phenotype expressed by each genotype

Materials

For each group of four students

- 1 30-mL dropper bottle of water
- 1 60-mL dropper bottle of methanol
- 1 60-mL dropper bottle of glycerin (glycerol)
- 1 10-mL graduated cylinder

For each team of two students

- 1 SEPUP tray
- 1 dropper
- 1 stir stick
- 1 salt packet
- 1 sugar packet
- 1 small piece of effervescent tablet

access to a balance

Procedure

1. Prepare a data table similar to the one below.

Table 1 Differentiating Liquids

Substance	Viscosity (low to high)	Density (g/mL)	Reaction With Effervescent Tablet	Dissolves Sugar?	Dissolves Salt?
Water					
Methanol					
Glycerin					

2. Work with your partner, but share your materials with the other team in your group as you perform the following tests. Record all results in your data table.

   a. Viscosity

   Viscosity describes a liquid's ability to flow. Honey, which flows relatively slowly, is an example of a liquid that has a high viscosity. You can examine each liquid's viscosity as you determine its density in Step 2b. Characterize each liquid's viscosity as low, medium, or high and record this in your data table.

   b. Density

   Density is calculated using this formula: $\text{density} = \frac{\text{mass}}{\text{volume}}$ or $D = \frac{m}{v}$

   To determine the density of each liquid, you must first detemine the mass and volume of a sample of each liquid by following the procedure below,

   (1) Find the mass of an empty graduated cylinder.

   (2) Add 10 mL of liquid to the graduated cylinder.

Procedure (cont.)

(3) Find the combined mass of the graduated cylinder and the 10 mL of liquid.

(4) Use the following equation (g.c. stands for graduated cylinder):

mass of liquid = mass of g.c. and liquid – mass of empty g.c.
(Step 3) (Step 1)

(5) Carefully pour the liquid back into its original container.

(6) Thoroughly clean and dry the graudated cylinder before finding the density of the next liquid.

Hint: Find the density of the glycerin last.

c. Reaction with effervescent tablets

In your SEPUP tray, add 20 drops of water to Cup 1, 20 drops of methanol to Cup 2, and 20 drops of glycerin to Cup 3. Add a small piece of effervescent tablet to each sample. Observe any bubbling that may occur and record your results under "Reaction With Effervescent Tablet" in your data table.

d. Solubility of sugar

In your SEPUP tray, add 20 drops of water to Cup 4, 20 drops of methanol to Cup 5, and 20 drops of glycerin to Cup 6. Using the scooped end of your stir stick, add one scoop of sugar to each cup. Stir each sample vigorously for one minute and record how well the sugar dissolved.

e. Solubility of salt

In your SEPUP tray, add 20 drops of water to Cup 7, 20 drops of methanol to Cup 8, and 20 drops of glycerin to Cup 9. Using the scooped end of your stir stick, add one scoop of salt to each cup. Stir each sample vigorously for one minute and record how well the salt dissolved. Clean up your equipment.

Analysis

Individual Analysis

1. Could you confidently identify a sample of an unknown liquid using only one of the properties you measured or observed during this activity? Provide evidence to support your answer.

Issue 3 Using Crops for Food vs. Using Crops for Fuel

Food Supplies

Two major crops used as feedstocks for ethanol production are corn and sugar cane, both of which are important food crops. In 1998, about 5.5 billion liters of corn ethanol were produced in the United States, which is equivalent to slightly more than 1% of total U.S. gasoline consumption. The production of this ethanol consumed about 6% of all the corn grown in this country. Tripling the annual U.S. corn ethanol production to 15 billion liters would require about 20% of the U.S. corn crop. Grain from the United States does not feed Americans only; Asia and Africa are major importers. The U.S. Office of Technology Assessment predicts that a production rate of 15 billion liters of ethanol per year will have a "substantial impact" on crop availability, potentially pushing prices up by one-third. This increase could have a considerable effect on the diet and survival of several hundred million people around the world who already have limited food supplies and spend a large percent of their income on food.

Lester Brown, director of the Worldwatch Institute, calculated the annual grain and cropland requirements of people and cars, as shown in Table 2. The figures can be used to estimate how many people could be fed using the grain that, if turned into ethanol, would be used by a typical car in Europe or in the United States.

Table 2 Annual Grain and Cropland Requirements for Food and Fuel

Consumer	Grain (kg)	Cropland (acres)
Subsistence diet	180	0.2
Affluent diet	725	0.9
Typical European car (7,000 miles @ 37.5 mpg)	2,800	3.3
Typical U.S. car (10,000 @ 15 mpg)	6,620	7.8

Corn is an important food resource for humans. We eat it directly and also feed it to the livestock that provide many other food products.

Economic Pros and Cons

Large-scale ethanol production would provide local economies with increased job opportunities and other economic benefits, but there are economic drawbacks. Producing the crops needed to supply an ethanol plant would require increasing the amount of cultivated land. This change could force poor landowners off their land, especially in less developed countries.

Running an ethanol production plant also uses a considerable amount of energy. One of the controversies surrounding ethanol technology is over the net energy balance. There is some concern that more energy must be used to make ethanol than is justified by the amount of energy provided by ethanol fuel. Although the amount of energy supplied by the sun is not included in energy balance equations for ethanol, there are considerable inputs of support energy. In addition to the energy used during fermentation and distillation, support energy includes the energy consumed in the manufacture and use of the fertilizers, pesticides, tractors, and trucks used to grow and transport the crops. According to a 1999 study conducted by the Center for Transportation Research at the

Argonne National Laboratory, the total amount of support energy required to produce corn ethanol is about 75% of the energy content of ethanol fuel. Although this is a net energy gain of 25%, ethanol must be burned to provide usable energy and much of the energy released during combustion, often over 70%, is lost to the environment.

However, energy balance concerns often do not have much practical significance. For example, the energy content of electricity is about 60% less than the energy content of the fuels that are combusted during electricity generation. Ethanol, like electricity, is a high-quality form of energy that is more versatile and useful than the resources from which it is made. An energy loss is the price that is often paid for the higher quality and greater utility of energy sources such as electricity and ethanol.

The prices of sugar cane, corn, and crude oil tend to vary significantly, which makes the economics of ethanol production uncertain. The World Bank has estimated that the consumer cost of ethanol made from sugar cane would be competitive economically with petroleum fuels if the cost of sugar cane were less than $15 per ton and that of crude oil over $30 per barrel. Even though oil prices have risen lately—above $50 per barrel in 2004—sugar cane production continues to fluctuate unreliably. However, even though ethanol costs more than gasoline or diesel fuel, some experts believe that the costs of its aggregate environmental impacts and risks over the entire production process are less than those of petroleum-derived fuels. Use of ethanol fuels in place of petroleum fuels would also make more crude oil available as a raw material for plastics and other petroleum products. Political instability in some countries is also a potential threat to the reliability of the international system for distributing crude oil. In an emergency, a more expensive, alternative fuel is better than no fuel at all. The U.S. Office of Technology Assessment considers corn to be the cheapest source of ethanol. They estimated that a corn ethanol plant with an output of 190 million liters per year would cost $70.4 million dollars; a sugar cane plant of comparable size would cost $132 million dollars.

Technological Innovations

The University of Pennsylvania has been studying the use of enzymes to convert wood to glucose syrup that could be used for ethanol production. If the development of the enzyme process is successful, trees that grow rapidly on dry or marginal land, such as poplar, aspen, and eucalyptus, could be used in place of food crops to produce ethanol. Scientists at the University of Pennsylvania estimate that it would require a poplar plantation slightly larger than the size of Pennsylvania (about 117,000 km^2 or 45,000 mi^2) to produce about 75 billion liters of ethanol, which equals approximately 15% of the volume of gasoline consumed in the U.S. in 2004. In related research, scientists at New York University have developed a process for treating sawdust or shredded paper with sulfuric acid to make sugars that could be used for ethanol production. The 1999 Center for Transportation Research study projected that in the near future, due to changes in production methods and through the use of biomass other than corn, the support energy needed to produce ethanol could fall to less than 10% of the energy contained in ethanol.

Issue 4 Using Ethanol as a Pollution-Reducing Fuel Additive

As an automobile fuel, ethanol burns much cleaner than gasoline. Many state and local regulations require the addition of a small percentage of ethanol or other chemical additives to gasoline to make it burn more completely and produce fewer pollutants. The decision to use one chemical over another involves assessing the trade-offs associated with each.

In the 1970s and '80s, as leaded gasoline was being phased out and advances in automobile technology were taking place, the pollutant levels in automobile exhaust were lowered significantly. Nonetheless, automobiles still remained a major source of air pollution and the government decided that changes in the chemistry of the fuel were needed.

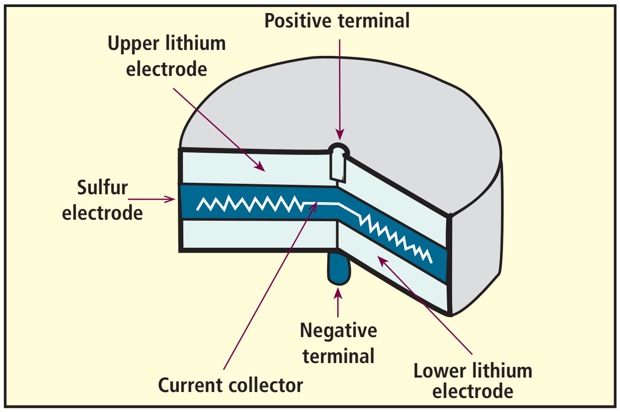
In 1990, Congress passed an amendment to the Clean Air Act requiring that air-cleaning chemicals be added to gasoline. The chemical additives in this reformulated gasoline, called oxygenates, add oxygen to the fuel so that more complete combustion occurs, thus decreasing the production of carbon monoxide and other pollutants.

Two organic chemicals—ethanol, C_2H_5OH, and **methyl tertiary butyl ether (MTBE)**, $C_5H_{12}O$—were the leading candidates for use as gasoline oxygenators. Both ethanol and MTBE are colorless, flammable liquids. The oil industry overwhelmingly chose to use MTBE mainly because MTBE, unlike ethanol, is synthesized from a waste product of the oil refining process and can be pumped through existing gasoline pipelines. The production of MTBE can reduce wastes generated by the petroleum industry and at the same time reduce air pollution.

According to an automobile and oil industry study begun in 1989, compared with the combustion of an equal volume of 100% gasoline, the combustion of a fuel mixture of 89% gasoline and 11% MTBE produces about ⅓ less ozone and significantly lower levels of carbon monoxide and other toxic exhaust products, such as benzene.

Recent studies have shown that MTBE can cause cancerous tumors in laboratory animals, and scientists now fear that MTBE could jeopardize human health. Since the introduction of MTBE as a fuel additive, drivers, as well as employees of refineries and gas stations, have reported ailments such as breathing difficulties, eye irritation, headaches, dizziness, nausea, rashes, and nosebleeds. For years, tons of MTBE have entered California's air every day from exhaust fumes; leaky underground storage tanks can potentially release thousands of gallons of MTBE into groundwater. MTBE has some properties that make underground leaks a serious threat to water supplies—it dissolves easily in water, allowing it to travel quickly through the soil, and it does not biodegrade, which makes it difficult and expensive to clean up. Due to the potential harmful effects of MTBE, some towns have been forced to stop using local water sources that have been contaminated with MTBE. By 2004, about half the states in the U.S. had adopted or were about to implement bans of MTBE. In other states, local officials continue to have to choose between using MTBE, to improve air quality, and not using MTBE, to safeguard water quality.

Figure 3 Lithium-Sulfur Battery



chemicals, which store the energy, cannot easily be transported from one location to another, especially if long distances are involved. Because the energy density (cal/g or J/g) of these reactions is low, they can be used only for on-site purposes, such as supplying heat. Also, finding the most efficient chemical reactions to use for the endothermic and exothermic reactions has proven to be challenging.

Batteries

Electricity produced from any energy source, including photovoltaic or solar thermal processes, can be stored as chemical energy in batteries. Batteries contain chemicals. When these chemicals react, they cause the transfer of energetic electrons. This transfer of electrons creates a flow of electricity. A battery "dies" when most of its reactant chemicals have reacted to form product chemicals and electricity. When there are too few reactant chemicals, the reaction rate and resulting electron flow become too low to be useful.

Batteries can often be "recharged" by reversing this chemical reaction: a battery charger forces electrons to flow in the opposite direction, causing the chemical reaction to proceed in the reverse direction, thereby changing the product chemicals back into the original reactant chemicals. When removed from the charger, the battery once again contains enough of the original chemicals to react and generate electricity. Rechargeable batteries have long been used in car batteries and miner's lamps, and more recently in electronic equipment such as laptop computers and video cameras.

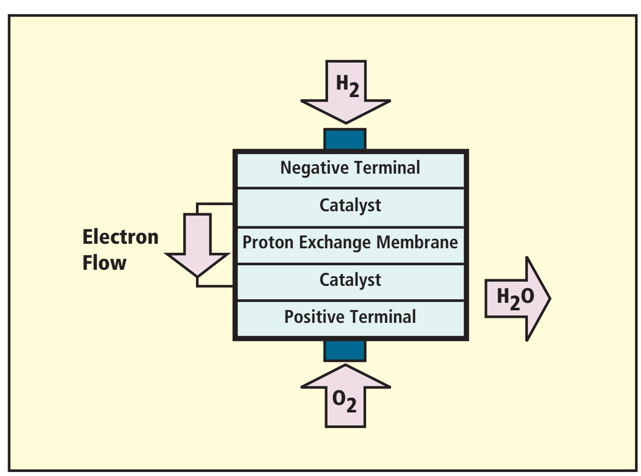
In the battery shown in Figure 3, lithium and sulfur are the reactants. When these two chemicals react, electrons are released. This type of battery produces a large amount of energy for its small size and light weight. Lithium-sulfur batteries are commonly used to power cellular phones and other electronic devices. Batteries that can provide enough electricity to start or operate a car or other large device are often very heavy; although powerful lightweight batteries have been developed, they are very expensive. Scientists and engineers are searching for inexpensive, lightweight materials from which to make improved batteries.

Hydrogen Fuel Cells

Fuel cells are similar to batteries in that they use stored chemical energy to produce electricity. However, fuel cells generate electricity much more effectively than batteries. When hydrogen combines with oxygen in a combustion reaction, the resulting products are water and a lot of heat, but no electricity. A fuel cell is a device that uses catalysts to control the reaction of hydrogen with oxygen; the products of a fuel cell reaction are electricity and hot water that has a temperature of about 70ºC.

Figure 4 is a diagram of a hydrogen fuel cell. The atoms of hydrogen gas fed into one side of the fuel cell are broken into protons and electrons. Only the protons can cross a membrane that separates the oxygen and hydrogen. The electrons flow through a circuit on their way to meet with the protons and oxygen atoms to form water molecules. This flow of electrons creates the electricity produced by the fuel cell. Because the reaction in a fuel cell proceeds at low temperatures, the nitrogen in the air does not react with oxygen to form NO_x pollutants. The only by-product of a hydrogen fuel cell is hot water.

Figure 4 Direct Hydrogen Fuel Cell



Fuel cells are being used in increasing numbers of office buildings around the country to provide electricity and hot water for heating, cooling, and dehumidifying. The U.S. Department of Energy is evaluating fuel cell buses in three California public transit districts. For example, AC Transit in the San Francisco East Bay area began a program with three hydrogen fuel cell buses in 2005. The program will gather information to compare hydrogen fuel cell buses to the diesel buses currently in use.

One of the problems with fuel cells is that pure hydrogen fuel is not naturally abundant. One of the challenges in fuel cell technology is that hydrogen gas is scarce, so it has to be produced. Natural gas, or methane (CH_4), is a source of hydrogen that is quite abundant: the methane can be "reformed" to produce hydrogen gas and CO_2. However, natural gas is a nonrenewable energy resource, and like oil, its consumption releases CO_2 as a by-product.

Another way of obtaining hydrogen is to use electricity to split water into hydrogen gas and oxygen gas in a process known as **electrolysis**. Electrolytic production of hydrogen has long been used on a large scale in industry. Hydrogen can be stored in pressurized containers until needed. Like hydrocarbon fuels, compressed hydrogen gas is flammable and must be handled with care. Environmental hazards associated with the production of hydrogen gas are related to the source of the energy used for reforming methane or for the electrolytic process.

Hydrogen is a fuel, but it is not a resource in the sense that fossil fuels or biomass are resources. The overall process of making hydrogen and then using it to react with air in a fuel cell consumes more energy than it yields. In the same way, more energy is required to generate electricity than is carried by the electricity. Hydrogen fuel, like electricity, "carries" energy in a form that is more useful than the energy inputs that are used to produce it. Some people imagine that someday there will be a device in every home that uses solar energy to make hydrogen by electrolysis. The hydrogen can then be used in fuel cells that provide electricity and heat for the home and as fuel for the car. Hydrogen fuel could also be available at solar-powered filling stations, or perhaps generated on board a vehicle from a fuel tank filled with water!

Analysis ?

Individual Analysis

1. Do you think that any of the energy storage technologies described in this reading could help us to develop a sustainable source of energy? Explain why or why not.
2. What additional information would you want to have about each type of storage technology to accurately evaluate its potential for widespread use in the future? Be as specific as you can.

Procedure

1. Consider the radioisotopes listed in Table 2 for use in each of the three scientific investigation scenarios described on the next page.
2. Record the radioisotope you would recommend for use in each situation.

Table 2 Some Common Useful Radioisotopes

	Half-Life	Decay Product	Major Radiation	Other Information
$^{14}_{6}C$ (Carbon)	5,568 yrs	$^{14}_{7}N$ (Nitrogen)	beta	used to date carbon containing samples less than 10 half-lives old
$^{41}_{20}Ca$ (Calcium)	103,000 yrs	$^{41}_{19}K$ (Potassium)	electron capture	more difficult to measure; longer half-life, which means that studies over longer time periods can be done
$^{47}_{20}Ca$ (Calcium)	4.5 days	$^{47}_{21}Sc$ (Scandium)	beta	smallest half-life, decreasing the exposure of the patient to radiation
$^{45}_{20}Ca$ (Calcium)	162.6 days	$^{45}_{21}Sc$ (Scandium)	beta	most researched of the calcium isotopes, and most readily available
$^{147}_{62}Sm$ (Samarium)	1.06×10^{11} yrs	$^{143}_{60}Nd$ (Neodymium)	alpha	used to date rocks containing samarium and parent or daughter compounds
$^{182}_{73}Ta$ (Tantalum)	114.7 days	$^{182}_{74}W$ (Tungsten)	beta	non-irritating and immune to body liquids


Throughout the world, humans rely on many different sources of energy. There are advantages and disadvantages associated with the use of each energy source.

Materials

For each team of two students

1 copy of *Material World*

For each student

supply of graph paper

Procedure

1. Tables 1 and 2, on the next page, include many statistics related to energy resources that can be used to compare and categorize different countries. Choose one or two statistics, or some combination of statistics, that you think will best allow you to distinguish those countries that use energy more sustainably from those that use energy less sustainably.

2. Use your chosen statistic(s) to create one or two bar graphs that illustrate which countries use energy more sustainably and which use energy less sustainably.

Note: 1 exajoule = 1×10^{18} J
1 gigajoule = 1×10^{9} J

3. Calculate the number of years that the world's reserves of fossil fuels will last, based on the 1993 estimate of the reserves and the 1999 annual production.

Table 1 1999 Energy Production

Country	Total (exajoules)	Per Capita (gigajoules)	Energy Source (%)			
			Fossil Fuels	Hydroelectric	Nuclear	Other**
World	411.2	69	79.6	2.3	6.7	11.2
United States	70.6	252	81.2	1.5	11.9	4.5
*Brazil	5.6	33	48.4	18.7	0.8	32.1
*China	45.7	36	78.5	1.6	0.4	19.5
*Cuba	0.1	20	46.2	0.2	0	53.6
*Ethiopia	0.7	12	0	0.8	0	99.2
*Guatemala	0.2	20	24.0	3.3	0	72.7
*India	9.9	17	49.4	1.7	0.8	48.1
*Thailand	0.9	26	63.3	0.8	0	35.9
Iceland	0.1	344	0	22.9	0	77.1
Israel	0.03	4	11.4	0.5	0	88.3
Italy	1.2	20	70.2	14.1	0	14.5
Japan	4.4	34	4.7	7.1	79.1	8.0
Kuwait	4.4	2,360	100	0	0	0
Mexico	9.34	96	91.8	1.3	1.2	5.8
Russia	39.8	272	94.4	1.5	3.4	0.5
United Kingdom	11.8	199	90.3	0.2	8.8	0.6

*Less developed country

**Geothermal, solar, wind and traditional (wood, charcoal, dung, etc.)

Table 2 1999 Energy Consumption and Estimated 1993 Reserves

	1999 Energy Consumption			Estimated 1993 Reserves		
	Total Energy Use (exajoules)	% Change Since 1989	Per Capita Total Energy Use (gigajoules)	Fossil Fuels (exajoules)	Uranium (exajoules)	Hydroelectric (exajoules/yr)
World	406.2	13	68	41,000	37,000	n/a**
United States	95.0	16	339	7,400	61,000	9.4
***Brazil**	7.5	31	45	110	27,000	34
***China**	45.6	29	36	3,500	0	67
***Cuba**	0.5	(26)	47	0.6	0	n/a
***Ethiopia**	0.8	25	12	0.8	0	5.1
***Guatemala**	0.3	47	23	2.5	0	1.4
***India**	20.1	38	20	2,100	0	5.8
***Thailand**	3.0	85	48	36	0	0.2
Iceland	0.1	57	478	0	0	2.0
Israel	0.8	57	131	0.1	0	0.1
Italy	7.1	12	123	12	800	1.5
Japan	21.6	24	170	25	1,100	3.6
Kuwait	0.7	1	392	560	0	0
Mexico	6.2	23	64	370	1,900	2.3
Russia	25.2	n/a	173	2,000	50,000	n/a
United Kingdom	9.6	9	163	64	0	0.1

*Less developed country
**n/a = not available

Analysis

Group Analysis

1. Explain the reasoning behind your choice of statistic(s) in Procedure Step 1. Be sure to describe your criteria for determining sustainable energy use.

2. Do more developed countries use energy more sustainably than less developed countries do? Explain your reasoning.

3. Table 3, on the next page, shows data from 1990 and 2001 for the U.S. and the world. Does the comparison to older statistics change your ideas about sustainable energy use in the U.S. and/or the world? Explain your reasoning.

4. If Table 3 included data from last year, how do you think that last year's statistics might have changed since 2001? Explain your reasoning.

5. What factors could affect the number of years the world's reserves of fossil fuels will last?

6. Should an international committee allocate the world's energy resources so that each country receives a fair share, or should the leaders of each country have complete control over the use of all energy resources that exist within their country?

Individual Analysis

7. Do you think that global societies could be sustained at current and future population levels if everyone in the world used energy at the same rate as an average U.S. resident? Explain.

8. How do you propose—on an individual level, a national level, and a global level—that humans prepare to meet future energy demands? What trade-offs are involved in your proposals?

Table 3 1990 and 2001 Energy Consumption in Exajoules

	1990				2001			
	World		United States		World		United States	
Total	378.0		87.9		419.9		95.5	
Fossil Fuels	321.2	(85.0%)	78.6	(89.4%)	333.8	(79.5%)	82.3	(86.2%)
Hydroelectric	8.5	(2.3%)	1.1	(1.3%)	9.2	(2.2%)	0.8	(0.8%)
Nuclear	23.2	(6.1%)	7.0	(8.0%)	29.0	(6.9%)	8.8	(9.2%)
Renewables (Geothermal, Solar, Wind, and Traditional)	25.1	(6.6%)	1.2	(1.4%)	47.9	(11.4%)	3.6	(3.8%)