clears the gastrointestinal tract). The best treatment is supportive, which usually means fluids; intravenous fluids are given if severe vomiting prevents ingestion.

Bacillus cereus

Bacillus species are aerobic, Gram-positive rods that are ubiquitous in the environment. A stray piece of soil might easily contaminate a food product. These bacteria are spore formers and therefore can survive cooking.

The illness is usually either nausea and vomiting, or diarrhea. The microbe has two enterotoxins: one is heat stable and induces vomiting, while the other is heat labile and causes diarrhea. In either case, the illness rarely lasts more than 24 hours because the body expels the toxin quickly.

Hepatitis A Virus (HAV)

HAV is well known for its distribution in the water supply, and it can be transferred to food when contaminated water is used to wash the food. HAV is also passed through shellfish, which, as filter feeders, can accumulate the virus in their tissues. Cooking kills the virus, but consumption of raw shellfish puts the consumer at risk. One of the biggest outbreak risks is handling of food by restaurant workers who have the illness, especially an infected worker who has poor personal hygiene and contaminates the food just before it is consumed.

The bad news is that this virus causes an illness that can last from 2 weeks to 3 months. Symptoms are typical for hepatitis: fever, malaise, abdominal discomfort, and nausea. The good news is that the illness is usually self-limiting, and most people recover without complication. Fatality is rare, probably around 0.1%. Exposure to HAV by the general population is surprisingly high, with some reports that 33% of the population is seropositive for HAV. A vaccine for HAV is now in use and appears to be very effective.

Ascaris lumbricoides

Ascaris lumbricoides is the largest nematode (roundworm) capable of parasitizing the human intestine. Adults can grow to 30 cm in length. These infections are common in tropical and subtropical countries, but they are rare in the United States. They can be acquired by consuming inadequately cooked pork products or by bringing hands into contact with the mouth after butchering an infected hog. However, the more common pathway of infection is through soil that has been contaminated with feces. If a person brings contaminated hands to the mouth, the *Ascaris* ova may be swallowed. These ova are quite environmentally resistant. The best defense against these parasites is the use of modern sanitary practices for fecal material.

Trichuris trichiura

Trichuris trichiura is another intestinal parasite, also known as the whipworm. Much shorter than the roundworm, with a maximum length of 50 millimeters, it has much in common with the roundworm, such as environmentally resistant ova, passage through contaminated soil, and defense through sanitary handling of human waste. While the roundworm causes a gradual wasting disease, the whipworm causes colitis.

SELECTED CASE STUDIES

Cyclospora in the Wedding Cake

Two reports of a wedding made more memorable by the presence of the parasite *Cyclospora* in the food have been published (Ho et al., 2002; Murrow et al., 2002). Typically, wedding guests come from many places, congregate in one place for a time, and then return home. The incubation period for *Cyclospora* is about 7–10 days, so the symptoms begin long after the wedding. One case (Murrow et al., 2002) occurred in Georgia at a brunch for the bridesmaids. Among the foods that were served were fresh strawberries, blackberries, and raspberries. While investigating the outbreak, the berries came under scrutiny because *Cyclospora* has previously been associated with berries.

Of course, the food had long been discarded prior to the investigation, and so no direct analyses were possible. Epidemiological analyses of samples from the people at the brunch were generally unhelpful because most guests had eaten a wide variety of foods and most became ill. Tracing the origin of the berries only determined that the berries were from farms in either Guatemala or Chile.

A similar outbreak occurred in Philadelphia (Ho et al., 2002). Guests at a wedding became ill with

long-lasting diarrhea, and the stool samples were positive for *Cyclospora*. Investigators again suspected berries as the vehicle for transmission; the wedding cake had been made with a butter cream filling and fresh raspberries.

In this case, the investigators were fortunate because the bride and groom had saved a portion of the cake in their freezer, with the intention of consuming it on their first anniversary. Of course, cake rarely lasts this long and is more safely consumed after returning from the honeymoon, but the important fact here is that the evidence was still available. The investigators acquired this cake and extracted DNA from the raspberry filling. PCR analysis demonstrated the presence of *Cyclospora*.

Tracing the origin of the berries in this case was not entirely successful until the investigators in Philadelphia conferred with those in Georgia. The only common source was a farm in Guatemala. However, an inspection of this farm by the FDA revealed no obvious source of contamination. *Cyclospora* can be difficult to isolate, and this type of contamination can be transient.

VIRUSES IN IMPORTED CLAMS

Shellfish are filter feeders that pass seawater over a specialized structure that captures particles of food. This tends to bioconcentrate certain undesirable substances, among them the viruses. In areas where untreated wastewater has come into contact with shellfish beds, the shellfish are no longer safe to eat. Thorough cooking will destroy the pathogens, but far too many people prefer to eat their shellfish raw or undercooked.

In 2000, an outbreak of both HAV and Norovirus occurred in New York after some clams were consumed raw. These clams came from China, where they were supposed to have been cooked and then canned, but apparently the cooking step had been omitted. China has an endemic HAV problem, and it would not be unusual for their clams to be contaminated.

As has been noted, when pathogen outbreaks occur, several things have gone awry at once. In this case, the clams should have been cooked but were not. The clams were served at a restaurant, and the chef there should have recognized that these clams were uncooked; the diners should also have noted that their food was raw, but apparently no one complained. These clams were also contaminated with Norovirus, and a coliform bacteria count was extraordinarily high: 93,000 per 100 grams of clam meat. Clearly, these clams came from a heavily polluted body of water. RT-PCR demonstrated the additional presence of HAV.

SICK AND IN JAIL

An outbreak of illness in a jail can be easily traced. After all, exactly where all the sick people have been and exactly what they have been eating are known. An outbreak of gastroenteritis in 2008 in a jail started with typical gastrointestinal complaints, starting just 8 hours after the previous evening's meal. The problem was quickly traced to a casserole that had been made with beef and turkey (Hsieh et al., 2009). The pathogen in this case was *Clostridium perfringens*; the enterotoxin from this microbe was found in stool samples. The casserole itself was highly contaminated, with 43,000 CFU per gram appearing on agar plates.

The more important question for this case study was how the microbe was transferred to the jail in the first place. Although the ultimate source of contamination remains unknown, the problem was exacerbated by handling the casserole items as leftovers. At improper storage temperatures, the bacteria may have multiplied significantly. Because *Clostridium* is a spore-forming microbe, initial cooking may not have been sufficient to eliminate the spores, and saving the leftovers allowed the spores to germinate.

O157 IN A DEER

Hunting is a popular pastime, and hunters often consume the game they kill. This meat has not been inspected by the USDA, of course, but this is not usually an issue. After all, humans have been hunting and eating their prey since prehistoric times. In one instance, however, the presence of a pathogen nearly proved tragic for the hunter's family.

In this case, a hunter in Connecticut shot a deer using a rifle (Rabatsky-Ehr et al., 2002). It is best to hit the deer in the vital organs (especially the heart) or in the head so that the deer dies quickly. In this case, the deer was shot in the gut, rupturing the

intestine, and the deer ran off. The hunter tracked the wounded animal for 2 hours, finally finding it dead. He field-dressed the carcass (i.e., split open the belly and removed the organs) but did not wash the interior in the field (washing is preferred). Unfortunately, the intestinal flora had contaminated the meat, and this contamination included *E. coli* O157, a particularly deadly pathogen.

Once at home, the hunter split the meat into smaller portions and froze it. Venison that had been ground into hamburger patties was soon used in a family cookout. The hunter's young son had one of these hamburgers, grilled rare. The *E. coli* in the interior of the patty was not killed by this level of cooking, and the child soon developed bloody diarrhea. The O157 serotype of *E. coli* is known to cause HUS in young children, an illness that can easily be fatal. Fortunately, the child recovered completely. This case demonstrates that diseases associated with domesticated animals can also be found in wild animals and that each hunter takes on a great responsibility in killing, cleaning, and cooking a harvested animal appropriately.

QUESTIONS FOR DISCUSSION

1. Why do you think some pathogens are identified with a particular food, the way *Salmonella* is associated with chicken?
2. Why is *E. coli* O157 associated with ground beef instead of regular cuts of beef?
3. How might food become contaminated in the home? What are some basic safety measures that everyone should follow?
4. Why is contamination at the production stage so dangerous?
5. In the case study with the imported clams, HAV was found using RT-PCR. Why was this method used?

References

Beauchat, L.R., and J. Ryu. 1997. Produce handling and processing practices. Emerging Inf. Dis. 3: 459–465.

Collins, J.E. 1997. Impact of changing consumer lifestyles on the emergence/reemergence of foodborne pathogens. Emerging Infect. Dis. 3: 471–479.

Downes, F.P., and K. Ito (eds.). Compendium of methods for the microbiological examination of foods, 4th ed. Washington, DC: American Public Health Association.

Ginsberg, M.M., L. Granzow, R.F. Teclaw, L.K. Gaul, S. Bagdure et al. 2007. Botulism associated with commercially canned chili sauce—Texas and Indiana, July 2007. Morbid. Mortal. Weekly Report 56: 767–769.

Ho, A.Y., A.S. Lopez, M.G. Eberhart, R. Levenson, B.S. Finkel, A.J. da Silva, et al. 2002. Outbreak of cyclosporiasis associated with imported raspberries, Philadelphia, Pennsylvania, 2000. Emerg. Infect. Dis. 8. Available from: URL: http://www.cdc.gov/ncidod/EID/vol8no8/02-0012.htm

Hsieh, H., J. Archer, R. Heffernan, J.P. Davis, and C.F. Neilsen. 2009. *Clostridium perfringens* infection among inmates at a county jail—Wisconsin, August 2008. Morbid. Mortal. Weekly Rep. 58: 138–141.

Jelen, H.H., J. Krawczyk, T.O. Larsen, A. Jarosz, and B. Golebniak. 2005. Main compounds responsible for off-odour of strawberries infected by *Phytophthora cactorum*. Lett. Appl. Microbiol. 40: 255–259.

Kingsley, D.H., G.K. Meade, and G.P. Richards. 2002. Detection of both Hepatitis A Virus and Norwalk-like Virus in imported clams associated with food-borne illness. Appl. Environ. Microbial. 68: 3914–3918.

Mead, P.S., L. Slutsker, V. Dietz, L.F. McCaig, J.S. Bresee, C. Shapiro, P.M. Griffin, and R.V. Tauxe. 1999. Food-related illness and death in the United States. Emerging Inf. Dis. 5: 607–625.

Murrow, L.B., P. Blake, and L. Kreckman. 2002. Outbreak of cyclosporiasis in Fulton County, Georgia. Georgia Epidem. Rep. 18: 1–2.

Rabatsky-Ehr, T., D. Dingman, R. Marcus, R. Howard, A. Kinney, and P. Mshar. 2002. Deer meat as the source for a sporadic case of *Escherichia coli* O157:H7 infection, Connecticut. Emerg. Inf. Dis. 8: 525–527.

Safranek, T., D. Leschinsky, A. Keyser, A. O'Keefe, T. Timmons, et al. 2009. Outbreak of *Salmonella* serotype Saintpaul infections associated with eating alfalfa sprouts—United States. Morbid. Mortal. Weekly Report 58: 500–503.