Hello again and welcome to the last lecture in Module 2. This is called Food Groups and Their Pathogens. This may seem like an unusual lecture to add here but the reason I added it is because if you have a given pathogen, it is often associated with a particular food. For example, you have raw chicken here. Raw chicken should immediately bring to mind *Salmonella* and *Campylobacter*. This can be very useful. For example, if you have a patient with *Campylobacter*, you might want to ask them if they have been exposed to raw chicken.

The overview for this lecture is as follows. The major food groups and their associated pathogens are discussed, including meats, poultry, eggs, dairy, produce, seafood, and water. The origin of the pathogens in each group are listed. Costs attributed to each pathogen group are discussed. Prevention methods unique to each food-pathogen group are suggested. Illustrated is the principal that when a given pathogen causes foodborne illness, the responsible food group can OFTEN be deduced.

This lecture also provides another way to look at our pathogens. It is good to see them in different contexts. In the first set of lectures we divided the pathogens as bacteria or viruses. In this lecture we look at which groups of pathogens are associated with which foods. Let’s begin with the pathogens associated with meat and poultry. You can see here *Salmonella*, *Campylobacter*, *Staphylococcus*, *E. coli*, *Trichinella*, *Toxoplasma*, *Taenia*, *Toxoplasma gondii*, etc. So needless to say, we have several groups represented including worms, bacteria, and even a prion.
Origin of Microorganisms in Meat

- High levels of bacteria are present on the hide, hair, and hooves of red meat animals.
- Contamination of muscle tissues during dehairing (hogs), hide removal, and other processing can occur.
- High levels of bacteria are also present in the gastrointestinal tract and may contaminate muscle during removal of abdominal contents.
- The processing environment (machinery, walls, floors, worker’s hands, etc.) has also contributed to contamination in red meats.

Origin of Microorganisms in Poultry

- Microorganisms are present on the skin, feathers, and feet of chickens.
- Contamination with feces can occur during transportation and during processing.
- Birds are hung and bled.
- Studies have shown that as many as 90% of chickens contain one or more pathogens when purchased from the grocery store.

What is the origin of microorganisms in meat? One the right hand side is a picture inside a slaughter plant. This facility is quite clean. Meat is moving along a production line but the facility is quite clean. There are high levels of bacteria that are present on the hide, hair, and hooves of red meat animals. Contamination of muscle tissues during dehairing, for hogs only. In other words, when they take the hairs off of the hog, the muscle tissue underneath can become contaminated. During hide removal contamination occurs and also during other types of processing contamination can occur. High levels of bacteria are also present in the gastrointestinal tract and may contaminate muscle during removal of abdominal contents. In other words, when you remove the GI tract, you must be sure not to pierce it as it can release microorganisms that can end up in tissues. This is very similar in traumatic injuries in which fecal matter can contaminate the inside of the abdomen. The processing environment (machinery, walls, floors, worker’s hands, etc.) has also contributed to contamination in red meats.

We want to discuss the origin of microorganisms in poultry. Your instructor loves the data chickens so here they are again! Since the 1990s, there have been 45 *Salmonella* outbreaks associated with raw poultry. One of the reasons this has been such a problem with poultry is because the microorganisms are present on the skin, feathers, and feet of chickens. Studies comparing free-range and caged chickens have failed to show differences between the two types of birds in terms of contamination with *Salmonella*. Contamination with feces can occur during transportation and during processing. Bird processing is not pretty, birds are hung and bled. *Salmonella* can spread bird to bird. Studies have shown that as many as 90% of chickens contain one or more pathogens when purchased from the grocery store.
We want to talk about the costs of foodborne diseases that are associated with meats and poultry. The cost of disease attributed to poultry, pork, and beef is $5.7 billion dollars. Remember that this is per year so this is quite an economic cost here. The pathogens in this group can lead to death including *E. coli* O157:H7, *Listeria*, and *Salmonella*. Recall that morbidity is also important and lifelong disability including liver and kidney damage may occur. These contribute to some of the high costs associated with these infections. On the right is a picture of raw poultry and a reminder that it contains several pathogens. One of the things we will talk about later is that it is now recommended that you do not rinse raw turkeys during preparation. The reason being is that turkeys already have microorganisms on their surface. The thinking is that if you rinse the bird before cooking, you will spread the microorganisms to your sink, hands, sponges, etc.

We want to separate out from the previous slide the cost of just contaminated poultry because we know it is a major player. It has the greatest public health impact among the foods. The two pathogens most commonly associated with poultry are *Campylobacter* and *Salmonella*. On the right is the statistic that 40% of all raw chicken breasts contain *Salmonella*. There are a lot of safety measures in place that attempt to prevent this from happening but it is very hard to separate *Salmonella* from chicken. Take a look at the picture, do you think it is a good idea to have raw chicken near raw produce? It cooked, this wouldn’t be a big deal but generally we like to keep these food groups separate to prevent cross contamination. Poultry disease costs are estimated at $2.6 billion. A safety tip is provided here for you. Make sure your grocery bags your poultry separate from the rest of your groceries. Do not let the grocery put raw chicken in with other items. The outside of the containers are contaminated. If you do use reusable bags, make sure you wash them often.
Preventing Foodborne Disease – Meats and Poultry

- Several steps during processing reduce or eliminate microorganisms from meats.
- Cooking meat products to proper temperatures will kill most pathogenic organisms.
- It is unsafe to serve raw or undercooked red meats, pork, or poultry.
- Irradiation is an alternative if meat is to be ingested raw.
- Safety Tip: if you are EVER served undercooked meat, don’t be shy, send it back or do not eat it!!

Changing food groups here we want to talk about the foodborne pathogens associated with deli meats and eggs. The major pathogens of concern here are *Listeria*, *Salmonella*, *Staphylococcus*, and *E. coli*. Please check your egg containers and see what the label says [if you have eggs in your house]. Many producers are now certifying that their eggs are humanely-produced. In fact, you may see many cage-free eggs. The reason for this is the common use of the battery cages as shown on the right. As you can see this is not safe and it is cruel to the animals. You can see there is a bird that has died here and other birds are walking on it. The head of the dead bird is impeding the flow of the eggs. All and all this is not safe. This practice has been condemned by the Humane Society and has led to a demand for cage-free eggs and many companies have moved to cage-free. Again, check your eggs at home and see if they do not use these processes. In fact, some of the companies have links to videos you can watch to see how their animals are processed.
We have previously discussed *Listeria* and how it is a danger associated with deli meats. You may wonder how the *Listeria* gets into the deli meats. If you look at a picture of a modern deli you will note that there are a large number of products available in the deli. And therefore cross contamination is always a concern. *Listeria* contaminates carcasses from feces during slaughter. *Listeria* can enter processing facilities through soil on worker’s shoes, clothing, and vehicles. *Listeria* growth is promoted in areas with high moisture and it is often found in drains, stagnant water, floors, residues, and processing equipment. *Listeria* can also survive cold temperatures.

You might also be asking yourself how did that *Salmonella* get in the eggs? It is estimated that approximately 1% of all eggs in the US food supply are contaminated with *Salmonella* serotype *Enteritidis*. Transovarian transmission results in the deposition of *Salmonella* inside the egg. In other words, when the egg is forming inside the chicken, the *Salmonella* gets deposited before the shell is added. Once this occurs there is little that can be done. Egg surface sanitizing processes fail to eliminate internalized bacteria. There are processes used to decontaminate egg surfaces but this is not something you want to attempt in your own home. The reason is related to the last point on this slide, eggs can become contaminated on the surface with feces. Eggs in the grocery are typically cold and when they become warm they begin to sweat. This opens up a highway of moisture between the outside of the egg and the inside of the egg. *Salmonella* on the surface of the egg is carried inside the egg. We therefore do not recommend that you clean your own eggs at home. It is also important to note that although most eggs are held cold, they don’t have to be and you may have found Farm Fresh eggs for example that are warm. These eggs will not sweat. If you have refrigerated eggs, do not get the eggs out way before you plan to use them and let them sweat on the counter. Get your eggs out right before you plan to use them.
Let’s talk about the costs associated with foodborne diseases due to contaminated deli meats and eggs. The cost is estimated at approximately $1.8 billion per year. *Listeria* is particularly dangerous to pregnant women and can lead to miscarriages. On the right is a woman named Stephanie who is a big promoter of STOP (Safe Tables Our Priority). She unfortunately contracted *Listeria* while pregnant. Her son Michael shown in the picture was born brain dead and died two days later. *Listeria* is extremely dangerous while pregnant despite what some like to say on the internet. Some people will eat deli while pregnant with no ill effects but this is a dangerous risk to take and you should never do this. *Salmonella* and *Listeria* contribute significantly to morbidity and mortality associated with food consumption.

As always we want to talk about prevention, in this case preventing foodborne disease from contaminated deli meats and eggs. There are dozens of safe handling practices aimed at preventing the contamination of deli meats which are Ready-to-Eat foods. The best things you can do are to make sure that machinery is decontaminated and do handwashing. As you can see in the picture on right, deli machinery can be very difficult to clean. There are a number of posters available from the FDA that detail how to clean these machines. This is a major area of concern for food inspectors. Inspectors may swab these machines to check if anything grows. Prevention methods for *Salmonella* in eggs have included egg handling procedures, washing the eggs (meaning the producer washes the eggs, not at home), and vaccinating chickens. Believe it or not there are vaccines in trials but none of them has proven effective against Enteritidis. There is a vaccine in use in Europe but their serotype is not Enteritidis. A good safety tip: pregnant women should never, never, never eat deli meat!

This brings us to the foodborne pathogens associated with dairy. You will see here that all of the pathogens are bacterial. On the right is a safety tip: despite what you may have heard or found on Google, there is no safe raw milk. I have mentioned this many times because it is so important that many pathogens are found in raw milk.
What are the origins of pathogens in dairy? *Bacillus cereus* is present in soil, it can spread to a cow’s udders and then into raw milk. On the right is a picture of cow udders. Cows can carry *Campylobacter* and spread it to raw milk. *Listeria* and *E. coli* are found in the environment and like *B. cereus* can spread to raw milk. *S. aureus* causes mastitis (infection) in cow udders and can spread to milk. Also one of the most costly diseases in agriculture and one of the main uses of antibiotics in cattle. We will talk later about the use of antibiotics in cattle and what factors result in these infections being so common.

How do we prevent foodborne diseases from dairy products? The easiest way is pasteurization as it will destroy most microorganisms in milk. The spores of *Bacillus cereus* will survive pasteurization and they will germinate. Especially true if milk is held at room temperatures. *Bacillus cereus* growth will produce a change in the taste and smell of the milk product. If you have smelled bad milk you have noted the changes due to *Bacillus cereus* making the milk rancid. On the right hand side you can see that there are pasteurizers for sale on Amazon. They sell these because many people like to make homemade cheeses. This makes those cheeses much more safe. Irradiation is an alternative to pasteurization but as mentioned before is controversial as discussed later.

That brings us to the organisms that are found in fruits and vegetables. Fruits and vegetables are lumped together under the category of produce. Students often ask if it is safer to be vegetarian but if you look at this list of pathogens you probably can deduce the answer to that question. You will see a lot of bacteria, some protozoans, some viruses, and I have written many parasites. I have included a picture of water chestnuts because they often contain an important parasite if grown in other countries. Check the labels on your water chestnuts, they may look like they were imported but they were likely grown here.
What is the source of the microorganisms in produce? In many cases the source of the microorganism can be traced back to growth conditions found on the farm. For example, if the farm had contaminated water sources, contaminated fertilizer, contaminated soil, or close proximity to animals you could end up with contaminated food. We do know of a case in which a field of lettuce was located downstream from a cow farm. Water from the stream was contaminated with feces and used to irrigate the lettuce. We have talked many times about preventing cross contamination as this can contaminate produce as well. You might not be familiar with aquaculture in which produce and fish are grown close together. People sometimes use feces from other animals to feed the fish. This can result in cross contamination of produce. In many other cases, disease occurs as a result of cross-contamination during food preparation, often from raw meats. You can also have contamination from poor personal hygiene.

Produce is a special case because it is not just contaminated but the organisms are allowed to survive as the food is not cooked. [note added: meat is contaminated but often cooked]. Careful washing of raw fruits and vegetables but many studies have found that these are no more effective than soap and water. A big key to produce safety is to avoid cross contamination, especially with raw meat. Irradiation is possible but remember this is controversial. [Note: I keep stressing this because irradiation is not currently available]. Safety tip: Wash hands frequently when preparing raw foods and avoid cross contamination. The easiest way to do this is to prepare raw foods first, move them away, then prepare foods that will be cooked.

You have probably noted that there are a number of microorganisms found in seafood. There are bacteria, viruses, worms, algae, scombrototoxin caused by bacterial infection, and shellfish toxins. A large number of potential problems I wanted you to see here.
Slide 21

What is the origin of microorganisms in seafood? In almost all cases the microorganisms found in seafood are due to contamination of waterways with feces of humans or other animals. There are many ways these organisms can end up in water but one of the common ways is sewage leakage. The seafood industry relies heavily on cleaning and testing to destroy or detect harmful organisms. So in other words, after harvesting, seafood goes through a number of cleaning, also known as processing steps, and is then tested on site for contamination. Certain waterways are so contaminated that fishing is prohibited. You can see on the right some of the signs warning not to fish. The water and the seafood found in that water are dangerous.

Slide 22

How do we prevent foodborne diseases from seafood? Most seafood illnesses can be prevented by proper cooking. If you plan on eating seafood raw, this strategy isn’t going to protect your food. Some can be prevented by eating smaller fish, particularly algae infections, and we will talk about this later [note added: can also prevent contamination due to mercury, etc]. Others can be prevented by irradiation. If we irradiated raw sushi and oysters, they would be safe. Probably the most important step is to detect the organisms before the seafood enters the food supply. So again, it is best to test on site. Safety tip: buy seafood from reputable sources, in other words, not from the guy on the side of the road who is also selling turtles. This is not included as a joke! There are a number of roadside stalls in Florida which have seafood, turtles, produce, etc. That guy does not have a license to sell foods (usually) and the products may not be safe.

Slide 23

What about organisms found in contaminated water and ice? Please recall that water and ice are regulated just like food and we will talk about them in our last module. In contaminated water we can find *Shigella*, *Vibrios*, hepatitis, in other words viruses and bacteria. There are also protozoans like *Cyclospora*, algae, and many parasites. In the picture you can see a little boy collecting water to drink and that water clearly is not clean.
Much like seafood, the origin of microorganisms in water and ice is usually feces. Feces can come directly from humans and animals, or from runoff from sewers, farms, etc. Freezing does not kill viruses and bacteria, but it often kills parasites. I add this because people often believe that if something is frozen it is safe and this is not true. We talked about this before with the margaritas and the ice and the transmission of ETEC (Please note instructor misspoke here and said norovirus). Please note in some cases there are health warnings that state “this water may cause ill effects to humans and animals”. You do not want to be in contact with this water.

How do we prevent foodborne disease from water and ice? Prevention requires the same techniques employed in water treatment plants. In other words, we use filtration, sedimentation which causes a lot of the contaminants to fall out, and chlorination. You don’t need to memorize the picture at right but in case you were interested, this is what it looks like when water goes through a water treatment plant. The cleanliness of water and ice must be maintained. So when the water is cleaned, you don’t want to place it in dirty containers and you don’t want to cross contaminate. We will talk later about chemical poisonings that occurred when water or food was placed in containers that previously held pesticides.

We have previously talked about the costs associated with meats, poultry, and deli and eggs. The costs associated with dairy, produce, seafood, bread, beverages, and complex foods (those foods with multiple ingredients) is $6 billion dollars. On the right is an example of a complex foods. This includes pathogens which result in serious disease and can cause deaths.
This slide is to summarize the pathogen-food combinations responsible for most illnesses. Recall that pathogens can be in many foods but usually when they are present, these are the foods responsible. When you find Salmonella in a sample, it likely came from poultry, complex foods, produce, or eggs. When you find Listeria, the source is probably deli meats or dairy products. Such as occurred with the Listeria – Blue Bell ice cream outbreak. *Toxoplasma* is usually found in pork and beef. *Campylobacter* is found in poultry. And norovirus is found in complex foods. On the right side is the top pathogens contributing to domestically acquired foodborne illnesses and death in the US in 2000-2009. Luckily norovirus, the leading cause of illnesses, is not responsible for most of the deaths. Most of the deaths are associated with *Salmonella*, *Toxoplasma*, and *Listeria*.

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This company can sell raw milk in Florida, if you “promise” to use it only for pet food!

I wanted to put a note here that a large portion of this lecture was adapted from Food Microbiology, an Introduction. You are not required to look at this book but if you want a reference, this is a great book. Also included is a note on raw milk. Florida prohibits the sale of raw milk for human consumption but allows its sale for animal consumption. This company shown at right can sell you raw milk if you promise only to use it from animal consumption. This is obviously a loophole in the regulations.

The following is the lecture summary. Microorganisms prefer to grow in foods with high water activity including meats, dairy, produce, seafood, and in water. We didn’t discuss many baked goods in this lecture because they have no water activity. A large number of organisms have adapted to these food groups. The food-pathogen combination is important in devising mechanisms to prevent the spread of pathogens via foods, often at the source. The rules of food safety, proper temperature management, preventing cross-contamination, and personal hygiene are important across all of the food groups discussed.