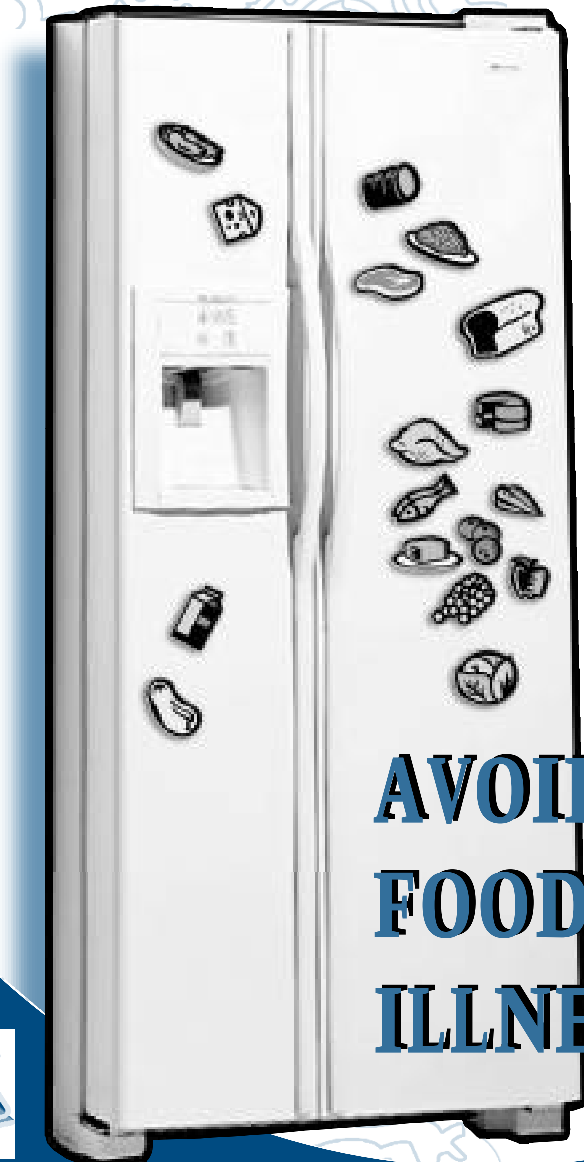
EATING SAFELY:



AVOIDING FOODBORNE ILLNESS

AMERICAN COUNCIL
ON SCIENCE AND HEALTH

EATING SAFELY:

Avoiding Foodborne Illness

Second Edition

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June 1999

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INTRODUCTION

Food safety is a matter of great interest and serious concern to consumers in the 1990s. But today's media, armed with red-flag words such as "toxin" and "carcinogen," often report alleged health hazards in the American diet as fact. This has led many consumers to believe, erroneously, that our modern food supply is inherently dangerous because it contains such synthetic chemicals as food additives and pesticide residues.

The real news tells another story, however. Reports of recent outbreaks of illness caused by the bacterium *Escherichia coli* O157:H7 (transmitted via hamburgers, apple juice, and sprouts); by various species of *Salmonella* bacteria (transmitted via orange juice, eggs, and sprouts); and by the bacterium *Listeria monocytogenes* (transmitted via soft cheeses and processed meats) have demonstrated that microbial hazards are more significant for food safety than are hazards associated with food additives and pesticide residues.

With the advent of the federal government's Food Safety Initiative in May 1997, the nation's attention was directed toward the real hazards: foodborne diseases caused by such microbes as bacteria, viruses, molds, and some parasites. This redirection puts food safety concerns into the appropriate order, as based on scientific documentation (see Table 1).

TABLE 1. THE FOOD AND DRUG ADMINISTRATION (FDA)'S RANKING OF FOOD HAZARDS, FROM 1 (MOST DANGEROUS) TO 6 (LEAST DANGEROUS)

1. microbial contamination
2. naturally occurring toxicants
3. environmental contaminants (e.g., metals)
4. nutritional problems (i.e., malnutrition, undernutrition)
5. pesticide residues
6. food additives

WHAT IS MEANT BY "FOODBORNE ILLNESS"?

Foodborne disease occurs when someone eats food contaminated with one or more disease-producing agents. These include both microbial agents (bacteria, some parasites, viruses, and fungi and their products) and toxic substances not of microbial origin (such as mercury or lead at high levels).

The most certain proof that contaminated food is the cause of an illness is detection of the disease agent in both the sick person and the remains of the food eaten by that person. Food may be implicated when two or more people become ill with similar symptoms at approximately the same time after having eaten the same food. Food may also be implicated when two or more people have been infected by bacteria or other agents with matching "DNAfingerprints," and it can be shown that the ill people ate the same food. Additionally, food may be suspected if the illness in question is one that is often or usually foodborne—botulism (a deadly intoxication of the central nervous system caused by the toxin produced by the bacterium *Clostridium botulinum*), for example.

Most foodborne illnesses are very mild. As a consequence, it is difficult to gauge the true incidence or the rate of change of incidence of foodborne illness in the United States. Only a small proportion of actual cases of foodborne disease are reported, and estimates of the incidence of such disease are based on assumptions as to what proportion of the illnesses are officially reported.

Frequently cited estimates of foodborne illness in the U.S. range upward from 6.5 million cases annually, even though fewer than 25,000 foodborne illnesses are reported each year to the U.S. Centers for Disease Control and Prevention (CDC). Moreover, systems of reporting foodborne disease in other countries are either quite different from those in the U.S. or nonexistent. Thus, there is no direct way to compare rates of foodborne illness in the U.S. with rates elsewhere.

Many diseases, some of which may have serious health consequences, are transmitted by foods. Food poisonings (called "intoxications") and infections are the two most common types. Both sometimes occur in large outbreaks.

Intoxications

Intoxication occurs when a chemical or toxin causes the human body to malfunction. For example, the sea-dwelling algae whose blooming causes so-called "red tides" produce poisons. Seafood contaminated with these poisons is not safe for human consumption. Some bacteria also produce harmful toxins that are not destroyed in the cooking process. One such toxin, staphylococcal enterotoxin, has been found in some canned mushrooms and in hard-cooked eggs. Certain metals can also cause intoxications if they are present in sufficient quantity.

To cause intoxication, bacteria or molds that produce toxins do not have to remain, alive, in food when it is eaten. Bacteria can have grown in a food previously and produced a toxin that persists in the food. Thus, the bacteria themselves do not have to grow in the human body for the organism to affect it. The best known of all intoxications is botulism—an intoxication caused by growth of the bacterium *Clostridium botulinum* in food.

Infections

Infections occur when food is eaten that contains living microorganisms that multiply in the digestive tract. Human intestines normally harbor many microbes, most of which do no harm. But certain pathogenic bacteria, viruses, and parasites that are occasionally ingested with food or water can cause illness. They do this by producing poisons in the body or by directly attacking the lining of the digestive tract. These pathogenic microbes may also attack other organs after being transported from the intestines in blood or lymph.

Infectious agents usually take from several hours to several days to overcome the body's defenses and to build up to levels that can cause disease. The illness thus can occur long after the contaminated food was eaten.

Though deaths sometimes occur, these infections are rarely fatal. The body's defenses usually prevail, but only after the microbes have caused the body a good deal of discomfort. In some instances, such as some cases of *Salmonella*, long-term consequences of the infection can lead to permanent disability.

Other Foodborne Illnesses

Other foodborne illnesses affect only certain people. Some illnesses result when sensitive individuals eat normal amounts of perfectly wholesome food but have allergic or intolerant reactions to specific components of that food. Such sensitivities often run in families and are genetically based.

An allergy is a reaction of the immune system, sometimes against food components and sometimes against other substances in the environment, such as dust or pollens. Immunity usually protects the body from dangers, but food allergies seem to have no useful protective function. Food components that cause allergies are usually, but not always, proteins.

An intolerance results when the body cannot process a food component normally. This sort of reaction often occurs because an essential digestive enzyme is not produced in the body. Most infants and many adults easily digest the natural milk sugar known as lactose. With age, however, many people become less able (some become totally unable) to digest it. Such intolerances tend to be inherited and so tend to be more common in specific ethnic groups. Lactose intolerance, for example, is far more common among persons of East Asian and African ancestry than it is among persons of Northern European ancestry.

It has been alleged that many other diseases are foodborne, but these allegations have not been confirmed experimentally. So-called "Chinese restaurant syndrome" (CRS), for example, has been attributed to the seasoning monosodium glutamate (MSG). There are at least two flaws in the logic linking MSG to CRS, however. First, MSG is present at high levels in some non–Chinese foods, either because it has been added or because there are high natural levels of glutamate in the food. Second, people who say they are subject to CRS—and therefore presumably sensitive to MSG—often fail to become ill appropriately when they are tested with a placebo or with an unmarked sample of MSG. At this time, neither the U.S. Food and Drug Administration (FDA) nor the World Health Organization (WHO) regards MSG as a cause of foodborne illness.

Similar findings have come from tests of alleged behavioral effects (hyperactivity and aggressive behavior among them) presumably caused by certain other foods or by food components (sugar, for example). Carefully performed experiments have repeatedly shown no effect of sugar on behavior: Hyperactivity and/or aggressive behavior have been found to be perceptible only when the observer has been told whether or not the subject has eaten sugar. If neither the subject nor the observer has known whether or not sugar has been consumed, the alleged behavioral changes have occurred randomly.

HOW DO DISEASE AGENTS GET INTO FOODS?

Some poisonous substances occur naturally in foods; others, including some of the deadliest, are produced by microorganisms (the toxin produced by *Clostridium botulinum*, for example). Infectious microbes are often present while foods are still in the field or the sea or on the farm. Other microbes may be introduced when food is mishandled during processing, distribution, or preparation.

The human body is continually being challenged by potential disease agents in food, in water and air, and on common objects. The human digestive tract is a long, continuous tube that extends from the mouth to the anus. Substances in the interior, or “lumen,” of this tube are regarded by physiologists as being outside the body. The lining of the digestive tract (the largest part of the body’s surface area) affords a barrier only one cell thick—about one thousandth of an inch, or 25 micrometers—between the things we eat and our blood, lymph, and tissue fluids.

Raw Materials

Quite simply, it is not possible to produce raw food materials that are absolutely risk free for everyone. Many plants are poisonous. Some of these—soybeans and cassava, for example—can be eaten safely only after proper processing. Others that are not poisonous routinely contain microbes that can cause foodborne disease. Food animals on farms carry microbes that can cause human disease. Fish and other seafood may be poisonous at times or may harbor parasites, bacteria, or viruses that can threaten human health.

Agents that can cause human disease are ubiquitous on both land and sea. Agricultural land carries additional disease agents when it is fertilized with animal manure or human waste. Food animals can be produced free of disease agents, but only under conditions that would cause the food to be prohibitively expensive. Essentially, all raw foods carry the risk of causing human disease if they are not properly cooked or handled before they are eaten.

Food Handling and Care

"Handling" includes anything that happens to food from the time it is harvested until it is eaten. Harvest or slaughter, processing, storage, distribution, retailing, final preparation, and serving all offer chances for contamination—the introduction of disease agents.

It is very difficult to slaughter and eviscerate animals without getting intestinal contents (which contain bacteria infectious for humans) onto the edible portion of the carcass. *Thus, it is most important that any surfaces or utensils that have touched raw meat or poultry be cleaned before they are allowed to come into contact with cooked meats or with other foods that will not be cooked before being eaten.* Even the liquid that drips from raw meat or poultry can get onto other foods or onto food-contact surfaces, resulting in what is known as "cross-contamination."

The Human Factor

People are another important source of food contamination. Infected people who handle food can introduce infectious microbes into or onto it.

Most of the precautions called for in food handling (wearing hair restraints, not sneezing or coughing on the food) are a part of basic hygiene. Such precautions have very little to do with prevention of foodborne disease, however. Most of the infectious agents that travel from person to person via food are shed primarily in feces. Thus, an important precaution to prevent contamination of food with infectious agents from humans is washing the hands thoroughly after toilet use, especially after defecation. This applies, of course, to anyone who handles food, but particularly to those who do the final preparation and serving. Any microorganism introduced at that late stage is likely still to be alive—and infectious—when the food is eaten.

Hands can also carry cross-contamination (from raw food to cooked food, for example), so they should be washed often *during* food handling. Gloves may be helpful in some situations, but they are not a substitute for hand washing.

Other significant sources of food contamination include insects, rodents, birds, and water that contains sewage. Facilities in which food is either stored or handled must be monitored carefully for these sources of contamination.

Time–Temperature Relationships

The length of time a food has spent at various temperatures affects the safety of the final product. Canned, dried, or otherwise “shelf-stable” foods can be stored safely at room temperature for long periods. Other foods—such as flour, sugar, and honey—have so little available moisture that microbes will not grow in them regardless of the storage temperature. Many foods, however, are “perishable”: Microbes can grow in them and cause them to spoil. Low-moisture foods become perishable when water is added to them; canned foods become perishable when the can is opened. Only a few of the bacteria and molds that cause food to spoil are also causes of human disease.

Perishable foods support the growth of disease agents. That is why the time these foods spend at temperatures between 40 and 140 degrees Fahrenheit (between 5° and 60° Celsius)—the “danger zone”—must be minimized. Hot foods must be kept hot; cold foods must be kept cold. Food that is heated and then stored cold must be chilled rapidly; this may require dividing a large quantity of food among several small or shallow containers so that the heat is removed efficiently. Chilled food that is to be cooked or reheated should be heated rapidly and thoroughly.

Although preventing spoilage is a concern, the principal reason to avoid “temperature abuse” is to prevent the multiplication of bacteria and, to a lesser extent, molds on food. At temperatures between 40 and 140 degrees F (5° and 60° C), bacteria can build up to highly infectious levels or can produce poisons that threaten human health. Molds tend to grow more slowly but may also produce poisons. Temperature-sensitive tapes are now available; these can be applied to food packages to reveal any previous temperature abuse.

Parasites and viruses cannot multiply in foods, but they can remain infectious. Poisons present in raw food cannot increase at improper storage temperatures, but some can be reduced by heating. Other factors that influence the growth of disease- and spoilage-causing microbes in food are moisture, acidity, nutrients, natural and artificial preservatives, oxygen, and the presence of other bacteria competing for the same resources.

SOURCES OF FOODBORNE ILLNESS

Foods can be classified into general groups: fruits and vegetables; grains; dairy products; and meat, poultry, and fish. These classifications will be useful as we survey the sources of foodborne illness more specifically. Spoilage and preservation will be addressed only as they affect potential for disease transmission.

Fruits and Vegetables

Contamination from the Field

Soil commonly contains spores of *Clostridium botulinum* and other disease agents of unknown origin. (For more information on disease-causing bacteria, see Appendix A on page 40.) Animal manure usually contributes several disease agents to soil. Some of these die off in time, but others persist for long periods. A few of the agents that find their way into soil from manure cause disease only in animals; others can cause human illness as well.

These disease agents get onto the edible parts of low-growing plants, either by splashing during rainstorms or in soil thrown up during cultivation. Disease agents usually cannot move through the tissues of the living plant, so contamination is limited to the surface and can largely be removed by careful washing. Effective washing may be difficult when the food surface is complex, however, as is the case with lettuce, cabbage, cauliflower, and broccoli. Also, the seeds from which edible sprouts are germinated have proved very difficult to decontaminate—among other factors, the sprouting process takes place at temperatures in the danger zone.

If the edible part of a plant develops well above the soil surface, there is relatively little chance that human disease agents will be present on it at harvest time. Food that develops close to the soil, on the other hand, can be contaminated far more easily. A large disease outbreak resulted from cole slaw contaminated with a bacterium, *Listeria monocytogenes,* that came from sheep manure used to fertilize the cabbage. *Listeria* can grow slowly at refrigeration temperatures; in this case, it apparently did so while the cabbage was being held in cold storage. Because the cabbage in cole slaw is not cooked, the agent was still infectious when the slaw was eaten.

Fresh-cut produce sold as prepackaged salad mix also offers considerable opportunity for transmitting contaminants from the field. Most often, this product has been a carrier of *Salmonella* or enterohemorraghic *E. coli*. But these bacteria—both of which probably originated in animal waste—at least will not grow in food that has been properly refrigerated.

Fruits growing close to the ground may also be subject to contamination from the soil. Under experimental conditions, eggs of the parasite *Ascaris lumbricoides* were shown to contaminate strawberries grown in infected soil: The people who ate the strawberries became infected with the parasite. (see Appendix C on page 43.) Hepatitis A virus in frozen strawberries and raspberries has caused disease outbreaks. The hepatitis A virus is transmitted by human fecal contamination, but how these berries became contaminated is unknown.

Concentrations of disease agents from soil are likely to be higher on underground than on above-ground plant parts, including the underground parts of carrots, onions, and potatoes. Because plant parts in contact with the soil are normally covered with a cuticle, a skin, or some other relatively impermeable coat, human disease agents do not readily penetrate the edible, interior portion of the plant. Insects, nematodes, or plant disease agents may pierce the outer covering, however, and so allow human disease agents entry to the inside of the plant.

Any crop harvested by human hands is at some risk of fecal contamination if toilet and hand-washing facilities are not provided for field workers. Inadequate sanitary facilities for field workers may have led to an outbreak of hepatitis A in the Louisville, Kentucky, area that was traced to lettuce from a faraway supplier.

Storage to Prevent Spoilage and Contamination

Plant tissues tend to contain high levels of water, so they are susceptible to microbial spoilage. Some plant tissues are also quite acidic, however, and this characteristic inhibits both spoilage and the growth of disease agents. Some old methods of food preservation still in use today are based on drying, on other means of reducing available moisture, or on generating acidity via fermentation. The more modern methods of canning and freezing have also become important means of preservation. Canning kills spoilage and disease agents. Freezing arrests their growth (at least temporarily) but does not totally eliminate disease agents.

COLD STORAGE. Acidic fruits will permit the growth only of yeasts, molds, and a few types of bacteria. These agents are principally causes of spoilage rather than of human illness. Molds cannot grow without oxygen, so, ideally, fruits should be packaged under low-oxygen or oxygen-free conditions for refrigerated storage. Freezing fruits will stop microbial activity but may change the fruits'texture.

Fruit juices are as acidic as the fruits they came from. Juices can usually be preserved successfully with limited heating and exclusion of air or by freezing. Unpasteurized orange juice has transmitted *Salmonella*, however, and on various occasions unpasteurized apple juice has transmitted both *E. coli* O157:H7 and *Cryptosporidium parvum*. In one instance frozen orange juice transmitted hepatitis A, apparently because the worker who reconstituted the juice put her soiled hands into it.

Proliferation of disease organisms on vegetables is unlikely during cold storage, with the exception of *Listeria*, as in the cole slaw example cited on page 11. Parasites and viruses that may contaminate the surface of vegetables cannot multiply under any circumstances, and most of the bacteria and molds that cause disease will grow only at higher temperatures.

If conditions are favorable, each bacterium or mold has a range of temperatures in which it can grow. Somewhere in this range is an "optimum" temperature at which growth is fastest. If other conditions—available moisture, acidity, air—are less favorable, the temperature must be nearer the optimum for the microbe to grow.

Fresh mushrooms may allow growth of the disease agent *Clostridium botulinum* during storage. Research has shown that fresh mushrooms packed in impermeable film use up the oxygen in the packaging, after which spores of *Clostridium botulinum* can revive, grow at room temperature, and produce toxin. This finding has led to a recommendation that fresh mushrooms be stored and commercially marketed in plastic wrap with a few holes in it to admit oxygen. Continuous refrigeration of the mushrooms would also prevent outgrowth of the types of *Clostridium botulinum* that are likely to be present.

DRYING AND CANNING. Drying has long been used to preserve fruits. Because molds can grow at very low levels of available moisture, however, fruits must be dried rapidly and thoroughly to avoid spoilage. Some molds that grow on fruits produce toxins such as patulin (sometimes found in apple juice) and byssochlamic acid. Proper storage conditions are crucial for dried foods to avoid moisture reabsorption.

Because of their acidity, fruits such as tomatoes are usually canned with limited heat processing. New varieties of tomatoes that are less acidic require either the addition of more acid (often in the form of citric acid) or more rigorous processing to eliminate the threat of the deadly intoxication of the central nervous known as botulism. All home-canned foods, if not strongly acidic or properly processed, present some risk of botulism.

In one instance, a Wisconsin woman opened a jar of her own *Clostridium botulinum*–contaminated home-canned carrots and tasted only what adhered to her finger. She decided not to serve the carrots to guests, but her small taste resulted in slurred speech and muscle weakness and necessitated 10 months of hospital rehabilitation. At a restaurant in Vancouver, British Columbia, a commercial preparation of chopped garlic in soybean oil (a preparation that should have been refrigerated) was evidently stored for several months at room temperature before being opened and served. At least 34 cases of type B botulism resulted.

Hazards generally do not increase with proper storage of vegetables, although potatoes that are exposed to light become green and produce solanine, which is poisonous to humans.

Preparation

If the surface of a food is dry and intact, contaminants on it are unlikely to multiply. Washing, peeling, and cooking are important means of getting rid of surface contaminants on fruits and vegetables. Hands should be washed with soap and water before food preparation.

Vegetables are likely to carry spores of *Clostridium botulinum* from soil into mixtures of food, whether frozen or fresh. A commercial frozen pot pie, insufficiently heated in an oven, left on an unrefrigerated shelf for two days, and then eaten without reheating, caused botulism in a woman in Los Angeles County, California. In Santa Cruz County, California, two turkey loaves were prepared using cereal, onion, and green pepper as ingredients. One loaf was eaten immediately, without incident. The other was left in the oven with the pilot light on (90° F; 32° C) until the next afternoon. It then was tasted, reheated for 20 minutes at 300 degrees F (149° C), and served. Two people got botulism: the person who prepared the loaves and tasted the second one before reheating it and one who ate from the center of the second loaf after it was reheated. Two other members of the household ate portions of the second loaf without ill effect.

All of these illnesses could have been prevented by properly refrigerating the cooked foods or by thoroughly reheating the foods before tasting or eating them.

Containers for acidic foods must be chosen carefully. A fruit punch served to a California junior high school class caused 29 cases of illness. The punch had been prepared and stored in a galvanized metal container and when tested was found to contain 2,000 parts per million of zinc that had evidently been dissolved from the galvanized surface by the fruit acid.

Grain Products

True cereal grains are members of the grass family, but many other food seeds are handled as though they were grains. Among these are the seeds—known as pulses—of such legumes as peas, beans, and lentils. The principal threats to human health from grains derive from field fungi and storage fungi.

In the Field

Fungi growing on plants in the field can produce toxins in the seeds of the host plants. Seeds affected by such fungal growth may look abnormal, but it may not always be practicable to separate them from wholesome seeds. Some fungal diseases, such as ergot, subtly affect grains in the field and make them hazardous even before harvest. Others, such as corn smut, look sickening but apparently are not injurious to humans.

Storage

Humans have stored grains and pulses in their dry state since prehistoric times. If the seeds are mature when harvested and can be dried and kept dry to prevent spoilage, storage of such dried foods is both economical and effective.

When fully mature and dried, seeds are usually so low in available moisture that bacteria cannot grow on them. Under most circumstances seeds are also too dry to permit mold growth, but it may be difficult to maintain this degree of dryness in humid climates or in especially humid years. Fungi may grow on grain that has too high a moisture level, and some of these fungi produce toxins that can cause a wide variety of human illnesses. The fungus *Aspergillus flavus*, for example, which grows on peanuts, corn, and soybeans, produces the toxin aflatoxin. This toxin can occur in the milk of cows fed moldy grains and in products made from such grains. In addition to causing digestive ailments, aflatoxin has been shown to induce liver cancer in some populations (see Appendix D, page 45).

Insects, rodents, and birds will all attack grain, so drying it to prevent microbial spoilage is not enough. The insects that contaminate grain do not need to drink water; they produce it as they digest the grain. The moisture from the insects'bodies can support mold growth in the immediate area of the insects'activity. The exclusion of insects, rodents, and birds from grain stored in the U.S. is assumed but is never 100 percent effective. In less developed countries a great part of the already inadequate food supply is often lost to such pests during storage.

<u>*Preparation*</u>

MILLING. Milling will not produce flour safer than the grain that went into the process, with one exception: Bleaching flour kills many bacteria. Any effect bleaching might have against fungal toxins in grain has not been studied; but, in any case, many milled products are not bleached.

Fungal toxins—which may be produced either before or after harvest—are very heat stable and unlikely to be destroyed in baking. Because of this, it is important that grain not have dangerous levels of toxin at the time it is milled. Once milled, grain products are subject to the same risks as stored grain: Excess moisture can permit mold growth; and incursions by insects, rodents, and birds can cause contamination.

Milled grain products have only rarely been sources of human disease agents, even though such products are sometimes used in ways that entail little heating.

BAKING. Flour is the principal raw material for baking. If it is made from grain that has been properly dried and stored, the flour is likely to be free of safety hazards. Doughs and batters must contain significant amounts of water, however; and this eliminates dryness, the main safety factor in the storage of grain and flour. Additionally, eggs and other ingredients may carry contaminants into baked goods.

Baking does not sterilize food, no matter how high the temperature, because baked goods contain water. Boiling temperature (212° F or 100° C) is never exceeded until all of the water has evaporated. (Pressure cooking, used in canning, can overcome this limit.) The outermost layer of a cake or loaf of bread may get hotter than 212° F, developing a darker color or forming a crust. But the center—the last part of the cake or loaf to which heat penetrates—will be "done" long before it reaches boiling temperature. A contaminant that can be destroyed at high temperatures therefore can survive baking. Toxins produced by molds are not inactivated in baking.

Fillings and coatings can also present hazards. Cream-filled pastries have been a frequent source of food poisoning when not refrigerated continuously to prevent bacterial growth. The bacterium *Staphylococcus aureus* is often the disease agent in such cases (see Appendix A, page 40). Pastry icings may also support the growth of *Staphylococcus* bacteria. Custard fillings and other preparations containing eggs are subject to any risk associated with eggs (see page 20).

Milk and Dairy Products

Early in the 20th century, milk was recognized as a leading vehicle of foodborne diseases, among them tuberculosis, scarlet fever, brucellosis, and diphtheria. Q-fever, listeriosis, salmonellosis, campylobacteriosis, and other bacterial infections have since joined the list of diseases transmitted by raw milk. The introduction of pasteurization about 80 years ago greatly increased the safety of the milk supply.

The Production of Milk

Cows and, to a much lesser extent, goats are the principal sources of milk in the United States. In other parts of the world sheep, reindeer, camels, water buffalo, yak, and even horses are milked. Milk in the udder of a healthy animal contains very few bacteria, but various infectious agents exist in the milk of animals afflicted with mastitis, a disease caused by an infection, usually bacterial, of the mammary gland.

Milk is an exceedingly good medium for bacterial growth and can be contaminated as soon as it is withdrawn from the udder. As a result, many changes may occur in the milk. Some of these changes have been used since prehistoric times to develop products that are more stable than milk itself.

Preparation

PASTEURIZATION. Despite some people's efforts to promote unpasteurized over pasteurized milk as more nutritious and healthful, the most straightforward principle in food safety is this: Don't drink unpasteurized milk! Unpasteurized milk continues to serve as a vehicle for various diseases in California. In Scotland milkborne disease declined sharply after the distribution and sale of unpasteurized milk were prohibited.

The Grade A Pasteurized Milk Ordinance—a regulation in use across the U.S.—emphasizes sanitation as well as pasteurization. Under the ordinance farms and dairy plants are inspected to ensure that proper equipment and cleaning measures are used and that the milk is kept at a proper temperature. Pasteurized milk has enjoyed an outstanding safety record in the United States, but in recent years equipment failure or improper operation or mishandling has led to both small and large outbreaks of salmonellosis and listeriosis from what was supposed to have been pasteurized milk.

OTHER PROCESSED MILK PRODUCTS. If the right kind of bacterial "starters" are added to fresh milk, controlled souring can produce acceptable homemade yogurt. Other fermented milk products are kefir, butter-milk, and cottage cheese. Freezing and whipping milk under controlled conditions, usually with some added sugar, produces ice cream, ice milk, and sherbet. If the original milk or milk at some intermediate stage (ice cream mix, for example) has been pasteurized, these products will be free of microbial hazards.

In the U.S., cheeses made with unpasteurized milk must be aged under specified conditions that will kill the bacteria that cause the infection known as brucellosis. Often, the milk in such cheeses has been heat-treated, but not for the full time or to the full temperature of legally defined pasteurization. There is, however, at least a possibility that this aging process is not sufficient to kill *Listeria*, a bacterium that often contaminates cheeses, especially soft cheeses, in which the bacteria can multiply when mold growth decreases the cheese's acidity.

Imported soft cheeses have been implicated in outbreaks of listeriosis and *Escherichia coli* diarrhea in the U.S., apparently because heat treatment of the milk used to make the cheese was not sufficient to kill the disease agents.

Storage

Spoilage of milk products is largely caused by the action of some low-temperature bacteria, molds, and yeasts. Bacteria are inhibited by the acidity of some dairy products and by the low available moisture in others, most notably salted butter. Pasteurized milk that has soured is not necessarily a health hazard. Such milk simply has a different flavor and consistency as a result of the bacterial conversion of lactose to lactic acid and the resultant conversion of protein. This process gives milk a sour taste and causes casein (milk protein) to settle out of the liquid, forming curds.

Dry milk products such as instant nonfat dry milk are so low in available moisture that they are microbiologically stable at room temperature. The temperatures used in processing these products do not sterilize them, however, so dry milk products must be handled under rigorously sanitary conditions to prevent outbreaks of salmonellosis.

Most cheese can be stored for long periods in the cold if air is excluded. The presence of air permits the development on cheeses of surface molds, some of which produce toxins. Aggressive trimming of hard cheeses will remove the mold and the toxin, but one-fourth to one-half inch of the cheese's surface must be removed. Molding of cheese can be delayed or prevented by such preservatives as propionate and sorbate. The bacteria used to make Swiss cheese produce propionate, so it is much less susceptible than other cheese varieties to mold spoilage.

Meat, Poultry, Fish, and Egg Products

Because of humans'relatively close evolutionary relationship to meat animals, many agents these animals carry can also make people sick. For this reason, the safety of the food supply in most developed countries is largely the responsibility of veterinarians. The food safety programs in these countries strongly emphasize zoonoses—diseases that are transmitted among animals, and occasionally from animals to humans, but that are not usually transmitted among humans.

From time to time new forms of zoonoses such as enterohemorrhagic *E. coli* emerge. Whether the use of antibiotics in animal agriculture contributes significantly to the antibiotic resistance increasingly seen in *Salmonella* and perhaps in other zoonotic bacteria remains an open question. The 1997 Food Safety Initiative targets elimination of zoonotic agents at the farm level; the means to accomplish this are not yet clearly apparent.

Contamination from the Farm and the Sea

MEAT. Bacteria are relatively uncommon in muscle meats, assuming that the muscle is intact. Bacteria contaminate the outside surfaces of meat while the carcasses are being skinned, eviscerated, and cut apart, however. These bacteria come largely from the intestinal contents and hides of the slaughtered animals and from the slaughter plant environment.

Sanitation in slaughter plants is under constant inspection by the Food Safety and Inspection Service of the United States Department of Agriculture (USDA). The USDA requires plants slaughtering and processing meat and poultry to develop what are known as "hazard analysis–critical control point" (HACCP) systems to enhance food safety. The conversion from previous inspection methods to the present system is very much a work in progress.

Many viruses infect food animals. Essentially none of these viruses infects people, so the mere presence of animal viruses in meat and animal products poses no threat to human health.

Parasites have become extremely rare in U.S. meat products, thanks to meat inspection measures. Hazardous bacteria and parasites associated with carcasses could be controlled or eliminated by irradiation, a process that—as of early 1999—is permitted by both the FDAand the USDA.

POULTRY. Two generations ago, the health risks associated with poultry were largely unknown or ignored. Chickens, in particular, were thought to have therapeutic properties. The free-running poultry of days gone by developed their distinctive flavors by feeding on some highly unsavory items: rotting garbage, carrion—even their own feces. Killed, plucked, and dressed to order on the neighborhood butcher's cutting block, yesterday's poultry was probably more contaminated than most of what is offered for sale today, especially since yesterday's carcasses often were not refrigerated.

In the United States today poultry, especially chicken and turkey, is a relatively inexpensive source of animal protein. Birds are usually raised in great numbers by systems designed to convert feed to edible product as efficiently as possible. The end product is meat that is tender, moist, tasty, and cheap. The safety of the modern poultry product is often questioned, however.

Clearly, the mass rearing and processing of poultry does carry some specific risks of contamination that may have been less manifest in the past. But other advances in poultry production have reduced the likelihood of contamination. Some poultry is distributed frozen. Much of the rest is held just below the freezing point of water to deter surface spoilage without actually freezing the meat.

A significant proportion of raw retail poultry carries *Salmonella* or *Campylobacter* bacteria on its surface. As with plants that process red meat, USDA–inspected U.S. poultry plants are now being required to institute HACCP systems in an effort to enhance food safety (see page 18).

Major campaigns in other countries to reduce the occurrence of *Salmonella* in market poultry have produced only partial reductions in *Salmonella* incidence accompanied by significant price increases. In this country the USDA has approved two processes, irradiation and dipping in a trisodium phosphate solution, to provide a further barrier to the transmission of *Salmonella* and *Campylobacter* bacteria from chicken. The use of these processes should not lull consumers into thinking that they can eliminate sanitary steps when handling chicken, however.

FISH AND OTHER SEAFOODS. Finfish from some areas of the world may be toxic when caught; other fish become toxic later, through improper handling. The U.S. Centers for Disease Control and Prevention inaccurately report illnesses from these causes as “chemical food poisonings” when, in fact, most of the toxins involved are produced by algae and bacteria. The safety of America’s seafood has been made the responsibility of the FDA, which is now requires the implementation of the HACCP system throughout the seafood industry.

Fish caught in fresh waters may contain tapeworm larvae; fish from ocean waters may contain roundworm larvae. In neither case is this contamination the result of poor sanitation: The fish acquire these parasite larvae even in waters not subject to human fecal contamination.

Bacteria are less of a problem in finfish than in other seafood, and viruses are seldom encountered in finfish. Bacteria and viruses transmitted to humans via fish are most often of human origin; they get into the fish by indirect fecal contamination after the fish are caught. One important exception is the spores of type E *Clostridium botulinum*, which occur in both marine and fresh waters and affect all kinds of seafood.

The *Clostridium botulinum* spores themselves do not affect humans; but if handled or prepared in certain ways, fish containing the spores may become toxic. People have acquired botulism from smoked whitefish chubs from the Great Lakes, from fish intestines in Hawaii, from "kapchunka" (a dried, salted fish product in which the intestines are still present) in New York City, and from other fish products around the world.

True shellfish (bivalve mollusks such as oysters, clams, and mussels) can collect bacteria and viruses from their environment—the waters in which they live. If the waters are contaminated with sewage containing human waste, the sewage-borne bacteria (especially *Vibrio chlolerae,* the bacterium that causes cholera) and viruses present a threat to human health. Other bacteria, such as *Vibrio vulnificus*, may also be present in shellfish. These bacteria are not generally produced in the human intestines but may be indigenous to the water. Depuration (a process by which mollusks cleanse themselves of microbial contaminants), irradiation, and cooking are all means used to eliminate or destroy these infectious agents. Depuration and irradiation are more effective against bacteria than against viruses.

Shellfish sometimes collect deadly toxins such as paralytic shellfish poison (PSP) that are produced by algae in blooms known as "red tides." Under the worst circumstances, eating shellfish contaminated with PSP can kill a person in under an hour.

These toxins withstand cooking, and no known means of preparation will remove them. As a safety measure, both the FDA and seacoast states usually monitor shellfish for the presence of PSP. After an algal bloom, most shellfish rid themselves of the PSP toxin and become safe to eat within a few days or weeks. Alaskan butterclams seem to retain the toxin much longer, however. Such poisonings are classified by the CDC as chemical in nature, even though they are of microbial origin.

The third large group of seafoods is the crustacea, a group that includes shrimp, prawns, crabs, and lobsters. These creatures tend to be extremely perishable but are seldom associated with agents of human disease, at least up to the time they are caught. (Crabs have been the source of occasional cases of cholera in the U.S. and may have been involved in the outbreak of cholera that spread from Peru through the Americas in the early 1990s.)

A more common safety problem with crustaceans arises from the labor intensity of preparing (peeling, deveining, etc.) some of these foods. In many countries outside the United States this preparation is performed by "cottage industries" under conditions that do not meet U.S. sanitary standards. It is partly because of concerns about these substandard sanitary conditions that the FDAis now requiring that safety systems comparable to the HACCP system mandated in the U.S. be applied to imported seafoods. United States–specified control systems will be very difficult to apply to the many seafoods produced abroad, however.

Eggs. At one time an egg with an intact shell was considered sterile, and shell eggs are still rarely refrigerated in Europe and in developing countries. It was clear, however, that the hazards were significant once the eggshells were removed. The USDArequires pasteurization of all processed egg products to eliminate infectious agents such as *Salmonella*.

In recent years strains of *Salmonella enteritidis* have emerged that infect the hen's ovary, allowing the infectious agent to occur inside the intact eggshell. If such eggs are not refrigerated, the *Salmonella* bacteria can multiply to levels that without thorough cooking can be dangerous. *S. enteritidis* is now the leading type of *Salmonella* causing foodborne disease in many countries, and it ranks very high in the U.S. Measures to eliminate this strain of *Salmonella* from laying hens are currently being sought. Cooking eggs until the yolk and the white are solid will prevent salmonellosis; this will be unnecessary when newer methods of pasteurizing eggs in the shell with irradiation or heat become available.

Preparation

MEAT. Eating any meat that is undercooked or raw can lead to foodborne illness. *Salmonella* is more common in chickens than in beef, but in the United States more salmonellosis is contracted from beef than from chicken—possibly because beef is more often consumed rare or raw.

Every new cut into meat carries some bacteria onto the newly created surface. When meat is ground, a great deal of new surface is created—and contaminated. Bacterial growth and spoilage are therefore much more rapid in ground beef than in intact pieces of beef, given equal storage temperatures.

Spoilage of ground meat can only be arrested by prompt cooking or freezing. More importantly, any disease-producing bacteria that were on the surface of the intact pieces of meat become mixed into the ground meat, and may multiply if refrigeration is inadequate. Since the center of a piece of meat being cooked is normally not as hot as the surface, these bacteria may survive incomplete cooking. This has led to outbreaks of infection with enterohemorrhagic *E. coli*, usually of type O157:H7.

Recent research has shown that color is not a reliable indicator of the interior temperature of cooked ground meat, so consumers are advised to use a thermometer and to cook ground meat to an internal temperature of 160 degrees F (72° C). Irradiation will kill disease bacteria in ground beef and retard spoilage, but recontamination must be prevented by proper packaging and handling.

Although the incidence of *Trichinella*–infected swine may be less than one in 200 at USDA–inspected slaughter plants, consumers must assume that pork contains the *Trichinella* parasite. Pork must be cooked thoroughly until a temperature of 150 degrees F (66° C) is reached throughout, or until there is no pink color in the meat, especially around the bones. Irradiation or prolonged freezing also will kill *Trichinella*.

Other parasites may also be present in pork, in lamb, and in beef. These parasites are even less prevalent than *Trichinella* and are unlikely to dissuade those Americans who prefer to eat their meat rare. One parasite, however, *Toxoplasma gondii*, causes enough birth defects from infections *in utero* to be regarded as a very high-ranking foodborne disease agent in terms of its cost to society.

Poultry. Although U.S. surveys generally find *Salmonella* in less than half of market chickens, all poultry should be handled with the assumption that *Salmonellae* are present. Precautions should include preventing drip from raw or thawing birds from contacting other foods; careful cleaning of all work surfaces and utensils; careful cleaning of hands that have touched the raw bird; thorough cooking to the bone (at 170° F/77° C and, for turkeys especially, using a meat thermometer); and, finally, taking care not to recontaminate the cooked bird by carving it on the same work surface on which it was prepared unless that surface has been thoroughly cleaned.

There is increasing concern today about the presence of *Campylobacter jejuni* in poultry; the precautions against salmonellosis recommended above will also control this disease agent.

Fish. Because tapeworm and roundworm larvae cannot easily be seen in fish muscle, fish cannot safely be eaten raw, even when it is prepared at an upscale restaurant. Freezing fish that is to be eaten raw offers some protection, but it is not as reliable as thorough cooking.

Home-canned salmon can be a hazard. The botulinum toxin that may be present in the product can be destroyed by thorough heating (at least 20 minutes of boiling). This should be done before the contents of a container are even tasted.

Fugu (or pufferfish), a Japanese delicacy, concentrate a deadly toxin in their gonads. Skill and training are required to remove the gonads and other viscera without contaminating the edible flesh with the toxin. Over the last 100 years about 10 persons have died in Japan each year from fugu fish poisoning.

Eggs. It is important to refrigerate eggs purchased in the shell and then to cook them thoroughly. It is often recommended that eggs kept in the refrigerator be stored on a shelf rather than in the egg rack on the refrigerator door in order to keep them at a lower temperature. Foods likely to contain raw eggs (eggnog and Caesar salad, for example) are better purchased in commercial versions made with pasteurized eggs. Persons with impaired immunity (infants, the elderly, AIDS patients, and people on immunosuppressive medications) should never eat raw or soft-cooked eggs that were purchased in the shell.

The safety of hard-cooked eggs has also come into question. Under some conditions bacteria can be drawn into the egg as it cools after having been boiled. If the hard-cooked egg is not refrigerated, the bacteria can multiply. At least two large food-poisoning outbreaks have occurred this way; both involved *Staphylococcus* in Easter eggs. Hard-cooked eggs that have been kept at room temperature should not be eaten. Though the bacteria in such eggs could be killed by thorough reheating, the toxins produced by the *Staphylococcus* bacterium are not destroyed by boiling.

READY-TO-EAT AND CONVENIENCE MEAT PRODUCTS. A great many products containing meat, poultry, and seafoods are sold "fully cooked, ready to eat." Other convenience foods may be considered ready to eat but have not been fully cooked. In either case, the preparation of these foods is very closely supervised by both the USDA and the FDAbecause such products are often safe only when the package directions are followed carefully. The formulations of these products are designed to make the products as inhospitable as possible to bacteria. Sanitation in processing such foods must be meticulous. Nevertheless, it is the consumer who must accept ultimate responsibility for storing and preparing these products as directed—a responsibility that can, quite literally, be vital.

Recently, food products formulated for cooking or heating in microwave ovens have caused some concern. Although package directions are undoubtedly tested in several types of units before such products are offered for sale, there is enormous variation in performance among microwave ovens. A given power setting may yield different results in ovens of different wattages or among different brands or models of ovens. Heating action may be unevenly distributed in the oven chamber, and performance may change as a unit ages. Deluxe oven models now offer features intended to improve uniformity and predictability, but to produce a safe result, the user of any microwave oven must pay close attention to directions and be willing to do some mixing and waiting for food. This is especially true when dealing with convenience foods containing meat.

Other Foods

Many popular foods and ingredients do not fit easily into one of the preceding categories. Some of these foods will be discussed here because of their real or supposed significance to food safety.

Ethnic Foods

The CDC lists Chinese food and Mexican food alongside such specific food items as beef, shellfish, and eggs as vehicles in reported foodborne-disease outbreaks. This suggests that these foods are intrinsically more hazardous than, say, Japanese food or Italian food; but there is no evidence to support such an assertion. If, for example, beef prepared in a Chinese or Mexican fashion were implicated as a vehicle for disease, the CDC would list that beef in the "ethnic" category rather than under "beef."

While such a system does introduce classification problems, the main function of the CDC's "ethnic" category may be to contrast traditional methods of food preparation with those used in modern restaurants. Again, however, there is no reason to suppose that this problem is specific to Chinese and Mexican cooking. Good personal hygiene and proper food-handling practices are critical to all types of food service, regardless of ethnicity.

Spices

Spices are typically grown in areas of the world where hygienic standards are not as high as they are in the U.S. food industry. Spices arriving in the United States from abroad often contain far higher levels of disease-causing bacteria than do other food ingredients. Even though spices are used in relatively small amounts in food preparation, in some circumstances microbes from a spice can outnumber microbes in the rest of the food and become the dominant contaminant.

Spices lose flavor when they are heated to control bacteria. Ethylene oxide and propylene oxide treatments have been used on spices instead, but these chemicals are now being limited or banned because of concerns about the safety of the workers who apply them. Today, irradiation with cobalt-60 gamma rays is widely used on spices. The effectiveness and safety of this technology are endorsed by the FDA, WHO, the Food and Agricultural Organization, and the International Atomic Energy Agency. Irradiated spices are being used in preparing combined foods but are not yet available to U.S. consumers at their grocery stores; they are routinely bought and used in some European countries, however.

Additives

Additives have been used for thousands of years for everything from taste enhancement to food preservation. Today, many substances are added to foods to enhance their flavor, color, texture, nutritional value, or storage quality. Under U.S. law, additives include “generally recognized as safe” (GRAS) substances, flavors and extracts, direct additives, and color additives, as well as unintentionally added substances such as packaging ingredients. There is no known instance of human illness resulting from food additives legally present in food other than those due to individual allergies or intolerances.

All substances present in food in the United States are under the jurisdiction of the FDA. While not every introduced substance is legally categorized as a food additive, those that are must be listed on food labels. Additives have been, and are continually being, tested for safety. Persons who have abnormal reactions to certain ingredients can use the information on food labels to avoid the substances that bother them.

Sugar and Honey

In recent decades many adverse effects have been attributed to sugar consumption. Although sugar may contribute to tooth decay under some circumstances, carefully performed experiments have not confirmed the alleged behavioral effects of sugar.

In these experiments, behavioral effects have been perceptible only when the observer has been told whether or not the subject has eaten sugar. If neither the subject nor the observer has known whether there was sugar in the food consumed, the alleged behavioral changes have occurred randomly.

Foods high in sugar are partially protected against microbial spoilage because the sugar makes the water in the food less available for microbial use. Honey, a concentrated sugar suspension produced by bees, seldom supports microbial growth because of its high sugar concentration.

There is no reason to believe that honey affects those who eat it any differently than do other forms of sugar. Honey should not be fed to infants less than one year old, however, because honey sometimes contains spores of *Clostridium botulinum*. When these spores reach the intestines of infants who do not already have a rich growth of other bacteria, the spores can germinate and colonize. The toxin produced by the bacteria then causes the child to go limp, lose sucking ability and, in the extreme, die of respiratory arrest. Infant botulism is considerably more common in the United States than is food-poisoning botulism. Most cases of infant botulism probably derive from other sources of *C. botulinum* spores, but honey is the only food specifically incriminated by laboratory testing and epidemiological studies.

Mayonnaise and Other Dressings

For many years consumers were told that salads and other foods made with mayonnaise were especially likely to allow the sort of microbial growth that could lead to food poisoning. Research has now shown, however, that mayonnaise and other dressings containing vinegar exert at least a temporary preservative effect: The acidity of the vinegar kills or delays the growth of some food-poisoning bacteria. Because preservation by the acetic acid in vinegar is temporary, however, salads made with vinegar-containing dressings still need refrigeration.

RELIANCE ON THE FOOD INDUSTRY

Contrary to popular opinion—and contrary to many stories in the media about dangers to health from the food supply—illness does not usually result from the commercial production or processing of food, from additives, or from trace levels of agricultural chemicals.

Most foodborne disease results from pathogenic microorganisms that proliferate because of the mishandling of food in food-service establishments (restaurants, for example) or in homes and other noncommercial settings. During 1988–1992, the most recent five-year period for which data have been released, foods eaten in restaurants and other commercial food-service establishments and in the home accounted for 40 percent and 18 percent, respectively, of the 2,423 foodborne disease outbreaks reported to the CDC. (The CDC data do not specify where the implicated foods were prepared.)

Few Americans today grow a significant proportion of their own food. Overwhelmingly, consumers depend for what they eat on the food industry, a term that encompasses producers (farmers, ranchers, and fishermen), processors, distributors, retailers, and food-service operators.

In most of the United States, food production is highly seasonal. People who wish to eat only fresh, unprocessed foods must pay to have those foods transported over great distances, perhaps from other countries. Alternatively, foods produced seasonally must be processed or preserved to make them available throughout the year. Whether processing or distributing, the workers who make up the American food industry have key roles to play.

Retailers and food-service operators comprise the consumer-contact segment of the food industry. Only when these two groups have completed their tasks is the work of the industry done. Safety is all important all along the food industry's "food chain," from the farm or fishery right up to the point at which the food is eaten. Because the companies and individuals who make up this chain realize that their reputations as suppliers of safe and wholesome products are their most valuable assets, they are highly motivated to minimize risks to the consumer.

How Does Processing Improve the Safety of Some Foods?

Processing generally converts raw materials to edible end products that can be stored and distributed safely and also removes or destroys hazardous components in food. The primary objective of most food processing is to extend shelf life or to create food products—such as breakfast cereals—from individual ingredients. The processing of food is strictly regulated by the FDA and the USDAand includes Good Manufacturing Practices (GMP) and inspection systems.

One such process, milk pasteurization, was instituted to prevent transmitting tuberculosis and other diseases to humans. The process of canning is intended to prevent botulism. The nitrite used in cured meats is also effective, when used together with salt, in preventing botulism. Freezing prevents the growth of disease-causing bacteria and may also kill parasites in meat and fish. Such processes are generally designed by the food industry to increase the shelf life of food—and any reduction in food spoilage and waste contributes, eventually, to a less costly food supply for everyone.

Irradiation has the ability to penetrate foods and destroy disease agents. It also provides other benefits, among them the prolongation of shelf life and the prevention of spoilage. Because the U.S. Congress has defined irradiation as a food additive rather than a process, however, it has been very difficult to make irradiated food available to the public.

The FDA has generally agreed with the World Health Organization and other scientific organizations that irradiation does not present a hazard to the consumer and may significantly enhance food safety. Approval of irradiation in specific applications in the United States has been very slow, however; and both the USDA and the FDA have chosen not to advocate its use. Unfortunately, from this lack of advocacy of the part of the FDA and the USDA the American public has been getting the message that there is something wrong with or dangerous about irradiation. Despite this, U.S. consumers have bought irradiated foods when such foods have been offered. When food processors and retailers finally make irradiated foods more widely available, they will be purchased.

How Does the Food Industry Insure the Safety of Its Products?

Once it became known that most foodborne disease hazards were microbiological in nature, the food industry, in cooperation with university and government laboratories, began to find ways to control most of the microbiological risks then known to be associated with foods. Even today, previously unknown hazards are being recognized, investigated—and controlled.

There is still a certain inevitable risk that human error or equipment failure will take place, however. Neither visual inspection nor laboratory testing can guarantee perfect safety all the time. This is why systems have been developed to monitor food processing and enhance safety throughout the food industry.

A great impetus to devise a zero-defect food processing system arose in the 1960s in connection with the U.S. space program. The costs of extraordinary quality-assurance measures for foodstuffs looked small when set against the potential costs of a space mission lost because of food poisoning among its astronauts. To address this problem, a major U.S. food company, in collaboration with the National Aeronautics and Space Administration (NASA), devised a system that has since come to be called “hazard analysis–critical control points” (HACCP).

The essence of the “hazard analysis” part of the system is the assessment of the risk associated with particular foods. The natures of a food’s raw materials are determined, and controls are applied relative to how those materials are processed or who is meant to eat them. The “critical control point” aspect of the system involves identifying specific operations that, if performed incorrectly, will lead to a significantly less safe product. These are the operations to which the closest monitoring is devoted.

Although the HACCP system was devised originally as a cost-is-no-object approach to quality assurance, the system makes food safer for less money than do more traditional regulatory approaches. The HACCP system is now in wide use throughout the food industry. In most instances, this resulted from the industry's recognition of the worth of such systems; but, lately, both the FDA and the USDAhave been requiring that HACCP systems in settings where they had not yet been used. The regulatory version of HACCP presents some significant differences as compared with the HACCP systems instituted by the food industry.

GOVERNMENT ACTIVITIES

Americans frequently look to government to guarantee food safety. It was only in the early 20th century, however, that the Pure Food and Drug Act and the Meat Inspection Act (both enacted in 1906) gave federal agencies jurisdiction over food sold in interstate commerce. At first the focus was more on economic fraud than on food safety, but today many government agencies are involved in ensuring the safety of America's food supply. Budgetary problems have limited the agencies'role in supervision, however, and have limited their ability to base decisions on scientific research findings. This is particularly true of the data needed for risk assessment. The federal government's May 1997 "Food Safety Initiative" seems to promise some change in this situation, but it is not certain that this promise will be fulfilled.

The USDA

The U.S. Department of Agriculture's Food Safety and Inspection Service is responsible for the inspection of meat and poultry in interstate commerce. It is also responsible for inspecting meat and poultry in intrastate commerce in about half the states—those that have chosen to relinquish their inspection role to the federal government.

A USDA–inspected plant is supposed to operate only when one or more "resident" inspectors are present. An inspector who observes hazardous or improper food handling can halt the plant's operation and detain all improperly handled food until the situation has been corrected. The recently mandated HACCP system seems likely to shift some of the inspection burden from the inspectors to the company's workers, but the inspectors' union has filed suit and is otherwise trying to prevent this.

The FDA

The FDA is responsible for the regulation of all foods in interstate commerce; all imported foods other than meat and poultry; and food additives, packaging materials, and processing methods. Additionally, the agency regulates food service on interstate carriers (airlines and long-distance trains) and along interstate highways and is charged with the regulation of many other, less obvious, aspects of food safety.

The FDA's basic mode of operation is the unannounced "drop-in" inspection. One or more inspectors visit an establishment, identify themselves, and proceed to observe and collect samples for later laboratory analysis. Food that is judged by the FDA inspectors to be illegal or hazardous is said to be "adulterated." It can be seized and the operators deemed responsible for its condition enjoined or penalized. More often, the FDA inspectors "advise" a recall, whereby the operator accepts responsibility for retrieving any of the questionable food already in distribution and then destroys or reprocesses it to meet the applicable standards.

It became clear some years ago that the FDA's level of staffing did not permit drop-in inspections often enough to assure that food operations were being conducted properly. To correct this deficiency the FDApre-scribed Good Manufacturing Practices (GMPs)—procedures designed to tell the food industry what they should be doing rather than what they should not be doing.

GMPs are now in use throughout the food industry. They specify not only modes of operation, but principles of equipment, of plant design, and of maintenance. HACCP is now being incorporated into GMPs as a prescribed part of safe food handling, and is specifically required in seafood handling.

Foreign food manufacturers and distributors who wish to export food to the United States are expected to adhere to the GMPs as well. The U.S. government has also proposed sending inspectors into other countries as a condition of trade. Both of these provisos may prove difficult to enforce under existing trade agreements, however.

Other Federal Agencies and International Organizations

A few other federal agencies play roles in enforcing food safety regulations. The National Marine Fisheries Service formerly conducted a voluntary inspection service for fish and seafood that seems now to have been supplanted by Congress's having put these products under the control of the FDA. The Bureau of Alcohol, Tobacco, and Firearms has jurisdiction over all production and distribution of alcoholic beverages. The Environmental Protection Agency (EPA) registers and establishes tolerances for herbicides and pesticides, including sanitizers used in food processing and preparation. The EPA also sets standards for drinking water (only potable water can be used in food plants) and for wastewater discharges.

The Centers for Disease Control and Prevention (CDC) helps with investigations of outbreaks, compiles reports of foodborne disease, and operates an active surveillance system, begun in 1997, called FoodNet. Finally, the Federal Trade Commission (FTC) oversees food advertising and industry competition. Below the federal level, all the states and many counties and municipalities have units that participate in the food safety enterprise.

There are also several international agencies that make important contributions to food safety. The World Health Organization (WHO), the Food and Agricultural Organization (FAO), and the International Atomic Energy Agency are all United Nations subsidiaries with substantial programs related to food safety, especially with regard to new technologies and international commerce. Codex Alimentarius is an international food standards code developed by the Codex Alimentarius Commission (CAC). The CAC was established by FAO and WHO to reconcile differences in food regulations among different countries. The International Commission on Microbiological Specifications for Foods is a program of the International Union of Microbiological Societies. The commission develops microbiological criteria and implements the HACCP system for food safety worldwide. None of these international organizations has any regulatory power of its own—the activities and recommendations of each are regarded as advisories to governments.

WHAT SHOULD GOVERNMENT AGENCIES BE DOING?

Government regulation is an important part of the food safety system. Because the agencies charged with this work probably never will be funded to the degree necessary to accomplish the job on the basis of direct inspection, however, government's potential is limited. Most of the day-to-day activity that insures the safety of our food supply thus comes from the private sector.

The adoption of GMPs and HACCP represents a major step in the direction of a prescriptive approach to safe food handling. Both the FDA and the USDA have repeatedly sought Congressional authorization to charge food companies for inspections. These "user fees" have been rejected; but the move to greater industry responsibility will have a similar effect, shifting the costs of inspection toward industry and away from government. Some of those who disagree with this trend see it as creating conflicts of interest that could compromise food safety.

The U.S. Congress and the state legislatures—with a great deal of urging from the press and various consumer groups—had long pushed food-regulatory agencies to focus on the added chemicals in foods. In 1997 the federal government's Food Safety Initiative properly identified microbes as the greater concern, but at present there are great differences in perception as to how this threat should be addressed.

Formerly, too, Congress had pushed food-regulatory agencies to focus on large, multistate food processing corporations. The Food Safety Initiative prescribes a "farm to table" approach, however. There may be significant contributions to be made toward food safety at the farm level, but advocating aseptic farming while not advocating a process such as food irradiation (which pasteurizes food) seems a major misplacement of priorities.

Another aspect of the Food Safety Initiative is an attempt to alert consumers to safe food-handling practices in the home. Some consumer activist organizations have endorsed this approach, but many such groups seem reluctant to admit that consumers share some responsibility in the area of food safety. More precisely, they maintain that foods should be pathogen-free so that consumers' lapses would have no adverse effects.

HOW CONSUMERS CAN PREVENT FOOD-BORNE ILLNESS

Consumers must find and use reliable sources of information about food and food safety. Unfortunately, much of what appears in the popular press is inaccurate or oversimplified. Newspaper and magazine writers proclaim miracle cures or describe mysterious ill effects that they then attribute to diet—with inadequate regard for the reliability of the information they are purveying. It is an atmosphere in which misinformation predominates.

One hopes that the federal government's new, consumer-oriented Food Safety Initiative will provide the public with needed information—and with a sense of personal responsibility. Once consumers learn how to keep their food safe, they will be able greatly to reduce the incidence of foodborne illness (see Table 2, below).

TABLE 2. THE WORLD HEALTH ORGANIZATION'S "GOLDEN RULES FOR SAFE FOOD PREPARATION"

1. Choose foods processed for safety.
2. Cook food thoroughly.
3. Eat cooked foods immediately.
4. Store cooked foods carefully.
5. Reheat cooked foods thoroughly.
6. Avoid contact between raw and cooked foods.
7. Wash hands repeatedly.
8. Keep all kitchen surfaces meticulously clean.
9. Protect foods from insects, rodents, and other animals.
10. Use pure water.

Tips for the Food Shopper

If someone cultivates a taste for—and eats—a wide variety of foods, he or she likely will consume a balanced diet, free of deficiencies. Unfortunately, a great deal of the advice printed in the media about what to buy and what to eat deals in simplistic and meaningless categorization: "good" food, "bad" food, "healthy" food, "junk" food. In truth, *any* food eaten in extreme quantities can be harmful—and any food eaten in moderation can be part of a healthful diet.

Following the advice set out in the USDA's food pyramid and reading the nutritional labels on food containers will provide more accurate information than is found in much popular food writing. Many consumers who lack knowledge of nutritional principles may still be confused, however.

There are really only three important principles of good food shopping to remember:

1. Read labels.
2. Buy a variety of foods.
3. If you are going to spend a significant amount of time in the store, arrange your route so that you pick up the most perishable items last.

Some additional tips follow:

- Avoid dented, damaged, or bloated cans.
- Do not buy food in torn or worn cartons, boxes, or containers.
- Buy and use foods before any expiration date on the label. (Do not, however, confuse an expiration date with a "sell-by" date. Food will not necessarily have spoiled or be unsafe by the sell-by date, which is intended to allow for reasonable storage time in the home after purchase.)
- Store foods at recommended temperatures, under recommended conditions.

Transporting and Storing Food After Purchase

Frozen and refrigerated foods should be selected last at the store and transported directly home to return them as quickly as possible to appropriate storage temperatures. Improper storage can undo all the cumulative effort that went into giving those perishable foods the levels of quality and safety they had at the time of purchase.

Labels generally state how a food should be stored. The "cool, dry place" specified on some packaging may not exist in some homes; but at the very least such packages should be stored out of direct sunlight and away from such warm spots as the top of the refrigerator.

The proper temperature for a freezer is 0 degrees F (-18° C) or less.

The proper temperature for a refrigerator is 32 degrees to 40 degrees F (0° to 5° C). These temperatures should be verified from time to time with an accurate thermometer. The USDAand other organizations have published specific recommendations about the periods of time that different raw, cooked, and frozen foods can be stored. Some of these recommendations are oriented more toward quality than toward safety, but the periods specified should not be greatly exceeded. Finally, incursions by insects and rodents should be combated rigorously.

Preparing Food for Home Consumption

Cross-contamination—a serious problem—has been discussed elsewhere in this report (see page 9), but it begs for further mention here. In good restaurants, raw meat and poultry are kept in separate refrigerators, away from other foods, to reduce the risk of cross-contamination. Few homes have the luxury of more than one refrigerator, however, so it is important to plan home storage so that drips from raw meat and poultry do not cause contamination.

Contact surfaces, utensils, and hands are other important potential sources of contamination. Soap or detergent and hot water are powerful tools for removing microbial contaminants from work surfaces, utensils, and hands. Kitchen sponges can be decontaminated by rinsing them and then microwaving them on “high” until they are steamy (30 to 60 seconds).

When new, cutting boards made of plastic or other modern materials are more easily cleaned and sanitized than are wooden boards; but a knife-scarred plastic board is more difficult to clean than a wooden one. The important thing to remember is to remove food residues from work surfaces before they soak into or dry onto those surfaces. Extremely hot water may help loosen fatty and oily deposits but can make some proteins and starches harder to remove. Plastic (and some wooden) cutting boards can be cleaned in the dishwasher, but such cleaning is usually not done until after the meal.

Dealing with Leftovers

Avoiding cross-contamination from other foods and storing at appropriate temperatures are the keys to safe leftovers. It is important to remember that cooked food is not sterile, no matter how high the nominal cooking temperature. Food that has been taken to a picnic or that has been brought home from a restaurant may be especially risky, because such food has often stayed at room temperature for too long a time.

Other leftovers should be put directly into the refrigerator or freezer in shallow containers that let heat escape quickly. There should be no “cooling-down time” on the kitchen counter. The old idea of a “cool-down time” is a holdover from the days of the ice box. (Putting hot foods into an ice box would melt the ice and thus reduce the ice box’s cooling potential.)

Most leftovers that have been refrigerated promptly will be safe in the refrigerator for one or two days. Longer storage calls for freezing, however. Thawing should be done in the refrigerator or quickly in a microwave oven to minimize the time the food spends at "danger zone" temperatures (see page 10). Thorough reheating of foods that are to be served hot will also help reduce hazards.

Amateurs in Large-Scale Marketing and Food Service

There is a widely held belief that large-scale food handling done by unpaid volunteers carries no risks, but the reverse is often the case. When food is mishandled at home, the impact is limited because only a few people eat the food. At food-marketing cooperatives or large gatherings where food is prepared by amateurs, however, the mishandling of food can affect greater numbers of people.

Food-marketing cooperatives—places where people volunteer their services in return for reduced food prices—sometimes sell food that has been mishandled because the amateur staffers are inadequately trained and supervised in safe food-handling procedures. Large gatherings such as family reunions and organization picnics often rely on recipes scaled up and followed by people who have neither the experience nor the facilities for such large-scale food preparation. As a result, sanitation, refrigeration, and cooking are often inadequate. Toilet and hand-washing facilities may also be deficient or nonexistent.

In short, outbreaks of disease that result from the mishandling of food by amateurs are common.

HOW SAFE IS "SAFE ENOUGH"?

A no-risk national food supply is not an attainable goal. A small increase in safety to our already-safe food supply would require large sums of money. This large potential cost must be weighed against any potential benefit.

Today, U.S. consumers spend less time earning the money to pay for their food than do people in any other country. Despite this, our inexpensive food supply is still inaccessible to the at least 20 million people in the United States who are undernourished according to the standards set forth by the World Health Organization. Any change that would increase the cost of food, with or without good reason, would mean that more people would go hungry. The food safety agenda should be modified, therefore, only after very careful consideration of both the risks and the benefits.

The Cost to Consumers of Mandating Greater "Safety"

It is important for consumers to realize that risk-free food cannot exist and that any proposed increment in food safety will add significantly to the cost of food.

To cite one example, unopened canned food is "commercially sterile" except in those cases where the cans are marked "keep refrigerated"; but most other foods contain numerous microorganisms. Many foods would become extremely unpalatable if they were to be processed for sterility. And even sterile processed foods might contain very small amounts of toxic substances (such as mold toxins) carried over from the raw material.

Some foods cannot be made safe as purchased, at least until irradiation becomes more widely available. Additional government regulation of fish and seafood may enhance quality and improve sanitation, but no amount of time and effort (and added cost) will yield a risk-free raw product. Improved sanitation will not eliminate parasites from fish, nor will it eliminate certain hazardous marine bacteria and toxins from shellfish. It is simply not possible to guarantee that fish and shellfish can safely be eaten raw.

If consumers are unwilling to accept the risks they face eating foods produced under present circumstances, they may mandate changes in the system. Such changes might include improved sanitation on farms, both domestic and foreign, and more rigorously controlled food-processing and food-distribution conditions. Changes of this sort would generally increase both the retail cost of food and the taxes necessary for additional government enforcement activities.

The consuming public must decide how much more it is willing to pay for slight reductions in risk. People who now are eating very well might be willing to pay more, but those who cannot now afford to eat adequately would surely view the matter differently.

CONCLUSION

To attain the most food safety at reasonable cost, it is important for consumers to learn what the real food safety risks are and to accept some responsibility for the actions everyone must take to keep food as safe as it was at the time of purchase. The U.S. food supply system is effective and working reasonably well. Any effort to improve it should be made very carefully, lest the "improvement" result in even more people in the U.S. finding themselves unable to afford to eat adequately. Unfortunately, consumers often view with suspicion efforts by government and the food industry to educate them about food safety. More, not fewer, such efforts are needed, however.

Most foodborne disease hazards are caused, not by additives or pesticides, but by microbes. Regulatory efforts should be allocated to reflect the fact that poor sanitation and preparation practices are more common in food-service operations and in the home than they are in food-processing establishments. The scientific knowledge necessary to eliminate pathogens at the farm level does not yet exist. Government agencies must cooperate to achieve the best possible results with their always-limited resources. The food industry must continue to improve food safety, but eating will never be totally risk free. Self-protection requires understanding of—and respect for—microbiological risks.

GLOSSARY

Allergy—a disease state, caused by exposure to a particular substance to which certain individuals have a heightened sensitivity (hypersensitivity), that has an immunologic basis.

Carcinogen—a substance that, when introduced into the body, causes cancer.

Carrier—a person who harbors, and at least occasionally sheds, a pathogen or parasite over prolonged periods of time, usually without displaying evidence of the disease the agent ordinarily causes.

Consumer—the person who eats a food product.

Contamination—the introduction of foreign microorganisms or disease agents into a foodstuff.

Cross-contamination—the contamination of one food from another (a thawing chicken dripping *Salmonella* onto a salad, for example).

Danger zone—the temperature range from 40 to 140 degrees F (5° to 60° C), a range at which bacterial disease agents and molds can grow in foods.

Decontamination—thermal (or other) food treatment that destroys a contaminant (pasteurization of raw liquid eggs to kill *Salmonella*, for example).

Depuration—a process by which mollusks are supposed to cleanse themselves internally and externally of microbial contaminants: Shellfish are held in decontaminated seawater, which they are expected to siphon until all disease agents have been eliminated.

Diarrhea—abnormal frequency and liquidity of fecal discharges.

Disease—any abnormal condition in the body, whether of intrinsic or extrinsic cause, that is perceptible to the host or to a clinician.

Dysentery—inflammation of the intestines, with frequent stools containing blood and mucus.

Enterotoxin—a toxin with specific action on the intestinal lining.

GMP (good manufacturing practice) (in the processing of food)—following well-established and prescribed procedures intended to assure a safe and wholesome product.

HACCP (hazard analysis–critical control points)—a system widely used in the food industry to enhance food safety.

Host—a living organism (often human) in which a microbe multiplies or a toxin exerts its effect.

Incidence (of foodborne disease)—the number of new cases of illness occurring during a particular time period.

Infection—a condition in which a microbe or parasite establishes itself and grows or multiplies in the host's body.

Intolerance—a disease state caused by a chemical that is toxic to certain individuals only because they exhibit some genetic variation.

Intoxication—an adverse reaction by the body to a foreign (toxic) substance, whether that substance was produced within or outside the body.

Irradiation—food processes using ionizing radiation (e.g., gamma rays) for any of several purposes, including destruction of microbial disease agents.

Jaundice—a symptom of liver disease characterized by the yellowish appearance of the patient's skin and eyes.

Mishandling—the treatment of food in such a way as to lead to the introduction into, or production of, a disease-causing agent; the degradation of food quality through improper treatment.

Outbreak—the occurrence of two or more cases of a disease, associated in time and place so as to suggest a common source.

Pasteurization (of milk)—holding at 145 degrees F (63° C) for 30 minutes or at 161 degrees F (72° C) for 15 seconds.

Pathogen—an agent or factor that causes disease and is therefore said to be pathogenic.

Preparation (of food)—the final stage(s) of readying a food to be eaten, whether commercially or in the home; usually done in a kitchen.

Processing (of food)—the treatment of food, usually on a commercial scale, to increase its usefulness, stability, or acceptability.

Production (of food)—the growing, usually under human supervision, of the basic animal or vegetable material of a food.

Recontamination—contamination after decontamination (a pathogen on thoroughly cooked pork, for example).

Retailing (of food)—the display and sale of food in a store for later consumption off the premises.

Service (of food)—the final preparation and sale or giving of food for consumption on the premises (as in a restaurant or cafeteria) or elsewhere (as in a take-out establishment); can also include outdoor group feeding as occurs at picnics, etc.

Source (of a contaminant)—where a foodborne disease agent originates (the dysentery-causing protozoan *Entamœba histolytica* originates in the human intestines, for example).

Spore (bacterial)—the inactive or resting form of a bacterium, which can withstand boiling; only some bacterial species can form spores.

Storage and distribution (of food)—the holding and transportation of food so that it will be available when and where it is needed, ideally without any alteration in the quality or safety of the product.

Temperature abuse—the holding of food at a temperature (and for sufficient time) to allow the multiplication of the pathogens or spoilage organisms it contains.

Vehicle—food or water in which a cause of disease is transmitted to a consumer.

Zoonoses—infectious diseases of animals that are transmissible to humans. The human host is often a “dead end” in that the diseases are not transmitted from person to person.

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Appendix A. **Common Foodborne Diseases Caused by Bacteria**

Disease (causative agent)	**Onset** (duration)	**Principal symptoms**	**Typical foods**	**Mode of contamination**	**Prevention of disease**
(*Bacillus cereus*) food poisonings –Diarrheal	8–16 hr (12–24 hr)	Diarrhea, cramps, occasional vomiting	Meat products, soups, sauces, vegetables	From soil or dust	Thorough heating and rapid cooling of foods
(*Bacillus cereus*) food poisonings –Emetic	1–5 hr (6–24 hr)	Nausea, vomiting, sometimes diarrhea & cramps	Cooked rice and pasta	From soil or dust	Thorough heating and rapidcooling of foods
Botulism –Food poisoning (heat-labile toxin of *Clostridium botulinum)*	12–36 hr (months)	Fatigue, weakness, double vision, slurred speech, respiratory failure, sometimes death	Types A&B—vegetables; fruits; meat, fish & poultry products; condiments; Type E—fish & fish products	Types A&B—from soil or dust; Type E—water and sediments	Prompt cooling of foods; thorough reheating
Botulism –Infant, <1 yr old, (infection by *Clostridium botulinum*)	Unknown	Constipation, weakness, respiratory failure, sometimes death	Honey, dust	Ingested spores from soil or dust colonize intestines	Do not feed honey—will not prevent all
Campylobacteriosis *(Campylobacter jejuni* or *coli)*	3–5 days (2–10 days)	Diarrhea, abdominal pain, fever, nausea, vomiting	Chicken, raw milk, pork	Infected food-source animals	Cook chicken and pork thoroughly; avoid cross-contamination; drink pasteurized milk
Cholera *(Vibrio cholerae*)	2–3 days (hours to days)	Profuse, watery stools; sometimes vomiting,	Raw or undercooked seafood	Marine environment? Human feces	Cook seafood thoroughly; general

		dehydration; often fatal if untreated			sanitation
(Clostridium perfringens) food poisoning	8–22 hr (12–24 hr)	Diarrhea, cramps, rarely nausea & vomiting	Cooked meat and poultry	Soil, raw foods	Thorough heating and rapid cooling of foods
(*Escherichia coli*) foodborne infections: –Enterohemorrhagic	3–8 days (2–9 days, sometimes weeks)	Watery, bloody diarrhea, kidney failure	Raw or undercooked beef, raw milk	From infected cattle and other ruminants	Cook beef thoroughly; drink pasteurized milk
(*Escherichia coli*) foodborne infections: –Enteroinvasive	at least 18 hr (uncertain)	Cramps, diarrhea, fever, dysentery	Raw foods?	Human fecal contamination, direct or via water	Cook foods thorough-ly; general sanitation
(*Escherichia coli*) foodborne infection: –Enterotoxogenic	10 hr–3 days (3–5 days)	Profuse watery diarrhea; sometimes cramps, vomiting	Raw foods	Human fecal contamination, direct or via water	Cook foods thorough-ly; general sanitation
Listeriosis (*Listeria monocytogenes*)	3–70 days	Meningoencephalitis; stillbirths; septicemia or meningitis in newborns	Raw milk, cheese, processed meats, and vegetables	From soil or infected animals, directly or via manure	Drink pasteurized milk; cooking
Salmonellosis (*Salmonella* species)	5 hr–3 days (1–4 days)	Diarrhea, abdominal pain, chills, fever, vomiting, dehydration	Raw and undercooked eggs, meat, and poultry; raw milk	Infected food-source animals; human feces	Cook eggs, meat, and poultry thoroughly; drink pasteurized milk
Shigellosis (*Shigella* species)	12 hr–4 days (4–7 days)	Diarrhea, fever, nausea; sometimes vomiting, cramps	Raw foods	Human fecal contamination, direct or via water	General sanitation; cook foods

Disease (causative agent)	**Onset** (duration)	**Principal symptoms**	**Typical foods**	**Mode of contamination**	**Prevention of disease**
Staphylococcal food poisoning (heat-stable enterotoxin of *Staphylococcus aureus*)	1–6 hr (6–24 hr)	Nausea, vomiting, diarrhea, cramps	Ham, meat and poultry products, cream-filled pastries, whipped butter, cheese	Handlers with colds, sore throats, or infected cuts; food slicers	Thorough heating and rapid cooling of foods; proper refrigeration
Streptococcal foodborne infection (*Streptococcus pyogenes*)	1–3 days (varies)	Various, including sore throat, erysipelas, scarlet fever	Raw milk, deviled eggs	Handlers with sore throats, other "strep" infections	General sanitation, drink pasteurized milk
Vibrio parahaemolyticus foodborne infection	12–24 hr (4–7 days)	Diarrhea, cramps; sometimes nausea, vomiting, fever, headache	Fish and seafoods	Marine coastal environment	Cook fish and seafoods thoroughly
Vibrio vulnificus foodborne infection	In Persons with High Serum Iron: 1 day	Chills, fever, prostration, often death	Raw oysters and clams	Marine coastal environment	Cook shellfish thoroughly
Yersiniosis (*Yersinia enterocolitica)*	3–7 days (2–3 weeks)	Diarrhea, pains mimicking appendicitis, fever, vomiting, etc.	Raw or undercooked pork and beef; tofu packed in spring water	Infected animals—especially swine; contaminated water	Cook meats thorough ly; use chlorinated water

Appendix B. **Common Footborne Diseases Caused by Viruses**

Disease (causative agent)	**Onset** (duration)	**Principal symptoms**	**Typical foods**	**Mode of contamination**	**Prevention of disease**
Hepatitis A (hepatitis A virus)	15–50 days (weeks to months)	Fever, weakness, nausea, discomfort; often jaundice	Raw or undercooked shellfish; sandwiches, salads, etc.	Human fecal contamination, via water or direct	Cook shellfish thoroughly; general sanitation
Viral gastroenteritis (Norwalk-like viruses)	1–2 days (1–2 days)	Nausea, vomiting, diarrhea, pains, headache, mild fever	Raw or undercooked shellfish; sandwiches, salads, etc.	Human fecal contamination, via water or direct	Cook shellfish thoroughly; general sanitation
Viral gastroenteritis (rotaviruses)	1–3 days (4–6 days)	Diarrhea, especially in infants and young children	Raw or mishandled foods?	Probably human fecal contamination	General sanitation

Appendix C. **Common Foodborne Diseases Caused by Protozoa and Parasites**

Disease (causative agent)	**Onset** (duration)	**Principal symptoms**	**Typical foods**	**Mode of contamination**	**Prevention of disease**
(PROTOZOA) Amebic dysentery (*Entamoeba histolytica*)	2–4 weeks (varies)	Dysentery, fever, chills; sometimes liver abscess	Raw or mishandled foods	Cysts in human feces	General sanitation; thorough cooking
Cryptosporidiosis (*Cryptosporidium parvum*)	1–12 days (<30 days)	Diarrhea; sometimes fever, nausea, and vomiting	Mishandled foods	Oocysts in human feces	General sanitation; thorough cooking
Cyclosporiasis (*Cyclospora cayetanensis*)	1 week (days, weeks)	Watery diarrhea, nausea, cramps, fatigue	Raspberries mesclun lettuce, basil	Oocysts in human feces, indirect?	Freezing, cooking

Appendix C continued

Disease (causative agent)	**Onset** (duration)	**Principal symptoms**	**Typical foods**	**Mode of contamination**	**Prevention of disease**
Giardiasis (*Giardia lamblia)*	5–25 days (varies)	Diarrhea with greasy stools, cramps, bloat	Various	Cysts in human and animal feces, directly or via water	General sanitation; thorough cooking
Toxoplasmosis (*Toxoplasma gondii*)	10–23 days (varies)	Resembles mono-nucleosis; fetal abnormality or death	Raw or undercooked meats; raw milk; mishandled foods	Cysts in pork or mutton—rarely beef; oocysts in cat feces	Cook meat thoroughly; drink pasteurized milk; general sanitation
(ROUNDWORMS, Nematodes) Anisakiasis (*Anisakis simplex, Pseudoterranova decipiens*)	Hours to weeks (varies)	Abdominal cramps, nausea, vomiting	Raw or undercooked marine fish, squid, or octopus	Larvae occur naturally in edible parts of seafoods	Cook fish thoroughly or freeze at 4°F (-20°C) for 30 days
Ascariasis (*Ascaris lumbricoides*)	10 days–8 weeks (1–2 years)	Sometimes pneumonitis, bowel obstructions	Raw fruits or vegetables that grow in or near soil	Eggs in soil, from human feces	Sanitary disposal of feces; cooking food
Trichinosis (*Trichinella spiralis*)	8–15 days (weeks, months)	Muscle pain, swollen eyelids, fever; sometimes death	Raw or undercooked pork or meat of carnivorous animals	Larvae encysted in animal's muscles	Thorough cooking of meat; freezing pork at 5°F (-15°C) for 30 days
(TAPEWORMS, Cestodes) Beef tapeworm (*Taenia saginata*)	10–14 weeks (20–30 years)	Worm segments in stool; sometimes digestive disturbances	Raw or undercooked beef	"Cysticerci" in beef muscle	Cook beef thoroughly or freeze below 23°F (-5°C) for >4 days

Fish tapeworm (*Diphylloboth-rium latum*)	3–6 weeks (years)	Limited; sometimes vitamin B^{12} deficiency	Raw or undercooked freshwater fish	“Plerocercoids” in fish muscle	Heat fish 5 minutes at 133°F (56°C) or freeze 24 hours at 0°F (-18°C)
Pork tapeworm (*Taenia solium*)	8 weeks–>10 years (20–30 years)	Worm segments in stool; sometimes “cysticercosis” of muscles, organs, heart, or brain	Raw or undercooked pork	“Cysticerci” in pork muscle	Cook pork thoroughly or freeze below 23°F (-5°C) for >4 days

Appendix D. **Common Foodborne Diseases Caused by Fungi Other Than Mushrooms**

Disease (causative agent)	**Onset** (duration)	**Principal symptoms**	**Typical foods**	**Mode of contamination**	**Prevention of disease**
Aflatoxicosis (“aflatoxins” of *Aspergillus flavus* and related molds)	Varies with dose	Vomiting, abdominal pain, liver damage; liver cancer (mostly Africa and Asia)	Grains, peanuts, milk	Molds grow on grains and peanuts in field or storage; cows fed moldy grain	Prevent mold growth; don’t eat or feed mol-dy grain or peanuts; treat grain to destroy toxins
Alimentary toxic aleukia (“trichothe-cene” toxins of *Fusarium* molds)	1–3 days (weeks to months)	Diarrhea, nausea, vomiting; destruction of skin and bone mar-row; sometimes death (mostly Europe?)	Grains	Mold grows on grain, especially if left in the field through the winter	Harvest grain in the fall; don’t use moldy grain
Ergotism (toxins of *Claviceps purpurea*)	Varies with dose	Gangrene (limbs die and drop off); or convulsions and dementia; abortion (now not seen in U.S.)	Rye; or wheat, barley, and oats	Fungus grows on grain in the field; grain kernel is replac-ed by a “sclerotium”	Remove sclerotia from harvested grain

Appendix E. **Common Foodborne Diseases Caused by Chemicals and Metals**

Disease (causative agent)	**Onset** (duration)	**Principal symptoms**	**Typical foods**	**Mode of contamination**	**Prevention of disease**
(TOXINS IN FINFISH) Ciguatera poisoning (ciguatoxin, etc.)	3–4 hr [rapid onset]	Diarrhea, nausea, vomiting, abdominal pain	"Reef and island" fish: grouper, surgeon fish, barracuda, pompano, snapper, etc.	(Sporadic) food chain, from algae?	Eat only small fish?
	12–18 hr (days–months)	Numbness & tingling of face & lips; taste & vision aberrations, sometimes convulsions, respiratory arrest, & death (1–24 hr)			
Fugu or pufferfish poisoning (tetrodotoxin, etc.)	10–45 min to ≥ 3 hr	Nausea, vomiting, tingling lips & tongue, ataxia, dizziness, respiratory distress/ arrest, sometimes death	Pufferfish, "fugu" (many species)	Collects in gonads, viscera	Avoid pufferfish (or their gonads)
Scombroid or histamine poisoning (histamine, etc.)	minutes to a few hours (few hours)	Nausea, vomiting, diarrhea, cramps, flushing, headache, burning in mouth	"Scombroid" fish (tuna, mackerel, etc.); mahimahi, others	Bacterial action	Refrigerate fish immediately when caught
(TOXINS IN SHELLFISH) Amnesic shellfish poisoning (domoic acid)		Vomiting, abdominal cramps, diarrhea, disorientation, memory loss; sometimes death	Mussels, clams	From algae	Heed surveillance warnings

Paralytic shellfish poisoning (saxitoxin, etc.)	≤ 1 hr (≤ 24 hr)	Vomiting, diarrhea, paresthesias of face, sensory & motor disorders; (rare?) respiratory paralysis, death	Mussels, clams, scallops (oysters)	From “red tide” algae	Heed surveillance warnings
(MUSHROOM TOXINS) Mushroom poisoning (varies greatly among species)	<2 hr to ≥ 3 days	Nausea, vomiting, diarrhea, profuse sweating, intense thirst, hallucinations, coma, death	Poisonous mushrooms	Intrinsic	Don’t harvest wild mushrooms
(PLANT TOXINS) Cyanide poisoning (cyanogenetic glycosides from plants)	(large doses), 1 to 15 min	Unconsciousness, convulsions, death	Bitter almonds, cassava, some lima bean varieties, apricot kernels	Intrinsic, natural	Proper processing; avoid some so-called foods
(METALS) Cadmium poisoning	depends on dose	Nausea, vomiting, diarrhea, headache, muscular aches, salivation, abdominal pain, shock, liver damage, renal failure	Acid foods, foods grilled on refrigerator shelves	Acid or heat mobilizes cadmium plating	Select food contact surfaces carefully
Copper poisoning	depends on dose (24 to 48 hr)	Nausea, vomiting, diarrhea	Acid foods, foods contacting copper	Acid mobilizes copper	Select food contact surfaces carefully

Appendix E continued

Disease (causative agent)	**Onset** (duration)	**Principal symptoms**	**Typical foods**	**Mode of contamination**	**Prevention of disease**
Lead poisoning	depends on dose	Metallic taste, abdominal pain, vomiting, diarrhea, black stools, oliguria, collapse, coma (also chronic effects)	Glazes, glasses, illicit whiskey	Lead dissolves in beverages & foods	Test glazes & glasses; avoid illicit whiskey
Mercury poisoning	Depends on dose	Metallic taste, thirst, abdominal pain, vomiting, bloody diarrhea, kidney failure	Treated seeds (fungicide); fish?	Intentional; food chain	Eat only seeds intended for food
Zinc poisoning	Depends on dose (24–48 hr)	Nausea, vomiting, diarrhea	Acid foods in galvanized containers	Acid mobilizes zinc plating	Select food surfaces carefully

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