



# Basic Facts About Microorganisms

In this chapter, find answers to the following questions:

**What are the most common causes of foodborne illnesses?** ..... (page 29)

**What are the major foodborne illnesses caused by bacteria and how can they be prevented?** ..... (pages 29-35)

**Botulism** ..... (pages 30)

**Campylobacteriosis or campylobacter** ..... (page 30)

**E. coli infection** ..... (page 31)

**Listeriosis** ..... (page 32)

**Perfringens foodborne illness** ..... (page 32)

**Salmonellosis** ..... (page 33)

**Shigellosis (bacillary dysentery)** ..... (page 34)

**Staphylococcal foodborne illness** ..... (page 34)

**What are the major foodborne illnesses caused by viruses and how can they be prevented?** ..... (pages 35-36)

**Gastroenteritis from Norwalk and**

**Norwalk-like Viruses/calicivirus** ..... (page 35)

**Hepatitis A** ..... (page 36)

**What are the major foodborne illnesses caused by fungi and how can they be prevented?** ..... (page 36)

**Molds** ..... (page 37)

**Yeasts** ..... (page 37)

*Continued on next page*

**What are the major foodborne illnesses caused by parasites and how can they be prevented?** ..... (pages 38-40)

**Cyclosporiasis** ..... (page 38)

**Giardiasis** ..... (page 39)

**Trichinosis** ..... (page 39)

**How do microorganisms grow?** ..... (pages 40-46)

**Stages of Growth** ..... (pages 40-41)

**Control Conditions to Prevent the Growth of Foodborne Microorganisms** ..... (pages 41-46)

**Summary** ..... (page 46)

**Check Your Knowledge—Growth of Harmful Microorganisms** ..... (page 47)



# Basic Facts About Microorganisms

## What are the most common causes of foodborne illnesses?

Most foodborne illnesses are caused by harmful microorganisms—tiny, living organisms that are so small they can be seen only with a microscope. There are two groups of microorganisms.

**Pathogens** are harmful microorganisms that cause some form of illness. Consuming a food or beverage contaminated with pathogens is the main cause of foodborne illness.

- **Bacteria** are the group of pathogens of greatest concern in foodservice.
- **Viruses** represent another group of pathogens that can cause foodborne illness.

**Spoilage microorganisms** include two groups of fungi: molds and yeasts. These microorganisms spoil food and may cause illness. More detail about pathogens and spoilage microorganisms can be found in later sections of this chapter.

Foodborne illness can also be caused by **parasites**. These are small organisms that live in a host organism such as cattle, swine, or fish. Proper cooking can kill parasites. More detail about parasites can be found in later sections of this chapter.

## What are the major foodborne illnesses caused by bacteria and how can they be prevented?

Bacteria are responsible for most outbreaks of foodborne illness. The word “bacteria” is actually the plural of the Latin word “bacterium.”

- A bacterium is a living organism made up of a single cell that can grow and reproduce.
- Some bacteria actually cause disease while other bacteria produce poisons, called toxins, as they multiply.
- Some bacteria produce thick-walled spores that are resistant to boiling, freezing, and some sanitizing solutions.

Being familiar with the harmful microorganisms that cause most foodborne illness is important in learning how to prevent foodborne illness. Major foodborne illnesses and the harmful microorganisms that cause them have been described in alphabetical order.

## BACTERIA

### Botulism (BOT-u-li-zum)

#### **Bacteria:** *Clostridium botulinum*

Foodborne botulism is a life-threatening illness caused by consumption of food contaminated with preformed neurotoxin produced by *Clostridium botulinum*. The bacteria and its toxin can be destroyed with thorough cooking at high temperatures. Although cases of botulism are not often seen, when untreated it can cause death. Symptoms usually begin from 18 to 36 hours after eating the contaminated food. Symptoms may begin with diarrhea or constipation; weakness; dizziness; double vision or blurred vision; difficulty speaking, swallowing, and breathing; and paralysis. Death can occur if the illness is not treated immediately and properly.

**Foods involved in outbreaks:** Foods that have been the cause of botulism include home-canned foods, improperly processed foods, and foods not stored at the proper temperature. Some specific examples of foods that have caused botulism are sausages; meat products; canned low-acid foods such as certain vegetables; untreated garlic-and-oil products; leftover, unrefrigerated foil-wrapped baked potatoes; and sautéed onions in butter sauce.

#### **Prevention**

- Discard a bulging can, a container with a bulging jar lid, a can that spurts liquid when opened, dented cans, and cracked jars.
- Do not use home-canned foods in a foodservice establishment.
- Do not mix and then store oil and garlic; buy only treated oil and garlic products and keep them refrigerated.
- Follow rules for time and temperature control.
- Sauté onions as needed; do not sauté and then store unrefrigerated, for later use.
- Do not store leftover baked potatoes in foil wrapping. Unwrap and chill correctly.
- Chill cooked hot foods from 135 °F to 70 °F within 2 hours and from 70 °F to 41 °F in an additional 4 hours for no more than a total cooling time of 6 hours. If the food has not reached 70 °F within 2 hours, it must be reheated immediately to 165 °F for 15 seconds.

### Campylobacteriosis or *Campylobacter* (CAM-py-lo-BAC-ter-i-osis)

#### **Bacteria:** *Campylobacter jejuni* (cam-py-lo-bac-ter je-jun-i)

After eating a food with these bacteria, symptoms are typically experienced in 2 to 5 days. Symptoms include diarrhea (watery or bloody), fever; nausea and vomiting, abdominal pain, headache, and muscle pain. It is the leading cause of bacterial diarrhea in the United States. The symptoms can last from 7 to 10 days and relapses are common.

**Foods involved in outbreaks:** Foods that can be contaminated with these bacteria include unpasteurized milk and dairy products, raw poultry, raw beef, and nonchlorinated or fecal-contaminated water. Birds and flies can also carry these bacteria and contaminate foods.

### Prevention

- Practice good personal hygiene.
- Follow handwashing guidelines.
- Follow procedures for avoiding cross-contamination.
- Cook all poultry, meat, and other foods to the required safe internal temperature and test with a food thermometer.
- Maintain good pest control.
- Use only pasteurized dairy products.
- Use water from approved sources.

### E. coli infection (e-CO-ly)

**Bacteria:** *Escherichia coli* O157:H7

*E. coli* O157:H7 is a bacterium that produces Shiga toxin, a poisonous substance that causes severe symptoms. *E. coli* infection is characterized by severe cramping and diarrhea, which begins as watery but may become bloody. Sometimes vomiting occurs. Some young children with this illness develop a Hemolytic Uremic Syndrome (HUS) that causes kidney failure and permanent loss of kidney function leading to death. The symptoms can be seen from 3 to 8 days after eating the contaminated food and last from 2 to 9 days.

**Foods involved in outbreaks:** These dangerous bacteria are found in the intestinal tract of animals, particularly cattle and humans. Foods that may be contaminated with these bacteria include raw or undercooked ground beef, raw milk or dairy products, unpasteurized apple cider or juice, imported cheeses, dry salami, and uncooked fruits and vegetables.

### Prevention

- Practice good personal hygiene.
- Follow procedures for avoiding cross-contamination.
- Cook all poultry, meat, and other foods to the required safe internal temperature and test with a food thermometer.
- Use only pasteurized milk, dairy products, or juices.
- Wash all fresh produce that will be served whole, peeled, or cooked in cold, running water.
- Chill cooked hot foods from 135 °F to 70 °F within 2 hours and from 70 °F to 41 °F in an additional 4 hours for no more than a total cooling time of 6 hours. If the food has not reached 70 °F within 2 hours, it must be reheated immediately to 165 °F for 15 seconds.


**Listeriosis (lis-TIR-ee-o-sis)**
**Bacteria:** *Listeria monocytogenes*

Listeriosis is a serious foodborne illness with early symptoms similar to flu, including the sudden onset of fever, muscle aches, and sometimes diarrhea or vomiting. The severity of the symptoms may vary. If the infection spreads to the nervous system, the symptoms may include headaches, stiff neck, confusion, loss of balance, or convulsions. The symptoms may be seen as early as 3 days or as late as 70 days, but usually appear about three weeks after eating contaminated food.

Listeriosis can be particularly dangerous for pregnant women and their unborn babies. Foodborne illness caused by *Listeria* in pregnant women can result in premature delivery, miscarriage, fetal death, and severe illness or death of a newborn from the infection.

Foods involved in outbreaks: *Listeria* bacteria can be found in soil and ground water, on plants, and the intestinal tracts of humans and animals. These bacteria can contaminate unpasteurized milk and cheeses, ice cream, raw vegetables, raw and cooked poultry, all raw meats, raw fish, prepared and chilled ready-to-eat foods, deli meats, luncheon meats, hot dogs, and certain soft cheeses such as feta, Brie, blue-veined cheese, and Mexican-style cheeses (example: “queso blanco fresco”). *Listeria* bacteria can grow at refrigerated temperatures as low as 37.4 °F, as well as in damp environments.

**Prevention**

- Practice good personal hygiene.
- Follow procedures for avoiding cross-contamination.
- Cook all poultry, meat, and other foods to the required safe internal temperature and test with a food thermometer.
- Use only pasteurized milk, dairy products, or juices.
- Wash all fresh produce that will be served whole, peeled, or cooked in cold, running water.
- Clean and sanitize food contact surfaces.
- Keep equipment, food preparation surfaces, and facilities dry.


***Perfringens* foodborne illness (per-FRING-ens)**
**Bacteria:** *Clostridium perfringens*

Severe abdominal cramping and diarrhea characterize *perfringens* foodborne illness. Usually there is no vomiting. The symptoms usually show up from 8 to 24 hours after eating the contaminated food, and they are usually over in 24 hours. The bacteria can be found in the intestinal tracts of humans and animals and can live in soil. These bacteria grow only in little or no oxygen.

**Foods involved in outbreaks:** *Clostridium perfringens* bacteria are called the “cafeteria germs” because many foodborne outbreaks result from food left for long periods on steam tables at improper temperatures or at room temperatures. Foods usually associated with this kind of foodborne illness are cooked meat and poultry, gravy, and beans. The bacteria grow when contaminated foods are not cooked to the right temperature or are not cooled properly. Cooking to required internal temperatures destroys bacteria, but some toxin-producing spores may survive.

### Prevention

- Practice good personal hygiene.
- Follow procedures for avoiding cross-contamination.
- Cook all poultry, meat, and other foods to the required safe internal temperature and test with a food thermometer.
- Chill cooked hot foods from 135 °F to 70 °F within 2 hours and from 70 °F to 41 °F in an additional 4 hours for no more than a total cooling time of 6 hours. If the food has not reached 70 °F within 2 hours, it must be reheated immediately to 165 °F for 15 seconds.

### Salmonellosis (SAL-mon-el-osis)

**Bacteria:** *Salmonella* bacteria

Symptoms of this foodborne illness can occur as early as 6 hours after eating a contaminated food or up to 48 hours later. Symptoms include stomach cramps, headache, nausea, fever, diarrhea, and sometimes vomiting. For infants and seniors (older adults), severe dehydration may result. The illness usually lasts 1 to 2 days.

**Foods involved in outbreaks:** The bacteria is found in a variety of foods that have been contaminated by soil, insects, and the intestinal wastes from domestic or wild animals and from humans. Foods most often associated with *Salmonella* bacteria include raw meats, poultry; eggs, milk and dairy products; fish; shrimp; yeast; coconut; sauces and salad dressing; cake mixes; cream-filled desserts and toppings; dried gelatin; peanut butter; cocoa and chocolate; sliced fresh fruits and vegetables such as melons, strawberries, and tomatoes; raw sprouts; and other produce.

### Prevention

- Practice good personal hygiene.
- Follow procedures for avoiding cross-contamination.
- Cook all poultry, meat, eggs, and other foods to the required safe internal temperature and test with a food thermometer.
- Chill cooked hot foods from 135 °F to 70 °F within 2 hours and from 70 °F to 41 °F in an additional 4 hours for no more than a total cooling time of 6 hours. If the food has not reached 70 °F within 2 hours, it must be reheated immediately to 165 °F for 15 seconds.


**Shigellosis (bacillary dysentery) (SHIG-a-losis)**
**Bacteria:** *Shigella* bacteria

These bacteria come from the human intestinal tract and are found in polluted water and are spread by flies and by food handlers with poor personal hygiene. Symptoms begin after 12 to 50 hours and last from a few days up to 2 weeks. Symptoms include abdominal pain, diarrhea containing blood and mucus, fever, nausea, vomiting, chills, fatigue, and dehydration.

**Foods involved in outbreaks:** The foods most often involved in outbreaks include meat salads, potato and pasta salads, lettuce and other raw vegetables, milk and dairy products, and moist and mixed foods.

**Prevention**

- Practice good personal hygiene.
- Follow procedures for avoiding cross-contamination.
- Use water from approved sources.
- Control flies.
- Chill cooked hot foods from 135 °F to 70 °F within 2 hours and from 70 °F to 41 °F in an additional 4 hours for no more than a total cooling time of 6 hours. If the food has not reached 70 °F within 2 hours, it must be reheated immediately to 165 °F for 15 seconds.


**Staphylococcal foodborne illness (STAFF-y-lo-COC-al)**
**Bacteria:** *Staphylococcus aureus*

Produces an enterotoxin (or toxin) that can cause foodborne illness. A toxin is a poisonous substance produced by a living organism such as bacteria. Symptoms of staphylococcal foodborne illness begin soon after eating the contaminated food and include nausea, vomiting, stomach cramping, and exhaustion. Victims usually recover in 2 or 3 days.

**Foods involved in outbreaks:** Humans and animals are the main carriers of these bacteria. In fact, it is estimated that half or more of all healthy people have “staph” bacteria present on their skin and hair and in their nose and throat. Food handlers are usually the main source of food contamination with these bacteria. Foods that are most often associated with outbreaks include leftovers, meat and poultry, eggs and products containing eggs, milk and dairy products, meat salads and potato salad, salad dressings, and sandwich fillings.



**Prevention:**

- Practice good personal hygiene.
- Follow procedures for avoiding cross-contamination.
- Cover a burn, cut, or wound with a waterproof bandage and wear disposable gloves while preparing and serving food.
- Cook all poultry, meat, and other foods to the required safe internal temperature and test with a food thermometer.
- Refrigerate food at 41°F or below.
- Chill cooked hot foods from 135 °F to 70 °F within 2 hours and from 70 °F to 41 °F in an additional 4 hours for no more than a total cooling time of 6 hours. If the food has not reached 70 °F within 2 hours, it must be reheated immediately to 165 °F for 15 seconds.

---

**What are the major foodborne illnesses caused by viruses and how can they be prevented?**

Viruses are another type of pathogen that can contaminate food and beverages. Unlike bacteria, viruses cannot reproduce outside a living organism because they are not complete cells. Therefore, they do not multiply in food but rather may be transported on food, food surfaces, and utensils. Once inside a human host, they can reproduce and cause foodborne illness.

Viral outbreaks are most commonly associated with poor personal hygiene or a contaminated water supply. However, they can also be food-related.

For example, eating raw or undercooked shellfish such as oysters, mussels, and clams that have been harvested from polluted water may cause foodborne viral illnesses. As a result, seafood should always be purchased from vendors with approved health-inspected facilities.

Prevention of viral contamination should include good personal hygiene, correct handwashing, good employee health (no fever and no diarrhea), and no bare-hand contact with ready-to-eat food.

Some common viruses and the foodborne illnesses they cause are described on the following pages.

## VIRUSES

### Gastroenteritis from Norwalk and Norwalk-like viruses/calicivirus (ca-LEE-see-virus)

**Virus:** Norwalk and Norwalk-like viral agents

These viruses cause a foodborne illness with symptoms of nausea, vomiting, diarrhea, abdominal pain, headache, and mild fever. These viruses come from the human intestinal tract and are transmitted through water or food. Only the common cold is reported more frequently than viral stomach upset. The symptoms begin from 1 to 2 days after the contaminated food or water is eaten, and they last for 1 to 3 days.

**Foods involved in outbreaks:** Contaminated drinking water is a source of these viruses as is shellfish from contaminated water. Other foods that can be contaminated, often by dirty hands, include raw vegetables, fresh fruits, and salads.

#### Prevention

- Practice good personal hygiene.
- Follow procedures for avoiding cross-contamination.
- Wash all fresh produce that will be served whole, peeled, or cooked in cold, running water.
- Use water from approved sources.
- Obtain shellfish from approved health-inspected sources and cook thoroughly.
- Cook all foods to required safe internal temperatures and test with a food thermometer.

### Hepatitis A (HEP-a-tie-tus)

**Virus:** *Heptovirus* or Hepatitis A virus

This virus is found in the human intestinal tract and urinary tract and also in contaminated water. The symptoms begin with a fever and also include fatigue, headache, nausea, loss of appetite, vomiting, stomach pain, and later jaundice (yellow skin and eyes). Symptoms may be seen 10 days to almost 2 months after the contaminated food or water is consumed.

**Foods involved in outbreaks:** Foods involved in Hepatitis A outbreaks have usually been contaminated by food handlers, either in processing plants or foodservice facilities. Water, ice, and most foods can be contaminated. Foods that are of particular concern are those that will not receive further cooking such as deli meats, sandwiches, fruit and fruit juices, milk and dairy products, raw fruits and vegetables, and salads.

### Prevention

- Practice good personal hygiene.
- Follow procedures for avoiding cross-contamination.
- Wash all fresh produce that will be served whole, peeled, or cooked in cold, running water.
- Use water from approved sources.
- Cook all foods to the required safe internal temperature and test with a food thermometer.

### What are the major foodborne illnesses caused by fungi and how can they be prevented?

Yeasts, molds, mildew, and mushrooms are all types of fungi found naturally throughout the environment. The two kinds of fungi that typically cause spoilage in a foodservice operation are molds and yeasts.

Bacteria and viruses can cause foodborne illness before food spoilage is evident; molds and yeasts actually cause food spoilage.

#### Molds

Although individual mold cells are microscopic, they grow quickly and soon become visible to the naked eye. Molds spoil food, causing discoloration, and an unpleasant smell and taste. Most people have seen mold on bread and on cheese.

Molds can grow on almost any food in any condition – moist, dry, acidic, non-acidic, salty, sweet, cold, and warm. A few cheeses, such as Brie, are processed to have a natural and safe mold coating. Examples of foods that are susceptible to mold include fruits, vegetables, meats, cheeses, and breads.

**Toxins can be dangerous.** Contrary to popular belief, certain molds can be dangerous to humans. They produce toxins, some of which have been linked to cancer in animals and to rare, isolated incidents of foodborne illness. Other molds can cause serious infection and allergies. Aflatoxin, which is produced by two specific molds, can cause liver disease.

**Discard molded food.** Discard any food with visible mold unless the mold is a natural part of the food such as Brie, Camembert, Gorgonzola, and bleu cheese. Although the cells and spores of molds can be killed by heating foods to 140 °F for 10 minutes, the *toxins are heat stable* and are not destroyed.


**Yeasts**

Jellies, honey, syrup, and fruit juices often harbor sugar-loving yeasts. While there is no evidence that yeasts found in food cause illness, they do spoil food, as evidenced by bubbles and an alcoholic smell or taste. Any food that has an unnatural color or smell should be discarded.

### What are the major foodborne illnesses caused by parasites and how can they be prevented?

A parasite is a living organism that depends on nutrients from a living host to complete its life cycle. Ranging in size from tiny, single-celled organisms to worms visible to the naked eye, parasites are more and more frequently being identified as causes of foodborne illness in the United States. Parasites can live in many animals that are used for human food including pigs and hogs, cattle, poultry, and fish. Parasites can be transmitted from animals to humans, from humans to humans, or from humans to animals. The illnesses they can cause range from mild discomfort to debilitating illness and possibly death.

This section describes three foodborne illnesses caused by parasites. Information on other common parasites can be obtained from USDA's Meat and Poultry Hotline (800-535-4555).



## PARASITES


**Cyclosporiasis (CY-clo-spo-RYE-a-sis)**

**Parasite:** *Cyclospora cayetanensis*

This tiny parasite is responsible for an increasing number of foodborne illnesses. Symptoms include watery diarrhea, stomach cramps, nausea, vomiting, muscle aches, low-grade fever, and fatigue. Some cases are without symptoms. The symptoms appear about a week after the parasite has been ingested and can last from a week up to a month.

**Foods involved in outbreaks:** The parasite may be in contaminated water, or it may be in or on anything that has touched the stool of a person or animal with cyclosporiasis. In recent years, outbreaks have involved berries from outside the United States, mixed lettuce products, and fresh herbs.

#### Prevention

- Practice good personal hygiene.
- Follow procedures for avoiding cross-contamination.
- Wash all fresh produce that will be served whole, peeled, or cooked in cold, running water.
- Use water from approved sources.

 **Giardiasis (GEE-are-DYE-uh-sis)****Parasite:** *Giardia duodenalis*

This microscopic parasite is found all over the world and can live in the intestines of animals and people. It is most frequently associated with waterborne illness but can cause foodborne illness. Symptoms include diarrhea, stomach cramps, and nausea. The symptoms appear from about 1 to 2 weeks after the parasite has been ingested and can last from 4 to 6 weeks. Sometimes there are no symptoms.

**Foods involved in outbreaks:** The parasite may be in contaminated water, or it may be in or on anything that has touched the stool of a person or animal with giardiasis. Adults and children in daycare centers are at risk.

**Prevention**

- Practice good personal hygiene.
- Use only pasteurized milk, dairy products, and juices.
- Wash all fresh produce that will be served whole, peeled, or cooked in cold, running water.
- Use water from approved sources.

 **Trichinosis (TRICK-a-NO-sis)****Parasite:** *Trichinella spiralis*

This parasite looks like a small, hairy, round worm. People contract trichinosis by eating undercooked pork or game that is infested with *Trichinella* larvae. Fortunately, there has been much progress in reducing *Trichinella* in grain-fed hogs. As a result, human cases of trichinosis are now on the decline, but it is still important to take precautions. Symptoms of trichinosis include nausea, vomiting, and abdominal pain. The symptoms appear anywhere from 2 to 28 days after eating infected meat. Later symptoms may develop to include sore muscles, a fever, or a rash.

**Foods involved in outbreaks:** Foods that could contain *Trichinella* larvae include undercooked pork and pork sausages. Ground meats could be contaminated through meat grinders that have been used to grind contaminated pork.

**Prevention**

- Cook all meat to the required safe internal temperature to destroy any live *Trichinella* larvae and test with a food thermometer.
- Prevent cross-contamination by washing and sanitizing equipment used in preparation of raw pork products, such as meat grinders and slicers.

The harmful microorganisms discussed in this section include bacteria, viruses, fungi, and parasites. These microorganisms are the most common food contaminants and can result

in foodborne illness. Knowing more about these pathogens and understanding how they can contaminate food will serve as an important reminder for foodservice personnel to use preventive measures.

## How do microorganisms grow?

### Stages of Growth

Bacteria are considered *vegetative* because they can grow and reproduce. Under certain conditions, they will reproduce very rapidly. In fact, in an environment that is ideal for growth, a single bacterial cell can turn into *billions* in only 10 to 12 hours!

Certain vegetative bacteria protect themselves by producing a thick-walled spore within the bacterial cell. A spore can become dormant and survive unfavorable environmental conditions such as boiling water, freezing temperatures, and some sanitizing solutions.

Given warmth, moisture, and a little food, bacterial spores may become vegetative and reproduce very easily. The vegetative cell simply enlarges and splits in two; these “offspring” then divide to create two more bacteria, and so on. This type of reproduction results in extremely rapid population growth.

Time	0 min	20 min	40 min	1 hour	1 hr 20 min	10 hr
#cells	1 cell ●	2 cells ●●	4 cells ●●●●	8 cells ●●●● ●●●●	16 cells ●●●●●● ●●●●●●	1 billion cells

When bacteria multiply, growth happens in four phases.

**PHASE 1: Lag phase**—When a food is contaminated with bacteria, the bacteria take some time to adjust. They do not grow much but get ready to grow. When the bacteria’s requirements for growth are minimized, they remain in the lag phase and rapid growth is prevented.

**PHASE 2: Log phase**—When the bacteria’s growth requirements are met, they can multiply rapidly by splitting in two. Bacteria in the log phase can double their number every twenty minutes. During this phase, a contaminated food becomes unsafe to eat. Bacteria continue to grow until the conditions they need deteriorate.

For most harmful microorganisms, the number of bacteria needed to cause a foodborne illness is very small.

**PHASE 3: Stationary phase**—If bacteria continue to grow, they reach a phase where the conditions are no longer favorable, and they begin to die. When some bacteria are still growing but the same numbers are dying, the bacteria are in the stationary phase.

**PHASE 4: Death phase**—This last phase means that more bacteria are dying than are growing.



### Heat kills bacteria!

- Heating foods to recommended safe internal temperatures kills vegetative bacteria and parasites. However, some bacteria can change into a different form called a spore.
- The spore forms a thick wall around the bacteria for protection; then the bacteria can survive conditions such as high or low temperatures, low moisture, and high acidity.
- A spore cannot grow, but when conditions are right again, the spore returns to the vegetative state and begins to grow.
- This explains why it is so important to cook foods to the right temperatures, chill them rapidly to 41 °F or below, and then reheat them to safe temperatures.

### Control Conditions to Prevent the Growth of Foodborne Microorganisms

Certain conditions affect the growth and reproduction of microorganisms. Except for viruses, all foodborne microorganisms need food, the right amount of acidity, appropriate temperature, time to grow, and water. Some bacteria need oxygen and others thrive without oxygen. **Because food handlers never know when a food has been contaminated with harmful microorganisms, the safe way to handle food means controlling the conditions needed for the growth of microorganisms.**

The acronym, FAT-TOM, is one way to remember the six conditions that can be regulated to control the growth of most microorganisms.

#### Control Conditions = Prevent Growth

- F** Food
- A** Acidity
- T** Temperature
- T** Time
- O** Oxygen
- M** Moisture

**F - Food****Condition for Growth: Food****How Food contributes to growth of bacteria**

Bacteria feed on protein and carbohydrates. Food that contains these ingredients can support growth of foodborne bacteria.

The *Food Code* defines potentially hazardous food as one that is natural or synthetic and that requires temperature control because it is in a form capable of supporting

- the rapid and progressive growth of harmful microorganisms,
- the growth and toxin production of *Clostridium botulinum*, or
- the growth of *Salmonella enteritidis* in raw shell eggs.

Potentially hazardous foods include

- Animal foods that are raw or heat-treated,
- Plant foods that are heat-treated,
- Raw seed sprouts,
- Cut melons, and
- Garlic-in-oil mixtures that are not modified to prevent the growth of harmful microorganisms.

These groups of food have the potential for contamination because of the way they are produced or processed. They have certain characteristics in common that allow harmful microorganisms to grow. Potentially hazardous foods are usually moist, high in protein, and are chemically neutral or slightly acidic.

**Everyone should be aware of the potentially hazardous foods that are included on menus.**

- All animal products are potentially hazardous (meat, poultry, fish, shellfish, eggs and egg products, milk and milk products).
- Vegetables and plant products may also be hazardous once they are cooked. This is because cooking destroys protective barriers in plants and converts proteins and carbohydrates into a form more usable by microorganisms. This makes vegetables and plant products, such as potatoes, tofu, beans, winter squash, pasta, stuffed pasta, and rice, potentially hazardous once they are cooked.
- Shelf-stable foods are potentially hazardous once removed from their containers.
- If not washed, raw fruits and vegetables may be potentially hazardous (onions, melons, apples).
- It is best practice to avoid serving raw seed sprouts and garlic-in-oil mixtures in Child Nutrition Programs.

**Be aware that most any food can be contaminated with harmful microorganisms and has the potential for causing a foodborne illness. Use safe food handling practices for all foods, not just the foods listed as potentially hazardous.**



**How to control the growth of bacteria in food**

- Purchase certified, inspected foods from certified, inspected vendors.
- Avoid cross-contamination of a food.
- Cook food to the required safe internal temperature and test with a food thermometer.

**A - Acidity**

**Condition for Growth: Acidity**

The indicator known as “pH” indicates the level of acidity or alkalinity of a food or other substance. The pH scale ranges from 0.0 to 14.0, with 7.0 being neutral. A pH less than 7.0 is acidic and a pH of more than 7.0 is alkaline. Distilled water has a neutral pH of 7.0.

**How Acidity contributes to growth of bacteria**

Bacteria can grow best in foods that are neutral or slightly acidic, in the pH range of 4.6 to 7.5. The pH value of meats and many other foods is optimal for bacterial growth. The scale below shows some typical pH values for common foods, but the values are not exact for any one specific food.

Acid				Neutral			Alkaline
0.0	2.2	3.5	4.3	5.9	7.0	7.5	14.0
	Lemon	Apple	Mayo	Grd.Beef	Egg		

**If the pH is:**

Below 4.6 ..... Bacteria will not grow well.

Between 4.6 and 7.0 ..... Bacteria will thrive.

Between 7.0 and 9.0 ..... Bacteria may survive.

Highly acidic foods, such as vinegar and the flesh of most fresh fruits, inhibit bacterial growth. However, *E.coli* O157:H7 can grow in unpasteurized apple juice that has a pH around 4.0.

Although commercially prepared mayonnaise has a pH below 4.6, adding it to a meat salad will not inhibit bacterial growth. The meat will increase the pH of the salad to a level where bacteria can multiply.

**How to control Acidity to control growth of bacteria**

Some food preparation techniques reduce the risk of bacterial growth by making the recipe more acidic. Examples of such techniques include using salad dressing made of oil, vinegar, and garlic or marinating meat or poultry in a mixture including fruit juice or vinegar.

## T - Temperature

### Condition for Growth: Temperature

#### How Temperature contributes to growth of bacteria

Given a little time and a nice warm environment, bacteria multiply rapidly. The temperature range between 41 °F and 135 °F is known as the *temperature danger zone*. Holding foods in the temperature danger zone is one of the primary causes of foodborne illness outbreaks.

A few bacteria, such as *Listeria*, can grow and multiply between 32 °F and 45 °F, and some can survive at temperatures as low as 19 °F. For this reason, it is important to monitor the length of time a product is kept in refrigeration. Bacterial spores can survive very hot or very cold temperatures, and when the conditions are right, they can begin to grow again.

#### How to control Temperature to control growth of bacteria

- Control the temperature of food during storage, preparation, holding, cooling, reheating, and service.
- Check the internal temperature of a food with a food thermometer.
- Store foods at the recommended safe temperatures for dry storage, refrigerator, or freezer storage.
- Cook food to required internal temperature and test with a food thermometer.
- Keep foods out of the temperature danger zone, at 41 °F or below or above 140 °F.

## T - Time

### Condition for growth: Time

#### How Time contributes to growth of bacteria

When a food has been contaminated with a microorganism, the bacteria need time to grow. The bacteria grow slowly at first, and then move into a very rapid growth period before the conditions become unfavorable and they begin to die. When a food is in the temperature danger zone, the clock is ticking because bacteria can grow. If allowed to thrive, one bacterium can become more than one million bacteria in just four hours.

#### How to control Time to control growth of bacteria

- Store received foods as quickly as possible to limit time in the temperature danger zone.
- Do not remove foods for preparation from refrigerator or freezer more than 20 minutes before they will be used.
- Prepare foods as close to the service time as possible.
- Check the temperature of holding cabinets to be sure they will maintain the internal temperature of hot foods at 135 °F or above.
- Cook food to the recommended safe internal temperature.

- Chill cooked hot food from 135 ° F to 70 °F within 2 hours and from 70 °F to 41 °F in an additional 4 hours for no more than a total cooling time of 6 hours. If the food has not reached 70 °F within 2 hours, it must be reheated immediately to 165 °F for 15 seconds.
- Mark the date for all foods stored in the refrigerator and freezer so the storage time can be monitored.
- Reheat leftover foods to an internal temperature of 165 °F for 15 seconds.

## O - Oxygen

### Condition for Growth: Oxygen

#### How Oxygen contributes to growth of bacteria

Various microorganisms have different oxygen requirements for growth. For example, aerobic microorganisms *require* oxygen to grow. Anaerobic microorganisms can grow only when oxygen is *not* present. For example, anaerobic microorganisms, *Clostridium perfringens* and *Clostridium botulinum*, grow without oxygen.

Facultative microorganisms are those that can grow *with or without* oxygen. Most bacteria that cause foodborne illness are in this group.

#### How to control Oxygen to control growth of bacteria

- Although the oxygen requirement is different for various microorganisms, there is no way to control this condition. Rather, it is important to control all the other conditions using the suggestions provided.
- Because *Clostridium perfringens* and *Clostridium botulinum* need an environment without oxygen, it emphasizes the importance of cooling foods quickly in shallow pans. In this instance, by using the time-temperature relationship principle, you can control the growth if the food has been contaminated.

## M - Moisture

### Condition for Growth: Moisture

#### How Moisture contributes to growth of bacteria

Bacteria need water for growth. Because they cannot take in solids, bacteria get their nutrients from water solutions. In other words, they can only use food when it is moist. Most fresh foods contain the ideal amount of water for bacterial growth.

Sugar products, cereal products, dried fruits, jams, and jellies have low moisture levels and are, therefore, resistant to bacteria.

### How to control Moisture to control growth of bacteria

- Lower the amount of moisture in food through freezing, dehydrating, adding sugar or salt, or cooking. Remember that even though bacteria cannot grow in foods low in moisture, they remain alive and can become potentially hazardous when moisture is added in cooking. For example, dry foods such as beans, pasta, and rice become vulnerable to bacteria when cooked.

By controlling the conditions necessary for growth, it is possible to prevent foodborne illness even when harmful microorganisms have contaminated a food.

## Summary

CHAPTER 3, **"Basic Facts About Microorganisms,"** describes the major foodborne illness caused by bacteria, viruses, fungi, and parasites. Because harmful microorganisms are responsible for most cases of foodborne illness, it is important for foodservice personnel to be familiar with how microorganisms contaminate food, grow, and reproduce. Bacteria are the microorganisms of greatest concern in a foodservice. Controlling the conditions they need to grow can control the growth of bacteria: food, acidity, time, temperature, oxygen, and moisture.

## CHECK YOUR KNOWLEDGE

### Growth of Harmful Microorganisms

**Directions:** This is a self-assessment for you to determine your own level of knowledge. Place the letter of the one best answer for each item in the box provided.

- |  |  |
|--|--|
| <p><input type="checkbox"/> 1. <b>A pathogen is</b><br/> a. A harmful microorganism<br/> b. Any microorganism<br/> c. Always a harmful bacteria<br/> d. All of the above</p> <p><input type="checkbox"/> 2. <b>The one way to be sure that bacteria are killed is to</b><br/> a. Cook at low temperature for a long period of time<br/> b. Keep the food out of the danger zone<br/> c. Freeze the food for four hours<br/> d. Heat to the required safe temperature for the required time</p> <p><input type="checkbox"/> 3. <b>The conditions that favor the growth of most foodborne microorganisms (excluding viruses) are</b><br/> a. Food, acidity, temperature, time, oxygen, moisture<br/> b. Food, time, and temperature<br/> c. Food and temperature<br/> d. Food, temperature, and moisture</p> <p><input type="checkbox"/> 4. <b>Which of the foods listed below would not be considered a potentially hazardous food?</b><br/> a. Lemon<br/> b. Sliced melon<br/> c. Baked potato<br/> d. Cooked rice</p> <p><input type="checkbox"/> 5. <b>Bacteria grow best at what pH level?</b><br/> a. Very alkaline<br/> b. Very acid<br/> c. Neutral to slightly acid<br/> d. Water</p> | <p><input type="checkbox"/> 6. <b>A food is in the temperature danger zone when the internal temperature is between</b><br/> a. 165 °F to 212 °F<br/> b. 41 °F to 135 °F<br/> c. 65 °F to 165 °F<br/> d. 0 °F to 40 °F</p> <p><input type="checkbox"/> 7. <b>When chilling a hot food from 140 °F down to 41 °F, it must be reheated immediately to 165 °F for 15 seconds if it has not reached 70 °F within</b><br/> a. 1 hour<br/> b. 2 hours<br/> c. 4 hours<br/> d. 6 hours</p> <p><input type="checkbox"/> 8. <b>Which of the following foods would be most likely to support bacterial growth if contaminated?</b><br/> a. Dry rice<br/> b. Cooked rice<br/> c. Fresh fruit<br/> d. Bread</p> <p><input type="checkbox"/> 9. <b>All of the following behaviors would help prevent foodborne illness except</b><br/> a. Washing hands.<br/> b. Avoiding jewelry except a plain ring, such as a wedding band<br/> c. Wearing closed toe shoes<br/> d. Using single-use gloves correctly</p> <p><input type="checkbox"/> 10. <b>Four types of pathogens that cause foodborne illness include</b><br/> a. Bacteria, viruses, fungi, and parasites.<br/> b. Viruses, fungi, bonechips, larvae.<br/> c. Bacteria, viruses, fungi, insecticide.<br/> d. All of the above.</p> |
|--|--|

Answers: 1-a; 2-d; 3-a; 4-a; 5-c; 6-b; 7-b; 8-b; 9-c; 10-a

## Food Safety Checklist

---

- What are the major foodborne illnesses caused by bacteria and how can they be prevented?
- What are the major foodborne illnesses caused by viruses and how can they be prevented?
- What are the major foodborne illnesses caused by fungi and how can they be prevented?
- What are the major foodborne illnesses caused by parasites and how can they be prevented?
- How do microorganisms grow?