TOPIC 2 A Growing Concern

Figure 3.5 The application of insecticides, herbicides, and water can increase food production for people.

In a normal healthy ecosystem, many species may access the same food source. But human beings have an advantage — agriculture allows us to carefully nurture a select group of plants for our use. To maximize the quantity of plants we can harvest, we control other species who compete for these plants. For example, if we grow potatoes, we might actively discourage potato beetles in our fields. In other cases, we hinder the growth of other plants that would compete with our crops for soil resources. Spraying crops with **pesticides** to control "pests," as shown in Figure 3.5, has become standard practice worldwide. Most pesticides are designed to affect only specific types of pest species. **Herbicides, insecticides,** and **fungicides** control weeds, insects, and fungus pests. Dealing with insect pests has long been the target of scientific and technological attention. The citronella candles and mosquito coils you burn to keep mosquitoes away from your deck or camp just send the insects away. Chemical sprays such as dieldrin and DDT actually kill the insects, raising issues which were not immediately recognized, as you will see in the next section.

Pause & Reflect

Do you think it is possible to develop a system of agricultural production that is not affected by pests and by crop and livestock diseases? Include reasons for your answer in your Science Log.

Issues Associated with the Use of DDT

The invention of DDT by the Swiss chemist Paul Hermann Müller was originally seen as one of the greatest advances in medicine during the twentieth century. Toward the end of World War II, the disease typhus (transmitted by lice) threatened 1.3 million Allied troops. This is the same disease that totally wiped out Napoleon's Grand Army on its retreat from Russia in the 1800s. The application of DDT completely removed the typhus threat. DDT proved so successful in controlling insect infestations that Paul Müller was awarded the 1948 Nobel Prize in Physiology or Medicine for "his discovery of the high efficiency of DDT as a contact poison against several arthropods."

In the 1950s it was hoped that DDT would prove equally effective in stamping out malaria. Each year, this mosquito-transmitted disease affects over 120 million people and is responsible for over 1 million deaths. In the next investigation, you will explore the scientific basis for explaining unforeseen consequences of introducing DDT into the environment.

Pause& Reflect

In 1955, the World Health Organization (WHO) sprayed dieldrin, a chemical pesticide similar to DDT, on north Borneo to control malarial mosquitoes. Although the mosquitoes were almost completely eliminated, so were the lizards that fed on the dead insects. Island cats that preyed on the lizards soon began dying as well, leading to an explosion of the rodent population as their natural predator died off. Plague carried by fleas on the rodents was a serious threat to the islanders until the British Air Force (on request by WHO) parachuted cats onto Borneo.

In your Science Log, write a short paragraph reflecting on how an understanding of the food chain could inform issues associated with killing insect pests.

INVESTIGATION 3-B

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

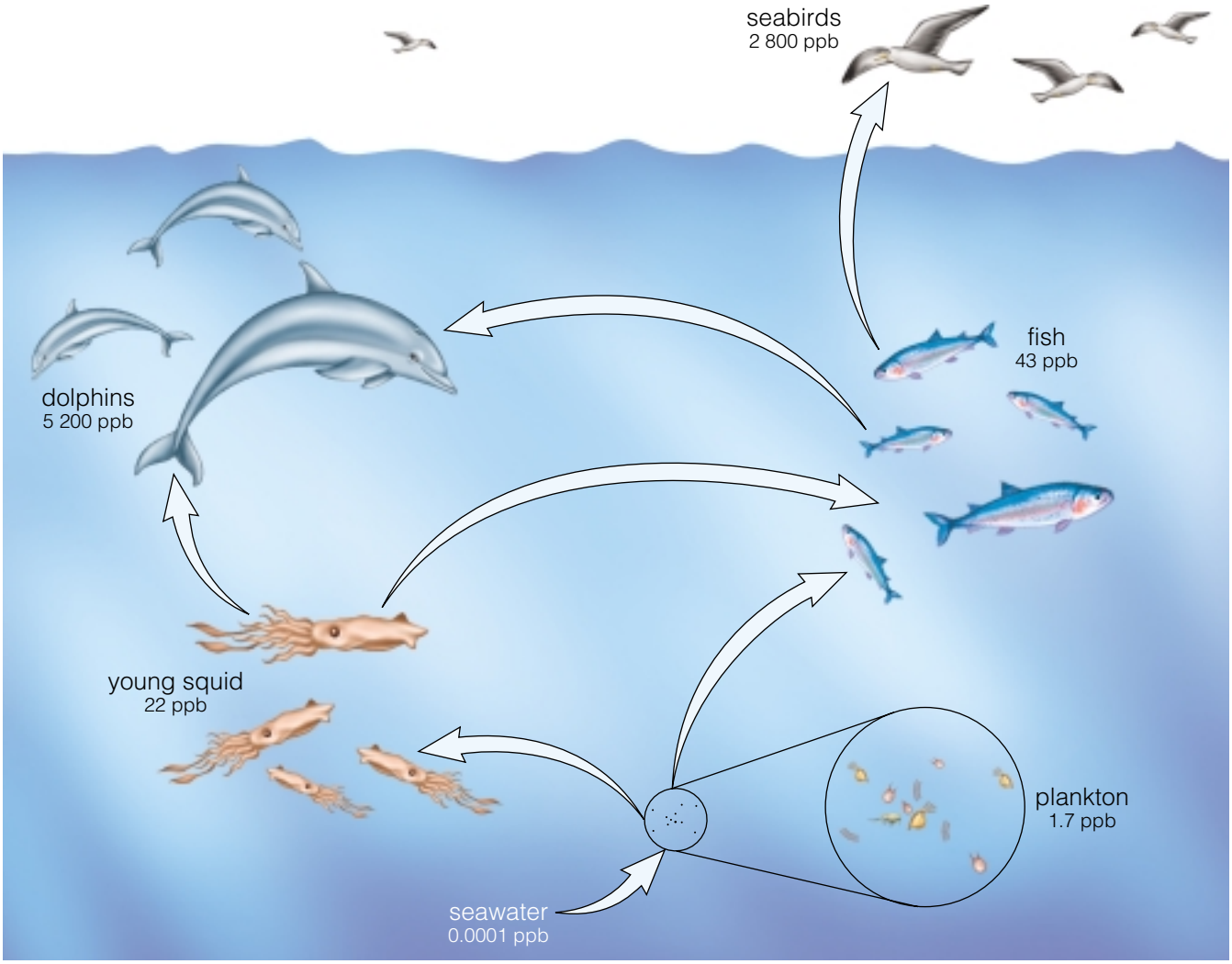
DDT in a Food Chain

Think About It

DDT (dichlorodiphenyltrichloroethane) is an example of a persistent pesticide that can remain in the environment for long periods of time. The longer a pesticide is present in the environment, the greater the chance that it will be consumed by organisms. Some pesticides can accumulate in the bodies of organisms. As a result, they can increase in concentration in specific tissues or organs. How do pesticides, such as DDT, enter food chains? In this investigation, you will trace the path of DDT in a north Pacific Ocean food chain.

What to Do

1. Study the following food web. Below the name of each organism is a number that indicates the amount of DDT in the organism's tissues, in parts per billion (ppb). One ppb is equivalent to 1 mg/1000 L.
2. Use the food web and the information about DDT on page 190 to answer the questions that follow.



DDT in a north Pacific Ocean food web, in parts per billion (ppb). The arrows show the flow of energy from one "trophic," or feeding, level to another. Seabirds feed on fish, so seabirds are at a higher feeding level than fish.

CONTINUED ▶

The DDT Story

The risks of using pesticides in ecosystems first became widely known during the 1950s and 1960s, when the toxic effects of the insecticide DDT were recorded. DDT was one of the first and most powerful insecticides developed. During World War II, it was used to control populations of insects (such as body lice, fleas, and mosquitoes) that can transmit deadly diseases to people. As a result, the rate of death from malaria, bubonic plague, typhus, and yellow fever fell dramatically. DDT was also used widely on crops to control damage caused by insect pests.

In 1962 biologist and writer Rachel Carson published a book entitled *Silent Spring*, which described how pesticides had spread throughout the environment. As a result of her scientific evidence and the demands from an alarmed public, the use of DDT was severely restricted in Canada after 1969. DDT has not been registered for use in Canada since the mid-1980s.

Rachel Carson

About ten years after the first use of DDT, signs of trouble appeared. Dead birds, fish, frogs, and other animals were found in areas that had been heavily sprayed with DDT. The fat in their bodies contained high levels of the insecticide. Harmless or beneficial insects, such as butterflies and honeybees, also started to disappear from areas that had been sprayed.

Tests of soil and water showed that DDT remained in the environment for many years. For example, DDT was still found in the soil of some heavily sprayed orchards ten years after the spraying was stopped. DDT was also found in the bodies of many different organisms in areas around the world where the insecticide had never been used. It also began showing up in the tissues of people.

An unexpected outcome of using DDT was its effect on populations of birds of prey. The numbers of hawks, eagles, and ospreys on farmlands across North America and Europe fell sharply during the 1950s and 1960s. Scientists discovered that DDT reduced the ability of these birds to produce normal eggshells. Affected birds laid eggs with thin shells that broke in the nest, so they were unable to produce the usual number of young. The adult birds had accumulated DDT in their bodies from the fish they ate. The amount of DDT had accumulated in the bodies of organisms, moving from producers to primary consumers, to secondary consumers, and so on. This process is called **biological magnification** or **biomagnification**. Eventually concentrations of DDT became large enough in birds of prey to affect their reproduction. Unfortunately, DDT continues to be used in some tropical countries because it is such an effective pesticide. It not only affects species that live in these countries but also species that live elsewhere in the world, including people who consume food products imported from the tropics.

Pesticides can severely affect the reproduction of birds of prey, such as this osprey.

DidYouKnow?

One part per billion (ppb) is equal to one glazed doughnut in a chain of doughnuts circling Earth two and a half times.

Analyze

1. How does DDT enter a food web?
2. Which organism shown in the food web on page 189 contains the most DDT?
3. Which organism is at a higher trophic level, dolphins or plankton?
4. What is the relationship between the trophic level of an organism and the concentration of DDT in its body?
5. In the food web on page 189, how many times greater is the concentration of DDT in the fish than in the seawater? How many times greater is it in the dolphins than in the seawater?
6. In your own words, explain why animals at the top of a food chain are particularly at risk from poisons in the environment.

Conclude and Apply

7. Use an example to explain how an animal living hundreds of kilometres from an area sprayed with DDT might get DDT in its body.
8. DDT is stored in body fat and remains toxic for many years. Explain why these characteristics are undesirable in a pesticide. What characteristics would you want in a pesticide to make it less harmful to non-pest organisms?

Extend Your Knowledge and Skills

9. After spraying crops with DDT for several years, farmers found that populations of insect pests rebounded. One reason was that the insects had developed resistance to the insecticide. Suggest another reason, based on what you know about populations, food pyramids, predators, and competitors.
10. When Rachel Carson published her book about the effects of pesticides on food chains and people, she had many opponents. Use your local library and/or the Internet to research Rachel Carson. How did she present her ideas to the general public and the scientific community? What methods would you use to inform people of a threat to the environment? Why were Rachel Carson's ideas initially opposed?
11. The table below gives DDT levels, in parts per million (ppm), found in the eggs of three species of seabirds. The eggs were sampled from two different locations along Canada's east coast. Pesticide levels found in birds' eggs are a good indicator of pesticide levels in the environment. Study the data and answer the questions that follow.

DDT Level in Atlantic Seabird Eggs

Species	Year	DDT level in eggs (ppm)	
		Bay of Fundy	Atlantic Ocean
Leach's storm-petrel (feeds on small organisms near the surface of the water)	1968	no data	1.46
	1972	6.81	2.48
	1976	1.75	0.75
	1980	1.13	0.46
	1984	1.05	0.40
Atlantic puffin (feeds on small fish)	1968	no data	0.89
	1972	2.57	0.76
	1976	1.27	0.59
	1980	1.03	0.55
	1984	0.74	0.30
Double-crested cormorant (feeds on larger fish)	1972	6.51	2.85
	1976	1.49	2.18
	1980	1.91	1.34
	1984	1.07	1.88

(a) Describe general differences between pesticide levels in birds' eggs from nesting sites around the Bay of Fundy and pesticide levels in birds eggs from nesting sites along the coastline of the Atlantic Ocean.

(b) Describe changes in pesticide levels from 1972, to 1984. What may account for the changes?

(c) Describe any differences in pesticide levels found in different species of seabirds. Suggest a reason for the differences.

What's Bugging You?

Although DDT is widely recognized as potentially hazardous, there are people who take issue with the ban on DDT. Why would this be so? One major concern is that a ban on DDT has serious health effects for the human population. In Zanzibar alone, the incidence of malaria dropped from 70 percent in 1958 to 5 percent in 1964 as a result of the application of DDT in that country. After the use of DDT was restricted, the incidence of malaria climbed upward, reaching 50–60 percent by 1984.

In attempts to find an acceptable substitute for DDT, the World Health Organization (WHO) screened approximately 2000 compounds for possible use as insecticides. Of the 30 compounds ultimately selected for field tests, none has proven as effective or as safe as DDT. Additionally, all of the substitutes are much more expensive to produce and deliver than DDT — an important factor for less developed countries.

To add to the problem, our attempts to produce safe and effective pesticides are hampered by the growing problem of pesticide resistance. Figure 3.6 illustrates the rise in the number of pest species that are resistant to the effects of pesticides in current use. This trend has implications for the future of pesticide use. The production of new pesticides, tests for safety and effectiveness, and the development of standards leading to guidelines for consumer use are all issues of critical importance in the future. The next activity will introduce you to more on this issue.

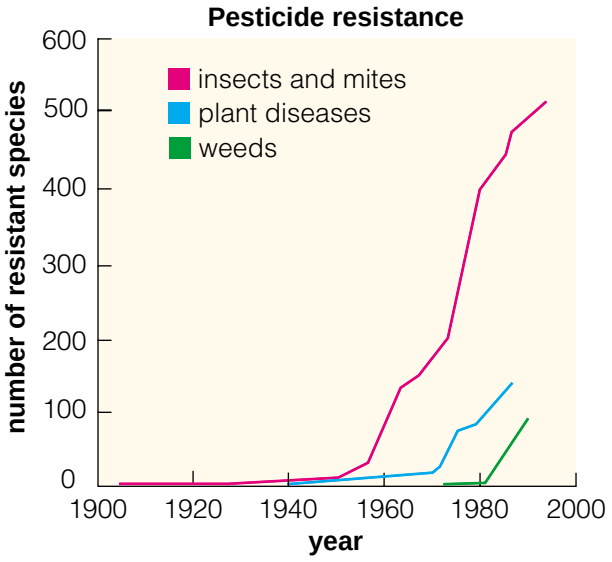


Figure 3.6 Growth in the number of pesticide-resistant species

Find Out ACTIVITY

The Use of Insecticides in Agriculture

Governments collect statistics on pesticide use to help develop and evaluate risk reduction programs. Such programs are then used to form the basis of government legislation and regulations. In this activity you will graph 1994 statistics comparing the use of insecticides in certain countries against the amount of agricultural land.

Materials

atlas of the world or access to the Internet

Country	Insecticide use (in Mt)	Agricultural area (in 1000 ha)
Canada	3 426	74 500
United States	103 419	420 250
France	8 848	30 119
India	41 994	181 030
Netherlands	439	1 971
United Kingdom	1 771	17 046

Procedure

Performing and Recording

1. The table gives the total amount of insecticides used and the agricultural area in selected countries for the same year. Use the data to calculate insecticide use per 1000 ha of agricultural area and make a bar graph to represent your findings.

What Did You Find Out?

Analyzing and Interpreting

1. Which country has the lowest ratio of insecticide use to agricultural area? The highest ratio?
2. Insecticide use is dependent upon the type of crop. Typically cereal crops (wheat, barley, oats) require fewer insecticides than either fruit or vegetable crops. Using an atlas, or statistics from the Internet, determine the major agricultural crop type for each of the countries. Do your results agree with what would be expected?

Skill FOCUS

For tips on how to make bar graphs, turn to Skill Focus 10.

STRETCH Your Mind

Researchers from the University of Guelph reported in the April 1995 issue of the *Journal of Agriculture and Food Chemistry* that vegetables treated with pesticides could be healthier than pesticide-free vegetables. Potatoes naturally contain small amounts of the toxin solanine. Solanine is known to cause damage to the developing fetus in mammals. Under insect attack, potatoes produce greater amounts of solanine, perhaps as a chemical defence against pests. The researchers found that potato plants attacked by the Colorado potato beetle showed a 50 percent increase in toxin levels. In contrast, potato plants attacked by the potato leafhopper showed no significant change in toxin levels. The difference in the potato plants' reaction to attack is believed to be due to the feeding habits of the two insects. Can you guess what the difference in their feeding habits might be?

INTERNET CONNECT

www.mcgraw.ca/links/sciencefocus9

You have an insect "infestation" that you want to get rid of, but your neighbour is concerned about the insecticide you have chosen to use. What are your obligations to your neighbours from a legal and ethical perspective? Go to the web site above, and click on Web Links to find out where to go next. Then write a letter to your neighbour explaining your point of view and how you plan to make use of the information you have learned.

INVESTIGATION 3-C

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

Organic Agriculture

Think About It

Canada is among the top five world producers of organic grains and oilseeds. Its organic agriculture sector is small but growing. Organic agriculture ideally uses natural processes and cycles to minimize environmental damage and optimize productivity.

In 1999 the Canadian General Standards Board published the *National Standard of Canada for Organic Agriculture*. This standard defines the guiding principles and regulations used to determine whether any product or operation can declare itself 100 percent "organic." In part, this act reads as follows:

"Operators of organic enterprises strive to reduce or eliminate reliance on practices using natural- or synthetic-based compounds that harm beneficial organisms within the soil, deplete non-renewable resources, compromise water and air quality, or which, through misuse, could endanger the health of agricultural workers, the agricultural community, or the consumer."

Canada's largest trading partner, the United States, has a similar set of guidelines in its 1990 Federal Organic Foods Production Act. In addition to outlining the rules and regulations governing the production and sale of organic products, this act includes a list of approved substances that may be used when circumstances warrant it. Interestingly, the list of approved substances includes pesticides derived from natural plants, microbes, insects, and mineral ores. In some special circumstances the use of synthetic pesticides may be approved.

Why is there a distinction made between organic and synthetic pesticides? Where do genetically modified organisms fit in the scheme of organic and synthetic pesticides? How can a naturally occurring mineral be used as a pesticide? What are the alternatives to the use of pesticides for controlling pests? How effective are those alternatives? In this investigation you will take a closer look at these questions.

How Can Science Help?

Our scientific knowledge has helped us develop synthetic pesticides and microbial pesticides, which contain micro-organisms. As well, we have learned to understand naturally occurring biochemical pesticides and the production of organic pesticides by plants after the addition of genetic material from another organism. The development and testing of new pesticides (regardless of type) require careful observation of the effects of a pesticide on all organisms, not just its intended target. The monitoring and critical analysis of any environmental effect allow scientists to weigh the benefits and risks associated with the possible use of that substance.

How does "organic" produce differ from produce grown by conventional methods?

What to Do

1. As a group, choose one of the following topics. Research your topic at your local library and/or the Internet. Prepare a one-page report summarizing your research.
   - **(a)** What methods are used by organic farmers to control pest species (insects, weeds, fungi, bacteria) and to maintain soil fertility? How do these methods achieve the end result? How effective are these methods?

Under what circumstances should an organic farmer use an approved pesticide?

(b) As a group, brainstorm the characteristics that a safe, effective pesticide might have. Then determine the following information for the approved pesticides *pyrethrum*, *rotenone* and *neem*:

(ii) source
(ii) active ingredient
(iii) effect on pest species, humans, and wildlife
(iv) persistence in tissues and the environment

Do your criteria for safe and effective pesticides match the characteristics of those pesticides investigated?

(c) Determine the following information for the approved microbial pesticide *Bacillus thuringiensis*, commonly referred to as Bt.:

(i) source
(ii) active ingredient
(iii) effect on pest species, humans, and wildlife
(iv) persistence in tissues and the environment

What concerns would organic farmers have regarding a neighbouring operation planting crop plants genetically modified by the insertion of Bt. genes? What regulations exist in Canada for the use of genetically modified organisms in agriculture?

(d) As a group, brainstorm the characteristics that a safe, effective pesticide might have. Elemental sulfur, boron (as boric acid), copper (as copper sulfate), and potassium (as a salt of fatty acids or "soapsalt") are all approved organic pesticides. Determine the effect on pest species, humans, and wildlife; and persistence in tissues and the environment of these pesticides. Do your criteria for safe and effective pesticides match the characteristics of those pesticides investigated?

2. Present a summary of your report to the class.

Analyze

1. A 1986 survey by Agriculture Canada found that farmers who chose organic methods did so because they felt organic methods were better for the health of their family and for the soil. Would the application of an organic pesticide change those expectations? Explain how the information you collected supports your answer.

2. Canada has been cited as ideal for organic agriculture due to its climate. Explain why climate might influence a country's suitability for organic agriculture.

Skill FOCUS

For tips on how to use the Internet for research, turn to Skill Focus 9.

DidYouKnow?

You can limit your exposure to pesticides, antibiotics, moulds, and bacteria by taking a few simple precautions.

- Wash and scrub all fresh fruits and vegetables thoroughly under running water.
- Discard the outer leaves of leafy vegetables and peel fruits and vegetables.
- Cut the fat off meat or eat lower on the food chain to reduce your exposure to bioaccumulated chemicals.
- Handle and store food carefully to prevent contamination with other foods or moulds.

Word CONNECT

The term "poison" (from the Latin *potare*, "to drink") generally refers to chemical substances in our food that cause illness or death. The term "toxin" is usually reserved for protein molecules produced by a biological organism, and comes from the Latin *toxicum*, "a poisoned arrow." The Latin word *toxicum* can be traced back to the ancient Greek word *toxon*, referring to any bow and arrow. Is it correct to refer to industrial chemical pollutants as toxic waste? Look up the term "toxic" in a dictionary and check your answer.

Where to Now?

Whether it is derived from naturally occurring substances in the environment or is specifically formulated in a laboratory, the role of a pesticide is to control pests. Concern about the potential of pesticides to harm non-target organisms has led to a greater societal emphasis on the control and appropriate use of such substances. Research and development into new and safer pesticides has resulted in pesticides that break down faster in the environment. It is now recognized that natural processes and cycles can minimize the use of pesticides in our agricultural economies. Despite this, the fact remains that some pesticides and their breakdown products may remain in the environment for many years. Much of our knowledge of pesticides is on an individual basis and one of the challenges facing us in years to come is to determine the effects of combinations of these substances on the environment.

TOPIC 2 Review

1. What is a pest? What are pesticides?
2. There does not appear to be any concern about running through a cloud of DDT in this picture below taken at Jones Beach, New York, in 1948. In fact, many people were grateful that such trucks operated in their neighbourhood. Explain why this event could occur in 1948, but not in 1978.

3. What is the difference between toxic and poisonous?
4. Define organic farming in your own words. Is it a better method of growing food than conventional farming? Consider cost and practicality in your answer.
5. **Apply** List three ways you could reduce the use of pesticides in your home or yard.
6. **Thinking Critically** Why are pesticides harmful to birds at or near the top of the food chain?