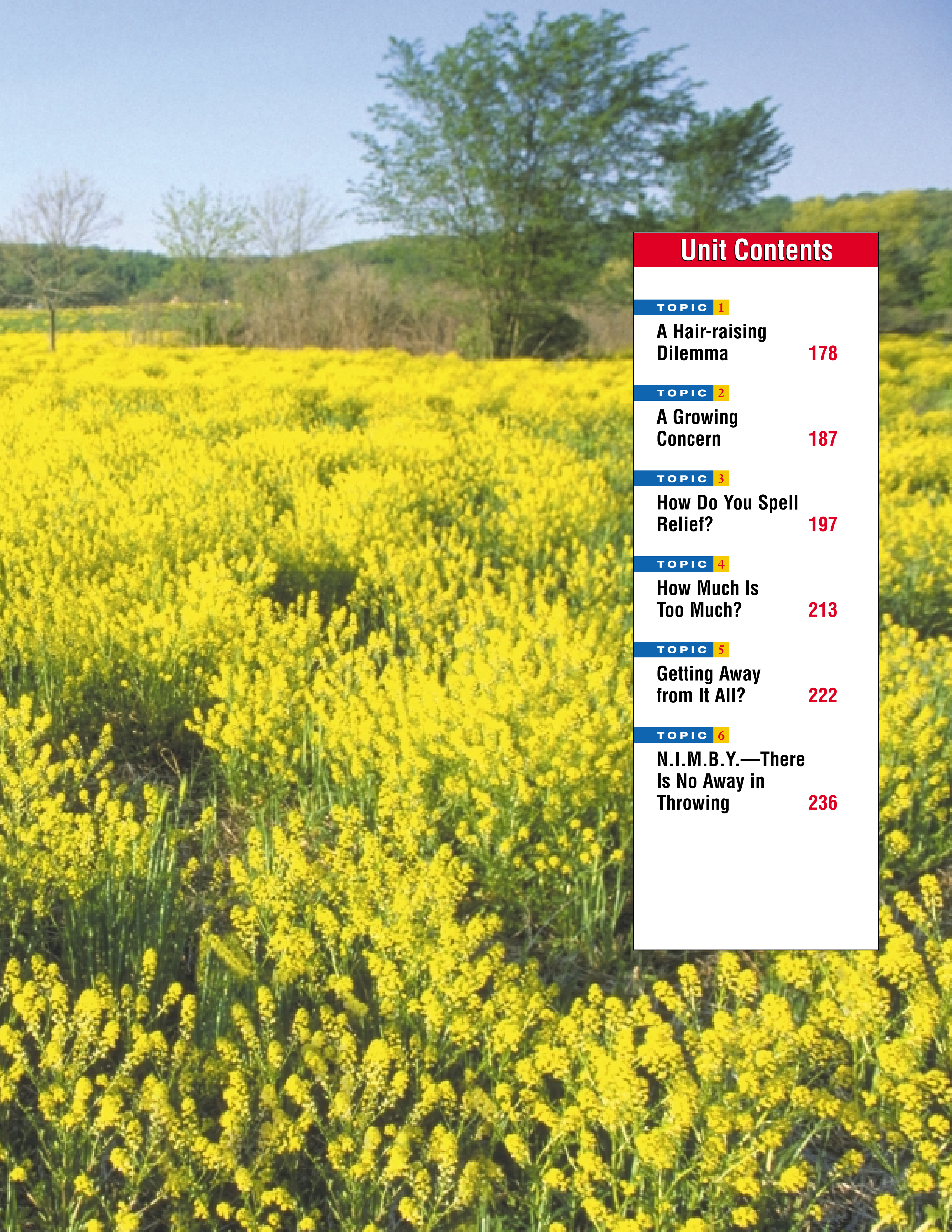
UNIT 3

Environmental Chemistry

Could we survive without chemicals? Our knowledge of chemicals and how they combine and interact enables us to produce medicines to fight hostile microbe invaders. We can create additives to increase yields of plant and animal food sources, and chemical agents to eliminate the pests that destroy these food sources. Our industries produce the synthetics that we use in our clothing and building materials. Most important of all, our bodies are made up of chemicals. Without chemicals, we would cease to exist!

Chemicals can seem benign—think of that harmless little shower of salt that you sprinkle on your fries. Or is it harmless? What about the salt we spread on icy roads in winter? It melts the ice, making our roads safer for driving. It also damages soil and growing plants. It runs into water courses where it may adversely affect fish, water plants, and the organisms that eat them. Clearly, we need to know what amounts of chemicals are toxic and how we might counteract any damage they cause. We need to understand the negative as well as the positive aspects of the interaction of chemicals with other substances.

In this unit, you will see some of the ways that we have made use of chemicals to improve our lives. You will also come to recognize the environmental costs associated with some of these lifestyle improvements. As a result, you will further develop your skill in the process of dealing with issues associated with our use of chemicals, and in developing alternatives that will help contribute to their safe, responsible use.



Unit Contents

UNIT 3

Preview

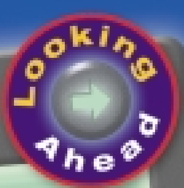
Focussing Questions

- What do our bodies need in order to remain healthy?
- What are we ingesting along with our food, water, and the air we breathe?
- What is pollution, and what can be done about it?

Human beings require specific nutrients and chemicals to build strong, healthy bodies. What nutrients DO we need, and where do we get them? What is a suitable response when other organisms compete with us for the same nutrients? What scientific information do you need, in order to assess risks to the environment when those other organisms are eliminated? Find the answer to these and other questions in Topics 1–3.

Why are some substances in the environment referred to as pollutants? In Topics 4 and 5 you can understand the basis for assessing how and why pollution is a problem.

What issues become clear when you study the environment from a chemical perspective? How are decisions made about these issues? Find out in Topic 6.



Read page 256, "A Simulation: Not In My Backyard." With your group, you will be assigned the role of a concerned party making a decision about the construction of a fertilizer plant in your "backyard." You can begin preparing right away.

- Start reading the newspaper for related articles.
- Watch the daily or evening news for stories of similar meetings.
- Gather background information from related sites on the Internet.
- Practise your decision-making skills by completing Investigations 3-C and 3-J.

TOPIC 1 A Hair-raising Dilemma

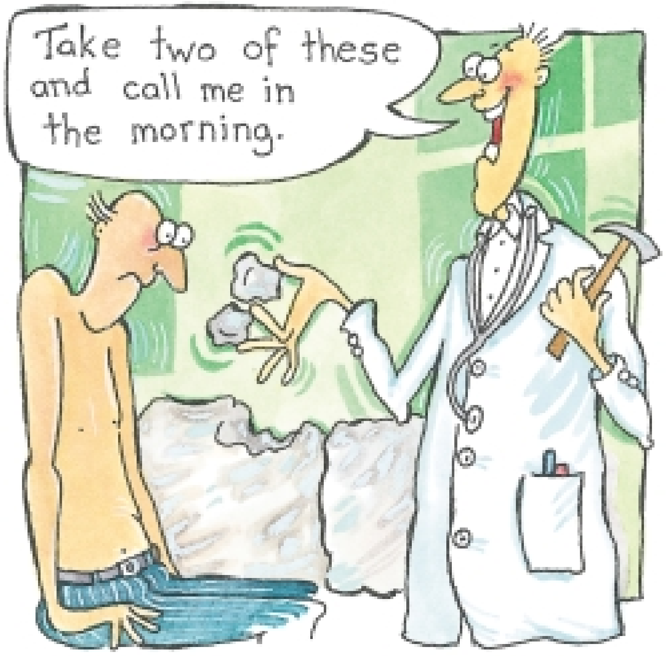


Figure 3.1 How does a doctor decide which chemical substance to prescribe for a patient? Could that substance be in a rock?

Imagine you are a doctor faced with the following problem. Your patient, a 70-year-old male, is complaining of an intense burning pain in his feet. The pain is so severe that he has had to give up his daily walk. The burning sensation in his feet eases when he is resting, but is still noticeable. Lately it is uncomfortable for him to even wear shoes. He has also noticed a burning sensation in his left arm and chest, after walking even short distances on level ground.

Your first thought might be "Hmm. Chest pain when exercising — this sounds like heart trouble. But what's that burning sensation in his feet? That couldn't be heart-related, could it?" You ask your patient questions to gather more information.

You learn that he eats healthy foods, but has some food allergies or intolerances. Could that be it? You order tests, including a chemical analysis of the patient's hair!

Take Two Pebbles...

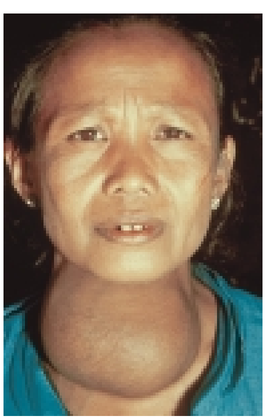
Why would you request an analysis of your patient's hair? What does his hair have to do with what he eats? You aren't likely to prescribe two chunks of rock to your patient, as the doctor in the cartoon is doing, but what does that really mean? What does the patient's diet have to do with the substances contained in rocks? And how does any of this affect your and your patient's decisions about his future treatment? Perhaps the test results will help answer some of those questions. While you and your patient await the test results, you have to consider his comfort level. Should you prescribe painkillers?

You discuss the problem with your patient. You tell him that his body is made up of chemicals, as is his food. The process of digestion breaks down the chemicals in the food into small, soluble molecules, which then pass through membranes into the blood vessels. In the blood, these chemicals (**nutrients**) circulate through the body to the cells where they are used for energy, growth, body building, and cell repair. These nutrients can be divided into two major groups, organic and inorganic.

The organic (carbon-containing) nutrients are classed as **carbohydrates**, **proteins**, **lipids**, and **vitamins**. Only green plants can form many of the organic compounds, while animals modify others. Regardless of the dietary source, they are essential for health.

DidYouKnow?

Goitre, a swelling of the thyroid gland at the base of the neck, is often caused by iodine deficiency. It is a common problem in many parts of the world, particularly where sea products are not frequently eaten.



Chemicals in the body transform these basic materials into more complex chemical materials. Table 3.1 shows you the dietary sources of carbohydrates, proteins, and lipids.

Table 3.1 Dietary Sources of Nutrients

Organic molecule	Role in nutrition	Typical Dietary Sources
carbohydrates	energy source for metabolism	• rice • grains • potatoes • fruits
proteins	structural molecule for body and helps chemical reactions	• meat • eggs • dairy products • legumes • nuts
lipids	storage of unused chemical energy	• vegetable oils • nut oils • some dairy products

Inorganic substances that are not destroyed by cooking or exposure to air are referred to as minerals. Mineral requirements are distinguished by the amount needed: **macromineral** (100 mg/day or more) or **trace element** (less than 100 mg/day). These minerals are essential components in **enzymes** (special protein molecules that regulate chemical reactions in living organisms) and vitamins (large organic molecules that help the enzymes function). Vitamins are a good example of nutrients that the human body cannot make itself and must get from food.

Now, what does this have to do with those two chunks of rock you see the doctor prescribing in the cartoon in Figure 3.1? Some of Earth's elements are examples of the chemicals the body needs in order to remain healthy. Sixteen of the naturally occurring elements occur in all living organisms. Green plants require 18 different elements for proper growth and functioning; humans require at least 22. You may recall from your Grade 8 science course that rock is made up of minerals and that minerals are elements or compounds. Table 3.2 on page 180 shows how elements are used in the human body.

Math CONNECT

The four most common elements in your body (by percent of wet mass) are oxygen (65 percent), carbon (18 percent), hydrogen (10 percent), and nitrogen (3 percent). Hydrogen and oxygen occur mainly in the form of water (H_2O), which makes up about 60 percent of your mass. Use the values given, to produce a circle graph that shows the chemical composition of your body. What percentage is composed of other elements not named? Use your computer to create the graph.

Pause & Reflect

Adding fluorine, in the form of fluoride, to water supplies is expected to decrease the amount of money paid by the Canadian health care system for dental care. This is obviously beneficial, so why do people oppose fluoridation of municipal water supplies in many locations? Write your speculations on this issue in your Science Log.

DidYouKnow?

Vitamin C helps form the connective tissue that holds our skin, muscles, blood vessels, and other body structures together. Humans are one of the few species of animals that cannot make vitamin C within their own bodies. Scurvy, a disease resulting from a lack of vitamin C in the diet, results in bleeding gums, loss of teeth, and bruising. Although scurvy is not fatal, it decreases resistance to other deadly diseases. British sailors in the 1700s were referred to as "Limeys" because of the lemons (called "limes" at that time) they ate to avoid scurvy.

Table 3.2 The Role of Elements in the Human Body

Element name	Role in the human body
calcium	crucial in nerve conduction, muscle contraction, blood clotting, proper functioning of cell membranes; forms bones and teeth
phosphorus	promotes proper bone formation, regulates metabolism, forms compounds that store and release energy
magnesium	component of bones and teeth, essential to enzyme function, helps regulate nerve activity
sodium	helps regulate nerve impulses in nerves and muscles
potassium	helps regulate nerve signals and muscle activity, involved in protein formation, required to regulate the acid/base balance
sulfur	elemental sulfur is not utilized, BUT sulfur in amino acids is the basis of all proteins
chlorine	helps regulate water balance, plays a role in proper cell membrane function, component of hydrochloric acid in the stomach
iron	crucial part of red blood cells that regulates oxygen transport
zinc	essential component of enzymes regulating protein formation and carbohydrate metabolism
iodine	major component of thyroid hormones, which regulate metabolism
selenium	component of an antioxidant enzyme that helps prevent decay of cell function
copper	promotes iron absorption and utilization, is a component of many enzymes, helps regulate nerve activity
manganese	component of some enzymes, involved in bone formation and protein metabolism
fluorine	helps regulate calcium deposition
chromium	activates vitamin B3 to control use of blood sugar in energy production
molybdenum	key component of three enzymes that regulate metabolism
cobalt	component of vitamin B12, which helps regulate red blood cells

Off the Wall

During the *Apollo 15* mission, astronauts David Scott and James Irwin landed on the Moon. Although both astronauts were in excellent health before leaving Earth, both Scott and Irwin developed irregular heart rhythm during moments of high exertion and stress. NASA doctors, concerned that low gravity might have some negative effect on humans, tested both astronauts upon their return to Earth. The doctors found that Scott and Irwin had low potassium levels from eating the highly refined, prepared foods that were supplied to them. As a result of their findings, potassium-enriched food and snacks were added to the menu of subsequent space missions.

A Balanced Approach

Although your patient has a healthy diet, he has developed an intolerance for certain foods over the years, so he tends to avoid those. He feels healthy, and he tries to eat according to Canada's Food Guide for the most part, so he doesn't see a problem with avoiding food groups that cause problems for him.

You and he decide that he will not take any painkillers for the time being. Everything the human body takes in has an effect on it. The chemicals in a painkiller might react with other chemicals in the patient's body, making diagnosis difficult. As well, if the painkillers mask the pain, the patient might decide not to bother following up on the problem, which may then worsen to the point where his body is damaged permanently. When you see the test results, you are not surprised. Your patient had a calcium level well below normal, and correspondingly low amounts of magnesium, copper, manganese, zinc, chromium, and selenium. His food allergies either caused him to avoid certain foods or prevented him from absorbing enough of the necessary chemicals from the foods he did eat.

You explain that this inability to digest foods can be caused by an inflammation of the digestive tract, which slows down normal absorption. This could be the cause of your patient's worrisome chest pain. You run further tests to find out if this is the case.

When the test results come back, you realize that your patient has a chemical imbalance, as well as an inability to digest some of the chemicals his body requires. How can you correct this problem? Chemicals to the rescue! Those two chunks of rock might be helpful after all — you prescribe 1000 mg/day of calcium and 400 mg of magnesium to correct the arterial spasm that caused the chest pain. The burning feet? They were a symptom of inflamed nerves, and the 50–100 mg doses of B-complex vitamins you prescribed relieved those symptoms.

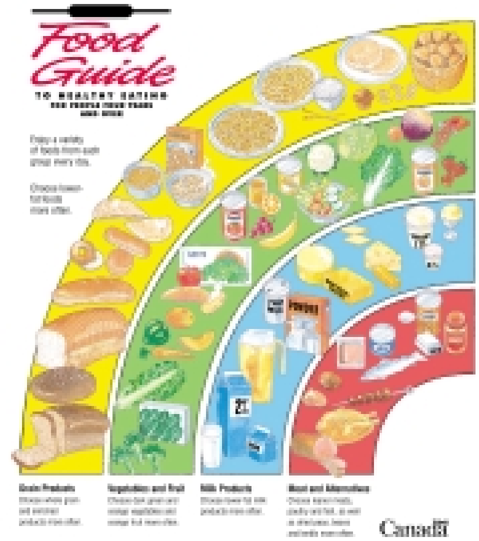


Figure 3.2 This Health Canada food guide recommends your daily intake of nutrients.

Six months have gone by since you started your patient on his new diet. As you watch him walk out of your office with a spring in his step and a clean bill of health, you reflect on the crucial roles of chemicals in the human body and the importance of keeping them in balance, as indicated in the Food Guide in Figure 3.2.

The Root Source

All living things need a constant supply of raw materials and energy to produce new cells for growth, to repair damage caused by normal wear and tear, and to remain healthy. For humans, most of the elements we need are found in the soil. Even if we could eat soil, it would do us little good. The elements are found in such low concentrations that we would have to eat enormous amounts of soil just to get the minimum amount of elements needed. It is a good thing that plants can extract the minerals for us — by some estimates as much as 6 000 000 000 t every year!

Word CONNECT

Life: the condition that distinguishes active animals and plants from inorganic matter, including the capacity for growth, functional activity, and continual change preceding death.

Find two definitions of *life* in various dictionaries and write them in your notebook.

DidYouKnow?

In 1930, Howard Dittmer at the State University of Iowa placed a single winter rye plant (*Secale cereale*) in a box of soil about 30 cm long, 30 cm wide, and 56 cm deep. Four months later, Professor Dittmer carefully freed the root system of that single rye plant and measured it. He was astonished to find that the total length of the root system was nearly 11 000 km (equal to about a quarter of the circumference of Earth) with a surface area of about 630 m^2 (the floor space of four or five houses).

The root systems of plants are uniquely suited for extracting minerals. Roots are covered with tiny "root hairs" to increase the surface area for absorption. They branch again and again as they grow, to get the most contact with water in the soil. Minerals dissolved in the water are taken up and concentrated into the root hairs. In some cases, the root hairs are able to produce mineral concentrations up to 10 000 times greater than the soil around them. The minerals absorbed by the roots move to other parts of the plant, where they are used to build organic compounds such as vitamins, proteins, and lipids. When we eat these plants, we access these valuable organic compounds. For example, compare the amounts of minerals present in plants versus that in human tissue and Earth's crust, as shown in Table 3.3. Which of the elements listed for Earth's crust are present in greater amounts in plants? In animals? Did you notice that the elements found in the largest amounts in humans and plants are not necessarily those that are most abundant in the crust?

Plants are essential to our health and survival. Without plants, we would not be able to obtain the nutrients we need. That is why many scientists are interested in what affects the development and growth of plants. In the next investigation, you will measure the effects of the addition of nutrients on the rate of seed germination and growth.

Pause& Reflect

The only source of nitrogen for humans is from eating plants. Using Table 3.3, determine how many times more abundant nitrogen is in humans than in the Earth's crust. What is the role of nitrogen in the human body? Would adding more nitrogen to the soil around plants make nitrogen more available to humans? Write your speculations in your Science Log.

Table 3.3 Comparison of the Elemental Composition of Earth's Crust, a Generic Plant, and a Human

Element	Symbol	Approximate % (by mass) of Earth's crust	Approximate % (by mass) of a generic plant	Approximate % (by mass) of a human
oxygen	O	49	75	65
carbon	C	0.09	13	18
hydrogen	H	0.88	10	10
nitrogen	N	0.03	0.45	3.3
calcium	Ca	3.4	0.07	1.5
phosphorous	P	0.12	0.06	1.0
potassium	K	2.4	0.28	0.35
sulfur	S	0.05	0.05	0.25
sodium	Na	2.6	trace	0.24
chlorine	Cl	0.19	0.04	0.19
magnesium	Mg	1.9	0.06	0.05
iron	Fe	4.7	0.03	0.005
manganese	Mn	0.08	0.01	0.0003
silicon	Si	25	0.36	trace
all others		<0.03	trace or less	trace or less

INQUIRY

INVESTIGATION 3-A

SKILLCHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

The Effects of Fertilizer Nutrients on Seed Germination and Growth

The growth and development of a plant from seed to mature form is affected by the amount of nutrients that the plant can extract from the environment and incorporate into its tissues. Growing plants require three essential elements for growth and reproduction. Phosphorus is necessary for seed germination, nitrogen is needed for stem and leaf growth, and potassium promotes flower and fruit formation. Commercial fertilizers are excellent sources for all three of these elements.

The numbers listed on a package of fertilizer refer, in order, to the amounts of nitrogen, phosphorus and potassium provided by that fertilizer. Under the same conditions, you might expect plant seeds to germinate (sprout) and grow at the same rate, but what if the conditions are not the same? How would changing the amount of a fertilizer affect the development and growth of a plant?

Question

How does the amount of a nutrient influence the growth and development of plants?

Hypothesis

Form a hypothesis about the effect of increasing nutrient levels on plant growth.

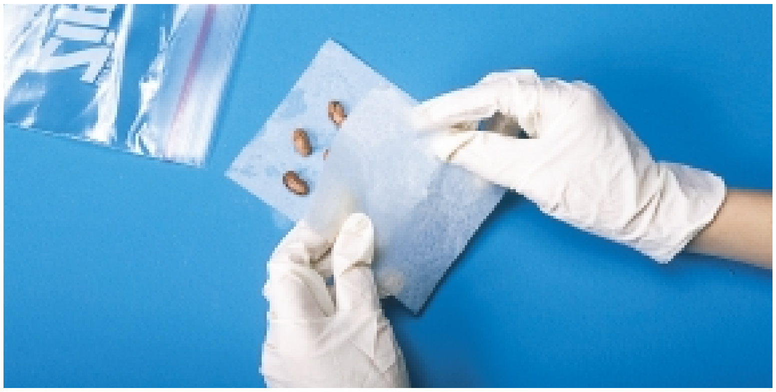
Safety Precautions

Apparatus

marker
scissors
50 mL graduated cylinder
four 50 mL beakers
stirring rod
metric ruler

Materials

5 Ziploc Bags
paper towels
25 seeds (mung beans or garden pea)
distilled water
commercial fertilizer
graph paper



Procedure

1. Label the 5 Ziploc™ bags: distilled water, 1 g, 5 g, 10 g, 15 g.
2. Cut paper towel into square pieces, sized to fit inside a Ziploc™ bag and place 2 squares in each bag.
3. Distribute 5 seeds inside each Ziploc™ bag between the plastic and paper towel. This will allow you to **observe** and **record** any changes to the seeds.
4. Add 5 to 10 mL of distilled water to the bag labeled distilled water, completely moistening the paper towel.
5. Using the graduated cylinder, prepare a solution of 1 g of the fertilizer in 25 mL of distilled water. Add 5 to 10 mL of this solution to the "1 g" Ziploc™ bag, making sure to completely moisten the paper towel. Save the remainder in a labeled beaker.

CONTINUED ▶

6. Repeat step 5 three more times substituting 5 g, 10 g, and 15 g of fertilizer in each case. Use the bags labeled "5 g", "10 g" and "15 g."

7. Make sure all bags are sealed tightly and place the bags in a dark, warm place designated by your teacher.

8. Examine the bags daily for 10 days. **Record** any changes that might have occurred. If the root is visible the seed is considered germinated.

9. Do not allow your towels to dry out. Moisten each bag with the appropriate solutions in equal amounts when necessary.

10. Each day, use the ruler to **measure** the root growth of each seed from the time it appears. **Record** the measurement.

11. Each day, use the ruler to **measure** any shoot (stem and leaf) growth from the time it appears. **Record** the measurement.

Analyze

1. Prepare line graphs to represent your results. Plot root growth on one graph, and shoot growth on a different graph. Use different colored pencils to represent each of the Ziploc™ bags.
2. What was the effect of increasing amount of fertilizer on root growth? On shoot growth?
3. From your observations, write a general statement about the effect of increasing nutrient levels on plant growth.

Conclude and Apply

1. What was the purpose of the bag of distilled water?
2. Did your findings support your hypothesis? Why or why not?
3. Read the label for the fertilizer that you used in this investigation. From the numbers listed for nitrogen and phosphorus for that fertilizer, would you expect a greater effect on root growth or shoot growth? Do your results confirm this expectation?

A neighbour has a small (3 m^2) backyard garden plot and plans to scatter a bag of fertilizer over the plot "to help the vegetables get started." What advice would you give your neighbour?

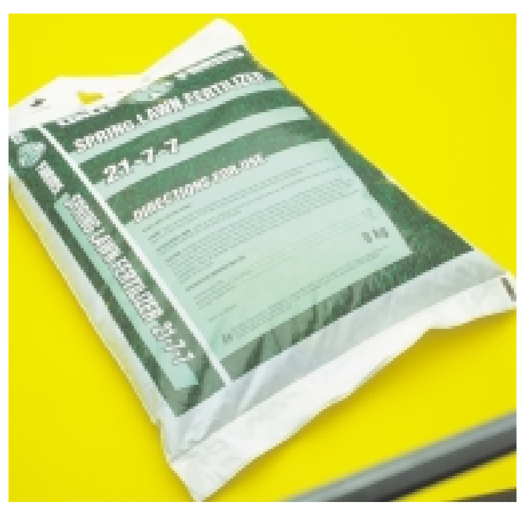
Skill FOCUS

To review writing a hypothesis and making predictions, turn to Skill Focus 6.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

Despite the fact that phosphorus is an essential nutrient for plant growth, it is associated with environmental pollution. The demand for and production of "phosphate-free" soaps and detergents has been one response to the need to reduce phosphorus in the environment. Why is phosphorus a concern? What can be done about it? To find out, visit the above web site. Click on Web Links to find out where to go next. In your notebook, write a brief explanation for the concern about phosphates.



Commercial Fertilizers

The three numbers on a bag of commercial fertilizer (see 21-7-7 in the photograph, previous page) are a convenient signal for gardeners. Different fertilizer mixes aid the growth of different parts of a plant. Leaves, roots, and flowers benefit, respectively, from high nitrogen, high phosphorus, and high potassium content. The numbers, always in the same order, refer to the percentage of mass of the fertilizer mix that provides nitrogen, phosphorus, and potassium.

As shown in Figure 3.3, commercial fertilizers typically provide nitrogen in the form of three nitrogen compounds that imitate a natural process called the nitrogen cycle: nitrates, ammonia, and urea. Plants cannot take nitrogen directly from the atmosphere. Plant roots readily absorb nitrates dissolved in water, however, and plants use the nitrates to make proteins. Nitrates are formed in soil in a two-step process. A few species of soil bacteria can "fix" atmospheric nitrogen by forming ammonia, and other species can then change the ammonia to nitrates.

Phosphorus is provided in commercial fertilizers as phosphate compounds. The mineral potash is the source of potassium. The 21-7-7 signal to the gardener accounts for 35 percent of the mass of a fertilizer mix. Find out about the remainder in the next activity.

Figure 3.3 In many parts of the world, artificial fertilizers add excess nitrogen to the environment.

Word CONNECT

Kwashiorkor: A childhood disease associated with a low-protein diet. This lack of protein causes mental and physical deficiencies. A deficiency in protein occurs in animals because the only way they can get nitrogen to make their own proteins is by eating plants or other animals. Which deficiency disease is the result of a lack of iodine in the diet?

Find Out ACTIVITY

An Analysis of Fertilizer Nitrogen

The front label on a package of fertilizer lists the amounts of the major nutrients (N, P, K). If you look carefully, you will find another label giving the "Guaranteed Analysis" of the specific ingredients. In this activity you are asked to inspect and investigate the "Guaranteed Analysis" of a fertilizer.

Materials

fertilizer, preferably for use on lawns
access to the Internet

Procedure • Performing and Recording

1. Examine the label listing the "Guaranteed Analysis" on the package of fertilizer. List the three ingredients that provide nitrogen from the most to the least amount.

What Did You Find Out? • Analyzing and Interpreting

1. Investigate why three types of nitrogen compounds are being used. In paragraph form, outline the results of your investigation. Be sure to include the reason each compound is included as an ingredient.
2. You will notice that iron (Fe) is one of the listed ingredients. What is the role of iron in a fertilizer?

Issues Emerging from High Productivity

Until the early 1900s, plants received nitrates only from nature. The production of artificial fertilizers changed that by increasing nitrogen levels available for plants. The use of artificial fertilizers and other human activities have increased the amount of nitrogen in the environment — by as much as 140 000 000 t per year!

The effect of this extra nitrogen is increased plant growth. Since 1950, crop production has doubled worldwide due to the use of artificial fertilizers and the development of high-yield food crops such as the one shown in Figure 3.4. These high-yield varieties have allowed most countries to increase food production dramatically. Land barely suitable for farming can yield large crops when planted with high-yield varieties and fertilized and watered well. This seems entirely positive, but consider the following issues.

Figure 3.4 What issues are associated with developing and maintaining the high yield of this corn field?

It takes a lot of fertilizer and water to produce a crop of high-yield varieties — a very expensive proposition for farmers. In addition, the planting of only one crop increases the chance of a disease spreading through the entire crop. A variety of plants usually means at least one crop might survive a disease. Chemical agents (pesticides) reduce the amount of crops lost to damage or disease, but they exact a cost — in dollars and environmental impact. The next Topic introduces you to the nature of a pesticide and what some of those costs can be.

TOPIC 1 Review

1. Describe the function of each of the following minerals in our bodies:
   - (a) phosphorus
   - (b) potassium
   - (c) iodine
   - (d) cobalt
2. What is the difference between a macromineral and a trace element?
3. Plants are a source of energy for human nutrition. Describe other nutritional needs that humans may meet by eating plants.
4. **Apply** Why are fertilizers available with different amounts of nitrates, phosphates, and potash?
5. **Thinking Critically** Vitamin D forms in our bodies in the presence of ultraviolet light from the Sun and can also be obtained through dietary sources. The Inuit people of the far north do not get enough ultraviolet light to form any significant amount of vitamin D, so where do the Inuit get their vitamin D?

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus9

To learn more about vitamin D, go to the web site above. Click on Web Links to find out where to go next. In your notebook, write a brief summary of the main role of vitamin D in the human body.