

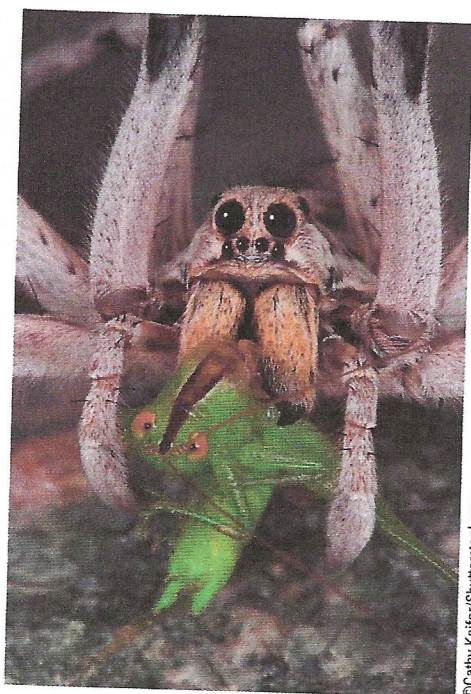
CONCEPT 12-4

We can sharply cut pesticide use without decreasing crop yields by using a mix of cultivation techniques, biological pest controls, and small amounts of selected chemical pesticides as a last resort (integrated pest management).

Nature Controls the Populations of Most Pests

A **pest** is any species that interferes with human welfare by competing with us for food, invading our homes, lawns, or gardens, destroying building materials, spreading disease, invading ecosystems, or simply being a nuisance. Worldwide, only about 100 species of plants (weeds), animals (mostly insects), fungi, and microbes cause most of the damage to the crops we grow.

In natural ecosystems and in many polyculture crop fields, *natural enemies* (predators, parasites, and disease organisms) control the populations of most potential pest species. This free ecosystem service is an important part of the earth's natural capital. For example, the world's 30,000 known species of spiders kill far more crop-eating insects every year than humans kill by using chemicals. Most spiders, including the wolf spider (Figure 12-22), do not harm humans.



©Cathy Keifer/Shutterstock.com

Figure 12-22 Natural capital: This ferocious-looking wolf spider with a grasshopper in its mouth is one of many important insect predators that can be killed by some pesticides.

When we clear forests and grasslands, plant monoculture crops, and douse fields with chemicals that kill pests, we upset many of these natural population checks and balances that help to implement the biodiversity **principle of sustainability**. Then we must devise and pay for ways to protect our monoculture crops, tree plantations, lawns, and golf courses from insects and other pests that nature has helped to control at no charge.



We Use Pesticides to Help Control Pest Populations

We have developed a variety of synthetic **pesticides**—chemicals used to kill or control populations of organisms that we consider undesirable. Common types of pesticides include *insecticides* (insect killers), *herbicides* (weed killers), *fungicides* (fungus killers), and *rodenticides* (rat and mouse killers).

We did not invent the use of chemicals to repel or kill other species. For nearly 225 million years, plants have been producing chemicals called *biopesticides* to ward off, deceive, or poison the insects and herbivores that feed on them. This battle produces a never-ending, ever-changing coevolutionary process: insects and herbivores overcome various plant defenses through natural selection and new plant defenses are favored by natural selection.

In the 1600s, farmers used nicotine sulfate, extracted from tobacco leaves, as an insecticide. Eventually, other *first-generation pesticides*—mainly natural chemicals taken from plants—were developed. Farmers were copying nature's solutions—developed, tested, and modified through natural selection over millions of years—to apply to their pest problems.

A major pest control revolution began in 1939, when entomologist Paul Müller discovered DDT (dichlorodiphenyltrichloroethane)—the first of the so-called *second-generation pesticides* produced in the laboratory. It soon became the world's most-used pesticide, and Müller received the Nobel Prize in Physiology or Medicine in 1948 for his discovery. Since then, chemists have created hundreds of other pesticides by making slight modifications in the molecules of various classes of chemicals.

Some synthetic pesticides, called *broad-spectrum agents*, are toxic to beneficial species as well as to pests. Examples are chlorinated hydrocarbon compounds such as DDT and organophosphate compounds such as malathion and parathion. Others, called *selective*, or *narrow-spectrum agents*, are effective against a narrowly defined group of organisms. Examples are algicides for algae and fungicides for fungi.

Pesticides vary in their *persistence*, the length of time they remain deadly in the environment. Some, such as DDT and related compounds, remain in the environment

for years and can be biologically magnified in food chains and webs (see Figure 9-13, p. 202). Others, such as organophosphates, are active for days or weeks and are not biologically magnified but can be highly toxic to humans.

Some second-generation pesticides have turned out to be highly hazardous for birds and other forms of wildlife. In 1962, biologist Rachel Carson published her famous book *Silent Spring*, sounding a warning that eventually led to strict controls on the use of DDT and several other widely used pesticides.

Since 1950, pesticide use has grown more than 50-fold and most of today's pesticides are 10–100 times more toxic than those used in the 1950s. Since 1970, chemists have continued to develop natural repellents and other biopesticides, again copying nature.

About one-fourth of the pesticides used in the United States are aimed at ridding houses, gardens, lawns, parks, playing fields, swimming pools, and golf courses of insects and other species that we view as pests. According to the U.S. Environmental Protection Agency (EPA), the amount of synthetic pesticides used on the average U.S. homeowner's lawn is 10 times the amount (per unit of land area) typically used on U.S. croplands.

Synthetic Pesticides Provide Several Benefits

Use of synthetic pesticides has its advantages and disadvantages. Proponents contend that the benefits of pesticides (Figure 12-23, left) outweigh their harmful effects (Figure 12-23, right). They point to the following benefits:

- *They have saved human lives.* Since 1945, DDT and other insecticides probably have prevented the premature deaths of at least 7 million people (some say as many as 500 million) from insect-transmitted diseases such as malaria (carried by the *Anopheles* mosquito), bubonic plague (carried by rat fleas), and typhus (carried by body lice and fleas).
- *They have been known to increase food supplies* by reducing food losses from pests, for some crops in some areas.
- *They can help farmers to increase their profits.* Officials of pesticide companies estimate that, under certain conditions, a dollar spent on pesticides can lead to an increase in crop yields worth as much as \$4.
- *They work fast.* Pesticides control most pests quickly, have a long shelf life, and are easily shipped and applied.
- *When used properly, the health risks of some pesticides are very low, relative to their benefits,* according to some scientific studies.
- *Newer pesticides are safer to use and more effective than many older ones.* Greater use is being made of chemicals derived originally from plants (biopesticides), which are safer to use and less damaging to the environment than are many older pesticides. Genetic engineering is also being used to develop pest-resistant crop strains

Trade-Offs

Conventional Chemical Pesticides

Advantages

- Expand food supplies
- Raise profits
- Work fast
- Are safe if used properly



Disadvantages

- Promote genetic resistance
- Can kill pests' natural enemies and harm wildlife and people
- Can pollute air, water, and land
- Are expensive for farmers

Figure 12-23 Use of synthetic pesticides has advantages as well as disadvantages. **Questions:** Which single advantage and which single disadvantage do you think are the most important? Why?

B Brown/Shutterstock.com

© Cengage Learning

and genetically altered crops that produce natural biopesticides.

Synthetic Pesticides Have Several Drawbacks

Opponents of widespread use of synthetic pesticides contend that the harmful effects of these chemicals (Figure 12-23, right) outweigh their benefits (Figure 12-23, left). They cite several problems.

- *They accelerate the development of genetic resistance to pesticides in pest organisms.* Insects breed rapidly, and within 5–10 years (much sooner in tropical areas), they can develop immunity to widely used pesticides through natural selection and then come back stronger than before. Since 1945, about 1,000 species of insects and rodents (mostly rats) and 550 types of weeds and plant diseases have developed genetic resistance to one or more pesticides. Since 1996, the widespread use of glyphosate herbicide has led to at least 15 species of “superweeds” that are genetically resistant to it.
- *They can put farmers on a financial treadmill.* Because of genetic resistance, farmers can find themselves having to pay more and more for a chemical pest control program that can become less and less effective.
- *Some insecticides kill natural predators and parasites that help to control the pest populations.* About 100 of the 300 most destructive insect pests in the United States were minor pests until widespread use of insecticides wiped out many of their natural predators, including spiders (Figure 12-22). (See the Case Study that follows.)
- *Pesticides are usually applied inefficiently and often pollute the environment.* According to the USDA, about 98–99.9% of the insecticides and more than 95% of

food, and nontarget organisms, including humans, livestock, and wildlife.

- *Some pesticides harm wildlife.* According to the USDA and the U.S. Fish and Wildlife Service, each year, some of the pesticides applied to cropland poison honeybee colonies on which we depend for pollination of many food crops (see Chapter 9, Core Case Study, p. 190). According to a study by the Center for Biological Diversity, pesticides menace one of every three endangered and threatened species in the United States.
- *Some pesticides threaten human health.* The WHO and UNEP have estimated that pesticides annually poison at least 3 million agricultural workers in less-developed countries and at least 300,000 workers in the United States. They also cause 20,000–40,000 deaths per year, worldwide. According to studies by the National Academy of Sciences, pesticide residues in food cause an estimated 4,000–20,000 cases of cancer per year in the United States.

The pesticide industry disputes these claims, arguing that if used as intended, pesticides do not remain in the environment at levels high enough to cause serious environmental or health problems. Figure 12-24 lists some ways to reduce your exposure to synthetic pesticides.

CASE STUDY

Ecological Surprises: The Law of Unintended Consequences

Malaria once infected nine of every ten people in North Borneo, now known as the eastern Malaysian state of Sabah. In 1955, the WHO sprayed the island with dieldrin (a DDT relative) to kill malaria-carrying mosquitoes. The program was so successful that the dreaded disease was nearly eliminated.

Then unexpected things began to happen. The dieldrin also killed other insects, including flies and cockroaches living in houses, which made the islanders happy. Next, small insect-eating lizards living in the houses died after gorging themselves on dieldrin-contaminated insects. Then cats began dying after feeding on the lizards. In the absence of cats, rats flourished and overran the villages. When the residents became threatened by sylvatic plague carried by rat fleas, the WHO parachuted healthy cats onto the island to help control the rats. Operation Cat Drop worked.

But then the villagers' roofs began to fall in. The dieldrin had killed wasps and other insects that fed on a type of caterpillar that had either avoided or was not affected by the insecticide. With most of its predators eliminated, the caterpillar population exploded, munching its way through its favorite food: the leaves used in thatch roofs.

Ultimately, this episode ended well. Both malaria and the unexpected effects of the spraying program were brought

Reducing Exposure to Pesticides

- Grow some of your food using organic methods
- Buy certified organic food
- Wash and scrub all fresh fruits and vegetables
- Eat less meat, no meat, or certified organically produced meat
- Before cooking, trim the fat from meat

Figure 12-24 Individuals matter: You can reduce your exposure to pesticides. **Questions:** Which three of these steps do you think are the most important ones to take? Why?

under control. Nevertheless, this chain of unintended and unforeseen events reminds us that whenever we intervene in nature and affect organisms that interact with one another, we need to ask, "Now what will happen?"

Pesticide Use Has Not Consistently Reduced U.S. Crop Losses to Pests

Despite some claims to the contrary, largely because of genetic resistance and the loss of many natural predators, synthetic pesticides have not always succeeded in reducing U.S. crop losses.

When David Pimentel, an expert on insect ecology, evaluated data from more than 300 agricultural scientists and economists, he reached three major conclusions. *First*, between 1942 and 1997, estimated crop losses from insects almost doubled from 7% to 13%, despite a tenfold increase in the use of synthetic insecticides. *Second*, according to the International Food Policy Research Institute, the estimated environmental, health, and social costs of pesticide use in the United States are \$5–\$10 in damages for every dollar spent on pesticides. *Third*, experience indicates that alternative pest management practices could cut the use of synthetic pesticides by half on 40 major U.S. crops without reducing crop yields (Concept 12-4).

The pesticide industry disputes these findings. However, numerous studies and experience support them. Sweden has cut its pesticide use in half with almost no decrease in crop yields. The soup company Campbell's® uses no pesticides on the tomatoes it grows in Mexico, and yields have not dropped.

Laws and Treaties Can Help to Protect Us from the Harmful Effects of Pesticides

More than 25,000 different pesticide products are used in the United States. Three federal agencies, the EPA, the USDA, and the Food and Drug Administration (FDA), regulate the use of these pesticides under the Federal Insecti-

icide, Fungicide, and Rodenticide Act (FIFRA), first passed in 1947 and amended in 1972.

Under FIFRA, the EPA was supposed to assess the health risks of the active ingredients in synthetic pesticide products already in use. However, since 1972, less than 10% of the active ingredients in pesticide products have been tested for chronic health effects. And serious evaluation of the health effects of the 1,200 inactive ingredients is only partially done. The EPA says that the U.S. Congress has not provided them with enough funds to carry out this complex and lengthy evaluation process.

In 1996, Congress passed the Food Quality Protection Act, mostly because of growing scientific evidence and citizen pressure concerning the effects of small amounts of pesticides on children. This act requires the EPA to reduce the allowed levels of pesticide residues in food by a factor of 10 when there is inadequate information on the potentially harmful effects on children.

Between 1972 and 2012, the EPA used FIFRA to ban or severely restrict the use of 64 active pesticide ingredients, including DDT and most other chlorinated hydrocarbon insecticides. However, according to studies by the National Academy of Sciences, federal laws regulating pesticide use are inadequate and poorly enforced by the three agencies. One study found that as much as 98% of the potential risk of developing cancer from pesticide residues on food grown in the United States would be eliminated if EPA standards were as strict for pesticides developed before 1972 as they are for newer pesticides.

q CONSIDER THIS . . .

CONNECTIONS Pesticides and Organic Foods: The Dirty Dozen

According to a 2012 report by the Environmental Working Group (EWG), you could reduce your pesticide intake by up to 90% by eating only 100% USDA Certified Organic versions of 12 types of fruits and vegetables that tend to have the highest pesticide residues. These foods, which the EWG calls the "dirty dozen," are apples, celery, cherry tomatoes, cucumbers, grapes, hot peppers, nectarines (imported), peaches, potatoes, spinach, strawberries, and sweet bell peppers. Pesticide proponents say the residue concentrations in those foods are too low to cause harm. But some scientists urge consumers to follow the precautionary principle and buy only 100% USDA Certified Organic versions of these foods.

Although laws within countries protect citizens to some extent, banned or unregistered pesticides may be manufactured in one country and exported to other countries. For example, U.S. pesticide companies make and export to other countries pesticides that have been banned or severely restricted—or never even evaluated—in the United States. Other countries also export banned or unapproved pesticides.

However, in what environmental scientists call a *circle of poison*, or the *boomerang effect*, residues of some banned or unapproved chemicals used in synthetic pesticides exported to other countries can return to the exporting countries on imported food. Winds can also carry persistent pesticides from one country to another.

Environmental and health scientists have urged the U.S. Congress—without success—to ban such exports. Supporters of the exports argue that such sales increase economic growth and provide jobs and that if the United States did not export these pesticides, other countries would.

In 1998, more than 50 countries developed an international treaty that requires exporting countries to have informed consent from importing countries for exports of 22 synthetic pesticides and 5 industrial chemicals. In 2000, more than 100 countries developed an international agreement to ban or phase out the use of 12 especially hazardous persistent organic pollutants (POPs)—9 of them persistent hydrocarbon pesticides such as DDT and other chemically similar pesticides. By 2011, the initial list of 12 chemicals had been expanded to 21. In 2004 the POPs treaty went into effect and by 2012 had been signed or ratified by 172 countries, but not by the United States.

q CONSIDER THIS . . .

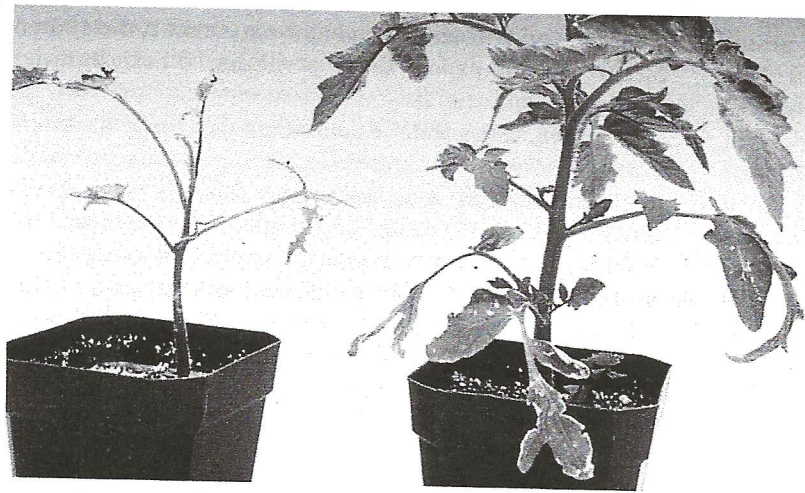
THINKING ABOUT Exporting Pesticides

Should companies be allowed to export synthetic pesticides that have been banned, severely restricted, or not approved for use in their home countries? Explain.

There Are Alternatives to Synthetic Pesticides

Many scientists argue that we should greatly increase the use of biological, ecological, and other alternative methods for controlling pests and diseases that affect crops and human health (Concept 12-4). Here are some of these alternatives:

- *Fool the pest.* A variety of *cultivation practices* can be used to fake out pests. Examples include rotating the types of crops planted in a field each year and adjusting planting times so that major insect pests either starve or get eaten by their natural predators.
- *Provide homes for pest enemies.* Farmers can increase the use of polyculture, which uses plant diversity to reduce losses to pests by providing habitats for the pests' predators.
- *Implant genetic resistance.* Use genetic engineering to speed up the development of pest- and disease-resistant crop strains (Figure 12-25). But controversy persists over whether the projected advantages of using GM plants outweigh their projected disadvantages (Figure 12-19).
- *Bring in natural enemies.* Use *biological control* by importing natural predators (Figures 12-22 and 12-26), parasites, and disease-causing bacteria and viruses to help regulate pest populations. This approach is nontoxic to other species and is usually less costly than applying pesticides. However, some biological control agents are difficult to mass produce and are often slower acting



normal plant's leaves are almost gone (left), whereas the genetically altered plant shows little damage (right).
Questions: Would you have any concerns about eating the genetically engineered tomato? Why or why not?

Monsanto

and more difficult to apply than synthetic pesticides are. Sometimes the agents can multiply and become pests themselves.

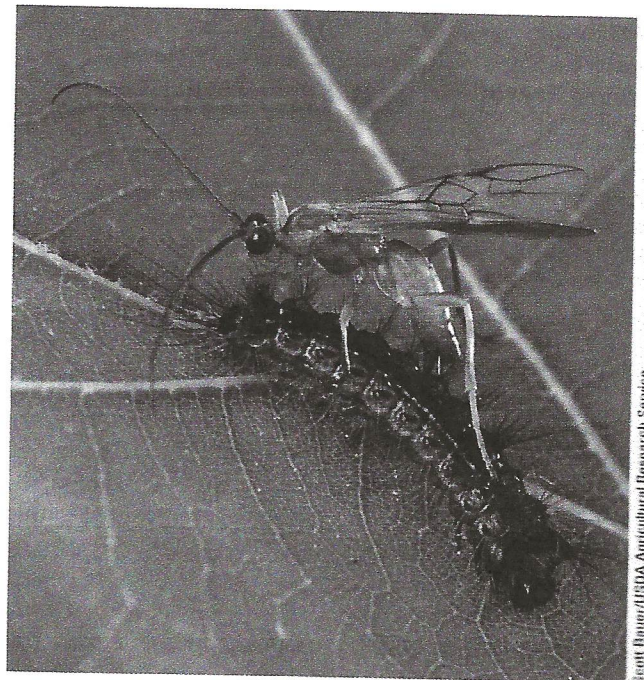
- *Use insect perfumes.* Trace amounts of *sex attractants* (called *pheromones*) can be used to lure pests into traps or to attract their natural predators into crop fields. Each of these chemicals attracts only one species. They have little chance of causing genetic resistance and are not harmful to nontarget species. However, they are costly and time-consuming to produce.
- *Bring in the hormones.* Hormones are chemicals produced by animals to control their developmental processes at different stages of life. Scientists have learned how to identify and use hormones that disrupt an insect's normal life cycle, thereby preventing it from reaching maturity and reproducing. Use of insect hormones has some of the same advantages and disadvantages as use of sex attractants has. Also, they take weeks to kill an insect, are often ineffective with large infestations of insects, and sometimes break down before they can act.
- *Reduce the use of synthetic herbicides to control weeds.* Organic farmers control weeds by methods such as crop rotation, mechanical cultivation, hand weeding, and the use of cover crops and mulches.

Integrated Pest Management Is a Component of More Sustainable Agriculture

Many pest control experts and farmers believe the best way to control crop pests is through **integrated pest management (IPM)**, a carefully designed program in which each crop and its pests are evaluated as parts of an ecosystem, and farmers use a combination of cultivation, biological, and chemical tools and techniques, applied in a coordinated process (Concept 12-4).

The overall aim of IPM is to reduce crop damage to an economically tolerable level. Each year, crops are rotated, or moved from field to field, in an effort to disrupt pest infestations, and fields are monitored carefully. When an economically damaging level of pests is reached, farmers first use biological methods (natural predators, parasites, and disease organisms) and cultivation controls (such as altering planting time and using large machines to vacuum up harmful bugs). They apply small amounts of synthetic insecticides—preferably biopesticides—only when insect or weed populations reach a threshold where the potential cost of pest damage to crops outweighs the cost of applying the pesticide.

IPM has a good track record. In Sweden and Denmark, farmers have used it to cut their synthetic pesticide use by more than half. In Cuba, where organic farming is used almost exclusively, farmers make extensive use of IPM. In Brazil, IPM has reduced pesticide use on soybeans by as much as 90%.



Scott Bauer/USDA Agricultural Research Service

Figure 12-26 Natural capital: In this example of biological pest control, a wasp is parasitizing a gypsy moth caterpillar.

According to the U.S. National Academy of Sciences, these and other experiences show that a well-designed IPM program can reduce synthetic pesticide use and pest control costs by 50–65%, without reducing crop yields and food quality. IPM can also reduce inputs of fertilizer and irrigation water, and slow the development of genetic resistance, because pests are attacked less often and with lower doses of pesticides. IPM is an important form of *pollution prevention* that reduces risks to wildlife and human health and applies the biodiversity **principle of sustainability** (see Figure 1-2, p. 6 or back cover).



Despite its promise, IPM—like any other form of pest control—has some drawbacks. It requires expert knowledge about each pest situation and takes more time than does using conventional pesticides. Methods developed for a crop in one area might not apply to areas with even slightly different growing conditions. Initial costs may be higher, although long-term costs typically are lower than those of using conventional pesticides. Widespread use of IPM has been hindered in the United States and a num-

ber of other countries by government subsidies that pay for synthetic chemical pesticides, as well as by opposition from pesticide manufacturers, and a shortage of IPM experts. **GREEN CAREER:** integrated pest management

A growing number of scientists are urging the USDA to use a three-point strategy to promote IPM in the United States. *First*, add a 2% sales tax on synthetic pesticides and use the revenue to fund IPM research and education. *Second*, set up a federally supported IPM demonstration project on at least one farm in every county in the United States. *Third*, train USDA field personnel and county farm agents in IPM so they can help farmers use this alternative. Because these measures would reduce its profits, the pesticide industry has vigorously, and successfully, opposed them.

Several UN agencies and the World Bank have joined together to establish an IPM facility. Its goal is to promote the use of IPM by disseminating information and establishing networks among researchers, farmers, and agricultural extension agents involved in IPM.

GOOD NEWS

we can improve food security by reducing subsidies, relying more on locally grown produce, and reducing food waste.

Government Policies to Improve Food Production and Security

Agriculture is a financially risky business. Whether farmers have a good or bad year depends on factors over which they have little control: weather, crop prices, crop pests and diseases, interest rates on loans, and global markets.

Governments use two main approaches to influence food production. First, they can *control food prices* by putting a legally mandated upper limit on them in order to keep them artificially low. This makes consumers happy but makes it harder for farmers to make a living.

Second, they can *provide subsidies* by giving farmers cash supports, tax breaks, and other financial support to keep them in business and to encourage them to increase food production. However, if government subsidies are too generous and the weather is good, farmers and livestock producers may produce more food than can be sold.

Some analysts call for ending such subsidies. They point to New Zealand, which ended farm subsidies in 1984. After the shock wore off, innovation took over and production of some foods such as milk quadrupled. Brazil also ended most of its farm subsidies. Some analysts call for replacing traditional subsidies for farmers with subsidies that promote more environmentally sustainable farming practices.

tion to be called the Centers for Urban Agriculture. It would be a national training center with a large urban

farm for research and development of sustainable farming practices. One goal would be to develop a functioning community food delivery system that could serve a large city and provide jobs, job training, and a nutritious food supply for those most in need of it.

Similarly, government subsidies to fishing fleets can promote overfishing and the reduction of aquatic biodiversity. For example, several governments give the highly destructive bottom-trawling industry (see Figure 11-2, right, p. 250) a total of about \$150 million per year in subsidies, which is the main reason fishers who use this practice can stay in business. Many analysts call for replacing those harmful subsidies with ones that promote more sustainable fishing and aquaculture.

Other Government and Private Programs Are Increasing Food Security

Government and private programs that reduce poverty by helping the poor to help themselves can improve food security (**Concept 12-1B**). For example, some programs provide small loans at low interest rates to poor people to help them start businesses or buy land to grow their own food.

Some analysts urge governments to establish special programs focused on saving children from the harmful health effects of poverty. Studies by the United Nations

10. One strategy for dealing with agricultural pests is integrated pest management (IPM). Describe IPM. As part of your description, include TWO specific pest-control approaches that are part of IPM.

11. Describe TWO ways that governments can encourage the use of IPM as an effective strategy against pests.