Food Microorganisms and Safety

EVERY YEAR, about one of every six (48 million) Americans experiences a foodborne illness. Approximately 128,000 people are hospitalized as a result. Despite modern medicine, an estimated 3,000 people die annually due to food poisoning or foodborne illnesses. This unit examines the microorganisms that cause foodborne illness and safety procedures to prevent illness.

Objective:

Describe the relationship between microorganisms and food safety.

Key Terms:

agar
agar plate
antimicrobial
bacteria
binomial name
capsid
cell culture
contamination
culture medium
eukaryote
filamentous
foodborne infection
food microbiology
food poisoning
food safety
Gram staining
habitat
inoculation
molds
morphology
nutrient agar
pasteurization
prokaryotic cell
protozoa
shelf life
spoilage
sterilization
stool culture
strain
substrate
taxonomy
virion
virus
yeasts

Understanding Microorganisms and Food

Many sources say the United States has the safest food supply in the world. Yet many people suffer from foodborne illnesses due to unseen microorganisms.

CLASSIFYING MICROBES

All known living things have been investigated by scientists and classified in some way. The classification of living things, including microorganisms, is **taxonomy**. In some cases, taxonomy is referred to as systematic, though systematics may have a somewhat broader meaning. Scientific taxonomy involves grouping together organisms that are alike in certain characteristics, including evolutionary relationships. Taxonomy helps communicate organism similarities and differences and provides for a system of naming.

The modern classification system (biological classification) involves grouping organisms into hierarchical categories. Sorting the organisms into groups is a major role of biological classification. Scientists use information gained from developmental patterns, biochemistry, molecular biology, genetics, and detailed morphology. DNA study is increasingly used in the classification of organisms. Scientists use a system that consists of seven divisions or stages of similarities and differences: kingdom, phylum or division, class, order, family, genus, and species. These stages are arranged from the broadest to the most specific. Microorganisms in a kingdom have shared broad characteristics while those in a species are very similar on many characteristics. Beyond species, some organism categories are further broken into strains or varieties. A **strain** is a subspecies within a species that has unique characteristics from others in the species. Three kingdoms have numerous species of microorganisms that serve many roles and may pose problems with food quality: Monera, Protista, and Fungi. In addition, the viruses are not classified into a kingdom. The kingdom Animalia and kingdom Plantae are comprised of organisms composed of many cells.

Monera

The kingdom Monera is comprised of simple, one-celled microorganisms. It has four phyla. The phylum Proteobacteria contains the **bacteria** (ubiquitous one-celled organisms that can cause infectious diseases), which are of most concern with food quality. They have incomplete cells and are known as prokaryotic organisms. Many strains of bacteria are found. They are distinguished by cell shape, the structures the cells form, DNA and RNA, and how the cells react to stain. Bacteria perform many useful functions as well as those that are bad. For example, one species lives in the human intestine and manufactures vitamin K, which is needed for blood clotting.

Nucleic acid analysis may be used to distinguish strains of bacteria. Nucleic acid is found in every living cell. The two main types of nucleic acid are DNA (deoxyribonucleic acid—the material that carries the genetic information in an organism) and RNA (ribonucleic acid—nucleic acid that translates genetic information into proteins). RNA translates genetic information in proteins. Several kinds of RNA are found, including transfer RNA, ribosomal RNA, messenger RNA, and small nuclear RNA. RNA is quite similar in structure to DNA. The content and sequence of RNA and DNA are used to distinguish between bacteria strains. The use of RNA and DNA testing is more definitive than other methods, such as visual microscopic comparisons. On the basis of RNA sequencing, bacteria are in two major groups: eubacteria and archaebacteria. Each group is further divided based on RNA sequencing.

Gram Staining

In 1884, Danish scientist Christian Gram developed a stain that would aid in classifying bacteria into one of two groups. **Gram staining** is a method of differentiating between bacterial species based on chemical and physical properties of cell walls. The method allows bacteria cells to be placed in two groups: Gram-positive and Gram-negative. Bacteria with cell walls containing small amounts of peptidoglycan and, usually, lipopolysaccharide are Gram-negative. In contrast, bacteria with walls containing large amounts of peptidoglycan and no lipopolysaccharide are Gram-positive. The exact staining reaction is not understood, but differences in cell wall reactivity are highly useful. Examples of Gram-negative bacteria are typhoid (*Salmonella typhi*) and intestinal bacteria referred to as *E. coli* (*Escherichia coli*). Examples of Gram-positive bacteria include mouth-living actinomyces (*Actinomyces odontolyticus*) and oral streptococci (*Streptococcus pyogenes*), which causes common sore throats.

- Bacteria are classified based on their response to oxygen and how they obtain energy. Bacteria species may be grouped into three classes based on their response to gaseous oxygen. Aerobic bacteria must have oxygen to exist. Yet anaerobic bacteria cannot survive in the presence of gaseous oxygen. Meanwhile, facultative bacteria prefer to live in gaseous oxygen, but they can survive without it.
- Bacteria species are in two classes based on how they obtain their energy. Heterotrophic bacteria consume organic compounds and break down the materials to gain nutrients. Bacterium in decaying material or those involved in fermentation and respiration are heterotrophs. Autotrophic bacteria create their own energy by using light or chemical reactions.
- Depending on the strain, bacteria may cause food to spoil and cause disease as well as serve useful roles in the environment. Some bacteria are used in food production, such as those used in making cheese, vinegar, and yogurt.

Protista

The kingdom of Protista has more than 65,000 species of eukaryotic organisms. The kingdom is usually organized into nine phyla, including Sarcodina. The kingdom includes amoeba and five phyla containing algae. Protista are unicellular, but some form colonies in which cells may specialize. Many algae have the ability to capture sunlight and use it to convert materials into chemical energy through photosynthesis. Species in the kingdom Protista are not as prominent in food spoilage as species in other microbe kingdoms. However, some cause illness. For instance, amebiasis is caused by the one-celled parasite *Entamoeba histolytica*.

Commonly, protozoa are classified with the Protista. **Protozoa** are eukaryotic microorganisms sometimes classified in the kingdom Animalia and sometimes in the kingdom Plantae. Some protozoa may be transported with food materials and cause human disease, as parasites in the human body. Others are transmitted in other ways. For example, those that cause malaria are transmitted by mosquitoes.

Fungi

The kingdom of Fungi has about 100,000 species in four phyla: zygomycota (black bread mold often found on bread, fruit, and other foods), ascomycota (includes yeasts, truffles, and others), basidiomycota (mushrooms), and deuteromycota (includes disease-causing species such as ringworm and is the source of penicillin, though some are used to flavor cheese). Some fungi are multicellular, as are the molds. Others are unicellular (one-celled), as are the yeasts. Fungi are eukaryotic, as they have complete cells. Many fungi are saprophytic, which means that they feed on dead organic material, including human food materials.

As with bacteria, DNA and RNA sequencing can be used to establish evolutionary relationships in the classification of Fungi. Once this has been done, a tree of evolutionary sequence can be prepared to depict relationships, similarities, and differences.

Molds are some of the easiest Fungi to find and study as related to food. For example, mold can be a fuzzy substance growing on the surface of bread. Some mold organisms typically grow end to end to form filaments or hyphae. A mass of hyphae forms a mycelium. Other mold organisms produce stalks and spores, as with mushrooms. **Yeasts** are smaller, unicellular organisms and are more difficult to identify.

Viruses

A **virus** is a biological particle comprised of genetic material and protein. Most scientists do not consider viruses to be living organisms; others disagree. Viruses are not cells, so they reproduce by invading other cells (e.g., bacteria). Viruses are not readily classified into existing systems. Therefore, they often are not included in modern classification systems.

A general system to classify viruses has been developed that is quite similar to living organisms. The International Committee on Taxonomy of Viruses has developed a classification system using five stages: order, family, subfamily, genus, and species. Another classification has been developed using seven groups that distinguish viruses based on their mode of replication and genome type. The two systems are used together in classifying viruses. Yet viruses can be classified on the basis of structure and observed characteristics (e.g., helical, icosahedral, enveloped, and complex viruses). Observation of structure is needed for this classification.

Binomial Nomenclature

Microorganisms are named using the binomial system derived from scientific classification, known as a **binomial name**, which is a designation that consists of two words. The first word is the genus of the organism; the second word is the species. In writing binomial names, the first letter of the genus is capitalized; all other letters are lowercase. The entire name is in italics or underlined. An example is the bacterium that causes whooping cough: *Bordetella pertussis*.

STRUCTURES

Bacteria, yeasts, and molds can usually be seen with a microscope. Viruses are typically too small for an ordinary microscope and must be studied with an electron microscope. Now tissue culture may be used with virus study. Structure involves morphological features.

Morphology is the study of the form and structure of organisms. A major distinction among microorganisms is that of cell structure: prokaryotic and eukaryotic.

Bacteria

The general structure of bacteria is that of a **prokaryotic cell**, which is a microscopic structure lacking a membrane-bound nucleus and membrane-bound organelles. The chromosomes are made of a single closed circle of DNA. Beyond that, they are of many shapes and sizes, though all are microscopic.

The cells of bacteria are incomplete when compared to most other cells. Bacteria exist in a wide range of temperatures and in conditions with or without oxygen. Bacteria reproduce by fission, which is the splitting of a cell into identical daughter cells. In general, bacteria have the following structural features:

- Capsule—a protective covering that prevents drying out and protects it from being engulfed by larger microorganisms
- Cell envelope—typically a three-layered membrane that encloses the organism
- Cell wall—a rigid wall composed of a protein-sugar (polysaccharide) molecule that encloses the cytoplasm
- Cytoplasm—(protoplasm) a gel-like composition of water, enzymes, nutrients, wastes, and gases that contain ribosomes, a chromosome, and plasmids
- Cytoplasmic membrane—a layer of phospholipids and proteins that encloses the interior and regulates the flow of materials in and out of the cell
- Flagella—a structure (or structures) used for locomotion by some species
- Nucleoid—the region of the cytoplasm where the chromosomal DNA is located
- Pili—hairlike projects on the outside of the cell (present in some species); help bacteria attach to other cells and surfaces (Without pili, bacteria that cause disease lose their ability to infect because they are unable to attach themselves to host tissue.)
- Ribosomes—structures inside bacteria that translate genetic code from nucleic acid to amino acids

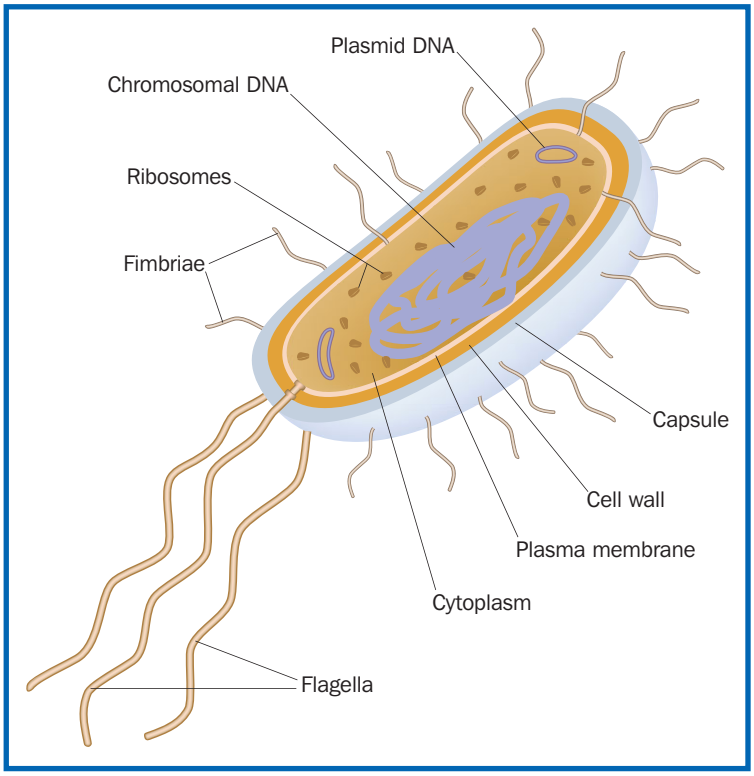

FIGURE 1. Structure of a bacterial cell.

Eukaryote Cells

Yeasts and molds are eukaryotic organisms. **Eukaryotes** are organisms with complex cells. The genetic material is organized into membrane-bound organelles. The eukaryotes include the kingdoms of plants, animals, and fungi (the kingdom Fungi includes yeasts and molds). These cells are typically larger than prokaryotic cells. (Note: Eukaryotes are sometimes said to be a superkingdom, empire, or domain because three kingdoms have the shared cellular attribute.) The overall structure of a eukaryote cell includes the following:

- Cell wall—a structure that provides rigidity for a cell and controls water influx by osmosis; present in fungi, algae, and plant cells
- Plasma membrane—present in all eukaryotic cells; located inside the cell wall on cells with walls; a structure that serves as a semipermeable barrier between outside and inside of a cell
- Cytoplasm—a watery substance that contains protein, sugar, and salt; organelles are suspended in cytoplasm; fungi and algae have single membrane-bound vacuoles
- Nucleus—a double membrane-bound organelle containing chromosomal DNA; contains nucleolus (where RNA synthesis occurs)
- Endoplasmic reticulum—membrane tubes and plates that synthesize and transport proteins and lipids
- Golgi bodies—flattened, membrane-bound sacs and vesicles; vesicles secreted by endoplasmic reticulum fuse with Golgi; secreted into organelles or plasma membrane after processing
- Peroxisomes—membrane-bound sacs secreted from Golgi; contain amino acid and fatty acid-degrading enzymes and catalase—the enzyme that detoxifies hydrogen
- Mitochondria—an organelle bound by a double membrane; involved in respiration and oxidative phosphorylation in aerobic organisms; ATP production occurs here
- Chloroplasts—plastids found in cells that carry out photosynthesis; comprised of chlorophyll
- Flagella—tube-like extensions of the cell membrane that provide mobility found on some cells, particularly those without cell walls

Yeasts

Yeasts are unicellular (one-celled) fungi. About 1,500 species of yeasts have been identified. Some are important in food production. One example is used in baking and fermenting beverages: *Saccharomyces cerevisiae*. It is a model used in cell biology research. A special database of *S. cerevisiae* is maintained: http://www.yeastgenome.org/.

Yeasts reproduce by binary fission or budding to create new cells from a parent cell. With binary fission, the parent divides into two parts of about equal size. Both cells are known as daughter cells; no parent cell remains. With budding, the nucleus has moved to the side of a cell, and a small portion protrudes from the cell similar to an outgrowth or a small bud. The nucleus divides with a small portion (daughter nuclei) in the outgrowth. Then a cell wall

grows between the parent cell and outgrowth resulting in separation of the outgrowth from the parent organism.

Molds

Molds are multicellular, eukaryotic fungi. Most molds are **filamentous** or threadlike in growth. Molds produce spores that are readily transported by air, water, and insects. In the right environment (e.g., a slice of bread), a spore begins to grow and produces hyphae (threads). The hyphae form a tangled mass, which creates a fuzzy appearance. The ends of the hyphae produce more spores that continue the cycle of mold growth. Most molded food should be thrown away. However, some molds are used in making food (e.g., Roquefort cheese).

Mold cell structures are similar to those of eukaryotic cells. Masses of mold cells appear as long threads with spores at one end. (Note: Mold and mildew are quite similar. Mildew is a grey, mold-like growth fungus organism. A fungus disease on some plants is referred to as mildew and can be controlled by the application of a pesticide known as fungicide.)

FIGURE 2. Molds are multicellular, eukaryotic fungi; most molds are filamentous.

Viruses

Viruses are not complete cells, though they consist of genetic material in a protective protein coat or **capsid**. Viruses are known as particles—not as cells or organisms. A complete virus particle is a **virion**. (Note: Viruses are contrasted with prions and viroids or virus-like structures that lack protein or genetic material.) Most scientists believe viruses are not living organisms because they do not meet the criteria of being living organisms. Viruses are typically much smaller than bacteria, though some may be as large. Their size is typically 10 to 300 nanometers. Consequently, scanning and transmission electron microscopes are used to see the particles.

The structure of viruses requires methods of observation more powerful than ordinary microscopes. Capsids contain subunits of protein, protect the genetic material in virions, determine if infection is suitable, and initiate an infection by attaching to and "opening" the target cell(s) into which it injects genetic material. Four morphological virus types have been found:

- Helical—a structure that resembles a spiral staircase composed of small tubes; rod-shaped virions may be short and rigid or long and flexible; genetic material is inside the tubes; an example is the tobacco mosaic virus.
- Icosahedral—the structure is ring-shaped capsomers (capsomers are morphological units of capsids) resembling a geodesic dome; this structure is an efficient way of enclosing

protein; an example is hepatitis B, which is comprised of 240 proteins assembled to form one capsid

- Enveloped—the structure has an additional outer ring comprised of proteins coded with the viral genome; this ring provides added protection from enzymes and chemicals; an example is HIV
- Complex—these viruses have additional structures over the others (e.g., a protein tail, outer wall, and central disk structure); examples are poxviruses

CONDITIONS FOR MICROBIAL GROWTH

Food microbiology is the study of microorganisms that affect food materials. The organisms may have a detrimental effect, or they may be used to gain desired food products.

Habitat

Microorganism growth is related to the habitat provided by food materials. **Habitat** is the place where organisms live, grow, and reproduce. Food materials provide an ideal source of food for the growth and reproduction of microorganisms. Unfortunately, microorganisms alter their habit; this causes changes in the food materials where they may exist.

Most microorganisms thrive in warm environments. For instance, food materials that are not kept refrigerated or frozen often provide ideal conditions for their growth. Milk will spoil rapidly unless it is refrigerated to slow the rate of microorganism growth. Most microorganisms need moisture to live and grow. As a result, dry conditions usually bring their activity to a near halt. Most food materials, however, contain moisture that promotes microorganism growth.

Most microorganisms need nutrients to live and grow. Food materials are, of course, ideal in this regard. Yet protecting food materials from exposure to microorganisms helps prevent contamination. Packaging is often used for this purpose. Microorganisms prefer a food pH range of 4.6 to 8.0. Acidic foods with a pH below 4.6 will discourage microorganism growth.

Assessing the Presence of Microorganisms in Food

The presence of microorganisms in food can be assessed in several ways. Certainly, growths on food or the presence of abnormal or undesirable odors and flavors are signs of spoilage. Food scientists use additional methods to assess the presence of microorganisms. Specimens of growth on foods can be examined with a microscope. Molds are usually readily identified in this manner.

Cultures of small amounts of substances with organisms from the food materials can be made to determine the presence of microorganisms. **Cell culture** is the process by which prokaryotic or eukaryotic cells are grown under controlled conditions. A culture is comprised of the microorganisms that grow in a **culture medium**—a solution containing all of the nutrients to support microorganism growth. Of course, the medium must be incubated in an

environment that promotes microorganism cell growth. The medium used by food scientists is typically agar.

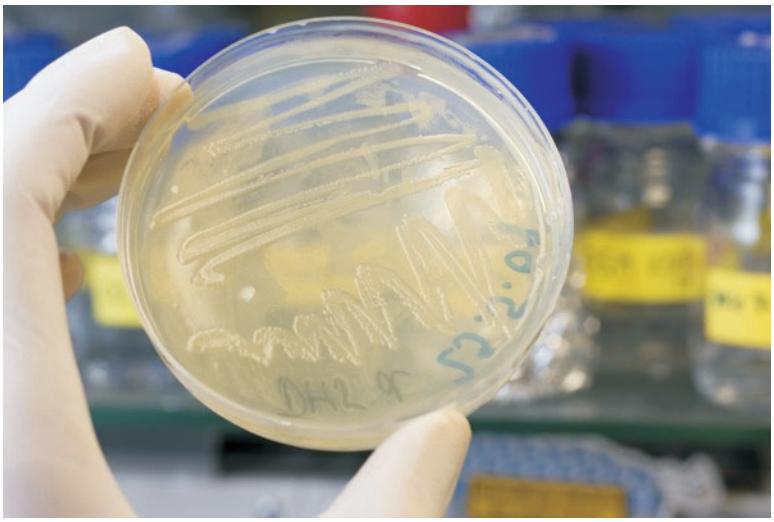

FIGURE 3. Scientists use cell cultures to assess the presence of microorganisms.

Agar

Agar is a culture medium that gels and stabilizes. It often involves extract from red algae or seaweed. **Nutrient agar** is a culture medium that has been enriched to promote the growth of bacteria, fungi, and other unicellular organisms or particles of viruses. An **agar plate** is a sterile petri dish that contains a culture medium. The preferred agar in some food and kitchen work is tryptic soy agar. It can be obtained as powder and prepared in the petri dishes, or ready-to-use dishes can be obtained. Agar is obtained for special purposes, as different microbes require suitable nutrient gels for growth.

Inoculation

Inoculation is the process of transferring potential microorganisms to the agar. Microorganisms placed on a plate and held at the correct temperature will produce colonies of microorganisms in several hours. The inoculated agar plate is incubated at a temperature of 95°F (35°C). Many are incubated for 24 hours. After incubation, agar plates are observed for the growth of microorganisms. In some cases, large colonies will develop and can be seen without a microscope. A hand lens may be satisfactory. In most cases, a microscope will be needed to closely examine the morphology of the organisms for proper identification.

CONTROLLING FOOD SPOILAGE

A major goal in the food industry is to control food spoilage by microorganisms. This is achieved in two major ways: preventing contamination and preventing the growth and reproduction of microorganisms.

Temperature

Temperature can be used to suppress or destroy microorganisms in food. The temperature range of 40°F (4°C) to 140°F (60°C) is the danger zone in which many microorganisms can thrive, particularly within the mid-part of this range. Higher temperatures destroy organisms, and lower temperatures make microorganisms inactive and unable to reproduce. As a result,

heat during canning and cooking destroys microorganisms. In addition, refrigeration and freezing reduce microorganism growth.

FIGURE 4. Refrigeration and freezing reduce the growth of microorganisms.

Moisture

Water activity refers to moisture levels in food materials. Some food products are dried, such as raisins and dates. Without a sufficient amount of moisture, microorganisms that cause food spoilage fail to survive, reproduce, and grow.

pH

pH is the level of acidicity or alkalinity. Most microorganisms thrive above 4.6 pH, but a pH above 9.0 tends to reduce their activity. They prefer neutral conditions, with a pH of 7.0. Orange juice, vinegar, and similar liquids are acidic, so they do not support the growth of microorganisms. Pickled cucumbers, eggs, and meat products resist spoilage because microorganisms cannot flourish in the acidic solution.

Oxygen

Most microorganisms need oxygen to live, grow, and reproduce. Though some bacteria are anaerobic, many species of bacteria, molds, and fungi thrive in the presence of oxygen. Therefore, removing oxygen (and air contaminated with microorganisms) will reduce contamination and fail to support microorganism growth.

Redox

Redox is a chemical process in which atoms have their oxidation number changed. The process involves reduction and oxidation. In reduction, an electron is gained by the molecule, atom, or ion. In contrast, oxidation involves the loss of an electron by a molecule, atom, or ion. Some substances oxidize others; other substances are reducers.

Antimicrobials

Antimicrobials are sometimes used to reduce or eliminate populations of microorganisms. **Antimicrobials** are substances that destroy or suppress microbial organisms. Often they are categorized by the species controlled. For instance, antibacterials (antibiotics in medicine) are used to control bacteria, and antifungals are used to control fungi. Prominent uses of antimicrobials are in cleaning surfaces where food products are produced or prepared for con-

sumption. An example is the use of a bleach solution to wash or wipe surfaces in kitchens and canneries. Antimicrobial resistance, however, is jeopardizing the use of antimicrobial products, such as those used in medicine.

FOOD SPOILAGE AND SHELF LIFE

Food safety is the process of keeping food wholesome and free of organisms or substances that cause illness. Following proper practices in food production, processing, storage, and preparation helps ensure safety.

Food Spoilage

Spoilage is food loss due to decay, improper processing or storage, and planning in terms of product acquisition and need. Spoilage often results from bacterial action in food materials. In most cases, the food is unsafe for consumption. Consuming spoiled food may lead to food poisoning, serious illness, and death. Some foods can be observed for signs of spoilage. Food that has a foul odor, an "off" or abnormal color, and an unnatural consistency is likely spoiled. Of course, some microorganisms may be in food and not be readily visible unless colonies have formed (e.g., mold on bread). Laboratory testing may be needed.

Contamination

Preventing contamination by spoilage agents is important, especially in the food industry. **Contamination** is the accidental or purposeful introduction of substances that cause food

ON THE JOB...

CAREER CONNECTION: Food Microbiologists

Food microbiologists study microorganisms in food with the goal of preventing foodborne illnesses. Their work concerns food handling, spoilage, and preservation. They research foodborne pathogens and work on disease prevention.

Food microbiologists are employed by food manufacturers, government agencies, and universities. They have a working knowledge of government regulations regarding food health and safety.

A bachelor of science in food science, microbiology, or biology is generally a minimum qualification. Food microbiologists may need an advanced degree for some positions.

spoilage, including microorganisms and chemical contamination. Preventing the introduction of microorganisms into food helps prevent later microorganism growth and activity.

Air Movement

Air movement should be controlled. Air carries molds, yeasts, and bacteria. Therefore, preventing air contact with food materials helps prevent contamination with food spoilage organisms. In some cases, filters can be used on fans to remove contaminants.

Surfaces

Counters, tables, and people working with food are sources of contamination. Keeping surfaces clean helps reduce the likelihood of contamination. Also, people handling food should wash their hands, wear clean clothing, use hair nets, and use other practices to reduce the likelihood of contamination.

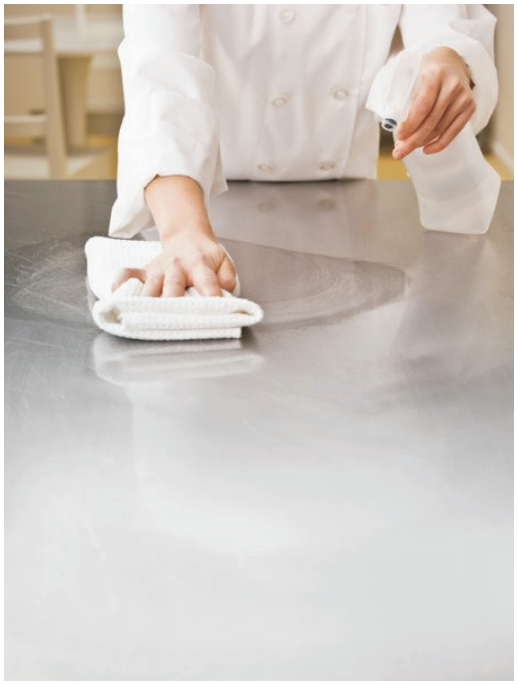

FIGURE 5. Keeping surfaces clean helps reduce the likelihood of contamination.

Temperature

Controlling the temperature at which food is stored will help reduce the likelihood of spoilage. Some foods and contaminants are sensitive to temperature, such as the bacteria in milk. Other foods may become rancid or develop an off-flavor if stored improperly and/or too long. Most microorganisms require moisture to live and grow. Any process that lowers moisture levels helps protect food from spoilage. Also, preventing the growth of microorganisms (e.g., establishing conditions under which microorganisms do not thrive) helps maintain food quality.

Heat can be used to destroy microorganisms because it causes the death of microbes, depending on how it is used. Two concepts are involved: sterilization and pasteurization. **Sterilization** is the destruction of all microorganisms present in food materials. It is the most effective approach in extending shelf life. **Pasteurization** is the use of heat to destroy selected pathogenic microorganisms present in food materials. Milk and fruit juices are often pasteurized. Different microorganisms have different temperature levels for destruction. Heating milk to 162°F (72.9°C) for 15 seconds destroys the pathogenic microorganisms typically found in milk. This, however, does not necessarily destroy other microorganisms that may be present.

Unfavorable Conditions

Inhibiting the growth of microorganisms is another practice that can be used with food products. The microorganisms are not destroyed, but the conditions under which they grow are made very unfavorable. Acid content of the food material is a factor as higher acidic foods

are less likely to support microorganism growth. In some cases, foods have the water removed. For instance, dried foods inhibit the growth of microorganisms.

Shelf Life

Shelf life is the length of time that a food product is safe to consume. Various methods of preservation and packaging are used to enhance shelf life. For example, canning is used to extend the shelf life of fresh peas. As a result of canning, peas can last for more than a few days. Canning enables people to keep the usable product for several months and/or years. Use-by-dates are often stamped on containers or labels. Milk containers, for instance, often have dates stamped on them, so the products should be wholesome and usable if properly stored until that date.

FIGURE 6. The dates stamped on milk containers indicate the shelf life.

FOOD POISONING AND FOODBORNE INFECTIONS

Foods sometimes pose threats to humans. These threats are often in two forms: food poisoning and food infections. It is sometimes difficult to separate these two forms. However, food infections are included in the broad meaning of food poisoning. Some people have allergies to certain foods (e.g., peanuts, milk, and eggs). As a result, the consumption of such foods may cause severe allergic reactions, even though the food products are wholesome.

Food Poisoning

Food poisoning is an acute gastrointestinal or neurologic disorder caused by bacteria and other microorganisms, viruses, parasites, and/or harmful chemicals in foods. Bacteria contribute to food poisoning in three ways:

- They infect the individual following consumption of contaminated food.
- They produce a toxin in food before it is consumed.
- They produce a toxin in the gastrointestinal tract after the food has been consumed.

Foodborne Infection

A **foodborne infection** is an illness caused by ingesting a microorganism in contaminated food. It is the most common microorganism-induced foodborne illness. These illnesses are in two groups: those in which the food is the carrier and those in which the food is a substrate and a carrier. A **substrate** is a substance in food from which the microorganisms derive

nutrients. Most food materials have an abundance of substrates for microorganisms (e.g., mold, bacteria, yeasts, and viruses). Several infectious bacteria are associated with food poisoning. Yet other organisms and viruses may cause food illnesses. If food toxins are said to be "performed," they are in food before preparation. Heat-resistant bacteria, for instance, may remain active in foods after they have been cooked, such as:

- *Staphylococcus aureus* is commonly called a staph infection. *S. aureus* is caused by a spherical-shaped bacterium that frequently lives on the skin and in the nostrils of a healthy person. It is a Gram-positive that appears as grape-like clusters when viewed with a microscope. Large, round golden-yellow colonies may be formed. The two subspecies are *S. aureus anaerobius* (an anaerobic organism; not commonly encountered) and *S. aureus aureus* (an aerobic organism; most common).
- *Clostridium botulinum* is the source of a potent toxin known as botulin. It can cause serious nerve damage and paralysis, resulting in respiratory and musculoskeletal paralysis. All forms of botulin can be fatal and should be treated as medical emergencies. On average, 110 cases occur in the United States each year.

Botulism

Three forms of botulism are foodborne, infant, and wound. Foodborne botulism results from consuming foods contaminated with the botulinum toxin. Slightly more than one-fifth of all botulin cases are foodborne. Infant botulism results from consuming spores of the botulinum bacteria. These spores grow in the intestines and release the botulin toxin. Nearly three-fourths of all botulin cases are of this type. Wound botulism results from toxin produced by a wound that has been infected with *C. botulinum*. It is a rare type that can largely be prevented through sanitation and proper wound care.

Poisons

Poisons are sometimes produced in the gastrointestinal tract. These are produced by organisms that survive cooking and are spore-forming bacteria.

- *Clostridium perfringens* is a Gram-positive, anaerobic, rod-shaped bacterium that forms spores. It is a normal part of the environment in rotting vegetation, soil, and insects. Also, it is in human intestines. This is the third most common cause of food poisoning in the United States. When cultured, *C. perfringens* produces flat, spreading, translucent colonies with irregular margins. Anaerobic conditions are needed, so a Nagler agar plat is used. The medium should contain 5 to 10 percent egg yolk. Half of the culture plate may be inoculated with antitoxin to serve as a control in identification.
- *Campylobacter jejuni* is the most common cause of human diarrhea. Though severely debilitating, it is rarely a life-threatening condition. It has been linked to other disease, such as the neurodegenerative disease known as GBS. *C. jejuni* is caused by a curved, rod-shaped, Gram-negative bacterium. It is commonly found in animal feces, particularly chickens. Contaminated drinking water, unpasteurized milk, incorrectly prepared poultry and meat, and lack of sanitation in the food preparation area lead to unsafe food.

- *Escherichia coli* is one of the main organisms that lives in the intestines. On an average day, a human excretes 100 billion to 10 trillion *E. coli* organisms in feces. The organisms are Gram-negative, non-spore-forming, and rod-shaped aerobic species. The bacteria ferment lactose, resulting in gas production within 48 hours at 95°F (35°C). The gas is released by flatulence. The presence of *E. coli* in water, on plants, and in food is an indication of fecal contamination. Therefore, sanitation is important in keeping *E. coli* out of food. Crop harvesters, food merchandisers, and food preparers should wash their hands thoroughly after using a toilet and must keep all surfaces clean. Wearing clean, noncontaminated clothing is also important. Many strains of *E. coli* exist, and some are useful in genetic engineering research. New strains that cause human illness regularly arise through evolution, with *E. coli* O157:H7 being most virulent. Those normally present in the human body usually pose no threat. New strains are more than likely the cause of human illness.
- Salmonellosis is an infection caused by *Salmonella* bacteria. Several species within the genus are known as potential sources of disease. Individuals with salmonellosis typically have diarrhea, fever, vomiting, and abdominal pain within 6 to 72 hours after being infected. Most people recover well without medical treatment. Dehydration may result, thereby creating the need for hospitalization to receive intravenous fluids. The most common Salmonellosis is caused by nontyphoidal *Salmonella*. It is contracted by eating raw or undercooked eggs, poultry meat and beef, and other foods that have been contaminated during preparation. Pet turtles, lizards, and other reptiles carry Salmonella bacteria on their skin. As a result, people should exercise caution in handling such animals and should always wash their hands thoroughly afterward.

Other foodborne illnesses include:

- Listerosis is caused by *Listeria monocytogenes* and is rarely a human health problem.
- *Vibrio parahaemolyticus* is a Gram-negative bacterium species found in saltwater. Ingestion usually occurs in contaminated seafood via fecal-oral contact.
- Yersiniosis is an infectious disease caused by the *Yersinia enterocolitica* bacterium. It is most common in young children and manifests itself as fever, abdominal pain, and diarrhea. Pigs are a major source of the illness. However, rodents, rabbits, sheep, cattle, horses, dogs, and cats may be a source of *Y. enterocolitica*.

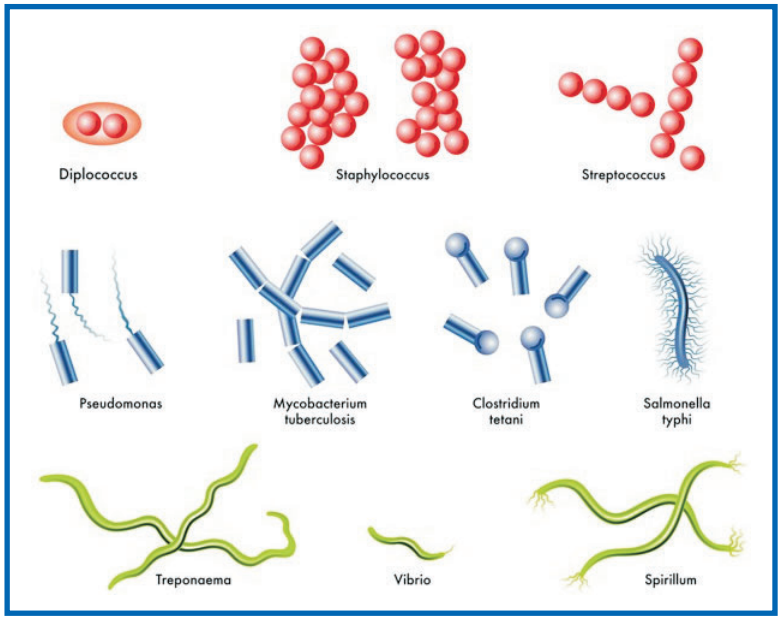

FIGURE 7. Some types of bacteria.

Nonbacterial Food Poisoning

The *Norwalk virus* (stomach flu) is a nonbacterial source of food poisoning. It was identified in 1972 after an outbreak in Norwalk, Ohio. In humans, the illness symptoms are stomach pain, diarrhea, and vomiting. The virus is characterized as having small round structures. Genomic study has found that this virus is in the Caliciviridae family. It is transmitted via fecal to mouth contact with contaminated food and water. Contaminated ice machines have been found as a transfer source. Also, it may be transferred from one person to another. Diagnosis of the Norwalk virus is routinely done with reverse transcription-polymerase chain reaction (RT–PCR) assays, with real-time RT–PCR tests now available. It is used to detect and quantify mRNA in small samples.

Controls

Agents causing food poisoning and foodborne infection are controlled through sanitation and proper handling before, during, and after preparation. Applying all methods of food spoilage prevention is essential. Here are some approaches to follow in preventing microbial foodborne illnesses:

- Store food at the proper temperature.
- Cook food until the proper internal temperature is reached.
- Separate cooked and uncooked food.
- Properly wash your hands and utensils.
- Marinate foods in the refrigerator.
- Consume only food that is not decaying or showing signs of deterioration.

FIGURE 8. Cook food until the proper internal temperature is reached.

Chemical Contamination

Food can sometimes be contaminated with chemicals that cause food poisoning. These are nonliving substances that enter food. Pesticides, petroleum fuels, cleaning agents, and other substances may be present in the food production and storage environment. Care should be used to prevent chemical contamination.

Bioterrorism

Another threat to food safety is bioterrorism or the deliberate contamination of food or water to make it unsafe for consumption. Steps are being taken to ensure food supplies are safe from bioterrorism.

Food Quality Assurance Programs

Food quality assurance programs are voluntarily being used by some food product producers. These programs provide guidance to assure that the food is safe to eat. Such regulations are more prominent in the pork and beef production industries than elsewhere. However, vegetable producers follow practices to avoid contact with growing crops by manure and other products that may contain organisms that cause food poisoning.

Stool Cultures

People who have diarrhea, vomiting, fever, and other symptoms may wish to have an accurate diagnosis to determine if it is caused by bacteria, parasites, viruses, or chemicals. A **stool culture** is the process of identifying the cause of an infection by analyzing a sample of feces. Collection requires a sample in a special container that must be hand-delivered to a physician within a designated period. All instructions on the container or from the physician should be followed. Laboratory analysis will be done to determine the cause. This may involve using chemicals as well as culturing samples using petri culture dishes similar to and including Gram staining.

Summary:

Three kingdoms of microorganisms pose problems with food quality: Monera, Protista, and Fungi. The general structure of bacteria is a prokaryotic cell, lacking a nucleus and membrane-bound organelles. Yeasts are unicellular fungi. Molds are multicellular, and most are filamentous.

Microorganism growth is related to the habitat provided by food materials. Growths on food or the presence of abnormal or undesirable odors and flavors is a sign of spoilage. Food scientists use additional methods for assessing the presence of microorganisms, such as cell culture.

Controlling food spoilage by microorganisms is achieved by preventing contamination and preventing the growth and reproduction of microorganisms. Spoilage is food loss due to decay, improper processing or storage, and planning in terms of product acquisition and need. Preventing contamination and inhibiting the growth of microorganisms prevent spoilage.

Food poisoning is an acute gastrointestinal or neurologic disorder caused by bacteria and other microorganisms, viruses, parasites, or harmful chemicals. A foodborne

infection is an illness caused by ingesting a microorganism in a contaminated food. Agents causing food poisoning and foodborne infection are controlled through sanitation and proper handling.

Checking Your Knowledge:

1. How are foodborne microorganisms classified?
2. What is the structure of bacteria, fungi, and viruses?
3. How is the presence of microorganisms in food assessed?
4. How can food spoilage be controlled?
5. How does food poisoning compare with foodborne infection?

Expanding Your Knowledge:

Create a poster focusing on a foodborne illness after conducting research. Include information on the causal agent, symptoms of the illness, and safety precautions that can be taken.

Web Links:

Food Safety
http://www.cdc.gov/foodsafety/facts.html

Food Safety
http://www.foodsafety.gov/

Foodborne Illnesses
http://digestive.niddk.nih.gov/ddiseases/pubs/bacteria/

Foodborne Illness and Disease
http://www.fsis.usda.gov/FACTSheets/Foodborne_Illness_&_Disease_Fact_Sheets/index.asp

Agricultural Career Profiles
http://www.mycaert.com/career-profiles