Objectives

After studying this chapter, you will be able to
identify three main types of food contaminants.
differentiate among the types of foodborne illnesses.
name pathogens that cause foodborne illnesses.
describe the two main ways pathogens enter the food supply.
use food handling procedures that will help prevent the growth of illness-causing microbes.
list the seven steps in developing a HACCP system.

Key Terms

- contamination
- biodegradable
- food spoilage
- foodborne illness
- pathogen
- toxin
- food intoxication
- food infection
- salmonellosis
- parasite
- host
- trichinosis
- virus
- capsid
- hepatitis
- cross-contamination
- HACCP (Hazard Analysis and Critical Control Point)

Types of Food Contamination

The United States has the safest food supply in the world. Even with this record, some people get sick from eating food. Some experts estimate up to half of all cold and flu cases in this country may really be foodborne illnesses. People’s lives depend on a reliable, safe food supply that is free from harmful contamination. Contamination is the state of being impure or unfit for use due to the introduction of unwholesome or undesirable elements. Food can be contaminated by insects, rodents, chemicals, microbes, or other foreign particles.

In this chapter, you will study how and when harmful contamination occurs. You will find out what steps you can take to help prevent it. You will also read about the differences among contamination, spoilage, and foodborne illness.

Contamination occurs when something not normally found in the food is added. Contamination implies the addition is not intended or planned. The substance added may or may not cause problems. Three main sources of contamination are from physical, chemical, and microbial sources.

Physical Contaminants

Physical contaminants are substances that become part of a food mixture. They may not change or damage the food itself. However, their presence can create health hazards for the consumer. For instance, metal filings or broken pieces of glass have occasionally gotten into foods. These materials would not spoil food, but they could cause injury if swallowed. Other examples of physical contaminants include packaging material, insects, and rodent droppings.

Insect and rodent contamination present two major problems. The first is the large volume of food that insects or rodents can eat and/or destroy. It is estimated that as much as 10% of the U.S. grain crop is destroyed annually by insects. The second concern is the microbes that may enter the food because of the insects or rodents. For example, flies pick up microbes on their hairy feet. When flies walk on food, microbes can transfer from the flies’ feet to the food. Insects and rodents also damage the surfaces of foods such as fruits and vegetables. This creates openings that allow microbes to enter and multiply within the foods.

Insects and rodents can contaminate the food supply at any stage of growth or production. For example, some insects lay eggs in wheat while it is growing in fields, 18-1. These eggs are not visible, and their presence in small amounts is not harmful to human health. Keeping all insect eggs out of the wheat supply would be extremely expensive. On the other hand, cockroaches are likely to enter the wheat supply during the processing...
stages. Their presence is less acceptable and can be affordably controlled by the food manufacturer. The FDA examines food products for insect parts. FDA inspectors want to identify the types of insects present. To do this, the inspectors must be able to recognize insects from fragments, such as antennae. Inspectors also need to know about the habits of insects and the processes used to produce foods. This helps the inspectors determine the amount of contamination and the point at which the contamination occurred.

Chemical Contaminants

Keeping insects and other pests under control can lead to chemical contamination. Insecticides are chemicals used to improve crop yields by reducing losses due to insects. Herbicides are used for the same reasons to control weeds. Both types of substances are pesticides. If pesticide residues remain on food, they enter the food supply. The United States Department of Agriculture (USDA) monitors all pesticides. Any substance used on crops must undergo thorough testing to see how effective it is. Foods are examined for residues. Tests are conducted to determine whether residues pose a health hazard.

A second way chemical contaminants can enter the food supply is in water. Water is used in the processing of nearly every food product. Water is an excellent solvent. Therefore, many poisonous substances will dissolve in and pollute water supplies. The term toxic is used for substances that are harmful in low concentrations. Mercury, cadmium, lead, chloroform, benzene, and polychlorinated biphenyls (PCBs) are among the toxic substances that may get into water supplies.

Signs of Spillage
- discoloration
- off odor
- foam or gas bubbles in the product
- bulging or corroded can
- cloudy appearance
- off flavor
- mushy texture
- soft spots or breaks in the skin on fruits and vegetables

If you suspect a food is spoiled, DO NOT TASTE IT!

Health Tip
To avoid risk of lead contamination, look for labels ensuring that ceramic cookware and dishes are lead free. When serving hot beverages, make sure you are using lead-free cups.

Microbial Contaminants

Physical and chemical contaminants do not change the food itself. They are potential hazards when consumed with the food. Another potential case of a surprising pollution source occurred in 1998 in Crescent, Oregon. The city water supply was contaminated when leaks formed in old, buried petroleum tanks. The tanks were from a bankrupt service station. Their removal was only 1 of 702 approved underground tank cleanups for Oregon in 1998. Building new subdivisions over old gas stations, landfills, or industrial sites increases the chance of pollutants reaching underground water tables. This, in turn, increases the risk of contaminants getting into the food supply.

Leads

The level of lead in the U.S. food supply was 90% lower in 1992 than in 1980. This reduction was due to tighter FDA regulations, changes in gasoline, and voluntary changes from the food canning industry. A major source of lead was leaded gas, which created exhaust that settled on crops and in water.
Many changes in food caused by spoilage make the food unpleasant to eat. This does not necessarily mean the food is unsafe. However, microorganisms often bring about unpleasant changes in food that can also cause illness. A sickness caused by eating contaminated food is called foodborne illness.

**Types of Foodborne Illness**

Many people who think they have "stomach flu" are really sensing the symptoms of a foodborne illness. These symptoms often include diarrhea, stomach cramps, and vomiting. There are approximately 76 million cases of foodborne illness each year.

An outbreak of foodborne illness is easier to detect when two or more people have the same symptoms. However, some people are more sensitive than others to foodborne pathogens. Therefore, two people can consume the same contaminated food, but they may not both become sick.

Most cases of foodborne illness are a result of pathogens in food. Pathogens are microorganisms that can cause illness in humans. The pathogens that cause foodborne illness do not necessarily cause undesirable changes in food. Many times, pathogens cause a food to be unsafe to eat before there are any visible signs of spoilage. Pathogens can cause illness in one of two ways: intoxication or infection.

**Food Intoxication**

Some microbes can give off a by-product that causes illness. Substances released by microbes that are harmful to humans are called toxins. In this case, it is not the microbe that makes people sick but the toxin it produces. A foodborne illness caused by a toxin released by a microbe is called a food intoxication.

It is important to remember that killing the microbes may not be enough to prevent cases of food intoxication. If the toxin is still present and has not been damaged or altered, the person will still become ill. The severity of the illness will depend on the amount of toxins present in the food eaten. It will also depend on how susceptible the person is to illness.

A number of microbes cause food intoxication. The following sections discuss those that cause some of the most common illnesses.

**Clostridium Perfringens**

The bacterium *Clostridium perfringens* causes one of the most frequent and, fortunately, mildest forms of food intoxication. This gram-positive microbe is anaerobic, but it survives in an oxygen environment. Its spores are very heat resistant, and small numbers often remain in cooked foods. These organisms can multiply to toxic levels during cooling and storage of prepared foods. *C. perfringens* is widespread in nature. It is found in soil, water, air, sewage, and on many food products.

Foodborne illness caused by *C. perfringens* is often traced to eating protein-based foods. This is because of changes these foods cause in the pH of the stomach. The low pH of stomach acid will normally kill *C. perfringens*. However, consumption of protein foods raises the stomach pH. This rise in pH allows the more acid-resistant spores to survive and enter the intestines, where conditions allow rapid growth. The toxin is a protein that is part of the spore coat. It causes fluids to move into the intestines. Enzymes released by *C. perfringens* damage the cells of the lining of the small intestine.

18-4 To prevent *C. perfringens* from multiplying, it is important to keep meats, gravies, and stuffings hot (above 60°C, 140°F) during serving.

**Onset of the illness** can occur anywhere from 2 to 29 hours after eating contaminated food. Symptoms include diarrhea, which is a result of the toxin pulling water into the intestines. The by-products of the pathogen include acids and large amounts of gas, which cause bloating and cramps. The symptoms last for 12 to 24 hours. A person with this illness can usually return to normal activities the next day. Because recovery rarely requires medical help, many cases go unreported. Death rarely occurs unless a person is already weakened by other illnesses.

Outbreaks of *C. perfringens* usually occur when large volumes of food are prepared at one time. Examples include catering services, hospitals, nursing homes, and school and workplace cafeterias. Protein-based foods involved in outbreaks have often been prepared a day or two in advance and then chilled. Large amounts of food are slow to chill and allow for rapid growth of the bacteria.

Controlling *C. perfringens* can be accomplished in three ways. First, food handlers must limit contamination. Preventing contamination is very difficult, but following sanitation procedures helps limit microbe populations. It takes a large number of *C. perfringens* cells to cause illness. The body is usually able to handle small amounts at a time.

The second method for controlling this illness is to prevent growth. Refrigeration temperatures slow the growth of *C. perfringens*, and most of the cells are killed when frozen. Maximum growth occurs at 50°C to 52°C (122°F to 125°F). Therefore, keep heated foods well above these temperatures. Place leftovers in shallow containers. Place the containers in a bath of water and ice so food will quickly drop below 50°C (122°F). Then place the leftovers in the refrigerator for storage.

The third way to control *C. perfringens* is to destroy the organism. Cooking easily kills active cells. Over 99% of the cells were killed in beef cubes held at 53.3°C (127.9°F). However, some spores are so heat resistant that food would be destroyed before the spores were. Therefore, it is safest to assume that spores have survived the cooking process. Gravies and sauces that may be contaminated need to be reheated by boiling for 10 to 15 minutes. Always throw away food that has not been properly heated or cooled.

**Staphylococcus Aureus**

*Staphylococcus aureus* is a gram-positive bacterium that occurs singly, in pairs, and in clusters. These bacteria can survive in aerobic or anaerobic conditions. They do not compete well with other bacteria. This means when other bacteria are present, *S. aureus* will not grow rapidly. Most strains of *S. aureus* will grow in salt solutions that kill or stop other bacteria. This is why *S. aureus* is a common cause of foodborne illness traced to cured meats. Pasteurization and reheating will kill *S. aureus*. However, the toxin it produces is more heat stable and can still cause illness after the microbe has been destroyed. Therefore, it is necessary to prevent contamination with and growth of the microbe to avoid illness.

*S. aureus* is found on healthy humans and most warm-blooded animals. It is found in pimples, boils, and open wounds. It is also on the skin and mucous membranes, such as the lining of the nose. The bacteria are easily transferred to the hands by touching infected surfaces, such as blemishes, the nose, or soiled tissue.

Growth of *S. aureus* occurs most rapidly at temperatures of 33°C to 38°C (91°F to 100°F). It takes about 3 hours at room temperature after contamination has occurred to produce enough toxin to cause illness. The illness usually begins within 30 minutes to 8 hours after eating the contaminated food. The symptoms can include nausea, diarrhea, vomiting, and abdominal cramps. The illness is rarely fatal and lasts only one to two days. The severity of the illness will depend on the amount of food consumed and the individual’s resistance to the toxin.

Foods most likely to be contaminated with *S. aureus* include red meats, especially ham, pork, potato, macaroni, and tuna salads; and custard- or cream-filled bakery products may also be involved in *S. aureus* contamination. In most cases, the food is contaminated after it is cooked. See 18-5.

Humans are the main source of *S. aureus*. Therefore, monitoring the health, hygiene, and work habits of food handlers is the best way to control the pathogen.
Green beans canned at home need to be processed in a pressure canner to avoid risk of *Clostridium botulinum*. This will kill any spores present. This bacteria grow best between the temperatures of 25°C and 37°C (77°F and 99°F). Prevention of botulism begins with washing vegetables to remove soil and as many *C. botulinum* organisms as possible. Fish should be carefully gutted and thoroughly washed. Growth of *C. botulinum* can be prevented by freezing food. Care needs to be taken when processing and preparing home-canned foods. This is especially true of low-acid foods, such as corn and green beans. The spores of *C. botulinum* can survive temperatures in excess of 100°C (212°F) for several hours. Therefore, low-acid foods need to be processed at a temperature of 121°C (250°F) to destroy the spores. (The toxins are destroyed at lower temperatures than the spores.) It is recommended that low-acid canned foods be heated to boiling (100°C, 212°F) after opening. Before these foods are eaten, they should be simmered for 10 to 15 minutes to guarantee the toxin has been destroyed. Home-canned low-acid vegetables should never be eaten cold. Cured and processed meats would be ruined at temperatures high enough to destroy *C. botulinum* spores. Therefore, chemicals must be used to destroy botulism in meat products. Cases of botulism have been traced to chicken liver pâté, luncheon meats, ham, sausage, lobster, and smoked and salted fish. Sodium nitrite can be added to these foods to fix the color and prevent growth of *C. botulinum*.

*C. botulinum* need a pH of 4.6 or greater and an oxygen-free environment to multiply. The bacteria grow best in the presence of the toxins at nerve fiber junctions will prevent nerve impulses from being transmitted. This results in paralysis of the muscles. 

Foodborne illness caused by *C. botulinum* is called botulism. Symptoms can appear anywhere from 12 to 24 hours after eating a contaminated food. The first signs of botulism are blurred vision; progressive weakness; and red, sore mouth, tongue, and throat. The patient may also experience diarrhea followed by constipation and abdominal pain. Paralysis begins in the throat and progresses to the chest, arms, and legs. The patient needs prompt medical attention to avoid death due to suffocation. The sooner treatment begins, the better the chance of survival.

Infants up to 12 months of age are more susceptible to botulism than people in other age groups. Honey can be a source of *C. botulinum* spores and should never be fed to infants. Spinach, which can promote the growth of botulism, is another high-risk food for infants. Some studies indicate 5% of infants who reportedly died of sudden infant death syndrome (SIDS) were infected with botulin.

Most cases of botulism are caused by home-canned foods that were improperly processed, 18-6. Other likely sources of botulism are improperly processed peppers, soup, asparagus, mushrooms, spinach, and ripe olives.

Controlling *S. aureus* means rapidly cooling susceptible foods or serving them quickly. Any susceptible food should be placed in containers that are no more than three inches deep for rapid cooling. Foods should reach a temperature of 4°C (40°F) within four hours. Foods that may be contaminated with *S. aureus* should not be eaten. This is because, although reheating will kill the bacteria, it does not destroy the toxin that causes illness.

UNIT V Food Microbiology: Living Organisms in Food

**Chapter 18 Food Safety: Sources of Contamination**

*Escherichia coli* are gram-negative, rod-shaped bacteria that live in the colons of mammals. They are transported to the food supply by sewage-contaminated water or infected food handlers.

There are four strains of *E. coli* that are known to cause foodborne illness. One strain causes illness when present in large numbers in the small intestine. A second strain seems to produce a toxin while in the small intestine. A third strain invades the mucous lining of the intestines. A fourth strain causes bleeding in the colon and kidney failure. This last strain is the deadliest, especially among small children and older adults. It can cause illness with as few as 10 cells in the food supply.

The time from exposure to onset varies from less than 1 day to 13 days. Most patients begin to exhibit symptoms between 18 and 44 hours after eating the contaminated food. The illness usually lasts from 3 to 4 days. The main symptom is diarrhea, but nausea, fever, cramps, weakness, aches, and vomiting may also occur. Treatment centers on replacing fluids and electrolytes.

Outbreaks of *E. coli* have occurred as a result of consuming soft cheeses, hamburgers, salads, and apple juice. Any food exposed to raw fecal matter is at risk of being contaminated. Ground meats are at risk because the grinding process can mix any *E. coli* present throughout the meat. Any patty not cooked until done would then have *E. coli* present in the center of the meat. See 18-7.

Steps for preventing contamination can be taken by communities as well as by individuals. Communities chlorinate water supplies to eliminate harmful bacteria. Anyone handling food must thoroughly wash his or her hands after using the bathroom. People who

![18-5 Some cases of illness caused by *S. aureus* have been traced to cream-filled pastries.](image)

![18-6 Green beans canned at home need to be processed in a pressure canner to avoid risk of *Clostridium botulinum*.](image)

![18-7 Hamburgers and other ground meat products need to be cooked to an internal temperature of 71°C (160°F). This will kill any *E. coli* that may be present.](image)
food infection

The second major cause of foodborne illness is the microbes themselves. Microbes release digestive enzymes that begin to damage body tissue and cause illness. This type of foodborne illness is called food infection. A food infection cannot occur if the microbes are killed.

Food infections may be caused by bacteria, parasites, and viruses. A large number of living organisms usually required to cause illness. Symptoms are related to damage caused by the organisms feeding on their hosts.

Listeria Monocytogenes

Listeria is a foodborne infection caused by Listeria monocytogenes. This is a rod-shaped, gram-positive bacterium. It is found in soil, water, and many species of animals. Food sources include soft cheeses, uncooked meats, unwashed vegetables, and unpasteurized milk.

L. monocytogenes is harder to kill than many other foodborne pathogens. It can grow and multiply at refrigeration temperatures. It is aerobic, but it grows best at reduced oxygen levels combined with increased carbon dioxide. It can grow in 10% salt solutions and at a pH of 9.

Symptoms of listeriosis include fever, headache, nausea, diarrhea, and vomiting. Listeriosis can also cause infections in pregnant women, which can result in miscarriage or stillbirth. Nearly 25% of serious cases result in death.

Those at greatest risk are pregnant women, newborns, and people with weakened immune systems, including many older adults. General guidelines for reducing the risk of listeriosis include thoroughly cooking raw meat and poultry and carefully washing raw vegetables. In addition, people in high-risk groups should avoid eating soft cheeses, such as feta, Brie, and blue-veined cheeses. Those at risk should also heat all precooked foods and processed meats, such as deli meats and hot dogs, until they steam. See 18-8.

Salmonellae

Salmonella is a genus of rod-shaped, gram-negative, anaerobic bacteria. These microbes cause an illness called salmonellosis. The bacteria attach to the lining of the intestines and release digestive enzymes. These enzymes damage the tissue of the intestinal lining. It takes a large number of salmonellae to cause symptoms. However, a small number of bacteria can attach to the intestines and reproduce until illness results. Body fluids are pulled into the intestines, which causes diarrhea. Other symptoms include cramps, fever, nausea, vomiting, chills, and headache. Treatment includes giving fluids to prevent dehydration. Use of antibiotics has no noticeable benefit and leads to strains of salmonella that are resistant to antibiotics.

Less than 1% of all reported cases of salmonellosis end in death. This makes salmonellosis far less dangerous than botulism. However, there are so many cases of salmonellosis that far more people die from it than from botulism. Young children, older adults, and people with other illnesses are at the greatest risk.

The time between eating a contaminated food and the onset of salmonellosis is generally 6 to 48 hours. Symptoms in adults usually last only 2 to 3 days. However, symptoms may last longer in children.

The Centers for Disease Control estimate that eggs are involved in about 75% of all salmonellosis outbreaks. Other foods most likely to be contaminated with salmonella are poultry, beef, dairy products, and pork. Poultry and livestock producers are working to reduce the number of salmonellae that occur in animals before and during slaughter. Poultry and poultry products are major sources of salmonella for two main reasons. The first is that salmonellosis live in poultry without causing the birds to become sick. The second is the broad use of antibiotics in poultry feed to increase poultry production. Many of the strains of salmonella that commonly cause illness are resistant to antibiotics. Salmonellosa also multiply quickly when other microbes have been killed or reduced in number by antibiotics.

Care needs to be taken to prevent salmonella contamination during food preparation. Salmonellae are often spread from one food to another by food handlers. These bacteria can survive on people’s hands for hours before being transmitted to foods where they will thrive and multiply. Therefore, food handlers should keep work surfaces and hands clean.

To prevent salmonella growth, cold foods need to be kept cold, and hot foods need to be kept hot. Salmonellae grow very quickly between 30°C and 50°C (86°F and 122°F). When heating and chilling, foods need to be moved through this temperature range as quickly as possible. Foods that are cooked just before eating will usually be free of salmonella. Care must be taken to cook ground meat and poultry until they are thoroughly done. When meat is ground, the salmonellae can be mixed all through the meat. If hamburgers are still pink in the middle, salmonellae could still be alive in the center of the patty. Poultry should always be cooked until the juices run clear. See 18-9.

Raw or improperly cooked eggs are a potential hazard. Many uncooked recipes for homemade ice cream, Caesar salad, hollandaise sauce, and mayonnaise call for raw eggs.
Pasteurized eggs should be used in place of raw eggs in these dishes. Pasteurized eggs have been heated to kill bacteria such as salmonellae. Shell eggs should be cooked until the yolk is thickened and the white is firm. Scrambled eggs should be cooked until they are no longer runny. See 18-10.

**Parasitic Infections**

Most of the pathogens that cause foodborne illness are bacteria. However, some illnesses are caused by parasites. **Parasites** are organisms that live in and feed on a host. A host is an animal or plant from which a parasite receives nutrients. Some parasites that cause foodborne illness are commonly found in contaminated water supplies. Raw fish can be sources of these parasites. Fresh fruits and vegetables cleaned with contaminated water can be sources, too. Hogs, cattle, and wild animals are common hosts of other illness-causing parasites.

**Trichinella Spiralis**

*Trichinella spiralis* is probably the best-known parasite that causes foodborne illness. This parasite is a microscopic roundworm. It occurs in hogs and wild animals, such as bears, boars, and rabbits. Humans can also serve as hosts of *T. spiralis*. This parasite can enter a host as adult worms or larvae through infected food. **Larvae** are immature parasites that are often surrounded and protected by a capsule or pocket. Within the host, digestion breaks down the cysts, releasing the larvae into the host’s small intestines. The larvae feed and grow into adult roundworms. The adult worms attach themselves to the intestinal walls, where they produce new larvae. The new larvae penetrate the intestinal walls and travel in the bloodstream to muscle tissue. Once imbedded in the muscle, the larvae form protective cysts. *T. spiralis* can survive for years in the muscle tissue of the host.

An infection caused by *T. spiralis* is known as trichinosis. During the first phase of the illness, the symptoms include nausea, abdominal pain, and diarrhea. Once the larvae enter the muscle tissue, symptoms will include muscle pain and fever.

Prevention is the best protection against trichinosis. *T. spiralis* larvae are destroyed when meats are adequately cooked. Curing, smoking, and fermenting processes will also destroy the larvae. Pork used to be the most widely eaten source of this parasite. Inspection and production procedures have effectively eliminated *T. spiralis* from commercial pork, 18-11. The USDA has recommended processing procedures that should destroy any *T. spiralis* in cured pork products. The main source of *T. spiralis* in the United States today is game meats. Like pork, fresh game, such as bear, boar, and rabbit, should always be cooked to an internal temperature of 71°C (160°F). Freezing will kill the larvae if the meat is held at -15°C (5°F) for at least 30 days.

**Viral Infections**

Viruses are a third type of pathogen that can cause foodborne illnesses. A virus is a microscopic disease-causing agent made up of genetic material surrounded by a protein coating. The protein coating is called a capsid. Viruses do not multiply in food, but some viruses can be transmitted in food.

A virus must attach to a host cell. Genetic material from the virus is injected into the host cell. The genetic material can attach to the host cell’s genes. This causes the host cell to make more virus particles. Eventually the large number of virus particles causes the host cell to rupture and die. The virus particles are then freed to find new host cells and repeat the process. The nature of viral infections is related to which cells the virus can attach to and destroy.

Health experts do not know how many virus particles a person must ingest for illness to occur. This is because viruses are difficult to detect in food. Experts do know that viruses must survive stomach acids and digestive enzymes for any illness to develop. Studies have found that viruses remain stable and able to contaminate food in a wide range of situations. For instance, poliovirus was found on fruit and vegetable crops fertilized with contaminated sewage sludge. This virus was able to survive on the fruits and vegetables up to 36 days. Viruses can also survive

- on glass, stainless steel, and tile for up to eight weeks at room temperature
- on low-moisture foods for over two weeks at room temperature and more than two months when refrigerated
- in ground meat for 8 to 14 days at 4°C (39°F)

**Pasteurized eggs should be used in place of raw eggs in these dishes.** Pasteurized eggs have been heated to kill bacteria such as salmonellae. Shell eggs should be cooked until the yolk is thickened and the white is firm. Scrambled eggs should be cooked until they are no longer runny. See 18-10.

**Recommended Cooking Times for Eggs**

<table>
<thead>
<tr>
<th>Item</th>
<th>Time and Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunny side up</td>
<td>7 minutes, uncovered 4 minutes, covered</td>
</tr>
<tr>
<td>Over easy</td>
<td>3 minutes on one side then 2 minutes on the other side</td>
</tr>
<tr>
<td>Poached</td>
<td>5 minutes in boiling water</td>
</tr>
</tbody>
</table>

**Salmonellae**

Salmonellae are destroyed when egg dishes reach an internal temperature of 71°C (160°F).
Viruses are usually transmitted through the fecal-oral route. This refers to the consumption of any food or beverage that has come in contact with feces. A viral infection can be transmitted from contaminated feces to food in two main ways. The first is failing to wash hands after going to the bathroom and then handling food. The second is using sewage-contaminated water or fertilizer on food crops.

Four main types of viruses have been found to cause foodborne illness. These include Rotavirus, Norwalk virus, and hepatitis. Threat of the fourth type, poliovirus, has largely been eliminated in the United States by vaccinations.

**Rotavirus**
Rotavirus occurs most often in young children. By age five, most children have been infected with this virus and developed immunity. Flu-like symptoms, including vomiting, diarrhea, and low-grade fever, will last for 2 to 10 days. This viral infection is most common during winter months. Good hygiene practices are the best prevention. Any food handled by an infected person and then eaten without further cooking is a potential risk.

**Norwalk Virus**
Norwalk virus is named for the first documented outbreak, which occurred in 1968 among school children in Norwalk, Ohio. This virus causes a mild flu-like illness. People need to monitor their health and wash their hands frequently to help prevent the spread of hepatitis. They should also wear disposable gloves when handling foods just prior to serving. Anyone who has been exposed or is at risk of exposure can be given a vaccine called immune serum globalin.

**Hepatitis**
Hepatitis is a viral infection that attacks the liver cells. Hepatitis A, or infectious hepatitis, is the strain of hepatitis that can be transmitted through contaminated food. Flu-like symptoms will last for one to three days. Three to four weeks later, symptoms of liver infection develop. Cases are usually mild. More severe infections can lead to liver failure and death.

Hepatitis A is destroyed when food is cooked. Foods at risk are uncooked salad ingredients, raw shellfish, and any food requiring handling after cooking. People who buy shellfish should make sure the seafood has come from clean waters that are free from raw sewage. Shellfish should not be eaten raw. Clams dropped in boiling water until they opened seemed to be the cause of one hepatitis outbreak. This indicates that limited heating is not sufficient to destroy the virus. See 18-12.

Most outbreaks of hepatitis have been traced to infected food handlers. Infected food handlers can transmit hepatitis for 7 to 10 days before they develop any symptoms. Therefore, food handlers need to monitor their health and wash their hands frequently to help prevent the spread of hepatitis. They should also wear disposable gloves when handling foods just prior to serving. Anyone who has been exposed or is at risk of exposure can be given a vaccine called immune serum globalin.

New strains of microbes develop due to minor genetic differences in a small percentage of microbes. For instance, when antibiotics are given to chicken, most of the bacteria present are killed. However, a small percentage of the bacteria has some minor difference. This makes them harder to kill and allows them to survive. These bacteria will reproduce. The result will be a new strain of bacteria that is resistant to the antibiotic. New strains of microbes that withstand higher temperatures, lower pH ranges, or different air mixes develop in the same way.

It is important to understand how microbes can get into the food supply. There are two main ways food can become contaminated with pathogens. Pathogens can be transmitted by animals and through improper handling procedures.

**Transmission by Animals**
You may have noticed that many of the foods linked to food infections and food intoxications are from animal sources. Animals are hosts or carriers for many microbes. Protein-based foods from animal sources also provide an environment in which microbes can grow and multiply.

**Warm-Blooded Animal Carriers**
All warm-blooded animals have microbes living in and on them. Animals can transfer these microbes to food products. One way this can happen is by allowing food products to come in contact with animal feces.

An example of this is found in apple juice contaminated with E. coli bacteria. One way this juice might have been contaminated is by deer. E. coli live in the colons of humans and other mammals, including deer. If E. coli enter the stomach and small intestines, they can cause illness. In the colon, however, these bacteria help break down waste products. E. coli can be passed out of the body in feces.

Deer will feed on apples that grow on the lower branches of apple trees. Deer also excrete in apple orchards while eating. Apples that fall from the trees may come in contact with deer feces. These fallen apples are likely to be bruised and will quickly spoil. They can, however, be pressed to make apple juice. The apples need to be thoroughly washed or the juice needs to be pasteurized. Otherwise, the apple juice can become contaminated with E. coli from the deer feces.

Another way microbes from animals can end up in foods happens when the animals are used as meat sources. During slaughter and packaging, microbes on the surfaces of an animal are often transferred to the cuts of meat. If the meat is not properly handled and prepared, it can become a source of foodborne illness. See 18-13.

**Raw Fish**
Various parasites live in fish and shellfish. If the fish is eaten raw, these parasites can enter the digestive tract, causing illness and death. Popular raw fish dishes that are at risk of causing illness include sushi, oysters, clams, and mussels. The FDA has recommended a procedure for fish that will be consumed raw.
fish should be quick-frozen to -35°C (-31°F) for 15 hours. The fish can also be held in a commercial freezer at -20°C (-4°F) for 24 hours. The fish may then be thawed and eaten.

**Meat and Dairy Products**

Meats, milk, and eggs are often associated with foodborne illness. There are three key reasons for this. First, these foods all provide a medium in which microbes can thrive. Second, these are popular foods that are widely consumed in the U.S. diet. Third, many people are uninformed about how to handle these foods to prevent illness. For example, some people believe raw eggs are a healthful ingredient in a protein shake. These people are unaware that salmonellae can get into an egg before the shell is formed. They do not realize that drinking a shake containing raw egg puts them at risk for salmonellosis.

Avoiding food from animal sources is not a wise way to prevent foodborne illness. These foods are important sources of nutrients in the diet. Learning how to properly handle these foods is a more appropriate prevention strategy.

**Improper Handling Procedures**

Once food is contaminated, improper handling can allow the microbes to multiply and cause illness when eaten. Improper handling procedures can be divided into three groups.

- **time and temperature abuse**
- **poor personal hygiene**
- **cross-contamination**

**Time and Temperature Abuse**

The number one cause of foodborne illness is the failure to properly cool food. Most pathogens multiply rapidly between 4°C and 60°C (40°F and 140°F). This temperature range is referred to as the temperature danger zone. Foods at risk for pathogens should be kept cold or hot during storage, transportation, preparation, holding, and service. All refrigeration units must be below 4°C (40°F) and heating units must be at or above 60°C (140°F). As a rule, the total time a perishable food is in the danger zone should not exceed two hours. This time includes mixing time at room temperature, standing time before or after cooking, and holding time during meal service.

**Poor Personal Hygiene**

The food industry works hard to provide a safe food supply that is as free from contaminants as possible. The FDA, EPA, and USDA inspect and monitor the food supply. They strive to protect consumers from contaminants during the growth, production, and processing of food. However, food handlers and customers are one of the major causes of unsafe food. Sources of human contamination include hands, breath, unsanitary food preparation surfaces, unshielded coughs and sneezes, and perspiration.

**Cross-Contamination**

Cross-contamination occurs in food when a contaminated substance comes in contact with another food. Any surface that comes in contact with food will cause cross-contamination if microbes are present. For example, suppose you use a cutting board for deboning and slicing a raw chicken breast for a stir-fry. Salmonellae are on the surface of the chicken. The salmonellae get on the cutting board. You give the board a quick rinse with warm water. You then use the board to slice raw vegetables for a salad. The salmonellae will be transferred from the cutting board to the salad ingredients. Although salmonellae on the chicken will be killed during cooking, the salad is not cooked prior to eating. See 18-14. Cross-contamination can also occur when plant foods are harvested and come in contact with the soil around them.

**Uninformed or Careless Consumers**

All three major causes of foodborne illness are related to uninformed and careless consumers and food handlers. It does not matter whether food is contaminated by improper heating, poor personal hygiene, or cross-contamination. The result is illness for anyone who eats the contaminated food. It is important to remember that pathogens can make people ill long before the food will show signs of spoilage.

Any food, if improperly handled, can cause foodborne illness. The leading cause of food-related illnesses is consumers and food handlers who are ignorant or careless. A certain hunter is an example of a consumer who was ignorant of the dangers associated with eating some foods. This hunter decided to feed bear meat to friends at a cookout. The hunter mixed the bear meat with ground beef to conceal the taste. He did not tell anyone that part of the meat came from bear. Those who chose to have their burgers cooked to the well-done stage were fine. Those who chose to have their burgers cooked to the rare or medium stage became ill. In this case, the hunter did not know that bear meat is often contaminated with parasites. The guests were uninformed as to what they were eating.

The school cafeteria workers mentioned at the beginning of the chapter are an example of careless food handlers. The health department traced the illness to a potato salad made by a cafeteria worker trained in food safety. The worker had made the potato salad for a potluck luncheon held to honor retiring cafeteria workers. The worker left the potato salad on her kitchen table while she dressed for the potluck. Then she left the salad in her hot car when she made some stops on the way to the luncheon. (The temperature in a closed car on a hot, sunny day can quickly exceed 38°C, 100°F.) At the potluck, the potato salad was placed on the serving table almost an hour before everyone was served. By the time the salad was eaten, it had been at or above room temperature for over two hours. Half of the county cafeteria workers ate some of the salad. Those who ate the salad were too sick to report to work the next day. This type of problem can easily occur at picnics, community dinners, church potlucks, restaurants, and family gatherings.

**Storage Tips**

Observe the following precautions to reduce the risk of foodborne illness:

- **When in doubt, throw it out!**
- **Use older foods first. (Remember this tip by the acronym FIFO, which stands for first in, first out.)**
- **Reheat leftovers only once. Discard any uneaten reheated food.**
- **Use refrigerated leftovers within three to four days.**

**Food Industry Sanitation Procedures**

The food industry works with government agencies to set up guidelines that will prevent contamination or growth of microbes in foods. The food safety system used most often by U.S. food producers is called HACCP (Hazard Analysis and Critical Control Point). A HACCP system looks at every point in the food production process where contamination can occur. This system views a hazard as anything that could cause harm. Hazards include microbes, toxins, chemicals, and foreign objects in food. A critical control point is any point in a food operation where hazards can be removed, prevented, or minimized.

Meat and fish producers became required to phase in HACCP systems between 1998 and 2000. The FDA published rules mandating HACCP for fruit juice producers in January 2001. For producers of other food products, HACCP is voluntary. However,
The second step is to develop a flowchart for each procedure in the company, plant, or restaurant. Each point in the process where hazards can occur is identified.

The third step is to set standards that are needed at each control point. Standards must be specific and measurable. This step also involves determining procedures for maintaining the standards. Examples include monitoring temperatures of heating and cooling units, identifying cooking times, and defining cleaning procedures. Employees must be trained to follow procedure directions exactly.

Step four is to monitor the critical control points. Regularly checking equipment for accuracy and keeping thorough records of procedures are part of this process.

The fifth step is to correct any problems as soon as they are discovered. For example, chili is to be held at 60°C (140°F) until it is served. A supervisor performs a temperature check and discovers the chili is at 57°C (135°F). The supervisor then checks the records to see how long the chili has been on the holding unit. If the chili has been held for longer than two hours, it is discarded. If the holding time is less than two hours, the chili is immediately reheated to 74°C (165°F) for 15 seconds.

Step six is keeping records. Procedures are to be clearly written and posted. Time and temperature logs are dated and kept for each batch of food prepared or processed. These records provide legal verification of procedures used.

The last step is to have the HACCP system verified once it is in place. This is usually done by an official inspector from the FDA, USDA, or local health department.

**HACCP in the Meat Industry**

Beef Products, Inc. is one of the world’s leading producers of boneless lean beef. Their HACCP system is a 24-hour process. A sample of finished product is pulled from the line every 10 seconds. A sample is pulled from each box on every pallet. Samples are combined from enough beef packages to fill a pallet. This composite sample is analyzed for fat, water activity, and protein levels. Each box on each pallet is bar coded with the date and pallet information. Every two hours, a portion of all samples drawn are sent to an independent lab for microbial testing. Each 2-hour sample is tested for total plate count, E. coli, coliform, Salmonella, Listeria, Staphylococcus, and E. coli 0157:H7. In addition, a daily composite sample is sent to an independent outside lab for central nervous tissue testing. All packaged products are moved immediately after packaging to a 15-level cold storage unit that holds up to 28 million pounds of meat.

Once the meat is packaged, a fully automated system moves the packages through temperature-controlled areas. The pallet packaging area is held at 27°F; the holding freezer is 0°F to -5°F, and the loading dock is kept at 40°F. In addition, none of the meat is released for shipping until all the microbial profiles have been completed and the meat is found to be safe. No matter how thorough such a HACCP system is, the final safety of any food product depends on the retailer and the consumer continuing to handle, store, and prepare all foods appropriately.

**Government Regulation of the Food Industry**

The FDA and USDA are two of the federal agencies that monitor the safety of the food supply. They are mainly responsible for food produced and shipped across state lines. These agencies set standards that often represent the minimum needed for safety. For example, the standard for chilling a food after cooking may be to reach 0°C (32°F) within one hour. It is fine if the chilling time is less than one hour. However, it cannot exceed one hour.
Summary

Food becomes spoiled when contamination causes undesirable changes. Spoiled food is unpleasant but not necessarily harmful to your health. Spoiled food has an unpleasant taste, texture, odor, and/or appearance. Spoilage is usually a result of enzymes and microbes naturally found in the food. Illness can result when foods become contaminated with harmful substances. Some food illness is caused by the toxins released by microbial action as a by-product. Both the bacteria and the toxins produced must be destroyed to prevent illness. Other cases of food illness are caused by the microbes themselves. To protect your family and yourself from food contamination, it is helpful to understand the pathogens that cause illness. You need to know what they require to survive, grow, and multiply. Each microbe has a preferred food source, temperature, and pH range. This information is your best weapon for fighting food contamination. Pathogens have been found to enter the food supply in several ways. The first source is through animal carriers. The second source is improper handling procedures. Uninformed and careless consumers are a major source of pathogens in food.

Government agencies and the food industry work together to monitor and maintain a safe food supply. HACCP is an efficient food safety system that reduces the risk of foodborne illness and the need for frequent inspections. A safe food supply requires the cooperation and education of everyone involved in the handling of food.

Critical Thinking

1. After enjoying a buffet at a family reunion, many guests report having diarrhea, stomach cramps, and bleeding in the colon 24 hours later. Which microbe is the likely cause?
2. Why are county fair entries of low-acid canned goods simmered for 15 minutes before judges sample them to select the winners?
3. After eating Brie that has been kept well chilled, an older adult experiences diarrhea, vomiting, and fever. What microbe is the likely cause?
4. Why is it best to sweeten an infant’s hot breakfast cereal with sugar rather than honey?

Check Your Understanding

1. List the primary sources of contamination and give two examples of each.
2. Describe two ways that insects and rodents can damage or contaminate food.
3. Explain the difference between contamination, spoilage, and foodborne illness.
4. Compare and contrast the two ways that pathogens can cause illness.
5. List four common microbes that cause food intoxication and a common food source for each.
6. Why are poultry and eggs the main sources of salmonellosis?
7. Name a parasite that can cause foodborne illness and its most common food source.
8. Name three viral infections that can contaminate food.
9. What are the three reasons that meat and dairy products are often sources of foodborne illness.
10. Name three basic ways that food is handled improperly. For each, name a safety guideline to follow to reduce risk of foodborne illness.
11. List the seven steps of the HACCP process.
12. Who is responsible for monitoring the safety of the food supply?

Explore Further

1. Math. Research the number of cases of foodborne illness last year reported by the Center for Disease Control. Calculate the percentage of foodborne illness caused by intoxication versus infection.
2. Technology. Use the computer to create an attractive, attention-getting poster or handout on food safety procedures for the school’s Family and Consumer Sciences food labs.
3. Writing. Write an article for the school newspaper on how to safely handle and store foods to prevent foodborne illness.
4. Application. Use the HACCP process to develop a procedure for monitoring the safety of the laboratory during and after conducting this chapter’s experiments. How will you ensure that bacteria samples do not contaminate surfaces that will be used for food production by other classes.
5. Analytical Skills. Read a recent article on the use of antibiotics in our society. Report how antibiotics are made, why they become ineffective, and what you recommend regarding the food industry’s use of antibiotics in the future.
**Experiment 18A**

**Mold Growth in Foods**

**Purpose**
Molds are found nearly everywhere. Molds are hardier than bacteria and yeast. They grow over a wider range of pH and temperature and at higher salt concentrations. Although molds spoil food, most are not a health hazard. In 1961, a mycotoxin (a toxin generated by some molds) named aflatoxin was discovered. Aflatoxin damages the liver and is a known liver carcinogen. These toxins are extremely lethal and frequently heat stable. Cooking mold-contaminated food will not destroy the toxins. In this experiment, you will examine how molds grow on foods. This will help you determine the safety hazards of unidentified molds.

**Equipment**
- paring knife
- microscope slides
- microscope

**Supplies**
- 1 slice apple
- ½ slice preservative-free bread
- 1 slice cheese
- 3 closed containers or resealable plastic bags

**Procedure**
1. Cut a piece as thin as possible off slices of apple, bread, and cheese.
2. Place each sample on a microscope slide.
3. Observe each sample under a microscope. Record your observations and draw a sketch of what you see in a data table.
4. Place the rest of the half slice of bread in a container or resealable plastic bag so there are 3 to 5 cm of airspace above the bread. Seal the container and label it with your lab group name or number.
5. Place the apple slice in a second container and the cheese slice in a third container, just like the bread. Label both containers with your lab group name or number.
6. Place all three containers on a table or window sill as directed by your teacher.
7. Each day, examine the food samples for visible mold growth.
8. When mold is visible, use a knife to remove a small piece of the aerial (above the food) mold from the bread. Place it on a slide.
9. Observe the mold under a microscope. Record your observations and draw a sketch in the data table.
10. Repeat steps 8 and 9 for the apple and cheese.
11. Scrape the visible mold from the surface of each food.
12. Cut a thin, cross-sectional sample of each food.
13. Place each sample on a slide and observe it under a microscope. Look for signs of submerged (under the surface) mold growth in the food. Record your observations and draw a sketch in the data table.
14. Discard all food samples and clean all surfaces with a sanitizing solution.

**Questions**
1. What texture changes occurred on moldy samples?
2. What, if any, differences were there in the appearance of the molds on each of the three samples?
3. How deeply does mold appear to grow into each of the three foods?
4. How can mold growth be prevented or delayed?

**Safety**
- Do not taste any of the samples.
- Clean all surfaces with a sanitizing solution at the end of the experiment.
Purpose
Bacteria is present everywhere. It is not visible unless it has grown into a large colony known as a *culture*. Cultures can be isolated and studied by microbiologists. Bacteria is placed in petri dishes on a substance called agar. Agar cools into a gel and contains nutrients that aid the growth of bacteria. In this experiment, you will collect bacteria samples and incubate them to grow cultures.

Equipment
- wax pencil
- incubator

Supplies
- 1 disposable petri dish with agar per student
- clear cellophane tape

Procedure
Day 1
1. Use a wax pencil to write your name on the outside of the lid of your petri dish. Draw two intersecting lines on the bottom of the dish to divide the dish into four quarters.
2. Tear off a short piece of cellophane tape. It should be long enough to fold in half with the sticky side out.
3. Gently press the sticky side of the folded tape against the surface to be tested. Immediately lift the lid of the petri dish and gently press the folded tape against the agar in one section of the petri dish. Quickly re-cover the petri dish and label the quarter on the bottom of the dish to indicate the surface tested.
4. Repeat steps 2 and 3 to test one other surface, as assigned by your teacher.
5. Lift the lid of the petri dish and gently place your thumb on a third quarter of the agar. Light pressure will reveal a thumbprint. Too much pressure will crack the agar. Label this quarter *unwashed*.
6. Wash your hands and then place a thumbprint in the last quarter of the petri dish. Label this quarter *washed*.
7. Tape the lid onto the petri dish. Turn the dish upside down and place it in an incubator as instructed by your teacher.
8. Your teacher will incubate the petri dishes at 37°C for 24 to 48 hours.

Day 2
1. Record descriptions of the bacteria colonies on your petri dish.
2. Examine the samples prepared by your teacher and record descriptions. One is the control that did not have the lid removed. The second was left open to the air for 15 minutes while samples were collected.
3. Examine the samples prepared by your classmates.

Questions
1. What procedure did you use to wash your hands?
2. How did the culture from your thumbprint compare to the cultures of your classmates’ thumbprints?
3. What, if any, difference did the hand-washing procedure used make in bacterial growth?
4. Did you find any sterile surfaces (surfaces that were free of bacteria)?
5. How easy is it to transfer bacteria from one place to another?
6. What differences did you observe between the control and the petri dish that was left open for 15 minutes? How could a culture start to grow on the dish that was left open?
Purpose
Bacteria are small and hard to see, even if magnified 1,000 times. To examine bacteria, scientists spread a mixture of bacteria and distilled water on a slide to prepare a smear. The slide is air dried before being passed over an open flame several times to heat fix the bacteria to the slide. Failing to dry the slide before heating will cause the heated water to distort the shape of the cells. The spread may be stained to determine whether the bacteria is gram-positive or gram-negative. You will also identify the shape of the bacteria cells.

Equipment
wax pencil
inoculating loop
gas flame source (Bunsen burner, gas stove)
1 clothespin per student
beaker or bowl
eyedropper
2 wash bottles
oil immersion microscope

Safety
❖ Do not taste any of the samples.
❖ Clean all surfaces with a sanitizing solution at the end of the experiment.
❖ Dispose of all bacterial cultures according to teacher directions.

Supplies
1 new microscope slide per student
 distilled water
petri dish with bacteria cultures from Experiment 18B
1 to 2 drops crystal violet
Gram’s iodine
ethyl alcohol
safranin
microscope tissue paper
2 drops immersion oil

Procedure
Preparing a Smear
1. Handle a new microscope slide by the edges. With a wax pencil, make a dime-sized circle in the center of the slide.
2. Sterilize your inoculating loop by holding it over a gas flame source until the loop is red hot.
3. Using the inoculating loop, place 1 or 2 loopfuls of distilled water in the center of the circle.
4. Sterilize your loop again. Allow the loop to cool so any bacteria you pick up with it will not be destroyed. Cooling takes about 30 seconds.
5. Use the sterilized loop to scrape a small amount of one of the bacteria cultures grown in Experiment 18B from the petri dish. Mix the culture with the water on the slide.
6. Spread the bacteria evenly within the ring.
7. Allow the smear to air dry. This will take about 2 to 4 minutes. Do not blow on the slide, as this will cause cell positions to shift.
8. After the slide is completely dry, use a clothespin to hold the slide as you pass it over the gas flame two or three times.

Gram’s Staining
1. Hold the slide over a beaker, bowl, or sink.
2. Use an eyedropper to cover the smear with 1 or 2 drops of crystal violet. Wait 30 seconds.
3. Wash the slide with distilled water from a wash bottle. Do not squirt the water directly on the smear but on the slide above it.
4. Cover the smear with 1 or 2 drops of Gram’s iodine. Wait 30 seconds.
5. Wash the slide with ethyl alcohol from a wash bottle until the alcohol runs clear.
6. Cover the smear with 1 or 2 drops of safranin. Wait 30 seconds.
7. Wash the slide with water from a wash bottle. Blot dry with microscope tissue paper.
8. Place the slide on the stage of an oil immersion microscope. Focus the microscope on the lowest setting.
9. Increase the magnification and fine-tune the focus.
10. Turn the lenses so 2 drops of immersion oil can be placed in the center of the circle on the slide.
11. Turn the 1000x immersion oil lens into place. Fine-tune the focus.
12. Sketch the bacteria and record observations. Identify the shape and gram type of bacteria seen.
13. If time allows, move to other stations to examine bacteria smears prepared by classmates.
14. Dispose of petri dishes with bacteria cultures and slides according to teacher directions. Wash all surfaces used with a sanitizing solution.

Questions
1. What types of bacteria were found?
2. Why is it important to wash the slide after each staining step?
3. Why do many doctors’ offices swab patients’ throats and conduct Gram’s stain tests on the bacteria collected?
4. What can food preparation workers do to help reduce contamination of food by bacteria?