To conclude our course on nutrition and health, we shall turn to the subject of food safety, food technology and concerns about what's in food in addition to "food". A quick look at the label of most any processed food reveals a list of substances not recognized as nutrients. Why are they in our foods?

We hear controversial statements about food contaminants, food additives and food preservatives. We are told that "organic" foods are better for us and also told that there is no nutritional difference in how foods are grown. We are told to eat fatty fish and then warned to avoid fatty fish because they contain higher levels of pollutants.

The safety of food in the United States is the responsibility of several agencies: Food and Drug Administration (FDA), Department of Agriculture (USDA) and Environmental Protection Agency (EPA) among them. In addition, the Centers for Disease Control (CDC) monitors outbreaks of food-borne illnesses. Internationally, the World Health Organization and Food and Agriculture Organization have interested in food safety issues.

According to the Food and Drug Administration there are six potential food safety concerns. We will talk a little about each of these.

- Food-borne infectious agents
- Food nutritional adequacy
- Environmental contaminants of food
- Natural toxicants
- Pesticide residues
- Food additives

Concern 1: Food-Borne Infectious Agents: Microbial Hazards in Food
Food poisoning affects millions and some 5000 die of food "poisonings" in the United States each year. "Food poisoning" can be caused by viruses, bacteria, fungi (molds) or protists. In addition, there are several parasites of fish and meats that can be hazardous to human health as well. A food poisoning can be caused by an organism that grows in the food and causes infection in us when we consume the food (**food-borne infections** or **food-borne pathogens**) – or – a food poisoning can be caused by an organism who grew in the food we consumed and produced a toxic by-product of that growth (**food-borne intoxication**).
Some common organisms responsible for food poisonings are:

Campylobacter jejuni - bacterium
Salmonella (many types) - bacterium
Staphylococcus aureus - bacterium
Clostridium botulinum - bacterium
Giardia lamblia – protist
Hepatitis A - virus
Escherichia coli – bacterium
Listeria monocytogenes – bacterium

Salmonella and *Campylobacter,* found in eggs and meat products, especially chicken, are the most common pathogens. *Staphylococcus* causes the most intoxications.
Most food poisonings are mild, lasting 24 - 72 hours, and symptoms include:

- Vomiting
- Abdominal pain and cramps
- Diarrhea with dehydration side effects
- Headache

By far the most deadly food toxin is botulism toxin, a protein toxin produced by the anaerobic *Clostridium botulinum*. This nerve toxin is fatal unless those infected get prompt treatment. Oddly, botulinum toxic is used for some nerve diseases – because it can "paralyze" nerves. It is also used in cosmetic surgery. Some mycotoxins (from fungi) cause serious liver damage, and some virulent strains, eg, O157:H7, of *E. coli* cause liver and kidney damage. Severe kidney damage can be fatal. *Listeria* is particularly dangerous for pregnant women.

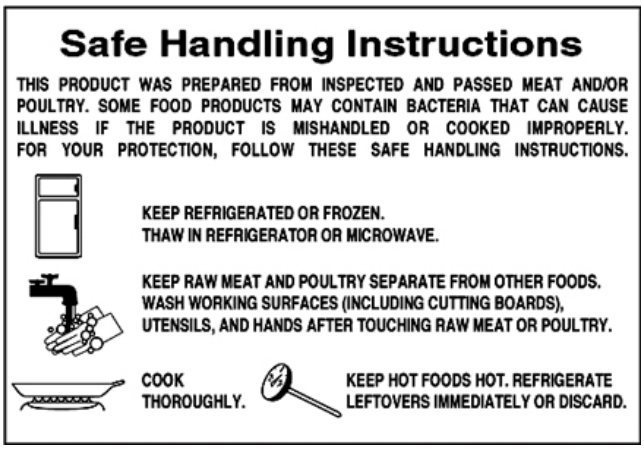
In addition to discussing how best to prevent contamination of food by disease-causing organisms, we will also mention what we do with additives to minimize spoilage by microorganisms.

Prevention of Food-Borne Diseases by Proper Food Handling and Food Storage

In the past, the focus on proper food safety has been at the consumer and home level. Fear of botulism was centered on home-canned foods, with the assumption that commercial canneries had mechanisms in place. Pasteurization of milk and other beverages ensured safety until the food was opened in the home. In recent years, emphasis has changed, in part due to serious contamination outbreaks in commercial settings. The Jack-in-the Box *E coli* infection of the mid-1990's brought consumer awareness. As more people in the United States consume more of their foods away from home, or purchase more "prepared" meals, we need to be concerned about proper food management in commercial settings as well as in the home.

Food-borne microorganisms thrive in raw foods, and in particular raw protein-rich foods. *E coli* and other fecal-from bacteria are also known to be in fresh produce, and microorganisms are common in cultured sprouts. (Speaking of which, recently, sprouts were listed as the most likely food to have infectious bacteria, and sprouts are commonly consumed raw.)

There are special considerations with meats, fish and poultry. Muscle tissues are more subject to handling and exposure to bacteria than many other foods and muscle tissue provides ideal growing conditions. In addition, there are non-host specific parasites that can be transmitted by contaminated muscle tissue that is not thoroughly cooked. Grocers now label meats with reminders to cook meats adequately and store them safely. Seafood is increasingly subject to pollutant contaminants.



The food industry **Hazard Analysis Critical Control Points** standards were designed to identify potential contamination hazards and take measures to control contamination at those sources. It is not in the interest of the food industry to market contaminated food; recall of contaminated foods after distribution is costly, as is thorough inspection before distribution. FDA inspections are limited, and less than 2% of all foods imported are inspected before being used or put on shelves. FDA and USDA rely heavily on industry self-inspection.

As consumers we have an important role, too. Cleanliness of food preparation settings (including both home and processing) and proper cooking and storage of food do much to minimizing food borne problems as well as minimizing spoilage. In this light, it never hurts to remind us to:

- Store foods at the appropriate temperature
    - Keep foods subject to spoilage cool (Refrigerator below 38)
    - Do not keep cooked foods at room temperature. Air-borne bacteria grow in less than 4 hours, and grow better in warmer temperature foods.
- Cook and process foods at the proper temperature
    - Use a thermometer when cooking, especially to test the internal temperature of large items
    - Botulism toxin is a protein that can be destroyed by boiling for 10 minutes. *Clostridium botulinum* (the organism) can be destroyed by steam pressure processing and/or acid storage. It grows only in the absence of oxygen in neutral or alkaline pH.
- Use good personal hygiene during food handling and keep preparation surfaces clean.

Food Spoilage by Microorganisms (and Some Macroorganisms)
In addition to microorganisms that cause food-borne illnesses, there are a "host" of bacteria and fungi that cause food spoilage. Ecologically, food spoilage is just a case of competition. The microbe and the person both want the same food source. They (the microbes) have a novel way of getting it, which is to make the food unpalatable for us, so we throw it away and they have lunch. For example, how many people eat a strawberry or a slice of bread covered with mold?

Spoiled food is less often a health hazard than food-borne infectious agents because we generally recognize the spoilage and do not consume the food stuffs.

Food spoilage is a serious financial problem, since world-wide about 40% of all food grown for humans is lost to some pest or microorganism, not to mention the tremendous sums of money spent on pesticides and the environmental degradation and health hazards associated with pesticide contamination (discussed soon).

However, some organisms have toxic metabolites and can cause problems if food they have growing on or in is consumed, or if these organisms become contaminants of food. Two examples of toxins produced by fungi that infect food crops are:

- Aflatoxin: A fungus contaminant of grains and peanuts
- Ergot: A fungus of rye and other grains (rare now)

Minimizing Contamination

- **Processing Foods to Inhibit Contamination/Spoilage**
  Foods can be processed to prevent or inhibit the growth of bacteria or fungi. Microorganisms need an environment conducive to growth. Their growth is affected by temperature, available water and oxygen and osmotic balance. Methods that change their environment to disfavor growth prevent or inhibit spoilage. Methods include:
  - Drying
  - Smoking
  - Curing (usually with salts and sometimes acids)
  - Freezing
  - Pasteurization
  - Refrigeration
  - Canning (Heat plus sealing)

- **Irradiation**
  Irradiation uses ionizing radiation (Cobalt 60 or Cesium 137) or sometimes e-radiation to destroy microorganisms and insect eggs on or in foods. Irradiation can also delay sprouting and delay ripening of fruits and vegetables. Irradiation affects the DNA structure of cells so that cell division cannot occur.

  Irradiation of spices to "sterilize" them has been in use for decades. Irradiation has been approved for many fruits and vegetables, as well as meats, although it is not used extensively. Some foods are not at all suited to irradiation because textures can be altered. Lettuce and other leafy vegetables and soft-tissued fruits get mushy. Eggs turn milky-colored and some high-fat foods get odd odors.

  Not all foods are approved for irradiation in the United States, and some countries do not allow import of irradiated foods for variety of reasons including fear of radioactive contamination. In the United States, foods that have been irradiated must have labels stating so. In contrast, other treatments for protection against microbial contamination do not require labeling.

  Irradiation does not make foods radioactive nor does irradiation affect DNA of those who eat the foods. DNA molecules in foods are digested just the same way as other nutrients. We do not use intact DNA from other organisms to synthesize DNA molecules in our cells.

  Anytime we use radiation there are associated risks. The radioactive elements used in food irradiation are the same as those used in medical and biological research. They are obtained by processing nuclear materials produced in reactors. An irradiation plant cannot explode, nor can the radioactive elements used in irradiation. Processing of nuclear reactor by-products is a hazardous industry, and nuclear reactors have hazards associated with them. These hazards are common to all uses of radioactive materials no matter what the purpose.

- **Use of Anti-Microbial Food Additives. (see later)**

Concern 2: Nutritional Adequacy of Food

Government agencies such as the FDA and USDA are also responsible by federal legislation for providing consumer information on nutritional adequacy of foods. We discussed many of the ways in which nutrient information is available to consumers in our section on nutrition guidelines. Federal agencies review population data and revise dietary recommendations "as needed". In response to consumer concerns, the federal legislature has, on occasion, increased or decreased agency responsibilities. Food and drug regulations are determined by legislation and responsibility for ensuring compliance rests with the designated agency. For example, the trans-fat label information, enacted in 2003, was in response to pressures that consumers need such information for health reasons. The absence of regulation on supplements is also legislated. That legislation was influenced by those whose interests were in not having regulations. The meat, dairy, grain and drug industries, etc., all have interests in how we federally regulate and make recommendations to consumers about nutrition and health. Health agencies, such as the American Heart Association and Diabetic Association are also involved, and now provide endorsements for foods that meet their standards for health.

Ultimately, consumer education about nutrition and health is the best way to ensure nutritional adequacy. Moreover, those who are educated about nutrition are better able to participate in the political decisions that result in legislation and regulation.

Concern 3: Environmental Food Contaminants

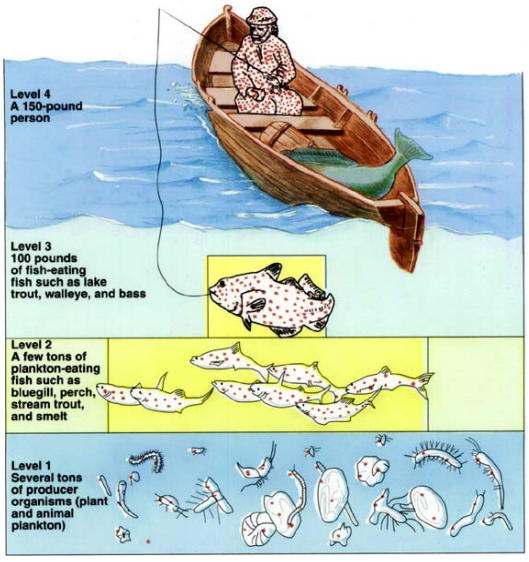
Most contaminants of food are incidental or accidental to the process of growing, harvesting, processing or packaging of food. Historically, fecal materials found on packages were a measure of contamination; such foods were more likely to have been poorly handled and stored and to have been exposed to infectious agents. Standards established in the past literally stated acceptable numbers of rodent hairs, insect parts, pebbles or grit allowed in foods.

Today, many contaminants cannot be seen, and are the result of our use of chemicals in air, water and soil, pesticide use in agriculture and pollution run-off in our waters. Contaminants include any number of these substances as well as leachate from packaging materials or cookware. Pesticide residues are considered as a separate food safety concern, as are antibiotic and other chemical contaminants.

How serious a health threat a given contaminant may be depends on its toxicity, concentration in food, exposure time, and persistence in the environment, aspects that can be difficult to determine. The Environmental Protection Agency and the Food and Drug Administration both set acceptable standards for contaminants in the United States. The EPA monitors fishing and determines if waters are too contaminated for safe harvest. It is as difficult to inspect imported foods for environmental contamination as it is for microbial contamination, and only a small portion of imported foods or foods grown in the United States is inspected.

Problems with Contaminants

Biomagnification. Pollutants that persist in the environment are particularly subject to biological magnification as they pass through the food chain. Terrestrial food chains typically have 3 → 4 levels. Aquatic chains have more. Contaminants accumulate at each step of the food chain so that consumers at the top of the food chain receive proportionally far more of the contaminant. Mercury in seafood and organic halide chemicals are both serious contaminants that accumulate. In the past, DDT accumulation was responsible for the decline of raptor populations.



Methyl mercury is a common water pollutant released from any number of industrial processes. Since the mid-1970's release of mercury contaminants has been more closely regulated, but contamination is still common, and residues persist. Mercury is naturally present in salt water, so marine organisms have more mercury naturally. Swordfish is considered to be the most likely to have high levels of contaminants, but any large predatory fish will have above normal levels of chemical contaminants.

In the 1950's and 1960's several deaths occurred in Minimata, Japan ultimately traced to mercury poisoning from consumption of contaminated fish. When salmon were first introduced to the Great Lakes in the 1970's, reproductive success was minimal because fry were so contaminated with mercury they died. Salmon harvested from some areas of the Great Lakes still contain sufficient contaminants that pregnant women and children are advised to consume them infrequently. Fish contamination is common in all waterways that have industrial run-off. Areas in Washington State are not exempt. Many agencies publish advisories for safe fish consumption. Agencies also publish advisories for fish consumption based on environmental concerns and fish population data to try and prevent over-fishing and loss of fish species.

Chlorinated halogens in the form of PBB and PCBs were responsible for a serious contamination in the State of Michigan in the mid-1970's. The chemicals were accidentally mixed with feed and used throughout the state. After it was detected, 30,000 hoofed animals and over a million chickens were destroyed, but based on tests, 97% of the Michigan residents were exposed to the toxic chemical. PCBs and PPBs cause birth defects, tumors and miscarriage.

Historically, **lead** has been a major contaminant of food and stuff that children eat that is not food, but legislation in the 1970's has greatly reduced lead exposure. Lead accumulates in bone tissue and causes nerve damage. Lead poisoning causes mental retardation and growth abnormalities. The primary sources of lead were:

- Solder in cans and water pipes – Replaced by other solder materials or plastic pipes
- Ceramics or pottery glazes – No longer used
- Leaded crystal – Available (and often very expensive)
- Paint – No longer in the United States
- Pollutant from gasoline, consumed by animals in forage and biologically magnified – Leaded gasoline is no longer available

Lead is still common in water pipes and paint in older homes. Children eat strips of peeling paint. Lead is leached from pipes, particularly if the water is acid. Wines can leach lead from crystal, so crystal decanters for wine storage are not recommended. Not all countries ban lead from ceramics; pottery and ceramics obtained from foreign countries not certified lead-free should not used for cooking.

Foods prepared in the **microwave** are exposed to high temperatures for short periods of time. Substances in packaging may undergo vaporization or chemical alteration if exposed for too long in a microwave oven. Some materials, such as Styrofoam and many plastics are not intended for microwave use and may release harmful substances when they "melt" and volatilize their hydrocarbons.

Controlling Contaminants

The best way to control environmental contamination is to control environmental pollution of air and water. We all share the environment, yet we hesitate to take on the responsibility when the economic cost is high. In the we have environmental regulation in the United States, but monitoring is costly. Enforcement is too –often lacking, as well. A regulation is only effective if we choose to comply with it.

Non-point sources of pollution are particularly troublesome, and often contribute significantly to overall pollution levels. As consumers, we get irate if we find a maggot in our green pepper or hear about a food warehouse that found rat feces on the plastic packaging that surrounded the pallet of cardboard boxes that contained cases of canned peaches, but are oblivious to the chemical runoff into our waterways that enters the food chain. We tolerate pollution because we don't want to pay more for our consumer goods and we are aware that producers pass the costs of pollution control on to their consumers. We are each responsible.

Concern 4: Natural Food Toxicants

Hundreds of foods we eat have some natural toxicant, including the well-known mushrooms and poisonous plants. Plants use toxins as their primary anti-predator defense. Plants can't flee their predators so to "fight back" they produce chemicals that will harm the predator so it won't consume the plant anymore. Most natural toxicants pose minimal risk at the amounts we consume. Those foods that are highly toxic harm us and we have learned over the eons not to eat them. If we fail to learn that, we die. (And yes, there are lots of books about poisonous plants.) None the less it's of interest to mention some of the more common natural toxicants to which we are exposed.

Primary Toxicants

- **Solanine** is in the tomato family, the Solanaceae. Many plants, such as the deadly nightshade, are highly toxic. Those we eat contain small amounts, more commonly in the leafy parts of the plants. People have different sensitivities, and few of the common foods eaten trigger reactions. Some who eat the green parts of potatoes get symptoms of solanine toxin.
- **Goitrogen** is the iodine antagonist from the Cruciferous vegetables. If one were to use Cruciferous vegetables for the foundation of one's diet, thyroid problems might result.
- **Avidin**, the biotin binder in albumin can cause problems if one eats two dozen raw egg whites daily.
- Many whole grains and seeds contain **oxalates** and **phytates** that bind minerals. They are not actually toxic, however; they just interfere with mineral absorption.
- Many seeds and pits of the Rosaceae contain **cyanide glucosides** that are highly toxic. Apricot pits contain fair amounts. Fortunately, we rarely consume the pits of these fruits, and even when we do, we don't digest them, since the fiber of the pits resists digestion. Apricot pit derivatives form the active ingredient of laetrile, marketed in the past as a cancer treatment. It had no known efficacy, and caused cyanide poisoning.
- **Amines** found in cheese, wine, pineapple and bananas are usually detoxified ed by liver. They are probable carcinogens.
- People who get ***Rhus* dermatitis** from exposure to the Anacardiaceae can get reactions from consuming cashews and pistachios. More people are sensitive to poison ivy or poison oak because the allergen is more concentrated in the leafy parts. Some who are very sensitive are sensitive to furniture made from wood of the plant family.
- Many herbal teas have **alkaloid toxicants**. Comfrey has been discouraged because it contains a serious alkaloid toxicant.

How do we deal with natural toxicants?

Avoid seriously toxic foods.

Secondary Food Toxicants

We can also ingest toxic substances by consuming foods that do not naturally contain a toxin but acquired a toxin by consuming a food that contains a potential toxicant. The original consumer often is not affected, but anything or anyone that then eats it, is poisoned.

- In Puget Sound, the most common secondary toxicant exposure is paralytic shellfish poisoning from consuming clams and mussels that ingested a toxic dinoflagellate protist.
- Ciguatera fish poisoning is often fatal, but the dinoflagellates responsible are tropical and infect tropical fishes. It is rare but occasionally found in Hawaii

Speaking of Natural

Before we continue with consumer concerns about foods, it may be useful at this time to define what is meant by the term "**natural food**".

Our conventional use of the term natural in connection with food is a food that has been grown and processed without added processed or refined chemicals. Often "natural" means about the same thing as organic in this sense. By the way, organic means that the food has been grown in the absence of synthetic pesticides, herbicides, or fertilizers. Organic foods can be exposed to pesticides, herbicides and fertilizers that are derived from living organisms.

For clarity, any substance that is derived from a living organism can be called natural. The identical chemical produced in a laboratory is said to be synthetic or artificial.

Natural in food manufacturing refers to **origin**. It has nothing to do with processing or added ingredients. A label that states "all natural ingredients" only means that the food contains chemicals that were originally synthesized by a living organism. A chemical extracted from a living organism is a molecule indistinguishable from an identical molecule synthesized in a laboratory. Many of our natural ingredients come straight from laboratories and chemical processing plants, including such products as high-fructose corn syrup, which is an all-natural ingredient, just as sucrose is, a substance most think is highly refined and processed. The term "all-natural" is nutritionally and health wise, meaningless when used in this sense.

Natural does not mean unprocessed nor does it mean nutritious. Many natural foods have just as much salt, fat, sugars, etc. as food that is not labeled natural. Many natural foods have as many added chemicals as the most unnatural foods one can think of – the infamous Twinkie and corn dog.

It's smart to be concerned about residues and contaminants in food, including pesticides. You may also want to minimize the degradation of our environment from contaminants, but it's most important to eat nutritionally dense foods and a variety of them.

Those who eat more whole grains, vegetables, legumes and non-fat dairy products, along with lean animal muscle tissues, if desired, have the best chance of maximizing health.

Many natural food stores carry many of the items that we should consume more of and many carry organically grown produce for those who choose to monitor their intake of possible food contaminants. Many such stores also carry products totally unrelated to better nutrition or health, but claim they benefit us because they are "natural".

Concern 5: Pesticide Use and Pesticide Contamination of Foods
Pesticides and herbicides have been widely used in agriculture since the mid-1900's. For the first twenty years of pesticide use, their benefits to food production and human health were not questioned. Unfortunately, few pesticides are pest-specific, and few kill their pest and disappear without a trace in the environment. Pesticide use and pesticide residues that remain on plants or accumulate in the food chain are problematic. Pesticide application can affect workers and those accidentally exposed to pesticides. Pest populations increasingly have pesticide resistance just as bacteria have antibiotic resistance. Many farmers are now turning to more integrated pest management ways, with less reliance on heavy pesticide use.

Pesticide approval lies with the EPA. The EPA also establishes the tolerable levels of pesticide exposure and residues permitted in foods. Monitoring pesticide residues in foods is the job of the FDA. Most foods most of the time have residues well within the tolerances established. The FDAs **Market Basket Survey** of 200 foods purchased four times annually tracks pesticide residues along with nutritional content of foods.

There are few incidents of pesticide residues above established tolerance levels, but there are also those among us who believe that tolerance levels are set too high, and exposure to any additional potentially toxic chemicals increases our long-term health risks, especially for cancers.

Other nations have different standards for pesticide use, and pesticides not approved in the United States may be used in other countries. About 70% of our fresh produce is imported, and residues from pesticides not allowed in the US may be in imported food. Pesticide residues on imported food crops also need monitoring, and when illegal pesticide residues are detected, importation is denied.

Pesticide Issues

- Pesticide poisoning of workers and families of workers, particularly in other countries is a concern of many.
- it is impossible to monitor all foods produced in the United States or imported. Samples may not reflect use. Pesticide application many not be uniform.
- New pesticides are developed constantly, and tolerance standards need periodic review based on current knowledge.
- Far too often target pest populations resist levels of pesticide used and the response is to increase pesticide concentration to kill more of the pest population. Pesticides are a strong selection pressure for pesticide resistance.
- Too many pesticides affect non-target organisms. BT, used to prevent lepidopteron larvae from eating crops, affect all lepidopteron. Bee hives have to be "imported" into orchards to ensure pollination because native populations have been decimated by overuse of pesticides.

Reducing Pesticide Use in Agriculture

Use fewer pesticides and accept more crop loss to pests.
practice sustainable agriculture, particularly with companion crops and rotation that minimizes annual hosts for pest life cycles.
Be willing to pay more for food that doesn't always look so nice
Pesticides are also used for food appearance reasons; we can be more willing to consume foods that do not have such a nice appearance. We could tolerate foods with pest damage, unappetizing as a maggot in one's Brussels sprout may seem.

Reducing Pesticide Residues before Consumption

- Most pesticides are on the surfaces of foods. To minimize residue possibility, **wash** fresh foods with dilute liquid detergent, such as Ivory Liquid, before eating and peel root crop foods. Some nutrient loss occurs with peeling some foods, such as potatoes. We each individually can set our priorities.
- Buying **organic** foods not only avoids pesticide residue exposure risk, but organically grown foods are better for soil quality and better for the decreased use of chemicals in our environment. There are compelling environmental quality reasons for purchasing and choosing organic foods.

  Organic foods are generally nutritionally equal to foods grown with the use of pesticides and inorganic fertilizers despite claims that organic foods are nutritionally superior. Organic foods can be as highly processed with as many additives as their non-organically grown counterparts. Organic foods may often have a higher risk of bacterial contamination, just because they are not treated for microbial pests. Those organic foods most subject to bacterial contamination should be pasteurized.

Concern 6: Food Additives

Thousands of substances are deliberately added to the foods we consume. One set of additives exists to minimize microbiological food hazards, and a second category of food additives includes those that improve the nutritional quality of foods. Additives are also used to improve flavor, and to enhance appearance, texture or stability of food. In addition to the intentional food additives, we have incidental or indirect food additives as a consequence of growth, handling, processing or preparation of foods.

Food additives can be used to:

- Maintain or enhance the sensory characteristics of food
- Facilitate food processing or food preparation
- Maintain, restore or improve the nutritional quality of foods
- Maintain food quality by preventing spoilage or disease of foods

In order to have an additive approved by the FDA, it must be shown to meet established criteria:

- The food additive must do what it claims to do, or be effective.
- The additive must be a detectable and measurable quantity in the product.
- The additive must be safe.

In addition, an additive is prohibited if it:

- Disguises an inferior product
- Deceives a customer
- Results in *significant* nutrient loss
- When sound and *economical* manufacturing practices can achieve the same thing without the use of the additive.

The FDA, as a part of its approval process determines the amounts of additives that can be used and the foods to which it can be added. All additives are subject to periodic review and revocation of approval.

Current standards are based on the 1958 Food Drug & Cosmetic act. That act established the **GRAS** list, which exempted as safe hundreds of additives that had been in use at the time of the legislation, and were **generally recognized as safe**. The Delaney clause, however, stated that any substance added to food that has been demonstrated to cause cancer in any animal must be banned, and over the years, several substances have been removed from the GRAS list for that reason. One exception was saccharin, known to cause bladder cancer in rats. The federal legislature, pressured by those who wanted saccharin to be available to consumers, exempted it from the Delaney rule. Many critics feel that the Delaney clause should be modified for risk-benefit analysis as we do we many other aspects of how we live, in part because we can detect much lower levels of substances today than historically. None the less, any new food additive must pass FDA testing procedures before approval for use. Recall that supplements not directly added to foods are not regulated as additives are. In additions, meats are under the Department of Agriculture and subject to different regulations.

Additive Testing

Manufacturers testing potential additives must use two sets of mammals to determine potential toxicity levels. The results are then projected to effects, if any on humans. The tests involve the following:

Determining the Metabolic pathway followed in the body

- LD_{50} Acute Toxicity Testing
  Establishing a dose that kills 50% of the test organisms
- Subacute testing
  Lowest dose for which no harm is seen
- Chronic testing
  Doses of 100 - 1000 times the expected consumption level for several (3 – 4) years
- Carcinogen Testing
  Chronic high dose testing for the natural lifetime of test organisms and projecting carcinogen test results on human populations
- Mutagen testing
  Chromosome alterations in offspring
- Teratogen Testing
  Birth defects in offspring

Food Additive Categories

1. **Antimicrobial agents** prevent spoilage by inhibiting the growth of microbes. Historically salt and sugar in concentration were the most common antimicrobial agents. Concentrated salt and sugar osmotically inhibit bacterial growth. Antimicrobial agents:
   - Increase shelf life of food items
   - Protect color and flavor of food
   - Examples:
     - Citric acid used in acidic foods
     - Propionates used in breads
     - Nitrates or nitrites used in cured meats
     - Sorbates used in cheese, fruit products, syrups, beverages
     - Sulfites are used in dried fruits and alcoholic beverages

   Safety of Antimicrobial Agents

   Nitrites are used to prevent spoilage and microbial contamination of cured meats, such as bacon, ham and lunch meats. Nitrites can prevent botulism.

   Nitrites combine with digestion products of proteins to form nitrosamines. High temperatures also promote the formation of nitrosamines in products that contain nitrites. Nitrosamines are potential carcinogens and have been linked to bladder tumors in some animals. Nitrosamines are naturally found in many foods and in water and saliva. Nitrosamines are also in cigarette smoke in high concentrations. If the diet has sufficient variety, occasional consumption of foods cured with nitrites should be fine.

2. Antioxidants, as discussed, prevent oxidation of foods. Many antioxidants are added to the packaging materials rather than the food. Antioxidants include:

- BHA (Butylated hydroxyanisole)
- BHT (Butylated hydroxytoluene
- EDTA
- Tocopherols (Vitamin E)
- Vitamin C

Sulfites and sulfur compounds maintain freshness and prevent discoloration of fruits and vegetables. They are also used in wine, beer and other alcohol distillations. Some people, especially those with asthma and similar problems, are allergic to the sulfiting agents so sulfite use on foods intended to be consumed fresh (raw) is prohibited. Foods with added sulfites must be clearly labeled. Public awareness of sulfite allergies has reduced the use of these agents.

3. Additives That Improve the Sensory Features of Foods

A. Food Colorings are added to improve the appearance of food. In some cases, colors are added because we associate certain colors with certain flavors. We think green treats are either lime flavored or mint flavored. Butterscotch candy that was green would be "peculiar". Some question whether an additive which has no food safety value or food nutrition value be used but the appearance of food is often important. We are more likely to eat a visually appealing food.

Colorings can be derived from synthetic or natural sources.

- All legal synthetic colorings must be certified, tested to meet US standards of purity and are given a FD & C label. Many in the past were derived from coal tars and were suspected of being carcinogenic.
- Yellow # 5, tartrazine, may cause allergic reactions, and is required to be on the label of foods to which it is added.
- Naturally-derived food colorings are not subject to certification.

B. Flavor Enhancers are used to have food taste more like an expected taste or to mask a bland or distasteful substance. Sugar, salt and MSG are common flavor enhancers. Most herbs and spices are used for flavor as well as a host of fruit flavors.

Tests indicate that more people prefer the "taste" of synthetic flavors over natural flavosr since synthetic flavors are frequently more intense. There are around 2000 flavor enhancers available. It is possible to manufacture the flavor of virtually anything and the flavor industry is as secretive as the fragrance industry. Any food manufacturer can commission a specific flavor for its signature foods.

Most flavors are considered innocuous. Salt, however, can promote hypertension and some people are sensitive to the commonly used MSG. Our willingness to consume sweet-tasting foods with added sugar is implicated in our over-consumption of calories. If we are also willing to consume nutrient dense foods if they taste better with added flavoring, we have a more nutritious diet.

4. Additives That Facilitate Food Processing or Preparation

A. Emulsifiers are substances that keep food ingredients from separating during processing and in storage. These additives are commonly added to ice cream, salad dressings, margarines, peanut butter and almost anything in which fat and water-soluble ingredients might separate. Examples of emulsifiers are:

- Lecithin
- Mono- and di-glycerides
- Propylene glycol

B. Stabilizers maintain or improve the texture of food. They are added to puddings, canned meats, all types of spreads, syrups and ice cream. Some ice creams are so stabilized they don't melt. Examples of stabilizers include:

- Gums
- Starches
- Carrageen
- Alginate
- Agar
- Pectin

C. Other Processing or Preparation Additives

- Humectants retain moisture of foods
- Firming Agents keep things, especially vegetables, crispy
- Chelating agents bind metals to prevent clouding and precipitation
- pH agents maintain appropriate pH (and sometimes taste)
- Anti-caking agents prevent lumps in crystalline foods
- Leavening Agents alter texture and volume of food. Yeast, the most common leavening organism, is not a food additive since the yeast is a living organism, therefore a whole food stuff.

5. Additives That Maintain or Improve Nutritional Quality

Additives can be used to enrich or fortify foods to improve their nutritional quality and, originally, to prevent nutrient deficiency diseases, such as goiter and scurvy. **Enrichment** restores nutrients lost in processing of foods. The original intention for **fortification** was to add nutrients to foods that would be otherwise difficult to obtain in our typical diet. Today, fortification is often used to market foods by appealing to our desire to obtain vitamins and minerals without choosing nutrient dense whole foods. The foods that are enriched or fortified on our grocery shelves today are far too numerous to mention.

Indirect Food Additives

There are a number of substances that may show up in food that are deliberate, incidental or accidental additives at some point in the food chain and remain in the food as residues. They can also be in food as a consequence of processing or packaging of food items.

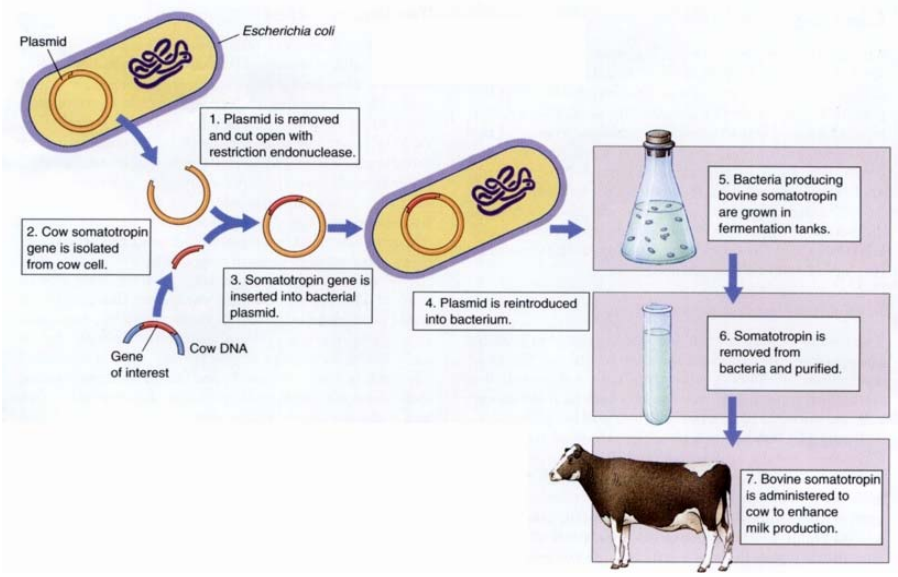
Dioxins, carcinogens, may be contaminants of any paper product that has been made from chlorine-treated wood pulp. All bleached paper products may have such contaminants. The amounts are small, and less chlorine is used today than in the past. Dioxin contamination from other chlorinated hydrocarbons is a far more serious environmental risk.

Residues of **methylene chloride** are found in decaffeinated coffee from the process used to decaffeinate. As with dioxins, Methylene chloride is used in a number of household products, and we are subject to more environmental contamination of methylene chloride than from coffee. There are also alternative methods to decaffeinate coffee.

Antibiotic residues may be in foods consumed. The use of antibiotics in animal feed is deliberate. With the crowded conditions in which we raise poultry and many meat-producing animals, antibiotics are routinely added to minimize infectious diseases. Regulation stipulate amounts and when the antibiotics are to be removed from feed, but mistakes happen. Antibiotic use is of concern because resistance to antibiotics is increasing. The more bacteria are exposed to antibiotics, the faster they become resistant. There are some in the medical community that want antibiotic use in animals restricted to antibiotics not used for humans.

Use of **hormones** in feed is also intentional. BGH (bovine growth hormone) produced through recombinant DNA technology, is commonly given to dairy cows in the United States because it promotes milk production. Cows also suffer more infections of the mammary glands and literally "wear out" from over-production of milk. This occurs in a nation that provides dairy price supports for farmers who produce more milk than they can market. surplus dairy products are purchased at a guaranteed price by the government which then distributes surplus dairy foods and sells excess to foreign markets at discounted prices.

Hormone residues are not supposed to be in marketed products. BGH, for example, is a natural hormone, and some BGH is naturally found in meat and in milk. How much more BGH is in milk because of additional hormone use is questionable. The FDA is not concerned because BGH is a protein that is denatured by pasteurization and milk in the United States is pasteurized. In the United States, those dairies that do not use added hormones for milk production often state this on their packages. In almost all cases, such milk is more expensive. Many grocery chains do not carry milk products from the smaller dairies that do not use BGH.



"Unnatural" Foods

Having inserted a section on natural foods into our consumer concerns discussion, and having just mentioned the genetically engineered BGH, it is perhaps fitting that we conclude our discussion of food and consumer concerns with mention of "**unnatural foods**" and **biotechnology**.

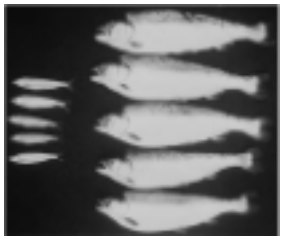
For thousands of years humans have used selective breeding in agriculture, horticulture and what was once called "animal husbandry" to obtain and maintain desired inheritable traits with many species of plants and animals. In this sense, humans manipulated genes for thousands of years before we had any knowledge about what a "gene" is.

We have taken advantage of the capabilities of many organisms to manufacture foods and beverages we like – yogurt, beer, wine and cheese are all examples of natural "biotechnology" which produces things we humans find useful. Drugs, such as penicillin are products of fungi, used for human benefit. The streptomycin drugs are bacterial derivatives. *Penicillium* mold was one of the first organisms deliberately "mutated" to produce better strains of the penicillin drug.

The field of **biotechnology** effects changes in the DNA molecule and/or in the organism in very precise and directed ways, for research and for industrial or commercial applications. We can alter existing DNA to promote or prevent the expression of certain genes or add genes to organisms to obtain characteristics that benefit.

One example of altered DNA is found in the commercial tomato industry. Biotechnology has been used to suppress the genes that promote ripening and softening of tomatoes so that tomatoes can stay on vines longer (to develop the proper flavor), but not get soft. Firm tomatoes are necessary for transportation purposes. Firm tomatoes have a longer shelf life.

Firm Tomatoes

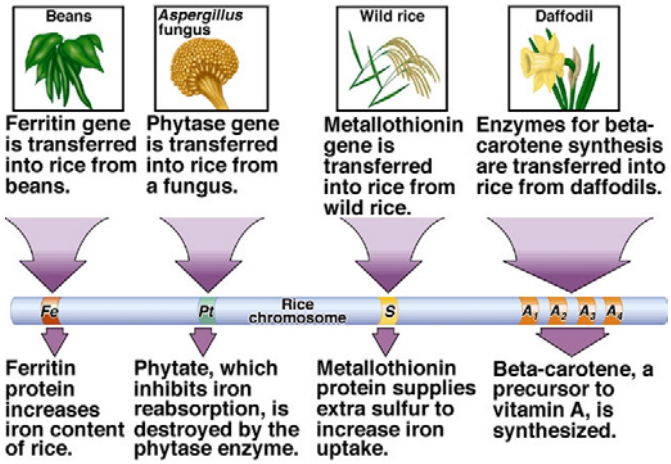


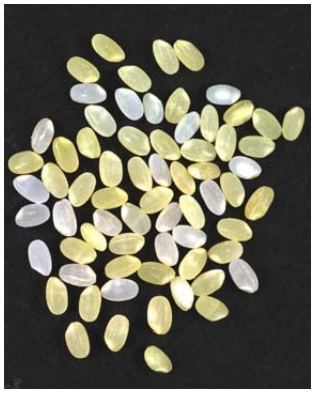
Salmonand Mice with growth hormone

Many chemicals are now produced using strains of bacteria or fungi, genetically selected for their ability to produce quantities of the desired chemical, similar to the way the *Penicillium* mold was cultured to obtain a strain that produced good quantities of penicillin. **Rennin**, used to make cheese, is obtained from bacterial cultures into which the rennin gene has been spliced. It's economically efficient.

We have a number of transgenic organisms into whose egg cells or early embryos a growth hormone has been injected. Such animals reach maturity much faster than normal so that they can be marketed sooner. The BGH mentioned earlier is another application of genetically engineered growth hormone

Golden rice was developed by a Swiss consortium using recombinant DNA techniques. This rice has genes to increase iron content, sulfur content, and b-carotene, as well as the enzyme phytase, which destroys the plant phytates that chelate iron. The goal of this project was to make a more nutrient rich rice, and targeted two nutrients, iron, and beta-carotene that are lacking in diets of those who rely on rice as the diet staple in much of the world. It is estimated that 40 million children suffer vitamin A deficiency and it is the leading cause of childhood blindness in third-world nations. Iron deficiency affects almost a quarter of the world's population.





Some of our crop plants have incorporated the protein from *Bacillus thuringiensis* (BT) that produces a toxin in the intestines of Lepidopteran larvae. This has greatly minimized the need for some pesticides. BT has been engineered into the strains of bacteria (*Pseudomonas*) that invade root tissue, so that roots can also have protection against larval pests.

A common bacterium, *Pseudomonas syringae,* which lives on the epidermis of plant leaves and stems, causes ice crystals to form at temperatures above freezing. This bacterium has been genetically altered so it cannot make ice crystals; therefore plant surfaces do not freeze until lower temperatures are reached, an agricultural bonus.

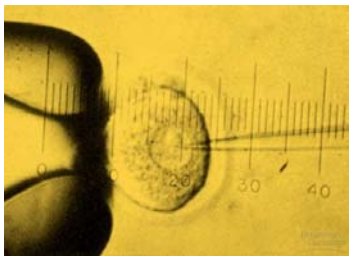
We also have herbicide resistance and wilt-resistant plants.

Wilt-resistant Carnations

Round-Up resistant Petunia

Weevil-resistant peas

Another use of DNA technology is to incorporate desired DNA into mammalian egg cells that develop into adults that produce certain needed human products. These engineered animals are sometimes called “pharm” animals. "Pharm" sheep milk contains a protein that minimizes lung damage associated respiratory diseases, including cystic fibrosis. Others hope to have vaccines for diseases incorporated into milk or into fruits to make the vaccine more readily available.



Injecting DNA into embryo cell

Pharm Sheep

A number of transgenic food crops have been approved. It is estimated that as much as 70% of the foods on our grocery shelves contain ingredients from crops that are genetically modified. However, most of these foods come from recombinant corn and soybeans. We eat little of the recombinant corn or soybeans as whole foods, but use oils processed from corn and soy, and high-fructose corn syrup from corn in hundreds of food products.

One concern consumers have with genetically modified organisms is that they may be exposed to protein allergens in the GMO that they were not previously exposed to. Someone allergic to peanuts might consume a food that had the peanut allergen gene added and the also be allergic to the GMO food without knowing. The reality is that almost everyone is probably allergic to at least one chemical – and most of us don't know. This is as true of genetically unaltered foods as it is those which have undergone DNA technology.

We also get concerned because we think that different DNA will change us or possibly cause something to happen in our cells. Those who know biology know that DNA in foods we eat is digested just as all molecules are. Some are concerned that they might be consuming DNA from a species that for any number of reasons is a species they do not eat, and it would be wrong for them to do so. What most of us fail to realize is that significant DNA sequences are the same in all of us, even in plants, so consuming a different DNA sequence is not the same thing as eating an entire organism, but each of us makes our own decisions about these kinds of things.

In the United States food manufacturers need not identify if their products contain ingredients that were obtained from an organism unaltered by DNA technology or not. The FDA has ruled that adding a piece of DNA that does not significantly alter the food and testing for food safety is not required. Adding genes that confer pesticide resistance by adding new chemicals into the organism do require testing for food safety before they can be marketed. Many consumer advocacy groups think consumers have the right to make decisions and all foods that have been genetically modified should be identified with labeling.

No matter how we might personally think about the changing rate with which we can manipulate genes, it is in each of our interest to learn as much as possible about genetics and DNA research so we can make informed decisions.