Welcome back! This is our first lecture in the third module and this is Food Toxicology 1. You will note that the next lecture is called Food Toxicology 2. What I separated out is the pesticides. They are very important and there is a broad amount of information there so they needed their own lecture. Please enjoy this lecture and I think you will find that are a few toxicants that can end up in your food that you may not be familiar with.

The objectives for this lecture are as follows. We will List and describe the microbial toxins found in foods. We will understand the potential for environmental toxins to cause unintended food hazards. You may not be aware that many foods contain natural hazards which pose health risks. And we will describe the conditions associated with the microbial, environmental, and natural toxins.

One thing we will not talk about in this lecture is the microbial toxins formed by bacteria. I have put a note on the bottom of this slide that we have already talked about botulism, the enterotoxin formed by \textit{Staphylococcus} and the \textit{Bacillus cereus} toxins so we will not cover them here. I mention them here because they are also microbial toxins. What we will cover in this lecture is fungi, a histamine-producing bacteria, and some algae.

Let’s begin with the fungi, some of which produce mycotoxins. I want to add a note here: there are a large number of mycotoxins that exist, but we are only discussing those that occur in the US food supply. In this lecture we will talk about \textit{Aspergillus flavus}, \textit{Claviceps purpurea}, and mushrooms that produce intestinal irritants. On the right hand side of the slide you can see a picture of corn on the top. That corn is infected with \textit{Aspergillus flavus}. On the bottom is \textit{Aspergillus flavus} under the microscope. If you have taken a microbiology laboratory you may have seen this fungus. It is very distinctive and often used in teaching laboratories.
Mycotoxin - Aflatoxin

- Aspergillus flavus produces a toxin called aflatoxin which causes an intoxication.
- Found in moldy grains and nuts including corn and pistachios, and also found in peanuts and soy. It can cause severe liver damage including cirrhosis, necrosis, and carcinoma.
- Often fatal.

Aspergillus fungus – Iowa State University.

Again we see Aspergillus on corn. You might not be surprised to know that this important pathogen is studied at Iowa State University. Remember that the heartland area of the United States produces quite a lot of corn making this an important pathogen for that region. Aspergillus flavus produces a toxin called aflatoxin which causes an intoxication. Aflatoxin is often considered the most toxic naturally occurring substance on the planet. That is arguable but it is definitely up there. It is found in moldy grains and nuts including corn and pistachios, and also found in peanuts and soy. It can cause severe liver damage including cirrhosis, necrosis, and carcinoma. Unfortunately, aflatoxin poisoning is often fatal.

Mycotoxin - Aflatoxin

- In 2013 there was a recall of dog foods contaminated with aflatoxin.
- Drought conditions resulted in overgrowth of Aspergillus fungus on corn.
- That corn was used to produce dog food.

Remember when we were talking about big food companies we mentioned that a number of them own many pet food brands. In 2013 there was a recall of dog foods contaminated with aflatoxin. There was a drought that year that led to overgrowth of Aspergillus fungus on corn. Please consider that many fungi do not need moisture, in contrast to most bacteria that do require moisture for growth. The contaminated food was used to produce dog food. Keep in mind that most potentially dangerous foods have high water activity. But with the fungi, they don’t need water and can grow on dry foods. Fungal food infections are fortunately rare in the US, but if we did have an aflatoxin poisoning, it could occur in dry foods like bread and cereals.

Mycotoxin - Aflatoxin

In the United States we routinely test foods for aflatoxin and human cases are rare. In places where detection is not used, large outbreaks with high numbers of deaths (125 above) can occur. Note the cause of this outbreak was contaminated corn.

Because we test foods in the US before sending them out on the market, the United States rarely sees an aflatoxin poisoning (please note instructor misspoke here and said infection, aflatoxin is a poisoning or intoxication). I wanted to show you a picture here of an outbreak that did occur in Kenya. In Kenya detection is not used, and large outbreaks can occur. In this case there were 125 deaths associated with this outbreak. The cause of this outbreak was contaminated corn.

Mycotoxins - Ergot

- Ergot is a toxin produced by the fungus Claviceps purpurea that infects rye.
- The toxins have hallucinogenic properties.
- Causes a syndrome known as ergotism or “St. Vitus Dance” which includes spasms and hallucinations.

This brings us to another mycotoxin that causes a disease known as ergot. Ergot is a toxin produced by the fungus Claviceps purpurea that infects rye. You can see a picture of the infection on the right hand side. The toxins have hallucinogenic properties. They can cause a syndrome known as ergotism or previously known as St. Vitus Dance. This name tells you the fungus has been known for a very long time. Symptoms include spasms and hallucinations.
There is an interesting side note here when discussing ergot. In Salem, Massachusetts in 1692 several women were accused of being witches after exhibiting strange symptoms including hallucinations and spasms. 20 people ended up being executed because it was believed that they were witches. Ergot is known to have infected rye in Salem at the same time this occurred. Therefore many people have speculated that the “witches” were in fact poison victims. As you can imagine the symptoms were very similar. [Note added: the symptoms of ergot poisoning were mistaken for possession]. If you visit Salem, you can see the memorial to the victims.

This brings us to the mushrooms. Poisonous mushrooms often look similar to hallucinogenic mushrooms. Unfortunately, people abuse mushrooms as a way to get high. However, they often mistakenly eat the wrong mushrooms. If you hunt mushrooms, you might want to take a look at one of the websites such as that shown on the right which can help with species identification. In particular, which species are poisonous. The mushrooms commonly produce gastrointestinal irritants or compounds that produce rapid, transient nausea, vomiting, abdominal cramping, and diarrhea. Some of the mushrooms are deadly. A photoshopped picture of a deadly mushroom is shown at right.

To illustrate the point, I am showing you an outbreak here that occurred in 2012. A caregiver at at Gold Age Villa Senior Care Facility accidentally used poisonous mushrooms to make a soup for elderly patients. Four people died and several other people became ill. Sadly this person was used to making soups with mushrooms picked from a different area. They were not aware that this area had poisonous mushrooms. Sadly, this happened again in 2015 at a different location.
This brings us to a different type of poisoning known as scombroid poisoning. This is an intoxication caused by ingesting large amounts of the chemical histamine. The histamine is produced by bacteria in seafood. The seafood implicated is usually tuna, mahi-mahi, and sardines. So again, the fish contains the bacteria which produces the histamine. If you ingest large amounts of histamine, you will get symptoms. Think about some of the things you already know about allergies and anti-histamines. This usually results from fish being held at high temperatures for long time periods. Again, we see a temperature abuse problem. The toxin is heat-stable. This is problematic because it may not be destroyed by cooking. Remember that seafood often has low cooking temperatures so as not to destroy the quality of the seafood. The symptoms include dizziness, burning, rash, headache, and can be fatal. Severe cases may require treatment with fast-acting antihistamines.

This is pretty rare but here is an outbreak that occurred in Louisiana and Tennessee in 2006. The two different locations had the same source for their seafood. Imported tuna was a common food in both outbreaks but elevated levels of histamine were not detected in remaining samples. The source remains unknown. Unfortunately, in a number of foodborne outbreaks we are never able to determine the source.

That brings us to the algae and the algal toxins. The algae rarely cause disease and foodborne infection is rare. But when they do cause occur most cases are due to the following type types of toxins; they are either ciguatoxin or paralytic shellfish toxins. Looking on the right you well see that the toxin data is collected by NOAA, the National Oceanic and Atmospheric Administration. This is an agency we rarely discuss as having a role in food regulation but here they are! Please note that pufferfish poisonings (not discussed in this course) have occurred here in Florida.
Our first algal toxin is ciguatoxin. Ciguatoxin is produced by an algae known as dinoflagellates. Dinoflagellates are very cool under the microscope and are commonly used in teaching laboratories. You can see them at bottom right. The algae are eaten by fish, which are in turn eaten by larger fish, causing the toxin to accumulate to dangerous levels in large fish. This process is known as bioaccumulation. Bioaccumulation is really important with some toxins and we will talk later about those that remain in the body are a concern while those that do not are rarely harmful. Prevention of ciguatoxin poisoning is eating smaller fish. The symptoms include nausea, diarrhea, vomiting, headache, excessive sweating, weakness, itching, etc. There is no specific treatment and disease is rarely fatal. On the right you can see a testing kit for ciguatoxin and seafood is usually checked before it goes out on the market.

There are a number of reasons for which there are size limits on the fish that can be caught and eaten and ciguatera is one of them. Human cases of ciguatera, the disease caused by ciguatoxin, usually occur following ingestion of barracuda, snapper, jack, and grouper. If you have lived in Florida long enough you are probably very familiar with grouper fish. Grouper is a huge economic food for the state of Florida and later we will talk about how grouper is often misbranded. In other words, people try to pass off other fish as grouper. Cases are common in Hawaii and Puerto Rico. However, if the fish are shipped cases can occur anywhere. In the report at right, cases occurred in New York City. The distributor of the fish is not named but reports show that they had already been issued a warning for ciguatoxin in the past. Later we will talk about how new FSMA guidelines will allow the FDA to block the importation of foods from companies that have habitual problems. It is important to note that we import most of seafood in the US and this puts us at risk for a number of pathogens.
This brings us to the shellfish toxins. Produced by several types of algae, including the species that causes “red tide”. If you have ever gone to the beach during red tide, you have probably seen a large number of dead fish wash up on the shore. So you probably already know these toxins can be dangerous. It is also dangerous to be at the beach when there is a red tide because crashing waves can send the toxin into the air which can cause respiratory issues. These toxin are heat-stable, in other words, cooking does not destroy them. It infects mussels, clams, oysters, crabs, lobsters, and scallops. We have picked on oysters a number of times in this class and described how cooking would kill hepatitis A, *Vibrios*, and other pathogens. However, in contrast the shellfish toxins are not destroyed by cooking. Symptoms can be confused with shellfish allergies: numbness and tingling at first followed by headache, dizziness, and nausea. Note that shellfish allergies can be treated with anti-histamines. In severe cases, muscle paralysis and respiratory failure occur. Death occurs within 2-25 hours.

Most paralytic shellfish poisoning cases occur in colder climates where the toxin from the algae accumulates in the shellfish. The most important toxin is saxotoxin. Saxotoxin is considered a select agent and there are concerns that it could be used for bioterrorism as it is a pretty dangerous toxin. At right two cases were reported in Alaska and in 2015 more cases were reported in Alaska.

Now we will switch gears and begin to talk about environmental toxins. You probably know a bit about environmental toxins but might not have concerned which might be a threat to food. If you are interested in learning more about environmental toxicology and risk assessment, we have many courses on this in my department: Environmental and Occupational Health. Please check out our courses if you want to learn more. Industrial processes can release contaminants into the environment. Polluted air, water, and soil can result in contaminated produce, dairy, meats, and seafood. Some environmental contaminants can cause health problems. These can range from very mild to severe problems. You are probably familiar with the problem of mercury in seafood. Looking at the picture on the right, you can see which types of seafood have high amounts of mercury. You have probably heard about tuna and it is very high and the top of the list is swordfish.
We want to talk about what makes an environmental toxin dangerous. There are characteristics that make certain chemicals more dangerous than others in the environment. One of which is the capacity for persistence. Persistence of toxins refers to the extent to which the toxin lingers in the environment or in the body. Some chemicals are readily destroyed by sunlight and/or water, some are readily flushed from the human body. For example, most of you have taken an antibiotic at some point in your life. Do you think that antibiotic is still present in your body? Contaminants present for a short time or eliminated by the body pose little health risk. This includes antibiotics. Contaminants which persist may also bioaccumulate. In other words, if the chemical is not eliminated, it may bioaccumulate.

This brings us again to this idea of bioaccumulation. Some toxins do not breakdown in the environment. These toxins move up through the food chain and they accumulate. Each level has a higher concentration than the one below. Eventually humans consume a food that contains high levels of a toxin such as mercury. Looking at the figure at right, start at the bottom. You might have very small traces of mercury that are in water. Plant plankton will pick up the mercury and then be eaten by animal plankton. Those in turn are eaten by smaller fish, and then larger fish, and finally tuna. If you have ever seen an actual tuna and I don’t mean the kind in a can. The actually, swimming tuna, you know they are huge. Think about the amount of mercury that can bioaccumulate over all of these trophic levels. You can end up with quite a bit of mercury.

In the interest of time in our class, we are only going to cover the EPA’s 1st 12 priority PBT pollutants. The Environmental Protection Agency has identified a number of persistent, bioaccumulative, highly toxic chemicals it is committed to removing from the environment. These compounds pose a health risk to both humans and ecosystems through food and water.
In the interest of time, we will only cover a few of these in detail. The first listed is Aldrin/dieldrin, it was used as an insecticide but has been banned. The next is benzo(a)pyrene a product of incomplete combustion. Exposure occurs due to fires and smoked foods. We can’t ban this because it is formed when many foods are cooked or smoked. It is also formed as a result of smoking cigarettes. It is also formed when things are burned and it can’t be banned but it is something to be aware of. I am sure you have heard that cooking some foods and in particular grilling foods can produce carcinogens. This is usually what that refers to, the presence of benzo(a)pyrene. Chlordane was a pesticide that was banned in the 1980s. I am sure you have heard of DDT, DDP, and DDE related pesticides which have all been banned. Hexachlorobenzene is a pesticide that has been banned. One of the reasons you see so many insecticides and pesticides that have been banned is that there are other products that can take their place. We wouldn’t necessarily ban the product if there was no alternative. For example, DDT is still used to kill mosquitoes overseas. Alkyl-lead is a fuel additive. You may be aware it was added to automobiles but leaded fuels have been banned and most gas stations carry unleaded fuel. It is still allowed in limited capacity in racing, marine, and aircraft fuels.

Continuing that list of PBTs, there are a few we will discuss in more detail on the upcoming slides because they play important roles in food. Mercury is one of those and we will talk about it on the next slides. Mirex was an insecticide that was banned. And please note the list is alphabetical and not in order of importance. Octachlorostyrene is formed during the production of magnesium. It is a dangerous compound but there is no way around this as we need it for magnesium production. PCBs will be discussed on the next slides. Dioxins and furans will be discussed on the next slides. And toxaphene was an insecticide that was banned in 1980.
This brings us to one of the environmental toxins known as mercury. Mercury is an element and it is used in the production of many products. It is used in chemicals, pharmaceuticals, switches, thermometers, and light bulbs. Once mercury enters the environment, microorganisms covert it to methylmercury which is the highly toxic mercury that builds up in fish and shellfish. This is very important, the mercury is toxic only after it has been converted to methylmercury by bacteria. This process is also required for it to become bioaccumulative. In other words, mercury used in pharmaceuticals is NOT methylmercury and is NOT dangerous. Exposure to methylmercury results in impaired neurological development in the fetus including cognitive thinking, memory, attention, language, fine motor skills, and visual spatial skills.

I wanted to add a lecture note here on mercury. Mercury is used in many pharmaceuticals as a preservative. It is added to multi-use vials to prevent the growth of microorganisms. Usually it is added in the form known as thimerosal. The form of mercury used in these applications is ethyl mercury, it is not methylmercury. This is important because it does not bioaccumulate and does not cause the health risks associated with other types of mercury. Many years ago there were claims that vaccines caused autism. This later morphed into thimerosal caused autism. Because of fears, many companies were forced to remove thimerosal from their products. Thimerosal was removed from all childhood vaccines in the year 2000 and yet we have seen no changes in the autism rate. This compound was unfortunately removed needlessly from vaccines. Since it was removed, a number of deaths have occurred because multi-use vials have become contaminated with bacteria, causing deaths.

Real mercury poisoning caused by methyl mercury looks very different and you can see pictures here on the right hand side. Between 1932 and 1968 a petrochemical and plastics manufacturer dumped an estimated 27 tons of mercury in Minamata bay in Japan. It poisoned the fish and it poisoned the people who ate the fish. Over 900 people lost their lives and over 2 million people suffer or did suffer from chronic health problems. On the right you can see what it looks like when babies are born to women with Minamata disease.
In 1968 in Japan a number of patients were reported to have symptoms including acne-like eruptions, pigmentation of the skin, and eye discharge. The cause of the disease was later found to be rice oil (Yusho means oil disease) contaminated with dioxin-related compounds. A total of 1961 people are registered as yusho, the name of the disease, patients. Despite the knowledge of this having happened in the past, it happened again in 1979 in Taiwan.

Environmental Toxins - PCBs
- PCBs are chlorinated hydrocarbons that were used in 100s of industrial and commercial applications.
- PCBs were banned in the United States in 1979 but they do not break down. Because they do not break down, we can find them in the environment, in wildlife tissues, and in the food chain. In other words, the damage has already been done. PCBs exert toxic effects on the body. In addition to causing cancers, they can damage the immune system, the endocrine system, the reproductive system, and the nervous system. You can find warnings in some places that state do not catch fish in this water, it is known to be contaminated with PCBs.

That brings us to the environmental toxins dioxin and furans. I placed these on the same slides because they are a family of toxic substances that have similar chemical structures. They are the products of industrial processes or are created during burning. You can produce them by burning waste or burning wood. They are found in the food chain in meat and dairy. This is due to accumulation in the environment again. Health effects include the following, a picture of chloracne shown at the bottom. It can cause other skin conditions as well. These would be seen in person who work with the chemicals or had large exposures. We know now that dioxins and furans can also cause immune system damage, developmental damage, reproductive damage, and cancers.

Environmental Toxins - Dioxins and Furans
- Refers to a family of toxic substances that have similar chemical structures.
- They are the byproducts of industrial processes or are created during burning.
- Burning of wood
- Burning of waste
- Result in the food chain is resent and dairy.
- Can be contaminated as in the environment.
- Health effects include the following:
  - Immune system damage
  - Endocrine system damage
  - Reproductive system damage
  - Nervous system damage
  - Developmental damage
  - Reproductive damage
  - Cancer

In 1968 in Japan a number of patients were reported to have Symptoms including acne-like eruptions, pigmentation of the skin, and eye discharge. The cause of the disease was later found to be rice oil (Yusho means oil disease) contaminated with dioxin-related compounds. A total of 1961 people are registered as yusho, the name of the disease, patients. Despite the knowledge of this having happened in the past, it happened again in 1979 in Taiwan.

Natural Toxins
- A number of plants contain natural toxins.
- Many of these toxins are designed to protect the plant from insect damage. These toxins are not harmful if ingested in small amounts. The most common are goitrogens, cyanogens, and solanine. The foods in the picture at right contain cyanogens. Tapioca can potentially kill you, just ask Sheldon Cooper. If you are a fan of the TV show “The Big Bang Theory” you may have remember that Sheldon Cooper
refused to eat tapioca pudding because it could kill you. Theoretically, he was right.

One of the natural toxins we want to talk about is the goitrogens. Goitrogens can cause enlargement of the thyroid gland by blocking the uptake of iodine. They are found in very small amounts in a large number of foods including cabbage, bok choy, turnips, mustard greens, etc. You can see the pictures here. Please note that these foods are very healthy for you and good for you to eat. If you don’t eat them in very large amounts, you will not have a problem. However, if you decide to go on an all kale smoothie diet, would you put yourself at risk?

That brings us to the cyanogens. Some foods contain cyanogens which can convert to cyanide. Sheldon cooper was very worried about these! The foods include apricot pits, peach pits, apple seeds, lima beans, and cassava. Lima beans with low levels of cyanogens are used in many foods. In other words, we have breed lima beans to have less cyanogens. Most people do not eat seeds though a few will not hurt you, and most people do not eat the pits of fruits. Cyanogens are not a big risk unless you choose to eat the seeds and pits. I looked online to see if I could find someone selling apricot pits and sure enough here is a seller.

Cyanogen poisoning is a big problem in places that have cassava as their staple food. It causes a disease known as konzo. Konzo is a neuromotor disease caused by exposure to cyanogen poisons in cassava. It causes altered gait, spastic movements, and cognitive disorders. This occurs when cassava is not processed properly to breakdown the cyanogens. Keep this in mind because later we will discuss how gmo technology has been used to produce a cassava low in cyanogens. When we get to that lecture, I would like you to have thought about gmo technology used in this manner.

Expanding on the cyanogens, I want to talk to you about laetrile. Laetrile is a product derived from apricot pits. It is not a cure for cancer but was marketed as such for many years. You must be careful of pseudoscience. There are a large number of people who will profit from the gullible. People who didn’t want to undergo chemotherapy bought laetrile which is poisonous. Some people lost their lives. Shown on the left is a story on a guy serving a long sentence for selling laetrile. However, I easily found another seller on Amazon.
Natural Toxins - Solanine

- Solanine is a narcotic-like poison found in potatoes.
- Largely found in leaves and stems but a limited amount is found in the peel.
- Poisoning is rare except in times of food shortage.

- Symptoms include:
  - Vomiting
  - Diarrhea
  - Abdominal pain
  - Coma
  - Convulsive twitching
  - Confusion
  - Hallucination

- Death is rare unless the person is dehydrated.

This brings us to another natural toxin known as solanine. Solanine is a narcotic like poison found in potatoes. Largely found in leaves and stems but a limited amount is found in the peel. Normally we do not eat the leaves and stems and poisonings usually occur in times of food shortage when the entire plant is eaten. Symptoms include vomiting, diarrhea, abdominal pain, coma, convulsive twitching, confusion, and hallucinations. Death is rare unless the person is dehydrated.

Lecture Summary

- Lecture Note: Information used in this lecture on Environmental Toxins was adapted from the Environmental Protection Agency Website (www.epa.gov).
- Foods are susceptible to toxic contamination from microbial, environmental, and natural toxins.
- The symptoms depend on the toxin present and there are few treatment options.
- Protecting the food supply from toxic contamination requires adherence to regulatory guidelines.

To wrap this lecture up much of the material was adapted from the Environmental Protection Agency website. Epa.gov is a great site for information on pesticides, toxins, water, etc. Foods are susceptible to toxic contamination from microbial, environmental, and natural toxins. The symptoms depend on the toxin present and there are few treatment options. Protecting the food supply from toxic contamination requires adherence to regulatory guidelines. We will talk in the last module about who regulates what.