Hello again and welcome to lecture 8, the Viral Food Pathogens. In this lecture we will cover a little background on viruses and how laboratories do testing. Then we will talk about some of the specific viral pathogens. You can see in the pictures here some information on the importance of norovirus. The CDC has this little ad on how to protect yourself from norovirus. Please take a quick look at this as it has some important information. We also have another interesting picture from cruise ships, which is again a warning about norovirus.

The objectives for lecture 8 are as follows. Identify food hazards posed by viruses. Describe disease due to viral pathogens. Discuss prevention and treatment options. Identify foods associated with each type of infection. Describe the emergence of new pathogens and their relation to food habits.

A quick note on this lecture. In this lecture we will first discuss the viruses which are directly transmitted to humans through the consumption of contaminated food and/or water. We will then discuss a few viruses which have emerged from animal reservoirs as a result of local food habits. I want you to take note on this second point. Animal reservoirs include those animals who carry diseases. Humans can get the disease if they eat these animals. However, these diseases are usually not considered foodborne. [Note added: for example, you can get ebola by eating an ebola-infected animal, but the disease is usually not spread in this manner.] Including these diseases in food safety lecture is somewhat controversial.

I wanted to talk to you briefly about viruses in the laboratory. You will recall when we talked about the epidemiology of foodborne diseases, we described that not a lot of data was available on noroviruses. In particular, we mentioned that FoodNet and PulseNet do not collect data on norovirus. The reason for this (in part) is the methods used to grow the viruses. Growing viruses is rather complicated and I would like to talk to you about that here. Unlike bacteria, viruses are difficult (and sometime impossible) to grow in the laboratory. Often cell culture is used for growth. Time-consuming expensive. Therefore, non-culture methods are preferred for viral pathogens.
by infecting the cells. Not all viruses can be grown in cell media. At the moment we cannot grow norovirus in cell culture but some advances in this area have occurred recently with new methods coming from our friends at UF. These are not yet widely used. Therefore, non-culture, which means not growing, methods are preferred for viral pathogens.

If we can’t grow it, techniques such as PFGE cannot be used for viral pathogens. Hence, PulseNet does not track viruses. FoodNet also relies on culture and does not track viruses. Despite their distinction as the leading cause of foodborne illness, much less data is collected on viral foodborne pathogens. You can collect some data and remember we did talk about surveillance systems for norovirus. You can use symptomology, rarely culture methods in cell culture, but often this is done using genomics. There is some data on you can see on the right the geographic distribution of HAV which is hepatitis A virus infection. This data can show you which countries are at high risk for hepatitis A. If you planned to travel to those countries, what would you want to do to protect yourself? Think about that before you move ahead to the hepatitis A slides.

You may be wondering how do we characterize these viruses? In some cases viruses may be characterized by sequencing their DNA. I have a picture of DNA sequencing on the right. You do not need to memorize this figure but it may be helpful to you if you are a student in microbiology. Viruses have the capacity to mutate quickly and are able to evade the immune system. This is especially true of certain viruses. You are probably familiar with this concept as influenza viruses mutate every year. Because of this mutation, the vaccine has to be changed every year. You must get your flu shot every year. I often encourage students in this course to get their flu shots as many students are not aware that people your age can and do die from the flu annually. We often think of influenza killing the elderly or infants but the fact remains that flu can kill anyone [note added: and if you get flu, you can spread it to other and potentially kill someone]. Sometimes food outbreaks are characterized by the strain of the virus causing the outbreak. For example GII.4 Sydney norovirus is often called Sydney norovirus. We will talk more about norovirus in upcoming slides.
While there are a few exceptions, treatment options for viral infections are extremely limited. I lumped them all together on this slide because there are not a lot of options for treated a virus. Please remember that antibiotics only kill bacteria, they do not kill viruses. If you take antibiotics and you have a viral infection, you will kill your normal flora and become more sick not better. So antibiotics should be used with care. In most cases, the recommended treatment for viral infections is rehydration. On the right hand bottom you can see someone with an IV. It is common for someone to need rehydration if they do have a severe viral infection. And vaccination can prevent some viral infections as shown here on the top right. Hepatitis A vaccination is available in the US and so is the rotavirus vaccine.

You should be aware, and especially if you are going into healthcare, that infants and children are highly susceptible to dehydration from infections that cause diarrhea and/or vomiting. They are much more susceptible than others and it is critical that rehydration occurs in a timely manner. Unfortunately, many of the deaths that occur are due to dehydration. Remember that small children put EVERYTHING in their mouths and viruses are often spread on shared toys, pacifiers, etc. In other words, children’s habits put them at risk for potentially deadly infections. Pedialyte is often the rehydration of choice for young children. This can be found over the counter at most grocery stores, CVS, etc. It is important to note however that some children will not drink Pedialyte and studies have shown that chocolate milk is also great for rehydration. Many people shy away from milk with a child when they are sick because they think it will make them throw up. In reality, they will throw up Pedialyte too. The idea is to get some rehydration, chocolate milk has electrolytes and protein much like Pedialyte.

So which of foodborne viruses are most important? The most common viruses found in food and water are norovirus, hepatitis A, hepatitis E, rotavirus, astrovirus, and sapovirus. There are some emerging viruses that could potentially be spread in foods and remember that including these here is controversial. These include SARS coronavirus, nipah virus, and avian influenza. I will remind you that I have included only those viruses most likely to be found in the US in the top half of this slide. There are plenty of other viruses that could be encountered in foods outside of the US. The right hand slide shows a picture of a child who is dehydrated. Remember that small children generally don’t vocalize that they are sick [note added: they don’t tell you, but they may cry]. These are some signs you can use to spot a problem. Take a minute to look at this picture before moving on.
This brings us to the first of our viruses, the norovirus and it is HIGHLY contagious. You will note that HIGHLY is in all caps because if one person in the family gets it, it tends to spread throughout the entire family. So what do you think happens when norovirus is on a cruise ship, at a daycare, or in a college? You can imagine that it spreads very quickly. The symptoms include vomiting, diarrhea, abdominal pain, headache, and low grade fever. We talked in our epidemiology lecture about how this virus is very important but I put the numbers here to remind you. Norovirus is the leading cause of foodborne illness, the 2nd leading cause of hospitalization, and the 4th leading cause of foodborne death.

Let’s take a minute to review those symptoms. Have you ever become ill from eating contaminated foods? Given the symptoms presented here, do you suppose you may have had norovirus? Have you ever thought you had foodborne illness and your symptoms were diarrhea, vomiting, nausea, and stomach pain? 1 in 6 people have probably experienced this in the last year. Less likely, people will also get fever, headache, and body aches. Recall that in most of us norovirus is quite mild but severe dehydration can occur. This is especially true in person most susceptible including the elderly and children. Looking back at our previous slide, it is the elderly, children, and immunocompromised who largely contribute to those severe outcomes associated with norovirus.

Many of the outbreaks can be linked to foods which were contaminated due to improper hand hygiene. One of three top causes of illness! Generally norovirus is spread by the fecal-oral route. Seafood and contaminated water are also implicated. There is no treatment but rehydration may be necessary in severe cases. Please take a look at this interesting figure on the right. When you have a known cause of foodborne illness outbreaks in the United States, look what percentage of these are norovirus. That is just one virus accounting for more outbreaks than all of the bacteria combined. Later on in lectures we will talk about the role of chemicals and other factors like physical hazards (in causing foodborne outbreaks) and we are going to talk about parasites in an upcoming lectures. But when we talk to people about what are their concerns regarding food safety, they generally will tell us things like gmos and pesticides. While those things are important, this figure really illustrates that they are not major players in the causes of foodborne illness.
**Norovirus - Prevention**

- Proper handwashing is key to preventing the spread of norovirus.
- In particular, food employees MUST wash hands after using the restroom as norovirus is spread via the fecal-oral route.
- Norovirus is unusually stable for a virus and can survive for long periods on surfaces:
  - Killed by 1:10 bleach solution.
  - Usually, once a person has had a particular strain of norovirus, they are immune to that strain!

Norovirus is one of the main reasons why lack of water/soap/towels is a critical restaurant violation.

You will not be surprised to learn that the easiest way to prevent norovirus infections is to wash your hands. This is one of the reasons why it is considered a major violation if a restaurant does not have water, soap, or towels. Proper handwashing is key to preventing the spread. Employees must wash hands after using the restroom. Norovirus is unusually stable for a virus and it can survive on long time periods on surfaces. Most of your viruses are quite weak. They do not survive for long outside of a body. Norovirus is an exception. It can be killed by a 1:10 bleach solution. Usually, once a person has had a particular strain of norovirus, they are immune to that strain. Please note the capital letters, norovirus does mutate and new strains come around every few years. In other words, you may be immune for a few years but a new strain will come and get you!

**Norovirus Epidemiology**

Just a quick look at norovirus epidemiology. If you were wondering where does the food contamination occur note that 64% of outbreaks originate in restaurants. Most foodborne outbreaks that do get reported are the result of restaurant outbreaks. We know that there is a reporting error here to consider. Outbreaks occurring outside of the home are reported, infections inside a home are usually not. If 100 people get an infection at the same time, it is more likely to get reported. Regardless, restaurants are a major player. Catering and banquets are a huge factor as well. You will learn as you work in healthcare that healthcare facilities also have a huge problem with norovirus.

**CDC Vessel Sanitation Program**

As I told you, norovirus is a huge problem on cruise ships. You might be interested to note that there is a program that is responsible for sanitation on cruise ships. It is run by the CDC and is known as the CDC Vessel Sanitation Program. The CDC aids the cruise ship industry in preventing the spread of gastrointestinal illnesses. Note that this is not just norovirus but also the other pathogens like ETEC. The program seeks to keep the cruise ships as safe as possible. This is a unique environment in which you have a large number of people in close quarters. Under these conditions it is likely that diseases that can spread, will spread. Any ship which carries over 13 people and stops at a US port of call is subject to announced, requested, or surprise inspection.

Note that the ship does not have to be owned by a company in the US, if it makes a stop in the US, the CDC may board that ship. The vessel sanitation data from 2013 to 2014 is shown on the right. Note that most of the causative agents for outbreaks are norovirus. You will see one ETEC in there as well. Note that all of the cruise ship companies have had outbreaks. The figure doesn't include some cruise lines but you can be sure that they have had outbreaks.
I wanted to add one last epidemiology note on norovirus Sydney. In 2012 epidemiologists discovered that the strain of norovirus usually detected in the United States (known as New Orleans norovirus) has been replaced by a newer strain (GI.4 Sydney norovirus). Sydney norovirus was new to the US in 2012 and most people did not have immunity. The lack of immunity resulted in more symptoms in patients but the Sydney strain is not more virulent. The reason I say this is because in 2013 there were a lot of norovirus cases. News media reported that this norovirus was very virulent and very dangerous. When in fact, it was just a new strain and many people became infected. The number of norovirus cases has remained constant over the last few years (it was in CDC data of late 2013). Noroviruses typically change every 2-4 years so we are due for a new norovirus and early data (late 2014) suggests a new strain is circulating. UPDATE: new strain GI.17 Gaithersburg is widely circulating in the US. Expect increased outbreaks generally occurring Nov- April.

We are going to change gears here and start talking about the hepatitis A virus. This virus (like norovirus) is also spread fecal-oral routes. We are going to see that fecal-oral route of spread is pretty common with the foodborne viruses. Outbreaks have occurred due to harvesting produce and placing it in areas that are contaminated with feces. Symptoms include fever, nausea, vomiting, abdominal pain, fatigue, jaundice due to inflammation in the liver. Jaundice refers to conditions in which you get yellowing of the skin and/or eyes. It is a very good sign that something bad has happened to the liver. Other conditions can cause jaundice so this doesn’t automatically mean hepatitis, but hepatitis should be part of your diagnostics. I wanted to show you this picture on the right which is a news story on a possible exposure to hepatitis A. In this case, the worker was sick and may have exposed THOUSANDS of people. As the quote says “do you want hepatitis A with that burger?” This article later discussing if hepatitis A vaccination should be mandatory for food workers. This is a question I would like you to consider before moving on to the next topic.
Continuing with hepatitis A, the virus can be found in any food which was in contact with humans and is present in some seafood. Vaccination is recommended for children and high risk groups. The treatment is passive immunization. This means treating with antibody made in another person. If a person is vaccinated, they will make antibody. You can then take that antibody from the vaccinated person and give it to the ill person. This is an expensive treatment and you need to have the antibody on hand. Prevention is washing hands and proper washing of produce. I show you a picture of oysters here on the right because oysters can carry hepatitis A but the virus is destroyed by cooking.

Shown here is an outbreak that occurred in 2013 caused by hepatitis A contaminated pomegranate seeds. In 2013 a common shipment of pomegranate seeds from Turkey resulted in an outbreak of hepatitis A. The foods implicated included Townsend Farms and Harris Teeter Organics Antioxidant Blend. You may know that Harris Teeter is a very large grocery chain. Berries are often sold (marketed) due to their antioxidant properties. In this case, the berries were contaminated. 162 people were confirmed ill, 44% were hospitalized.

So if you take a look at the epidemiology, and recall that we have stressed the value of making graphs, you can see that suddenly there is a very large peak in hepatitis A symptoms. Then they start going back down. Recall that this is what we would expect with a common source outbreak.

So let’s take a snapshot of what happened when hepatitis A vaccination was introduced. Hepatitis A infections can be prevented by vaccination. Vaccination is recommended for children and others at high risk. You may recall that I mentioned before that hepatitis A vaccination is not recommended in every state. But in places that have had a high incidence of hepatitis A, it is recommended, including Florida. The figure at right shows the dramatic drop in hepatitis A incidence following the introduction of the vaccine. If you look at the top figure you see the average incidence from 1987-1997. You can see that hepatitis A was very common. After vaccine introduction, look what happens to the incidence (bottom right) in 2003. Do you think vaccination should be mandatory for food workers? This is a hotly debated topic and one you may someday see on the ballots in this state.
This brings us to another hepatitis virus and this is hepatitis E virus. It causes a self-limiting acute disease of the liver. The symptoms are very similar to other hepatitis viruses including fever, fatigue, loss of appetite, and jaundice. Spread is by the fecal-oral route. Note in this figure from the CDC that hepatitis E virus is endemic in the United States. Studies have shown that up to 25% of persons in the US have antibody, suggesting they have been exposed to the virus. So 1 in 4 of us have had exposure to hepatitis E.

Hepatitis E virus is usually mild and doesn’t cause many problems. However, if a person already has other co-morbidities, for example malnutrition, it can cause major problems. You can see here a report from Doctors Without Borders on an outbreak they responded to in a South Sudan refugee camp. Refugee camps are a unique situation in which you have crowding, presence of infectious diseases, etc. Nearly 6,000 people were infected in this hepatitis E outbreak. The most common vehicle for spread of hepatitis E is fecally-contaminated drinking water. Outbreaks in foods have included water [Note added: I said water on purpose here, water is considered food and we will see more of this later], undercooked pork, deer meat, and shellfish.

And here we have a hepatitis E outbreak that occurred on a cruise ship. A number of studies have demonstrated that hepatitis E is present in shellfish. Postharvest processing to kill hepatitis E is under investigation. Much research on killing pathogens in seafood is performed in Florida as it is quite important to the state economically speaking. Including studies of postharvest processing in an attempt to kill various pathogens. Consumption of raw/undercooked shellfish was associated with an outbreak of hepatitis E on a world cruise as shown in the article at right.

This brings us to an extremely important pathogen, rotavirus. In the US, rotavirus does not cause as much disease as it used to, but globally it is one of the leading child killers as shown on right. Symptoms of rotavirus infection include the following; severe watery diarrhea, vomiting, fever, and abdominal pain. Rotavirus causes more than 500,000 deaths in children under the age of 5 annually.
Rotavirus is the leading cause of gastroenteritis in the world. Dehydration from rotavirus infection is one of the leading causes of death. Rotavirus WAS the leading cause of diarrheal disease in the United States before the introduction of the vaccine. The impact of the virus on healthcare annually WAS (before the vaccine) as follows; 400,000 doctor visits, 200,000 ER visits, 55-70,000 hospitalizations, and 20-60 deaths. Again, rotavirus used to be a major problem in the United States. On the right hand side here you can see philanthropist Bill Gates holding up a rotavirus vaccine. The Gates Foundation has donated a huge number of vaccines to various countries. This story is a press release in which donors pledged $4.3 billion for vaccines for the poor.

It is very important to remember that the rotavirus vaccine is available. There are two vaccines available and as seen on the right, the vaccine is administered orally. Vaccination is currently recommended for all children and is required by many daycares where spread of the virus is particularly dangerous.

Rotavirus is spread by the fecal-oral route. In daycares this probably occurs due to shared toys. However, it can also spread in foods. This includes contaminated water and any food can potentially become contaminated with rotavirus. On the right we see oysters again. We already discussed that these can be contaminated with hepatitis A and Vibrio, but they can be contaminated with rotavirus as well. Rotavirus (as well as those other two pathogens) is destroyed by cooking.

Shown here is a foodborne outbreak of rotavirus that occurred among college students. The incidence of foodborne outbreaks of rotavirus has dropped with the introduction of the vaccine. However, when they do occur, they usually involve large scale food production like this outbreak that occurred in a college dining hall in 2000. Remember that rotavirus vaccine is fairly new so many adults have never had it. If they are susceptible, you sometimes see outbreaks amongst adults. Luckily adults do not have the severe hydration seen in children [note added: many adults are immune from having rotavirus as children]. In this outbreak, 108 students became ill, most likely from eating contaminated deli sandwiches. Given what you learned about rotavirus, what do you think caused this outbreak? Think about that before moving on.
Now we will talk about the astroviruses which you have probably never heard of. If you look at the picture on right, you can see why they are known as astroviruses as they look very much like stars. Symptoms of disease include diarrhea, nausea, vomiting, and malaise. If you don’t know what malaise means, please look it up before you move on. The virus infects poultry which may be the source of human infections but poor hygiene has also been described. It may be spread in food and water and there is no known treatment. The reason many of us have never heard of this virus is the symptoms. It is a mild disease it is unlikely to be reported.

It is estimated that the virus we never heard of, causes 3 million illnesses a year in the United States. Most are in children under the age of 2. Keep in mind that young children get many viruses and it is difficult to know if they are foodborne or some other sort of illness. Diarrhea is the primary symptom usually lasting 2-3 days but can be up to 2 weeks. Incubation period is 3 to 4 days. Therefore people may not be aware they are infected and spread the disease.

It is difficult to find outbreaks of astrovirus but a group that studies this virus in Japan sometimes has publications. Outbreaks of astrovirus in the United States are usually linked to daycares and most people are seropositive for virus exposure by age 9. What this means is that if we take blood from a person and check it for antibodies against astrovirus, almost all people are positive by age 9. At right is a common source foodborne outbreak of astrovirus that occurred in Japan and infected more than 4700 people! Needless to say, if your outbreak is that big, it is going to get reported.

This brings us to a similar virus no one ever heard of, that is the sapovirus. The symptoms include diarrhea, vomiting, fever, and headache. Again these are very non-specific symptoms. Very little is known about sapovirus foodborne infections but they seem to originate with infected food handlers. They are included in this lecture because they are detected in the US food supply. However, there is very little epidemiology information and we know little about this virus. Prevention probably requires good hand hygiene. Again, note how many viruses are fecal-oral route of spread. Once again, the only reports come from Japan. They were looking at oyster-related outbreaks and found a sapovirus was present. However, the oysters also contained norovirus.
This brings us to the topic of emerging viruses. These viruses have emerged at least in part due to local food practices. These include SARS coronavirus, nipah virus, and avian influenza. Technically you can include ebola in this list as the current (2014-15) outbreak was started by someone eating bush meat. Including these in a foodborne virus lecture is somewhat controversial. Other instructors may not agree with including these but I think they are interesting and something you might want to know. These are currently not a threat to the US food supply but some have suggested that they may be in the future. I would footnote this in that we currently (Sum/Fall 2015) are having an avian influenza outbreak in our food supply. In case you were unaware, several state primarily in the Midwest have had to destroy birds (chickens, turkeys, ducks) that were infected with avian influenza.

As mentioned, ebola could technically be considered foodborne and Newsweek ran a story on this in late 2014. A back door for ebola, smuggled bush meat could spark a US epidemic. We know this is a problem, bush meat is smuggled into the US frequently. Many more viruses could potentially be spread via food but this route is uncommon in the US. In the interest of time, just a few viruses are covered in this lecture.

SARS coronavirus is traditionally spread by the respiratory route and results in severe disease with pneumonia. Two routes of foodborne spread have been hypothesized:

Consumption of animal carriers of SARS and food handler transmission of the virus. The FDA considers transmission of SARS via food to be highly unlikely but I wanted you to know that some people are looking into this.

Are you a fan of one of those shows on TV where people travel to other countries or locations in the US and eat bizarre foods? When I watch those shows, I always consider the viruses, bacteria, parasite, or prions that could be present in those weird foods. This is one of the viruses I consider. The nipah virus causes influenza-like illness that can lead to encephalitis, convulsions, and death. The proposed route of transmission is ingestion of bat meat, ingestion of bat blood, and contaminated fruit juice. Bat soup is considered a delicacy in some countries and eating it could expose you to nipah virus.
This brings us to avian influenza which is commonly known as bird flu. Please note all the very tightly packed birds on the right. If one bird is infected, they can quickly spread the virus to other birds. Often called “bird flu”, avian influenza has killed many birds (including ducks, chickens, etc) and has caused often fatal illness in humans. The major foodborne concern is consumption of contaminated birds. Most cases appear to be related to live bird markets and spread was likely airborne rather than foodborne. People shopping or working in the markets get exposed to contaminated birds and the virus jumps species into the human. Avian influenza can be deadly in humans and we always worry that pandemics may be started by avian influenza. Again recall the avian influenza outbreak occurring in the United States resulting in the destruction of many birds.

Influenza viruses are complicated but the food supply plays an important role in their evolution. The virus mutates each year in part due to rearrangement with bird and swine flu viruses. You probably have heard of bird flu and I know you have heard of swine flu as we had an outbreak of this a few years ago. The picture shows an influenza strain from a human and an influenza strain from a bird being passed to a pig. In the pig, these two viruses reassort and become a new strain. This occurs every year which is why we have to get a flu vaccine every year. Once a new strain comes, it can spread to humans. Sometimes the strain is the run of the mill average flu which still causes upwards of 35,000 deaths annually in the US alone. But sometimes the strains are particularly dangerous and cause huge pandemics.

I wanted you to also consider the historical perspective and take a quick look at polio. Polio infects the brain and spinal cord and causes non-reversible damage. You may have seen pictures of polio paralysis. Polio outbreaks have occurred due to contaminated water and raw milk, however, most cases were spread person-to-person. Historically polio was considered a foodborne disease. Think about the importance of polio eradication. Hopefully you are aware of the worldwide campaign to eradicate polio. Unfortunately, the small number of countries that still have polio, are those in which it is hardest to eradicate the disease. As seen in the figure, some groups are against the polio vaccination and have gone so far as to kill vaccine workers. This and other factors has slowed efforts to eradication polio.
This brings us to our lecture conclusions. Due to a combination of lack of detection methods, lack of surveillance, and mild disease symptoms, many of the viral foodborne illnesses are never reported. Norovirus is by far the most common foodborne pathogen.