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Descriptions of Recent Incursions of Exotic Animal Diseases

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Descriptions of Recent Incursions of Exotic Animal Diseases

Abstract
Historically, livestock and poultry diseases have been introduced into new areas by the uncontrolled importation of animals and trade (including smuggling), through the movements of people and wildlife, and by vectors. Some diseases spread widely in the past. Rinderpest or “cattle plague,” for example, devastated farms as it was transported across continents by invading armies and their cattle, as well as by trade, the development of railways, and other factors. Other pathogens remained fairly localized for various reasons. Most of the parasites that cause African animal trypanosomiasis, for instance, must be transmitted by tsetse flies, and these insects have not become established outside the “tsetse fly belt” of Africa. As livestock production became more sophisticated, countries with sufficient resources set up border controls and surveillance to prevent the introduction of new diseases. Many nations have also eradicated serious diseases such as classical swine fever, highly virulent Newcastle disease, foot and mouth disease, glanders, and bovine babesiosis. However, some countries do not have the resources or the veterinary infrastructure for such efforts. In these areas, diseases that are exotic to the rest of the world remain a persistent problem, causing illness and deaths among animals, loss of productivity, and in some cases, human disease. Through international travel, livestock trade, and other routes, such agents can be accidentally reintroduced to nations that have become disease free.

Disciplines
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Comments
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Historically, livestock and poultry diseases have been introduced into new areas by the uncontrolled importation of animals and trade (including smuggling), through the movements of people and wildlife, and by vectors. Some diseases spread widely in the past. Rinderpest or “cattle plague,” for example, devastated farms as it was transported across continents by invading armies and their cattle, as well as by trade, the development of railways, and other factors. Other pathogens remained fairly localized for various reasons. Most of the parasites that cause African animal trypanosomiasis, for instance, must be transmitted by tsetse flies, and these insects have not become established outside the “tsetse fly belt” of Africa. As livestock production became more sophisticated, countries with sufficient resources set up border controls and surveillance to prevent the introduction of new diseases. Many nations have also eradicated serious diseases such as classical swine fever, highly virulent Newcastle disease, foot and mouth disease, glanders, and bovine babesiosis. However, some countries do not have the resources or the veterinary infrastructure for such efforts. In these areas, diseases that are exotic to the rest of the world remain a persistent problem, causing illness and deaths among animals, loss of productivity, and in some cases, human disease. Through international travel, livestock trade, and other routes, such agents can be accidentally reintroduced to nations that have become disease free.
All countries, including the United States and Canada, periodically experience outbreaks of exotic or emerging diseases. Some incidents are limited to one or a few cases, and are quickly controlled. Others involve massive outbreaks that take months or even years to resolve. In the worst case scenario, an exotic disease can become established or re-established in a country. The effects of some epizootics on a nation’s animal populations and economy may be devastating. This chapter describes some outbreaks of foreign animal diseases that have occurred in various countries, their impact, the control measures taken, and the success or failure of the eradication efforts. These descriptions illustrate the potential scope of disease outbreaks, the variety of measures taken for their control, and the diversity of sources from which an agent may be introduced.

### Foot and Mouth Disease

**in the United Kingdom**

One of the most devastating epidemics in the last 10 years was a foot and mouth disease (FMD) outbreak that occurred in the United Kingdom in 2001. Although it is not a life-threatening disease in most adult animals, FMD can cause suffering from oral and foot vesicles and erosions. It also results in major economic and trading difficulties for infected countries. Because FMD virus can spread on fomites as well as in apparently infected animals, it can sweep through a country rapidly in spite of control measures. The 2001 FMD outbreak illustrates how a FAD spread widely in a country with a veterinary infrastructure similar to that of the U.S. and Canada, as well as how the international community reacted to the outbreak.

#### How it Began

On February 19, 2001, a veterinary inspector from the State Veterinary Service of the Ministry of Agriculture, Fisheries and Food (MAFF) was conducting routine inspections at an abattoir in Little Warley, Essex, and found vesicular lesions on 27 sows and one boar. Vesicles (skin blisters) are a characteristic sign of FMD, as well as of some other diseases such as vesicular stomatitis, swine vesicular disease, and vesicular exanthema of swine. In this case, laboratory tests confirmed the disease to be FMD. On February 20, MAFF announced an immediate “stop movement” of all susceptible livestock in the U.K., including the movement of animals to abattoirs, sale markets, and pastures.

Efforts to trace the disease back to the infected farm and suppress the outbreak began immediately. The infected pigs had arrived at the abattoir on February 16 from farms in Buckinghamshire and the Isle of Wight. They were traced back to a farm at Heddon-on-the-Wall, Northumberland. By the time the outbreak was discovered, FMD had spread to a cluster of holdings in the County of Essex through the movement of pigs, people, and fomites, and by localized airborne spread. Infected sheep from the farm at Heddon-on-the-Wall had also been moved to the Longtown market near Carlisle. Sheep often have minimal clinical signs when they are infected with FMD virus, and can spread the virus unnoticed. In the U.K., infected sheep transmitted the virus to other animals when they moved through markets, and these animals eventually spread the disease to thousands of additional sheep and cattle holdings in other parts of Great Britain.

#### What is Foot and Mouth Disease?

FMD is a highly contagious viral disease that can affect all cloven-hoofed animals including cattle, swine, deer, goats, and sheep. It can also infect some other species such as hedgehogs, armadillos, kangaroos, capybaras, rats, and elephants. The FMD virus can be found in all secretions and excretions from acutely infected animals, which may begin shedding this virus before the onset of clinical signs. Many animals acquire the virus during close contact with infected animals, but it is also spread in aerosols and on fomites such as manure-contaminated tires, boots, and clothing. The disease is characterized by fever and vesicles found mainly in the mouth, nares, muzzle, feet, or teats. The vesicles break quickly to become painful erosions. Affected animals can be lame or refuse to eat, can salivate profusely, and may lose weight. Sheep and goats show very mild, if any, signs. Adult animals generally recover within a few weeks but secondary infections may lead to a longer recovery time. High mortality rates are sometimes seen in young animals.

#### How it Entered the U.K.

Seven immunologically distinct serotypes of the FMD virus are known to exist. The virus in the U.K. was identified as serotype “O” Pan-Asian. The strain involved in this outbreak was first recognized in India in 1990 and has since spread to a number of countries around the world. It is identical to the virus found in recent outbreaks in Africa, including one in South Africa where the virus was traced to pig swill—waste food from human tables—sold illegally from an Asian boat.

The source of the 2001 epizootic in the U.K. is thought to have been pig swill. The feeding of pig swill is a practice that has been going on for generations. Today, pig swill comes from restaurants, schools, and anywhere humans eat and waste food on a large scale. In recent years, the feeding of pig swill has declined because it is thought to be inefficient and outmoded. In 1998, a government panel of agricultural experts advised that it be banned; however, the advice was rejected by ministers who did not want to impose new costs on hard-pressed farmers. Only about 1 percent of producers in the U.K. were using pig swill at the time of the outbreak. Farmers are supposed to treat the swill by heating it to 100°C.
The Spread

By March 2, FMD had spread to 40 locations, with many foci linked to infected markets. A total of 25,000 animals had been destroyed and incinerated on-farm. Cases were also confirmed in County Armagh in Northern Ireland. On March 9, at least 127 locations were known to be affected. The MAFF sent information to farmers and veterinarians on how to avoid spreading FMD and how to report suspected outbreaks. It also publicized the details of the clinical signs in sheep, as the illness in this species can be subtle.

The U.K. soon developed a shortage of qualified “clean” veterinarians to investigate suspect farms. People may harbor the FMD virus in their nasal passages for a period of time, and investigators could not move rapidly from farm to farm due to the risk of transmitting the virus. At the start of the outbreak, MAFF veterinarians who had been on infected premises were required not to have contact with uninfected, susceptible animals for five days. Private practice veterinarians and government veterinarians from other nations were enlisted to help. The U.S. sent the first group of 20 veterinarians the week of March 5, and another 125 individuals as the outbreak progressed. Canada contributed 68 veterinary and para-professional personnel to support the U.K. response during the outbreak.

One month after the start of the outbreak, MAFF decreased the time required to become “clean” from five to three days to enable more veterinarians to investigate potentially infected premises. Out of necessity, the time required to become “clean” eventually decreased to 24 hours to visit a highly suspect farm. Veterinary teams for infected premises, surveillance, and trace back from sale markets were established to better utilize personnel.

The control measures established to stop FMD transmission resulted in a number of difficulties. Because animal movements were restricted, cows could not cross roads for milking or be moved to fresh grazing pastures. Pregnant ewes were prevented from moving to shelter for lambing. This resulted in intense public criticism and an outcry to allow some animal movement for welfare reasons. To reduce the transmission of the virus by humans, public footpaths were closed and the public was strongly discouraged from going anywhere near livestock farms. Carcass disposal also became a problem. The MAFF initially planned to render the carcasses of destroyed livestock rather than incinerate them on-farm. However, the large number of carcasses resulted in a lack of sealed trucks for hauling carcasses to rendering plants, delays in burial, and shortages of material for incineration. About one month after the start of the outbreak, the military became involved to coordinate the process.

In spite of control measures, the epidemic continued to spread and cases began to appear outside the U.K. On March 13, FMD was confirmed at La Baroche-Gondouin in northwestern France. The infected farm was already in a movement control zone, put in place around a sheep farm that had imported animals from the U.K. two weeks earlier. The sheep had been prevented from moving to shelter for lambing. This overturned the 15-year E.U. policy of prohibiting vaccination for FMD.

Virus is believed to have reached the Netherlands via a shipment of veal calves from the Republic of Ireland. The calves were rested in an animal holding near La Barouche Gondouin for 12 hours, where they were apparently infected by sheep coming from the U.K. To fight the spread of FMD, European Union veterinarians in Brussels agreed to limited emergency vaccination in the Netherlands around infected farms and animals awaiting slaughter. This overturned the 15-year E.U. policy of prohibiting vaccination for FMD.

In the U.K., the MAFF decided on March 15 to begin “ring depopulation.” In ring depopulation, all susceptible livestock within a specified radius of infected premises are killed, whether they are diagnosed with the disease or not. In this case, a ring was defined as three kilometers. A total of 251 farms were infected at the time, and about a million healthy animals were scheduled to be culled. On March 20, FMD was found in the Republic of Ireland, near the infected farm.
that has been found earlier in Northern Ireland and within its surveillance zone. On March 30, there were 60 new foci of infection in the U.K., the highest daily total of the epidemic so far. By that time, 839 infected premises had been identified altogether. The farming and tourism industries had been devastated, and even politics was affected. On April 2, Prime Minister Tony Blair announced that the general election scheduled for May 3 would be delayed until June 7 because of the FMD crisis. Eventually, the severe control measures succeeded in controlling the epidemic. By June 12 the spread had slowed; only four new locations were found that day, bringing the total number of new foci to 1,736. By this time, over three million animals had been slaughtered, and 8,334 premises had been affected.

The last case of FMD was reported on September 30, 2001, bringing the total number of confirmed cases in the U.K. to 2,030. Many more animals had been killed to prevent the spread of the disease. According to official U.K. government figures, more than four million animals were culled. Unofficial figures from the Meat and Livestock Commission put the number of animals slaughtered at more than 10 million. Those figures include animals slaughtered for welfare reasons such as dwindling feed and space, animals killed because there was no market for them, and animals killed with their mothers and only counted as one animal. On January 22, 2002, the OIE declared that the U.K. had regained its previously recognized FMD-free status without vaccination, clearing the way for international export trade in animals and animal products. With the exception of a limited outbreak in 2007, caused by a laboratory accident, the U.K. has remained FMD-free since that time.

The International Reaction

The U.K. was required to notify the World Organization for Animal Health (OIE) of the outbreak within 24 hours of the first case. On the following day, February 21, the European Commission banned the export of live animals, germplasm, fresh meat, meat products, milk and milk products, hides, and skins of FMD susceptible species from all of the U.K. The last case of FMD was reported on September 30, 2001, bringing the total number of confirmed cases in the U.K. to 2,030. Many more animals had been killed to prevent the spread of the disease. According to official U.K. government figures, more than four million animals were culled. Unofficial figures from the Meat and Livestock Commission put the number of animals slaughtered at more than 10 million. Those figures include animals slaughtered for welfare reasons such as dwindling feed and space, animals killed because there was no market for them, and animals killed with their mothers and only counted as one animal. On January 22, 2002, the OIE declared that the U.K. had regained its previously recognized FMD-free status without vaccination, clearing the way for international export trade in animals and animal products. With the exception of a limited outbreak in 2007, caused by a laboratory accident, the U.K. has remained FMD-free since that time.

The U.S. and Canadian Response to FMD in the U.K.

Immediately after FMD was confirmed in the U.K., the USDA stepped up its efforts to guard against this disease. The importation of swine, ruminants, any fresh swine or ruminant meat (chilled or frozen), and other products of swine and ruminant origin from the E.U. was temporarily prohibited. Travelers were stopped from carrying into the U.S. any agricultural products, particularly animal products from the E.U. that could spread the disease. Security was tightened at ports of entry and airports to ensure that passengers, luggage, and cargo were checked as appropriate. The USDA also took steps to monitor the situation, in coordination with state agriculture officials, and developed a public education campaign that included additional signs in airports, public service announcements, an information hotline, web site, and other tools to inform the public about the issue. In addition, the U.S. sent a team of experts to the E.U. to monitor, evaluate, and assist in containment efforts. As the FMD outbreak grew in the U.K., the USDA established an emergency operations center to coordinate communication, answer technical questions, and provide consumer and traveler information about FMD and other related issues. The USDA also reviewed its programs and staffing to ensure that appropriate resources were available to prevent the entry of FMD into the United States, both short and long-term, and to confirm that appropriate federal and state emergency operations plans were in place to act quickly if an outbreak occurred.

Canada’s response to the confirmation of FMD in the U.K. was similar to that of the U.S. Canadian imports of susceptible animals from the U.K. were prohibited and the CFIA worked closely with the Canada Border Services Agency to increase vigilance at all Canadian borders. Both agencies contributed to heightening travelers’ awareness, particularly among those coming from the U.K., of their responsibilities to declare all food, animals, and animal products, which could carry FMD virus. The Department of Foreign Affairs and International Trade also issued a travel advisory reminding travelers from the U.K. to notify customs officials if they had visited a farm while abroad and if they planned to visit one in Canada in the near future. In addition the CFIA developed and published a detailed FMD response plan in 2006 known as the Foot-and-Mouth Disease Hazard Specific Plan. The diagnostic and management principles contained in this plan conform to the World Organization of Animal Health (OIE) International Animal Health Code. This plan draws on concepts and information from similar plans that exist in the U.K. and Australia. This document is part of an overall management plan used by the CFIA to respond to an incursion of an exotic animal disease into Canada and is regularly reviewed by all stakeholders.

Canada, the U.S., and Mexico have also established the North American FMD vaccine bank (NAFMDVB) to provide emergency FMD vaccines if needed during an outbreak.

Foot and Mouth Disease in Uruguay

Foot and mouth disease (FMD) also occurred in Uruguay at the same time as the epidemic in the U.K. Although these two countries are approximately the same size, their livestock composition is quite different. Uruguay had nearly 10.6 million cattle, compared to 1.6 million in the U.K., but fewer sheep and pigs. Faced with a similar number of FMD-infected farms, the two countries’ approach to this disease...
was drastically different. The U.K. used a stamping-out policy with no vaccination, while Uruguay culled few animals and concentrated its efforts on a massive vaccination campaign. In the U.K., more than six million animals were killed. In Uruguay, a little over 6,900 animals were killed, and over 24 million doses of vaccine were used. The two outbreaks lasted about the same time, but the overall cost to control the epidemic was far less in Uruguay. The FMD outbreak in the U.K. is estimated to have cost approximately $5 billion to agriculture and the food chain and an additional $5 billion from loss of tourism. The cost of the outbreak in Uruguay was $243.6 million, with much of this due to the loss of export markets. This outbreak illustrates how in some situations vaccination can be effective in controlling and eradicating an FMD.

**Foot and Mouth Disease Control in South America**

In 1987, the countries of South America established the Hemispheric Plan for the Eradication of Foot and Mouth Disease (PHEFA). Under this plan, comprehensive vaccination with modern, improved vaccines was the backbone of eradication efforts, but depopulation was also conducted if the disease threatens a disease-free region. The adoption of PHEFA led to a decrease in the number of FMD outbreaks reported in South America from 955 in 1990 to 130 in 1999.

Livestock production is the major agricultural activity in Uruguay, and a significant contributor to its economy. Livestock represent more than 65% of all exports. However, the presence of FMD or vaccination for this disease places significant restrictions on trade. In the 1990s, the European Union decided to stop general vaccination for FMD, prompting South American meat-exporting countries to discontinue vaccination if possible, to acquire a more favorable trade status. In 1994, Uruguay was recognized by the OIE as “FMD free where vaccination is practiced.” In the same year, it discontinued vaccination, in the hope of obtaining the status of “FMD free without vaccination,” a goal it achieved in 1996. Also hoping to achieve the coveted “FMD free without vaccination” status, Argentina and Paraguay stopped vaccinating in 1999, as did portions of Brazil in 2000. However, Ecuador, Peru, Bolivia, Colombia, Venezuela, and parts of Brazil continued to report FMD outbreaks through the 1990s and continued to vaccinate.

As a result of discontinuing vaccination, Uruguay, Argentina, Paraguay, and parts of Brazil were at great risk for FMD. Their increased susceptibility was due in part to the progressive loss of immunity in large cattle populations over a short period of time, the continual danger of the spread of FMD from the remaining endemic areas, and the movement of large numbers of now-susceptible young livestock to fattening areas. Within a few years, FMD invaded the southern region of South America.

**The Re-Introduction of FMD Into the Region**

In 2000, Argentina, Brazil, and Uruguay reported outbreaks of FMD with both the type O and the type A viruses. FMD types A and type O were reported in Argentina, where 124 premises were eventually involved. Twenty-two facilities were affected in Brazil, with 12 confirmed as type O, and three farms were infected in an adjacent part of Uruguay. All three countries conducted depopulation (‘stamping-out’) campaigns and, by the end of 2000, believed the viruses to be eradicated. However, in February 2001, Argentina reported the first cases of a massive FMD outbreak that would eventually affect all three countries. This virus, a type A, spread rapidly and explosively through the central and eastern part of Argentina, although a special control region prevented the epidemic from extending into the south. Despite extensive depopulation efforts, the disease had affected over 2,000 premises by the end of 2001 and was still out of control in Argentina. Brazil reported its first outbreak with this virus in May 2001, in the state of Rio Grande do Sul. The affected herd and contact animals were immediately culled, and a vaccination campaign was initiated that prevented the virus from spreading outside this state. Ultimately, Brazil would report 37 outbreaks of FMD in Rio Grande do Sul in 2001.

On April 23, 2001, FMD type A appeared in Uruguay, apparently spread from Argentina. The first infected farm was reported in Palmitas, Soriano Department (state). Palmitas is approximately 70 km from Uruguay’s border with Argentina, the Uruguay River. Thirty-nine of the 430 cattle on the affected farm had signs of FMD. Lesions were not seen on the farm’s 640 sheep. The affected and exposed animals were killed the following day. On April 26, FMD was found on a neighboring farm, which had a mixed population of cattle, sheep, and pigs. At the same time, several infected premises were found in adjacent Colonia Department, 25 km from the Uruguay River and 40 km from the first cases. The zone where the outbreak first occurred is economically integrated with the adjacent region of Argentina, which was experiencing FMD outbreaks, and the virus is assumed to have spread from this region via fomites or people.

Quarantines were immediately placed on both affected departments and, the following day, the remaining affected and exposed animals were destroyed and buried. In total, 5,093 cattle, 1,511 sheep, and 333 pigs were culled. Three days later, the government was forced to suspend the stamping-out procedure because of strong resistance by local farmers and the discovery that the disease had spread to other areas of the country. Authorities learned that, a few days before the first cases were recognized, cattle had been sold at auction and delivered to other parts of Uruguay. The movement of people, agricultural equipment and machinery, and milk and beef trucks are also thought to have contributed to the spread of the virus. On April 26, Uruguay began ring vaccination of cattle within a 10 km radius of the affected farms. Beginning on April 27, all movement and trade of...
animals were prohibited throughout the country. On April 30, vaccination was extended to form a protective barrier to prevent the virus from entering uninfected states or neighboring countries.

The Vaccination Program

On May 5, Uruguayan authorities initiated a massive vaccination program for all cattle. The Uruguayan veterinary services established a vaccination timetable, scheduling routes, dates, and times. The vaccine was provided to farmers free of charge, and the farmers were responsible for vaccinating their animals within a given time period. Animals in areas adjacent to the state of Rio Grande do Sul were vaccinated first in order to protect Brazilian livestock. Vaccination proceeded from north to south and from east to west, and was completed on June 7; movement and transit restrictions were then relaxed. In total, nearly 11 million cattle were vaccinated. Government-administered serological tests at the completion of the vaccination program suggested that compliance had been 99%. Uruguay’s 12 million sheep, which share pastures with the cattle, were not vaccinated; however, this did not seem to hamper the eradication of the virus. The approximately 270,000 pigs were also left unvaccinated, as the vaccine used was not thought to be effective in this species. At the height of the epidemic, 40-60 infected farms were being found each day; however, by the end of the first round of vaccination, there were fewer than 10 new foci per day.

From June 15 to July 22, Uruguay conducted a re-vaccination program. A total of 24 million doses of FMD oil-adjuvanted vaccines were distributed during these two vaccination rounds. In November 2001, an additional 4.5 million young cattle that had been born since 2000 were vaccinated or re-vaccinated, and each animal was identified by an ear-tag tracking system. This re-vaccination effort boosted immunity in the cattle population to the optimum levels, and decreased the risk that vaccinated animals might become carriers. A few days after the completion of the second round of vaccination, only a few sporadic cases were being found. The last case of FMD was found on a dairy farm on August 21. By October, Uruguay was again classified as “FMD free where vaccination is practiced” Re-vaccination of all cattle was carried out again in February 2002 and May 2002.

There have been some concerns about the use of vaccines in eradication efforts. Some FMD outbreaks in the past were linked to incompletely inactivated, older vaccines. Although newer vaccines use better inactivation methods, there are still fears that this could occur. It may also be possible for animals to become FMD carriers, even when vaccinated. In this South American epidemic, there were no documented cases of vaccinated animals causing new outbreaks.

The Cost of the Outbreak

From April 23 to August 21, 2001, a total of 2,057 farms or facilities in Uruguay were affected by FMD, a number similar to the farms affected by the epidemic in the U.K. However, Uruguay was able to eradicate its extensive outbreak solely by restrictions on livestock movement and the vaccination of cattle, in spite of having a large and fully susceptible sheep population in close contact with the cattle. The total direct cost of eradication was estimated at $13.6 million. Vaccine purchases accounted for $7.5 million, with the remainder used for compensation payments to farmers, cleaning and disinfection, and operating expenses. The $13.6 million does not include some expenses incurred by the Army, which collaborated by controlling illegal livestock movements in border areas and providing other support. Argentina and Brazil also managed to control their epidemics, in part by vaccination.

The loss of export markets and a pronounced decrease in livestock prices associated with the epidemic were costly for Uruguay. The estimated losses as a result of the closing of external markets to Uruguayan farmers exceeded $200 million. Financial losses to meat and dairy producers, in particular, had a significant negative impact on the national economy. In addition, movement restrictions on the entire livestock sector affected many workers and associated industries such as packing plants. Losses associated with closed packing plants, as well as the return of 380 containers of meat that were in transatlantic transit at the time of the outbreak, added approximately $30 million in costs. In total, the epidemic cost Uruguay approximately $243.6 million, a much smaller figure than the approximately $10 billion in losses to agriculture, the food chain, and tourism during the outbreak in the U.K. In addition, approximately 6,900 animals were culled in Uruguay compared with the more than four million animals killed in the U.K. As of September 2009, Uruguay was recognized by the OIE as “FMD free where vaccination is practiced.”

Classical Swine Fever

in the United Kingdom

Like foot and mouth disease, classical swine fever (CSF) is a disease that can spread widely among naïve herds, and has a devastating effect on international trade. An outbreak of CSF in the United Kingdom illustrates the tracing, control, and eradication of an FAD before it became widespread.

On August 4, 2000, a suspected outbreak of classical swine fever in a pig herd was reported to the Ministry of Agriculture, Fisheries, and Food (MAFF) Animal Health Divisional Office at Bury St Edmunds, Suffolk. The herd consisted of 3,500 weaned pigs in seven houses. The pigs had been ill since July 11, when weaned pigs had been introduced from a breeding/multiplier unit. The infection had spread to four houses and, as of August 4, a total of 1,110 pigs were ill
and about 200 had died. A MAFF veterinary officer visited the premises the same day and, after examining the pigs on site, placed the holding under official movement restrictions and took blood samples to test the pigs for classical and African swine fever, two very similar FADs. On August 7, two incidents of suspected classical swine fever were reported on other farms. One case was in a herd of rearing pigs. The second was in a breeding herd that had supplied weaned pigs to the other two infected farms. Both herds were immediately placed under quarantine and blood samples were sent for laboratory examination.

An outbreak of classical swine fever was declared on August 8, 2000. National and local crisis centers were established to deal with the outbreak. Three-kilometer protection and 10-kilometer surveillance zones were established around the infected premises and the movement of all pigs within the zones was prohibited. The remaining 3,300 pigs on the first identified farm were killed on August 10 and their carcasses destroyed by rendering. The premises were cleaned and disininfected on August 11. The other two farms were also depopulated. The movements of pigs, feedstuffs, vehicles, and people onto and off the premises were traced to identify possible sources of the virus and limit the spread of infection.

During the next few months, classical swine fever was found on several more farms. Before the first farm had been placed under quarantine, it had sent infected pigs to four other premises. The disease also spread to two contiguous outdoor pig farms. From one of those, classical swine fever spread to another contiguous holding and then, through the movement of pigs, to two additional premises. Two more outbreaks occurred in pig units owned by haulage operators. A total of 16 infected sites were confirmed in Britain between August 4 and November 3. However, by December the outbreak had been contained. All controls relating to the 16 infected premises were lifted on December 30, 2000.

What is Classical Swine Fever?

Classical swine fever, also known as hog cholera, is a highly contagious disease of pigs caused by the CSF virus. Pigs can become infected by ingestion, inhalation, genital (semen) infection, or wound contamination. CSF virus is often spread by contact with infected pigs or the feeding of inadequately cooked garbage (swill), but the virus can also be transmitted on fomites. Virus shedding can begin before the onset of clinical signs, occurs throughout the course of acute or subclinical disease, and may go on continuously or intermittently for months in chronically infected pigs. CSF virus can also remain infectious for long periods in refrigerated, frozen, smoked or cured meat. The clinical signs vary with the strain of virus, and the age and susceptibility of the animal. Acute cases, which are caused by highly virulent isolates and have a high mortality rate, are likely to be diagnosed rapidly. However, infections with less virulent isolates can be more difficult to recognize, particularly in older pigs that have developed some immunity after exposure. These infections may be relatively mild, and can resemble other diseases. In some herds where this virus has become endemic, the only symptom may be poor reproductive performance or the failure of some pigs to thrive. The wide range of clinical signs and similarity to other diseases can make CSF challenging to diagnose.

Tracing the Virus

In the U.K., the source of the outbreak appears to have been the breeding farm identified on August 7. The epidemiological inquiry found that the CSF virus probably entered the breeding unit on May 1 then spread to the index farm and herd of rearing pigs by the movement of infected pigs. These three farms were all owned by or contracted to the U.K.'s largest outdoor pig rearing company. The company’s pigs were born on breeding units and remained there for approximately three to four weeks before being moved to rearing premises where they remained for a further six to eight weeks. From the rearing units, the pigs moved to finishing units where they remained for 10 weeks before being slaughtered. This method of swine production was designed to reduce the transmission of enzootic diseases from older finishing pigs to young growing pigs, by weaning the pigs early and distributing them to a series of remote locations.

All rearing and finishing premises that had received pigs born after May 1 at the breeding unit were traced, tested for classical swine fever, and placed under official movement restrictions. All pigs on premises that had received pigs born after June 1 were treated as “dangerous contacts” and were destroyed. The other 47 breeding herds owned by or contracted to the production company were traced, placed under quarantine, clinically inspected by a MAFF veterinary officer, and sampled for evidence of CSF. The government traced the movements of the transporter who took weaned pigs to the other two infected farms. Both herds were immediately placed under quarantine and blood samples were sent for laboratory examination.

During the next few months, classical swine fever was found on several more farms. Before the first farm had been placed under quarantine, it had sent infected pigs to four other premises. The disease also spread to two contiguous outdoor pig farms. From one of those, classical swine fever spread to another contiguous holding and then, through the movement of pigs, to two additional premises. Two more outbreaks occurred in pig units owned by haulage operators. A total of 16 infected sites were confirmed in Britain between August 4 and November 3. However, by December the outbreak had been contained. All controls relating to the 16 infected premises were lifted on December 30, 2000.

What is Classical Swine Fever?

Classical swine fever, also known as hog cholera, is a highly contagious disease of pigs caused by the CSF virus. Pigs can become infected by ingestion, inhalation, genital (semen) infection, or wound contamination. CSF virus is often spread by contact with infected pigs or the feeding of inadequately cooked garbage (swill), but the virus can also be transmitted on fomites. Virus shedding can begin before the onset of clinical signs, occurs throughout the course of acute or subclinical disease, and may go on continuously or intermittently for months in chronically infected pigs. CSF virus can also remain infectious for long periods in refrigerated, frozen, smoked or cured meat. The clinical signs vary with the strain of virus, and the age and susceptibility of the animal. Acute cases, which are caused by highly virulent isolates and have a high mortality rate, are likely to be diagnosed rapidly. However, infections with less virulent isolates can be more difficult to recognize, particularly in older pigs that have developed some immunity after exposure. These infections may be relatively mild, and can resemble other diseases. In some herds where this virus has become endemic, the only symptom may be poor reproductive performance or the failure of some pigs to thrive. The wide range of clinical signs and similarity to other diseases can make CSF challenging to diagnose.

Tracing the Virus

In the U.K., the source of the outbreak appears to have been the breeding farm identified on August 7. The epidemiological inquiry found that the CSF virus probably entered the breeding unit on May 1 then spread to the index farm and herd of rearing pigs by the movement of infected pigs. These three farms were all owned by or contracted to the U.K.’s largest outdoor pig rearing company. The company’s pigs were born on breeding units and remained there for approximately three to four weeks before being moved to rearing premises where they remained for a further six to eight weeks. From the rearing units, the pigs moved to finishing units where they remained for 10 weeks before being slaughtered. This method of swine production was designed to reduce the transmission of enzootic diseases from older finishing pigs to young growing pigs, by weaning the pigs early and distributing them to a series of remote locations.

All rearing and finishing premises that had received pigs born after May 1 at the breeding unit were traced, tested for classical swine fever, and placed under official movement restrictions. All pigs on premises that had received pigs born after June 1 were treated as “dangerous contacts” and were destroyed. The other 47 breeding herds owned by or contracted to the production company were traced, placed under quarantine, clinically inspected by a MAFF veterinary officer, and sampled for evidence of CSF. The government traced the movements of the transporter who took weaned pigs to the other two infected farms. Both herds were immediately placed under quarantine and blood samples were sent for laboratory examination.
pigs from the breeding premises. All premises that the transporter had visited were tested and placed under official movement restrictions.

The origin of the virus and its route of introduction were not established with complete certainty. However, the evidence strongly suggests that CSF virus was not established by the introduction of infected pigs, contact with feral pigs, contaminated vehicles or personnel, discharges of effluent, or contaminated vaccines and biological products. It is more likely that the infection was introduced in contaminated pig meat in food discarded by people; a public footpath runs adjacent to the outdoor paddocks containing dry sows on the breeding farm. The viral strain is in the same genetic group that was isolated during a classical swine fever outbreak in Belgium, Italy, the Netherlands, and Spain in 1997–98.

New World Screwworm

*(Cochliomyia hominivorax)*
in the United States

Screwworms are parasitic flies whose larvae feed on the flesh of living animals. New World screwworms were once endemic throughout the southern United States, but they were eradicated by a program that involved the release of sterile male flies. These parasitic flies still exist in South America and parts of the Caribbean, and North American veterinarians in private practice have occasionally identified cases in imported animals. Although some infestations occur in pets, which have minimal import requirements, an outbreak in 2000 illustrates the importance of remaining vigilant even when an animal has been imported through a quarantine facility. If screwworm larvae are allowed to drop to the ground and pupate, the resulting adult flies could reestablish the species in North America.

On February 27, 2000, a shipment of 17 horses from Argentina arrived at a quarantine facility in Miami, Florida. Two days later, 16 of the 17 horses were released from quarantine. On March 1, the one remaining horse, a four-year-old chestnut thoroughbred gelding, was also released. The next day, a private practitioner performed a physical examination on this horse and found minor discharge from the prepuce, no swelling, and a foul odor—and, on closer examination, a number of insect larvae in the penis. The practitioner collected 50-100 larvae from the distal penis of the horse and contacted federal authorities. On March 3, a USDA APHIS foreign animal disease diagnostician (FADD) submitted samples of larvae from the horse to the USDA National Veterinary Services Laboratories (NVSL) in Ames, Iowa, and appropriately treated the horse and premises. On March 4, the NVSL confirmed that the samples from the horse were screwworm larvae in the third instar stage. The horse received a second treatment on March 6 and remained in quarantine until its wound was completely healed. It was released from quarantine on March 15, after being examined by a federal veterinarian. The other 16 horses in the February 27 shipment were traced and each horse was examined twice by a FADD, at three to five day intervals. No evidence of disease was found in any of these horses. APHIS Veterinary Services began intensive screwworm surveillance in Florida and sentinel animals were placed in the West Palm Beach area from March 10 to April 17. Screwworms were not found.

What are Screwworms?

Screwworm myiasis is a devastating parasitic disease that has long been a leading cause of livestock losses in tropical areas of the Western Hemisphere. The larvae of the New World screwworm fly, *Cochliomyia hominivorax*, feed on the open wounds of warm-blooded animals, including humans. Female flies are attracted to wounds or mucous membranes, where they lay their eggs. After hatching, the larvae burrow into the flesh. Unlike ordinary maggots that subsist on debris and dead tissue, screwworm larvae attack living flesh, causing debilitation and sometimes even death. Wounds prone to screwworm infestation include those caused by feeding ticks, the bites of vampire bats, castration, dehorning, branding, shearing, wire cuts, sore mouth in sheep, and shedding of the velvet in deer. The navels of newborn mammals are also common sites of infestation. Once screwworm larvae have matured, they leave the wound and drop to the ground, where they pupate and emerge as adult flies.

New World screwworms were once found throughout the tropical and subtropical areas of North, Central, and South America, but they have been eradicated from many countries by a series of cooperative programs involving the release of...
sterile male flies. This approach, conducted and sustained by the USDA APHIS, has systematically eliminated screwworms from the U.S., Mexico, Mexico, Puerto Rico, the Virgin Islands, Curacao, and all of Central America. Screwworms were last reported in Panama in 2005, and an eradication program is ongoing in Jamaica. Because screwworms are still widespread in South America, sterile fly releases across eastern Panama continue to be necessary even though Panama has become screwworm-free. The sterile flies create and maintain a biological barrier in Panama’s Darien Gap, halting the pest’s northward migration at the Panama-Colombia border.

West Nile Virus

in the Americas

West Nile virus (WNV) is a mosquito-borne virus that, until 1999, was found only in the Eastern Hemisphere. In 1999, this virus was introduced in the New York City area. Despite eradication efforts, WNV became established in North America and eventually in Central and South America. This outbreak provides lessons about detecting and responding to a new disease, including the importance of local disease surveillance and response systems, communication among public health agencies, and links between public and animal health agencies. It also illustrates the dangers of FADs that can become established in arthropod vectors and/or wildlife, and the difficulty in preventing their establishment despite vigilance and a prompt response.

Tracy McNamara, DVM, head of the department of pathology at the Bronx Zoo, became concerned in early August 1999, when she heard that a large number of crows had been dying around the zoo. By late August, 40 crows had died. Then birds at the zoo began to die. Over the Labor Day weekend, the zoo lost a Guanay Cormorant, three Chilean flamingos, a pheasant, and a bald eagle. Because these deaths followed those of the crows, experts strongly doubted that the disease originated in the zoo. Necropsies of the birds revealed streaking in the heart and brain hemorrhages. Eastern equine encephalitis was suspected but McNamara was skeptical because the emus in her care, which are very susceptible to eastern equine encephalitis virus, were thriving. “It was becoming more and more suggestive that this was not a regular bird disease,” McNamara said. When two more flamingos died on September 9, she sent samples to the USDA’s National Veterinary Services Laboratories (NVSL) in Ames, Iowa. The NVSL ruled out avian influenza and Newcastle disease viruses. The Centers for Disease Control and Prevention (CDC) was also sent samples, as were doctors at an Army laboratory in Fort Detrick, Maryland.

Meanwhile, on August 23, 1999, an infectious disease physician from a hospital in northern Queens contacted the New York City Department of Health (NYCDOH) to report two patients with encephalitis. On investigation, NYCDOH initially identified a cluster of six patients with encephalitis, five of whom had profound muscle weakness. Testing of these initial cases was positive for St. Louis encephalitis virus, an endemic mosquito-borne flavivirus, on September 3 at the CDC. The earliest cases occurred among residents of a two square mile area in northern Queens. On the basis of these findings, aerial and ground applications of mosquito adulticides and larvicides were begun in northern Queens and South Bronx on September 3.

The Identification of West Nile Virus

In Ames, Iowa, the NVSL isolated a virus from the birds’ tissues and, after ruling out several viral agents that cause encephalitis in birds, performed electron microscopy to examine its structure. Forty nanometer virus particles with the morphology of togaviruses or flaviviruses were observed. On September 20, the NVSL forwarded the virus cultures to the CDC for identification and characterization. Testing at the CDC on September 23 indicated that the isolate was closely related to West Nile virus, which had never been isolated in the Western Hemisphere. CDC experts also detected flavivirus antigens in one of the human autopsy specimens by immunohistochemistry and found a West Nile-like virus genomic sequence in a human brain specimen from an encephalitis case. The genetic sequence was identical to that derived from the bird tissues. Concurrently, specimens of brain tissue from three human encephalitis cases, forwarded by the New York State Department of Health to the University of California, Irvine, were reported as positive for West Nile-like virus sequence by genomic analysis.

By September 28, 17 confirmed and 20 probable human cases and four deaths had been reported in New York City and the surrounding counties. Although cases were seen in patients as young as 15 years, most occurred in older patients, with the most severe clinical cases and all fatalities occurring among the elderly. In October 1999, the NVSL first isolated WNV from the brain tissue of a Long Island horse that had clinical encephalitis. WNV was also isolated at NVSL from two additional encephalitic horses in 1999, and WNV antibodies were identified in ill horses in Suffolk and Essex counties, New York. Retrospective classification of likely West Nile cases occurring prior to October resulted in a total of 25 equine cases.

What is West Nile Virus?

West Nile virus is a flavivirus that, like St. Louis encephalitis virus, belongs to the Japanese encephalitis subgroup of the Flaviviridae. This subgroup contains closely related, mosquito-borne viruses, which may cross-react in serological tests. WNV was first isolated in the West Nile province of Uganda in 1937. It is a mosquito-transmitted virus that cycles between birds and mosquitoes in endemic regions. In
some birds, viremia can persist for more than three months, possibly contributing to the overwintering of the virus. Most infected birds in the Eastern Hemisphere carry this virus asymptomatically. When environmental conditions favor high viral amplification, mosquitoes can also spread the virus to mammals. Horses, humans, and most other mammals are dead end hosts that cannot infect mosquitoes; however, squirrels and chipmunks, as well as alligators, have higher levels of viremia and might be capable of amplifying the virus. Among mammals, symptomatic infections mainly seem to occur in humans and horses. Occasional cases have also been reported in other species including alpacas, sheep, reindeer, wild squirrels, harbor seals, rhinoceroses, and dogs. Approximately 80 percent of people who become infected with WNV remain asymptomatic, while 20 percent develop flu-like symptoms. Fewer than one percent develop neurological signs, but these cases can be severe, with signs of encephalitis, meningitis, or flaccid paralysis that resembles polio. Severe cases and neurological signs are more likely to occur in people over 50 years of age and patients who are immunocompromised. Like humans, most infected horses are symptomatic, but some animals develop neurological signs and may die.

**The Response to the Outbreak**

Vector control measures had been initiated in northern Queens and the South Bronx on September 3, when the disease was still thought to be St. Louis encephalitis. These measures were followed by a citywide pesticide application, after a laboratory confirmed a case of West Nile encephalitis in a Brooklyn resident with no travel history to Queens, and two additional cases in the South Bronx. Surveillance of wild birds and sentinel chickens was used to assess WNV distribution in the region. Emergency telephone hotlines were established in New York City and in Westchester County to address public inquiries about the encephalitis outbreak and pesticide application. Approximately 300,000 cans of DEET-based mosquito repellant were distributed citywide through local firehouses, and 750,000 public health leaflets were distributed with information about personal protection against mosquito bites. Recurring public messages were announced on radio, television, web sites, and in newspapers, urging personal protection against mosquito bites. Recommended actions included limiting outdoor activity during the peak hours of mosquito activity, wearing long-sleeved shirts and long pants, using DEET-based insect repellants, and eliminating any potential mosquito breeding niches. Spraying schedules were also publicized and people were advised to remain indoors during spraying to reduce pesticide exposure.

By the end of 1999, WNV had been identified in a limited area of the northeastern United States in wild birds, mosquitoes, humans, and horses. Illness in humans and horses occurred only from early August through late October and was limited to New York. WNV activity ended for the season because of various factors, including climate and vector control activities. In all, 62 human cases, with seven deaths, were recognized in 1999. Twenty-five cases of West Nile encephalitis were also identified in horses, all in Suffolk and Nassau Counties on Long Island, New York. Because horses do not play a role in the transmission of WNV, quarantines were never placed on any asymptomatic horses in the outbreak area. However, some horse movements were restricted, particularly the export of horses from affected areas to the European Union and the shipment of any horses to the E.U. via Kennedy airport.

In genetic sequencing studies, WNV isolates from the New York outbreak showed strong similarities to isolates from Israel, suggesting that this region may have been the origin of the virus. How WNV was introduced into the United States is unknown, but most speculation has centered on infected birds or mosquitoes.

**The Continuing Spread of West Nile Virus**

Although authorities hoped that the outbreak had ended with the coming of winter and the resulting death of mosquito populations, WNV reemerged in the U.S. in 2000. Twenty-one human cases of West Nile encephalitis were reported. Two elderly patients, an 82-year-old man in New Jersey and an 87-year-old woman in New York, died of the disease. Sixty equine cases were confirmed in seven states, and infections were found among birds in 12 states and the District of Columbia. Evidence of WNV infection was also reported among wild mammals. In 2001, the virus was transported through bird migration south to Florida and west to Iowa. By the end of the 2002 mosquito season, WNV occurred...
Throughout the Midwest and was spreading into the western states. By 2005, it was found in all U.S. states except Alaska and Hawaii.

In Canada, WNV was first detected in birds and mosquitoes in the provinces of Ontario and Quebec in 2001. The first human cases were reported in these same provinces in 2002. Since then WNV has become endemic and human cases have been reported in the provinces of Alberta, Saskatchewan, Manitoba, Ontario, and Quebec. Sporadic human cases detected in some of the other Canadian provinces and territories have generally been attributed to travel outside the province. In 2002, WNV was diagnosed for the first time in horses in Quebec, Ontario, Manitoba, and Saskatchewan and in 2003 in horses in Nova Scotia and Alberta.

West Nile virus also spread to Central and South America and the Caribbean. This virus was first reported from some countries in South America in 2003. As of 2009, it appears to be present in Columbia, Argentina, and Venezuela.

**Wild Birds and Reptiles**

In the Eastern Hemisphere, West Nile virus usually has little or no effect on birds. However, some North American species, which were exposed for the first time, have been affected by the outbreak. In the U.S., this virus has killed large numbers of crows, blue jays, and other corvids, as well as American robins, house wrens, eastern bluebirds, tufted titmice, chickadees, and sage grouse. Unexpectedly, some species of crows, jays, magpies, gulls, and other birds were found to shed WNV in oral and cloacal secretions. These birds are able to transmit the virus directly, and one outbreak occurred among crows in the winter. Outbreaks have also been reported in domesticated geese, pheasants, and partridges, and occasional cases occur in captive psittacine birds or zoo birds. The effects of WNV on threatened or endangered avian species could be significant. California condors and greater sage grouse, which are both susceptible to this virus, are of particular concern. There are also concerns about native bird populations if the virus were to be introduced into Hawaii.

In North America, WNV has also revealed an unexpected ability to cause neurological disease in reptiles. At one U.S. alligator farm with more than 10,000 animals, 250 alligators died in an outbreak one year, and more than 1,000 died the following year. Young alligators were more severely affected than adults. WNV can also cause disease in experimentally infected garter snakes.

**Future Prospects**

West Nile virus continues to change and evolve as it becomes established in the Americas. The virus that was originally introduced to New York seems to have disappeared, replaced by a variant that spreads more efficiently. A few attenuated strains have also been isolated in the Americas since 2003. In the U.S., relatively few people have antibodies to WNV, and outbreaks are expected to occur each summer. Surprisingly, far fewer clinical cases or deaths have been reported in Central and South America. The reason for this pattern of disease is not known; however, it might involve protective immunity to cross-reactive flaviviruses, the occurrence of WNV isolates with decreased virulence, decreased surveillance and diagnosis, or other causes. In areas where dengue, another flaviviral disease, is present, some West Nile infections could be misdiagnosed as this disease.

Commercial vaccines are now available for horses in North America. As a result, the number of West Nile virus cases in U.S. horses decreased from more than 15,000 in 2002, to approximately 1400 in 2004. Vaccines are sometimes used “off label” to protect sensitive birds or other species. For instance, in an effort to minimize the impact of West Nile virus on endangered California condors, captive condors have been vaccinated since 2003, and attempts have been made to vaccinate wild chicks in the nest. No human vaccine is available yet.

**Bovine Spongiform Encephalopathy in the United Kingdom and Other Countries**

Occasionally, an outbreak is caused by a disease that is recognized for the first time. One of the most wide-reaching incidents occurred in the 1980s, when bovine spongiform encephalopathy (BSE) appeared in the United Kingdom. This orally transmitted disease, which has an incubation period of years, had been spreading through the cattle population of the U.K. via ruminant feed, possibly since the 1970s. It erupted as a mysterious epidemic that ultimately killed more than 170,000 cattle in the U.K. over the next 20 years, spread to humans, housecats, and some zoo animals, and affected nations around the world. As a consequence of this epidemic, the composition of animal feed was changed, new tests, procedures, and rules were developed for meat inspection, and even the screening of human blood donors was affected.

**The First Cases of BSE**

The first clinical cases of BSE were reported in 1984, although it would be two years before the nature of the disease was actually recognized. On December 22, 1984, Peter Stent of Pitsham Farm in Sussex called Dr. David Bee, a private veterinarian, to examine a cow with an arched back and weight loss. This animal developed a head tremor and incoordination before dying a few weeks later. Over the next few months, animals on Pitsham Farms continued to have unusual neurological syndromes, and by the end of April, five more cows had died. Dr. Bee requested assistance from the Winchester Veterinary Investigation Center of the Veterinary
Emerging and Exotic Diseases of Animals

Investigation Service, and tissue samples were sent to the Central Veterinary Laboratory (CVL) of the State Veterinary Service for analysis. Although a wide range of tests was done and some possible diagnoses were suggested, no definitive diagnosis could be made. The CVL suggested that Mr. Stent submit a live affected cow for euthanasia and necropsy. The pathology report on this animal, together with an analysis of the feed on the farm, suggested that the problem was caused by mycotoxins in contaminated feed. No new cases appeared after this time and the veterinarians assumed the problem had run its course.

The mysterious disease soon appeared on other farms in Kent and Bristol. By the end of 1986, the Pathology Department of the CVL had identified the disease as a probable new transmissible spongiform encephalopathy (TSE) of cattle and named it bovine spongiform encephalopathy. Epidemiological investigations suggested that BSE was caused by the consumption of meat-and-bone meal (MBM), a common supplement made from animal carcasses that was incorporated into cattle feed. At first, cattle were thought to have been infected when they ate MBM contaminated with the agent that causes scrapie, a TSE of sheep. Scrapie is not a new disease, but rendering methods that had previously inactivated the scrapie agent had been changed, and might have allowed it to remain infectious. It eventually became apparent that BSE was widespread in U.K. cattle, and the cases of BSE identified between 1986 and 1988 were not index cases caused by eating scrapie-contaminated feed. The BSE agent had apparently been amplified when tissues from BSE-infected cattle were recycled into MBM and other ruminant feed supplements, and fed to other cattle. Because the incubation period for BSE is very long, large numbers of cattle had been infected by the time animals began developing clinical signs. Although the origin of the disease will probably never be known, it was probably present in cattle since the 1970s or earlier. The two most popular hypotheses are that the BSE agent originated as a spontaneous mutation of a cellular protein in cattle, or that it originally came from a mutated scrapie agent in ruminant feed.

What are Transmissible Spongiform Encephalopathies?

Transmissible spongiform encephalopathies (TSEs) are neurodegenerative diseases caused by prions. Prions are infectious proteins that are thought to replicate by converting a normal cellular protein, which is found on the surfaces of neurons, into copies of the prion. TSEs affecting animals include scrapie in sheep and goats, bovine spongiform encephalopathy (BSE, “mad cow disease”) in cattle, transmissible mink encephalopathy (TME) in mink, and chronic wasting disease (CWD) in cervids. Although some prion diseases usually occur in one or a few closely related species, other prions can cross species barriers. BSE has a particularly wide host range. Cattle are the most important hosts for this disease, but some other ruminants, cats, lemurs, and humans can also be affected; in cats, the disease is known as feline spongiform encephalopathy (FSE), and in humans, it is called variant Creutzfeldt–Jakob disease (vCJD).

Although some prions can also be transmitted by other routes, the BSE agent is acquired only by eating contaminated tissues from infected animals, or by iatrogenic routes such as blood transfusions and organ transplants. BSE prions occur mainly in the central nervous system, although they may also be found in a few other locations such as the ileum. Once an animal becomes infected, it carries the prions for life, and its tissues are infectious even if it remains asymptomatic. Cooking or rendering an infected tissue does not make it safe to eat.

Animals that have been infected with TSEs usually remain asymptomatic for long periods, typically several years, before developing clinical signs. Clinical BSE, FSE, and vCJD are characterized by behavioral changes and other neurological signs. Once the clinical signs develop, these diseases are always progressive and fatal.

Early Precautions

The Southwood Working Party was an advisory board set up to provide initial recommendations on the implications of BSE. In 1988, the group advised that cattle showing signs of BSE be destroyed and that compensation be paid to farmers. It also concluded in 1989 that the risk of transmission of BSE to humans seemed remote and that “it was most unlikely that BSE would have any implications for human health.” At the time, very little was known about TSEs other than scrapie, which is not zoonotic. The Southwood Working Party assumed that BSE was probably derived from scrapie and could be expected to behave like it. Precautions...
were put in place that went beyond the Working Party’s recommendations, and an expert committee was set up to advise BSE research.

Once MBM was identified as the probable source of BSE in 1988, the government banned the incorporation of ruminant protein into ruminant feed. Although this ban reduced the escalating rate of infection, cross-contamination between ruminant feed and other products in feedmills allowed thousands more cattle to become infected. Because the incubation period for BSE is usually 2-8 years, this was not apparent at the time. It was later discovered that a cow could become infected by eating a piece of infectious tissue as small as a peppercorn. Cases of BSE continued to be found, and the regulations were revised in 1994 and a rigorous enforcement campaign was begun. After March 1996, when it had become apparent that BSE was not limited to cattle, the incorporation of all animal protein in animal feed was banned in the U.K. The BSE epidemic in the U.K. peaked in 1992, with nearly 1,000 new cases confirmed each week. At the time, the annual incidence in affected herds was approximately 2-3 percent. As a result of the feed bans, the incidence declined to approximately 5-10 new cases per week by 2004.

Recognition of the Risks to Humans: Variant Creutzfeldt-Jakob disease

In June 1989, a precautionary ban was placed on the use of specified bovine offal (SBO) in human food. Specified bovine offal includes the brain, spinal cord, spleen, thymus, tonsils, and intestines of cattle. Concerns were also raised about the possibility that scraps of spinal cord might remain after meat processing, or that neural tissues might remain in mechanically recovered meat (mechanically removed scraps attached to the vertebral column). Instances of failure to remove all of the spinal cord from the carcass were discovered and, in December 1995, the extraction of mechanically recovered meat from the spinal column of cattle was banned.

As time passed, increasing knowledge about BSE made the theory that it would behave like scrapie less and less viable. Scientists suspected that, if BSE were to spread to humans, it would resemble Creutzfeldt-Jakob disease (CJD), a neurological disease that occurs in people with genetic changes in the cellular equivalent of the prion protein. Creutzfeldt-Jakob disease occurs sporadically among individuals, and the median age of onset is 65 years. In 1991, surveillance for atypical cases or changing patterns of CJD was put in place. Three dairy farmers with BSE-infected herds were diagnosed with CJD between 1992 and 1994. The fourth annual report of the CJD Surveillance Unit, issued in August 1995, noted the apparently high incidence of CJD in farmers. The Spongiform Encephalopathy Advisory Committee wrote a press release about suspected CJD in a cattle farmer in October 1995. In 1995, cases also began to appear in patients who were unusually young for CJD, including Stephen Churchill, an 18-year-old who was later confirmed as the first known victim of the new disease.

To differentiate it from the genetic form of CJD, which is not contagious or zoonotic, the new disease was called variant Creutzfeldt-Jakob disease. Variant CJD, like BSE, is acquired by eating contaminated bovine tissues. Because cooking does not destroy the BSE agent, there is no practical way to prevent human infections except to keep BSE-contaminated tissues out of the human food chain. Bans on the use of certain bovine tissues in human food have been put into place in the U.K. and many other countries. In some countries, rapid tests are done on higher risk (or all) cattle at slaughter, and carcasses cannot be used in human food until this test is negative. Although these measures have decreased the incidence of vCJD, the incubation period for TSEs is long and, not surprisingly, cases continue to be diagnosed. Iatrogenic routes of spread including blood transfusions have also been recognized. As a result, restrictions have been placed on blood donations from donors with a known risk for vCJD. Annual vCJD-related deaths in the U.K. rose gradually to a high of 28 in 2000, and gradually fell to five cases per year in 2005 through 2007, with one case reported in 2008 and no cases in the first half of 2009. As of May 2009, 210 cases of vCJD had been reported worldwide, including 165 cases from the U.K. and 24 from France. Many people with vCJD had lived in the U.K. between 1980 and 1996 and had been exposed to BSE there. As of 2009, all vCJD cases diagnosed in the U.S. and Canada are thought to have been acquired in other countries.

Feline Spongiform Encephalopathy and Other BSE-Linked Diseases

The first feline TSE was recognized in May 1990, in a cat diagnosed with a ‘scrapie-like’ spongiform encephalopathy. This disease, which was named feline spongiform encephalopathy (FSE), was later linked to the ingestion of the BSE prion in beef products. Between 1990 and 2007, FSE was diagnosed in nearly a hundred housecats and 22 zoo cats. Tissues that have a high risk of transmitting BSE have been banned from pet foods in the U.K. since 1990, and are no
longer fed to zoo cats. The FSE outbreak has been declining with the BSE epidemic. The two most recent cases in housecats were reported in a cat from the U.K. in 2001, and a Swiss cat in 2003. A cheetah in a German zoo was diagnosed with FSE in 2007, and had probably been infected in the Netherlands where she was born.

BSE has also been reported from exotic ruminants, including nyala, kudu, gemsbok, eland, oryx, and bison, in zoos. Field cases were documented in two goats, and experimental infections have been reported in both sheep and goats. Two lemurs at a French zoo were apparently infected in contaminated feed.

**BSE Outside the United Kingdom**

As a result of the BSE epidemic, the European Union and many individual countries prohibited the importation of live cattle and bovine products from the U.K. Despite these measures, BSE spread to countries outside the U.K. – not a surprising result given the long incubation period for this disease. The prevalence of BSE in countries where it has become endemic varies widely. In some countries, the estimated prevalence may be more than 100 cases per million cattle; in others, there may be fewer than two cases per million. The peak of the epidemic curve has varied, occurring later in countries where feed bans were established more recently than the U.K.

**BSE in Canada**

Following the recognition of BSE in the U.K. in 1986, Canada required in 1987 that all cattle imported from the U.K. be certified as originating from a farm that was free of BSE. Canada also prohibited the importation of rendered products from all countries other than the U.S. beginning in 1998. In 1990, Canada imposed an importation ban on live cattle from countries reporting cases of BSE. In addition, active surveillance of cattle imported from the U.K. between 1982 and 1990 was initiated. In 1991, BSE was declared a reportable disease in Canada and, in 1992, a surveillance program for BSE was initiated targeting cattle older than three years of age with neurologic signs that could not be attributed to rabies. In 1993, BSE was diagnosed in a beef cow that had been imported from Britain in 1987. This animal and its herdmates and offspring were destroyed, as were cattle imported from the U.K. between 1982 and 1990.

To further decrease the risk of introducing BSE into the Canadian herd, Canada implemented a feed ban in March of 1997 which prohibited the feeding of ruminant-derived meat and bone meal (MBM) to ruminants.

Canada announced the detection of its first indigenous case of BSE in a 6-year-old beef cow from northern Alberta in May of 2003. Since this animal was condemned at slaughter, no potentially infective material entered the human food chain. However, the carcass minus the head was rendered and processed into animal feed ingredients intended to be fed to animals other than ruminants. Although the probability of recycling the agent to ruminants through animal feed was deemed low, three farms with cattle that may have consumed poultry feed with rendered products derived from this case were quarantined and the cattle destroyed. The index case might have originated from any of eight herds; therefore, its birth cohort was assumed to include animals from all eight herds. This culminated in the destruction of over 2700 animals that might have been exposed to a common feed source, along with the infected cow. Over 2000 of these animals over 24 months of age were tested for BSE and found to be negative. The economic impacts of this single case of BSE to the Canadian beef production and related industries were catastrophic due to the loss of export markets, but domestic consumer confidence in the safety of Canadian beef remained strong. The most likely source of BSE in this case was a limited number of cattle imported into Canada and the U.S. from the U.K. in the 1980’s. The tissues from these animals had entered the animal feed chain prior to the implementation of the feed ban. A case of BSE diagnosed in the U.S. in December 2003 was also traced back to a farm in Alberta.

At the conclusion of the investigation into the 2003 BSE case, the Canadian government announced regulations to remove BSE specific risk material (SRM) from all cattle at slaughter. SRM are tissues that, in BSE infected cattle, are most likely to contain the BSE prion. These tissues include the skull, brain, trigeminal ganglia, eyes, tonsils, spinal cord, and dorsal root ganglia of cattle aged 30 months and older, and the ileum of cattle of all ages. The removal of SRM eliminates almost all BSE infectivity from bovine products and serves to safeguard the human food supply. In addition to banning SRM from the human food chain, Canada implemented an enhanced BSE surveillance program in January of 2004 which involved targeted testing of cattle at highest risk of having BSE, i.e., down, diseased, dead, or dying cattle over 30 months of age. As of September 2009, roughly 260,000 cattle have been tested through this program and Canada has identified 15 additional cases of BSE, all of them on farm. These cases have ranged in age from 4 to 16 years with the majority being 6 to 8 years old. Two cases were detected in 2005, five in 2006, three in 2007, four in 2008, and one in 2009. The majority of these cases were from Alberta but three cases were from British Columbia and one was from Manitoba. No part of any of these animals entered the human food or animal feed chains and all of the animals were removed from the farm and incinerated. No additional cases of BSE were detected during the investigation of these 15 cases. Some of these BSE cases were attributed to feeding ruminant MBM to cattle in their first year of life when such practices were still legal. Later cases, which arose after the implementation of the feed ban, have been ascribed to possible residual contamination of the feed system through the presence of old food in the system or cross contamination during manufacture, mixing, or distribution.
July of 2007, Canada introduced an enhanced feed ban which prohibits SRM from being incorporated into all animal feeds, pet foods, and fertilizers. Canada expects to detect a small number of BSE cases over the next 10 years as it progresses towards its goal of eliminating BSE from the national herd.

Consistent with OIE guidelines, Canada’s current investigation practices include trace-out of any animals born on the farm of origin 12 months before or after the affected animal, as well as an investigation of how the animal may have become infected, which includes feeding practices and purchases on the premises. Live animals identified through trace out are permanently identified and their movements controlled. Their carcasses are completely destroyed at slaughter or death. The OIE no longer recommends including the offspring of infected cattle in BSE investigations because vertical transmission is not a scientifically recognized pathway of BSE spread. However, Canada takes appropriate measures to meet the export certification requirements of countries that prohibit the importation of such animals. In 2007, the OIE categorized Canada as a controlled risk country for BSE in recognition of the effectiveness of Canada’s surveillance, risk mitigation, and eradication measures.

After the first case of BSE was diagnosed in Canada, the U.S. closed its border to the importation of live Canadian cattle and their products. The border was subsequently opened to cattle under 30 months of age destined for immediate slaughter or restricted feedlots. Currently, any bovine born in Canada on or after March 1, 1999, the date that the U.S. recognizes as the effective date for Canada’s ruminant-to-ruminant feed ban, is eligible for importation.

**BSE in the United States**

To prevent BSE from entering the United States, restrictions were placed on the importation of live ruminants and certain ruminant products from BSE-infected countries in 1989. These restrictions were later extended to include the importation of ruminants and certain ruminant products from all European countries. In August 1997, the Food and Drug Administration (FDA) banned the feeding of most mammalian proteins to ruminants.

Active surveillance efforts by the USDA Animal and Plant Health Inspection Service (APHIS) were instituted in May 1990. As a result of this surveillance, BSE was found in a Holstein dairy cow in Washington State in December 2003. The cow had been imported from Canada in September 2001, along with 81 others. Samples were taken from 255 animals located on farms in the U.S. where cows from the index herd in Canada were being raised. All tested negative to BSE. In response to this case, the USDA banned the use of certain bovine tissues in human foods and made extensive changes in slaughter and processing facilities to reduce the risks to human health. In addition, APHIS undertook an intensified testing program to determine whether BSE currently exists in U.S. cattle and at what level. This surveillance is targeted particularly at high-risk cattle such as nonambulatory animals and those with neurological signs. These animals cannot be used in human food, and the carcass is held until BSE testing is complete. The U.S. also conducts passive surveillance for this disease. When an infected animal is identified, the affected herd is quarantined, and the source of the infection is investigated.

The intensified surveillance found two cases of BSE in indigenous animals. In 2004, a 12-year-old Brahma cross cow from Texas was sold in a livestock sale and transported to a packing plant. The animal, which was dead on arrival, was sent to a pet food plant, where it was sampled for BSE. The carcass was incinerated and it was not used in pet food. The infected animal was traced to the ranch in Texas where it had been born and raised. All adult animals that left this farm after 1990, and the two calves born to the infected cow within 2 years of its death were traced. Most of these animals had been slaughtered, died, or were presumed to be dead, although a few animals were untraceable. One surviving animal was tested and found to be negative, and another was determined to be of no interest due to its age. The investigation suggested that this cow, which had been born before the USDA implemented the ruminant-to-ruminant feed ban, had been infected from that source. The second indigenous case of BSE, found on a farm in Alabama in 2006, occurred in a Santa Gertrudis cow that was at least 10 years old, and could also have exposed to BSE before the feed ban. This cow was euthanized by a private veterinarian, and it was buried on the farm after sampling. Both indigenous cattle were later found to have an atypical form of the BSE prion. These atypical forms, which have been found in some countries with intensified surveillance for prion diseases, might represent additional strains of BSE or spontaneously occurring prions. Relatively little is known about them. The OIE has classified the U.S. as a controlled risk country for BSE.

**Monkeypox in the United States**

Veterinarians work to prevent, diagnose, and treat disease in a wide variety of species, but they also take on the role of gatekeeper to reduce disease transmission between humans and animals. Veterinarians need to have a knowledge of zoonotic diseases, and should question animal owners about illness if a zoonosis is suspected in animals or people. The 2003 monkeypox outbreak demonstrates the importance of close cooperation between the medical, public health, and veterinary communities in addressing zoonotic diseases. It also illustrates how gaps in our knowledge of some diseases, particularly unusual diseases that have their reservoirs mainly in wildlife, can result in the introduction of a pathogen.

In May 2003, an unusual illness occurred in a three and a half-year-old Wisconsin child who had been bitten on the hands by an infected pet prairie dog. On May 11, the
Wisconsin PHD that electron microscopy had detected an orthopoxvirus in tissues from both the prairie dog and the child’s mother. The following day, the Wisconsin PHD organized a teleconference between physicians and representatives from federal, state, and local agencies. Images of the lesions and viruses found by the Marshfield Clinic were placed on the Internet, and plans were quickly made to ship specimens to the Centers for Disease Control and Prevention (CDC) Poxvirus Laboratory. On June 6, the CDC analyzed samples from three patients by PCR, and found evidence of monkeypox virus. The following day, sequencing at the CDC confirmed that the samples contained a monkeypox gene, and on June 6, monkeypox virus was found in a virus culture of the prairie dog’s lymph node. An epidemiological investigation revealed that 11 people including the exotic pet distributor, his wife, members of the public who bought prairie dogs, two veterinarians who had treated prairie dogs, and employees of two different pet shops had symptoms consistent with monkeypox. On June 7, 2003, public health officials from the CDC and the states of Wisconsin, Illinois, and Indiana reported the first outbreak of human monkeypox outside Africa.

What is Monkeypox?

Monkeypox is a rare, zoonotic viral disease that occurs primarily in the rain forests of Central and West Africa. In Africa, the monkeypox virus circulates in unknown animal hosts and emerges periodically as a zoonosis in humans. Outbreaks have also been seen occasionally among captive nonhuman primates in other parts of the world. With the exception of primates, few of the natural hosts of this virus were known in 2003; however, a variety of rodents and other small mammals are now recognized to be susceptible. Two genera of African squirrels, Funisciurus spp. (rope squirrels) and Heliosciurus spp. (sun squirrels), have been suggested as possible reservoir hosts. Other susceptible species include Gambian giant pouched rats, dormice, African hedgehogs, North American black-tailed prairie dogs, ground squirrels, groundhogs/woodchucks, and opossums.

Humans are usually exposed to the monkeypox virus via infected animals. This virus may be transmitted to people in animal bites, in aerosols during close contact, or by direct contact with lesions, blood, or body fluids. In Africa, human outbreaks have often been linked to handling, preparing, and eating wild animals. In the U.S., most cases occurred among people who had close direct contact with captive prairie dogs; some infections were apparently acquired in scratches and bites, or through open wounds. Human-to–human transmission can also occur.

In people, monkeypox resembles smallpox, but the symptoms are generally milder and, unlike smallpox, the lymph nodes are usually enlarged. The initial symptoms are flu–like, and are followed by a maculopapular rash. The skin lesions become vesicles and pustules (“pocks”), which umbilicate,
form scabs and are eventually shed. The number of skin lesions varies from fewer than 25 to more than a hundred. Confluent rashes and recurrent febrile periods can occur in severe cases. Subclinical and very mild cases are also seen. Two clades of monkeypox viruses, the West African and Congo Basin (Central Africa) viruses, have been identified. The Congo Basin viruses are more virulent. Although most patients survive in West Africa, 10-17 percent of the cases in the Congo Basin are reported to be fatal.

How did Monkeypox Get to the United States?

In the U.S. outbreak, traceback investigations found that the source of the infection was a shipment of animals from Ghana imported into Texas on April 9. This shipment contained hundreds of small mammals including six species of African rodents. Some of these animals had reportedly become ill and died suddenly, soon after their arrival in the U.S. The CDC tested some of the surviving animals and found monkeypox virus in Gambian giant pouched rats, rope squirrels, and dormice. Infections were also documented in other captive species including a groundhog/woodchuck, an African hedgehog, a jerboa, and two opossums. Species that developed antibodies after exposure, but had no evidence of viral DNA or infectious virus included chinchillas and coati mundis. Many other species were exposed to the infected animals, but did not become seropositive.

Before the outbreak was detected, the monkeypox virus had spread into several states in these animals and in prairie dogs. Some of the imported animals were shipped from Texas to an Iowa distributor and then to a distributor in Illinois. In Illinois, the Gambian rats and dormice were kept in close proximity to North American black-tailed prairie dogs, which were highly susceptible to this virus. The prairie dogs were then sold to other dealers and individuals in several states, including the Milwaukee animal distributor, who bought prairie dogs and a Gambian giant rat. In May, some prairie dogs were sold to two pet shops in the Milwaukee area, and others were sold or traded at the pet “swap meet” in northern Wisconsin. All of the exposed prairie dogs could not be traced during the investigation.

The CDC advised physicians, veterinarians, and the public to report instances of rash illness associated with exposure to prairie dogs, Gambian rats, or other animals to local and state public health authorities. In total, 37 laboratory-confirmed and 35 suspected human cases, all infected by exposure to captive prairie dogs, were reported in Illinois, Indiana, Kansas, Missouri, Wisconsin, and Ohio. Most people in the U.S. had a fairly mild form of the disease, with less marked lymphadenopathy than reported in Africa, relatively few lesions, and a self-limiting course. In many patients, the skin lesions were localized and confined to the extremities; generalized rash was rare. Skin lesions sometimes occurred at a bite or scratch, the apparent inoculation site, before systemic signs developed. Two patients, both children, had serious illnesses. One child developed encephalitis, an unusual complication. The other child had generalized lesions including some in the throat, and severe cervical and tonsillar lymphadenopathy, which caused difficulty in breathing and swallowing. An adult developed complications of keratitis and corneal ulceration, and received a corneal transplant.

However, this outbreak was unusual in that no human deaths were reported. The strain that entered the U.S. was a West African virus. This factor, together with the availability of advanced health care facilities and good supportive care, as well as the absence of poor nutrition and concurrent diseases, may account for the relative mildness of the outbreak.

The CDC recommended that people who had close or intimate contact with a confirmed case be vaccinated with the smallpox vaccine. Seven people, including three veterinarians, two laboratory workers, and two health-care workers received pre-exposure prophylaxis. Another 23 people were vaccinated after exposure. The CDC also issued procedures to medical workers and veterinarians on preventing monkeypox transmission.

Clinical cases were also reported in some animals. In prairie dogs, blepharoconjunctivitis was often the first sign. Other clinical signs included fever, coughing, sneezing, oral ulcers, nasal discharge, respiratory distress, lymphadenopathy, and a nodular rash. Some prairie dogs died and others apparently recovered. Fatal infections were also reported among rope squirrels, dormice, and one Gambian giant pouched rat, while another Gambian rat had mild clinical signs and limited skin lesions, and some Gambian rats appeared healthy but were seropositive. Veterinarians who suspected monkeypox in an animal were asked to contact the state health department for information on specimen submission. They were advised not to perform necropsies or biopsies because of the risk of infection. The CDC recommended that all animals with suspected monkeypox be humanely euthanized to prevent the further spread of the disease and the carcasses be incinerated. If the animal was associated with a human case, it was tested to confirm the disease. In addition, the CDC recommended that all rodents from the April 9 shipment, and any prairie dogs on the premises at the same time as these African rodents, be euthanized. Because so little was known about the susceptibility of most species, other mammals that had been in contact with infected animals were placed under quarantine for six weeks.

On June 11, 2003, the CDC and the FDA issued a joint order announcing an immediate embargo on the importation of all rodents from Africa. The joint order also banned within the U.S. the sale, distribution, transport, or release into the environment, of prairie dogs and six genera of African rodents implicated in the monkeypox outbreak. On November 3, 2003, the joint order was replaced by an interim final rule in which the CDC restricts importation of these animals and the FDA restricts domestic interstate and intrastate movement, with exemption procedures to accommodate

Chapter 5 — Descriptions of Recent Disease Incursions
special circumstances. No human cases of monkeypox have been reported in the U.S. since June 22, 2003, and there is no evidence that the virus became endemic in North American pets or wildlife populations.

**Influenza Viruses**

**and Their Changing Host Relationships**

Viruses rarely jump from one species into another. When they do, the outbreak tends to be brief; typically, the virus is poorly adapted to the new host and cannot be transmitted efficiently. Two characteristics of influenza A viruses – their high mutation rate and their ability to recombine with each other – help them adapt to new hosts. Since the 1990s, some H5N1 avian influenza viruses have revealed an unexpected capacity to cause severe disease in mammals and wild birds, equine influenza viruses have jumped into dogs for the first time, and swine influenza viruses have contributed gene segments to a new influenza virus causing a human pandemic. Preventing the establishment of these changeable viruses in animal or human populations requires regular surveillance and awareness of their potential.

**What are Influenza A viruses and How Do They Jump From One Species to Another?**

Influenza viruses belong to three genera in the Orthomyxovirus family. Viruses in the genus influenza virus A, which are also known as influenza A viruses, circulate in birds, humans, pigs, horses, and recently in dogs. The viruses that are usually found in each species are known, respectively, as avian influenza viruses, human influenza viruses, swine influenza viruses, equine influenza viruses, and canine influenza viruses. Waterfowl and shorebirds seem to be the reservoirs for the influenza A viruses; these birds carry a tremendous variety of viruses, but very rarely become ill themselves. Relatively few influenza A viruses have become established in each mammalian species.

Influenza A viruses are classified into subtypes based on two proteins, the hemagglutinin (‘H’) and neuraminidase (‘N’). There are at least 16 different hemagglutinin proteins (H1 to H16) and 9 neuraminidase proteins (N1 to N9). Because the influenza viruses are highly variable, viruses that share a subtype are not necessarily closely related and may differ greatly in their virulence, host specificity, or other factors. For example, one virus with the subtype H1N1 is a human influenza virus, another is a swine influenza virus, and others are found only in birds. Waterfowl and shorebirds carry many different influenza A subtypes. In contrast, only a few subtypes circulate in each species of mammal. Equine influenza viruses, for example, belong to the subtypes H3N8 and H7N7.

Influenza viruses are able to jump from one species to another. This is generally a rare event, although it seems to happen somewhat more often in swine, which have receptors for both avian and mammalian influenza viruses. Species jumps are aided by the influenza virus’ tendency to change quickly. Due to poor proofreading during gene replication, influenza viruses can quickly accumulate small mutations, a process called ‘antigenic drift.’ In addition, they can exchange genes with other influenza viruses, an ability facilitated by their segmented genome. If two influenza viruses infect a cell simultaneously, the segments may mix when new virus particles are assembled. An influenza virus can ‘reassort’ with any other influenza virus, regardless of its origin. For example, if a cell is infected by a swine influenza virus and a human influenza virus, the new viruses budding from that cell might contain some pieces from the swine influenza virus and other pieces from the human influenza virus—a process that could help the swine virus infect human cells. Sometimes,
an influenza virus can also infect a different species without reassortment. Usually, the virus is poorly adapted to the new species, cannot be transmitted efficiently, and quickly dies out. Occasionally, a virus is able to replicate and spread well in the new hosts, and a permanent jump is made.

Recently, the world has seen several examples of changing relationships between influenza viruses and their hosts. The first occurred when highly virulent H5N1 avian influenza viruses caused epizootics in poultry, and some of these viruses revealed an unexpected capacity to cause severe disease in mammals including humans, as well as in wild waterfowl.

**H5N1 Avian Influenza Epizootics**

**Low and High Pathogenicity Avian Influenza in Poultry**

Although many wild birds, particularly waterfowl and shorebirds, are infected with avian influenza viruses, these viruses are usually carried asymptomatically. In poultry, however, influenza viruses regularly cause disease. The viruses that cause serious illness in poultry, or carry the genetic potential to do so, are known as “high pathogenicity avian influenza (HPAI) viruses.” Flocks infected with these viruses usually have severe clinical signs, and up to 90-100% of the birds may die. All other avian influenza viruses, which are associated with much milder clinical signs or asymptomatic infections in poultry, are known as “low pathogenicity avian influenza (LPAI) viruses.” All HPAI viruses that have been detected so far carry the H5 or H7 hemagglutinin; LPAI viruses can be of any subtype. For example, if an H3N2, H2N1 or H8N5 virus is found in a chicken, it is almost certain to be an LPAI virus; however, an H5N1 virus might be either LPAI or HPAI, and this can be determined only by testing it. H5 and H7 LPAI viruses can mutate into HPAI viruses when they are circulating among poultry, which makes them a concern.

Outbreaks of high pathogenicity avian influenza occur periodically in poultry flocks throughout the world. HPAI viruses are often spread by poultry themselves, but outbreaks can also occur when viruses carried in wild birds are transmitted to poultry. Until recently, this almost always involved the transfer of an LPAI virus from wild birds to poultry, followed by reassortment with other avian influenza viruses and/or mutation of the virus to become an HPAI virus.

**The Emergence of High Pathogenicity Asian Strain H5N1 Influenza Viruses**

Many new isolates of avian influenza viruses come from southern China, where farmers often mix different species of terrestrial poultry, waterfowl, and pigs – a situation that allows influenza viruses from different species to acquire gene segments from each other. The island territory of Hong Kong, which imports large quantities of poultry from China, is considered to be a sentinel for these new viruses. Hong Kong maintains a comprehensive surveillance program that allows it to detect and respond to new influenza viruses quickly. From 1997 to 2002, Hong Kong experienced repeated outbreaks with various H5N1 influenza viruses. These disquieting outbreaks raised the suspicion that new, virulent reassortants of H5N1 were becoming established in the region.

The first outbreak occurred in Hong Kong poultry flocks in 1997. Before this epidemic, avian influenza viruses were not thought to cause serious disease in humans. Occasionally, conjunctivitis was reported among people who had been exposed to these viruses, but these infections seemed to be of little concern. The outbreak in Hong Kong, which began among poultry in late March, was caused by a strain of HPAI with the subtype H5N1. In May, an H5N1 avian influenza virus was isolated from a fatal case of acute pneumonia and respiratory distress syndrome in an otherwise healthy three-year-old boy. This virus, which seemed to be transmitted to people by contact with sick birds, eventually killed five more Hong Kong residents and caused serious illness in 12 others. The discovery that the H5N1/97 virus was pathogenic for humans added urgency to the eradication efforts. Approximately 1.5 million chickens in live bird markets and farms were slaughtered in a successful bid to stop the epidemic.

The H5N1 virus that caused this epidemic was a reassortant that contained genes from several different species of birds. One of the ‘parent’ viruses was an H5N1 virus from geese, while another segment was contributed by influenza viruses found mainly in quail. The reassortment between these viruses was probably facilitated by the mixing of bird species in Hong Kong’s many retail live bird markets. These markets, where poultry is bought live, and killed and plucked in front of the customer, are very popular among Hong Kong consumers. In 1997, the live bird markets contained waterfowl such as ducks and geese, and terrestrial birds such as chickens, quail, and guinea fowl. In addition to allowing new reassortant viruses to arise, these markets facilitate their spread; birds not sold at the market and returned to the farm may carry new infections with them.

To prevent the reemergence of another H5N1/97-like virus, Hong Kong established a central slaughterhouse for ducks...
and influenza viruses found in these aquatic poultry separate from other influenza viruses found in terrestrial birds. Terrestrial poultry—chickens, quail, pigeons, pheasants, and guinea fowl—continued to be sold and slaughtered in the retail live bird markets. After 1997, Hong Kong also established an elaborate system of blood tests, inspections, and quarantine rules to screen imported birds, as well as a surveillance system to test birds at the central slaughterhouse and in the live bird markets. Although the zoonotic H5N1 virus isolated in 1997 was successfully eradicated from poultry, individual viruses containing its gene segments continued to circulate among birds in the region.

**Avian Influenza in Hong Kong, 1998-2002**

After 1997, Hong Kong continued to maintain surveillance for new viruses and rapidly stamped out each outbreak. The poultry population of Hong Kong was partially or completely depopulated three times in five years.

For a time, Hong Kong’s separation of terrestrial and aquatic poultry seemed to work. From 1999 to 2001, H5N1 viruses were intermittently isolated from geese and ducks at the central slaughterhouse, but no H5N1 viruses were found during routine surveillance in the live terrestrial poultry markets. Then in April 2001, H5N1 viruses were found in apparently healthy poultry in three of eight retail markets. There were no clinical signs of HPAI until mid-May, when three markets reported that the mortality rates in their poultry had increased greatly. More than a million birds in markets and on farms were euthanized to stop this outbreak, at a cost of nearly $4 million. This time, avian influenza viruses from waterfowl had been able to infect terrestrial poultry by reassortment with other waterfowl viruses. There were fears that such viruses might reassort with viruses still circulating among quail in the live bird markets, and produce another isolate that could infect humans. After the 2001 outbreak, Hong Kong authorities prohibited selling live quail where other poultry were sold in live bird markets. To interrupt the amplification of any viruses that might enter the retail markets, a once-a-month “rest-day” was also introduced. On these rest days, the live bird markets are completely emptied of poultry, any remaining poultry are slaughtered to be sold as chilled carcasses, and the markets are thoroughly cleaned before being restocked the following day.

Late in 2002, Hong Kong once again had an outbreak with H5N1 viruses—this time in wild birds at two nature parks. These viruses caused neurological signs in various resident waterfowl including geese, ducks, swans, and flamingos, and killed many of these birds. Terrestrial and feral birds at the parks, such as captive psittacine and passerine birds and free-ranging pigeons, seemed to be unaffected. Both parks were closed, drained, and disinfected, and the surviving waterfowl were killed or quarantined. At the same time, H5N1 viruses were found in dead chickens in live bird markets and on a local chicken farm. H5N1 viruses were also isolated from dead egrets, herons, and other wild migratory birds that overwinter in Hong Kong. More than one virus seemed to be responsible for these outbreaks; at least three different H5N1 viruses isolated in late 2002 were able to cause severe disease and death in experimentally infected ducks.

Epidemics of avian influenza are very unusual in wild birds. These viruses seemed to be stable in their normal reservoir hosts. Before the 2002 H5N1 outbreak, researchers had seen little or no evolutionary change in the viruses isolated from wild waterfowl over the last 60 years. Earlier viruses found in Hong Kong, including the H5N1 virus isolated in 1997, did not replicate well in ducks and had been asymptomatic in waterfowl. The repeated outbreaks of H5N1 viruses in Hong Kong in 1997, 2001, and 2002 suggested that H5N1 viruses had become widespread in the region, and that new epidemic or epizootic strains might emerge through reassortment. During this time, there were also hints that viruses pathogenic to humans might be circulating in Mainland China. In 2003, an H5N1 virus was found in two members of a Hong Kong family who had traveled to China. The five-year-old son recovered, but his father died. Another family member died of a respiratory illness while in China, but was not tested for the virus.

**Avian Influenza in Southeast Asia, Europe, and Africa, 2003-2009**

In 2003, a new outbreak occurred. This time, it was widespread. From late 2003 to March 2004, HPAI (H5N1) viruses were reported among poultry, particularly chickens, in a number of countries in Asia. More than 100 million birds died or were culled in an effort to stop the epizootic. In rare instances, this virus was able to infect humans. Thirty-five human cases were confirmed in Thailand and Vietnam. Most were the result of direct contact with birds. In many parts of Southeast Asia, people live in close contact with their animals, including poultry, facilitating the spread of zoonotic pathogens. The human cases were severe, and 24 of the 35 infections were fatal. By March 2004, eradication efforts seemed to have contained the poultry epizootic, and human infections were no longer being reported in most nations. However, beginning in June 2004, Asian countries once again began seeing HPAI in poultry. Human cases were again reported. Vaccination of poultry was used with success in some countries, resulting in a reduction in the number of human cases. Although at times this epidemic appeared to be under control, eradication was never complete. The U.S. Centers for Disease Control and Prevention (CDC) warned that the H5N1 virus seemed to have become endemic among birds in Asia.

In 2005, H5N1 viruses spread beyond Southeast Asia. They were first reported in Russia and Kazakhstan. Authorities in these countries hoped to confine the virus to Asia by intensive control methods. However, in 2006, the virus spread to Europe and Africa. The virus continued to evolve, with new strains appearing that were able to infect humans with severe, sometimes fatal outcomes. As of 2009, the virus remained a major threat to both humans and domestic poultry in many parts of the world.
eradication efforts, but within a few weeks, an Asian strain
H5N1 virus passed the Ural Mountains, the boundary
between Europe and Asia, and appeared in Turkey and
Romania, prompting mass culls. The outbreaks continued to
smolder and spread, and eventually Asian strain H5N1 viruses
reached other parts of Asia, Europe, Africa, and the Middle
East. Although some countries have been able to eradicate the
virus, new outbreaks continue to occur each year.

The Asian H5N1 strains responsible for this epidemic have
a disquieting ability to cause serious disease in species other
than poultry. As of July 2009, they have been responsible for
approximately 430 human infections, generally as the result
of close contact with poultry; about 60% of these cases were
fatal. These H5N1 viruses have also caused disease in other
mammals including tigers, leopards, housecats, dogs, palm
civets, and stone martens. In addition, numerous deaths have
been reported in migratory wild birds, which usually carry
avian influenza viruses asymptomatically, and lethal infections
have been reported in songbirds. There are fears that an avian
H5N1 virus could eventually become adapted to humans,
resulting in a severe human pandemic. Recombination
between an avian H5N1 virus and a human influenza virus
might facilitate such an event. Because the human population
does not have immunity to H5N1 (the currently circulating
human influenza viruses are H1N1, H1N2, and H3N2), a
human-adapted H5N1 virus might spread rapidly and widely.
Reports of sustained person-to-person transmission would
be a signal that the H5N1 virus is adapting to humans. As of
July 2009, there have been no reports of such an event, and
no evidence that any H5N1 viruses have recombined with
human influenza viruses.

The Discovery of Other Zoonotic Avian
Influenza Viruses

Awareness that avian influenza viruses can cause serious disease
in people has led to the recognition of zoonotic infections
with other subtypes of these viruses. Between 1997 and 2009,
sporadic human infections were reported with various H7
viruses and H9N2 viruses. Most zoonotic infections with non-
H5N1 viruses have been limited to conjunctivitis or relatively
mild respiratory disease, but rare severe or fatal infections
have also been seen. Human cases mainly seem to result from
direct contact with infected poultry, although rare instances of
limited person-to-person transmission have been documented.
These discoveries have increased zoonotic concerns about all
HPAI outbreaks among poultry.

High Pathogenicity Avian Influenza
in the U.S. and Canada

High pathogenic avian influenza is a foreign animal disease
in both the U.S. and Canada. Only three or four outbreaks
have been recorded in the U.S. since 1900. The first, in 1924-
1925, was associated with live bird markets. HPAI was seen
again in 1929, either as a new outbreak caused by the same
virus or as a new introduction. This disease was not reported
again until 1983, when an H5N2 virus caused an extensive
epidemic in Pennsylvania and the surrounding states. This virus
was very similar to an LPAI virus that had been circulating in
the area for six months. As a result, some birds had immunity
to the HPAI virus, which complicated diagnosis and probably
helped the virus spread further. Control and eradication of
this epizootic, which was not completed until 1984, cost over
$63 million in federal funds and an additional $350 million
in increased consumer costs. In 2004, a different H5N2 HPAI
virus was isolated from a south-central Texas broiler chicken
flock that supplied live bird markets. This virus did not cause
severe disease in chickens; however, its genetic makeup, which
suggested that it had the potential to do so, caused it to be
classified as an HPAI virus. As a result, the USDA and state of
Texas culled the birds in the flock. Events such as these have
raised awareness of the potential for LPAI viruses to mutate
to HPAI viruses. All H5 and H7 viruses, whether classified as
HPAI or LPAI, are now reportable to the OIE.

Before 2004, Canada had not reported a case of HPAI to
the OIE but, in March 2004, HPAI was identified in British
Columbia and in September 2007, in Saskatchewan. Both
outbreaks are thought to have been introduced into poultry
from wild birds. These two outbreaks followed very different
courses, primarily due to the differences in the poultry
industry in the two regions, i.e., highly concentrated in British
Columbia and widely distributed in Saskatchewan. In March
2004, HPAI (H7N3) was detected in birds from a commercial
chicken breeder farm in British Columbia’s Fraser Valley. LPAI
(H7) had been found in older poultry from this same farm
approximately three weeks earlier. By mid-May, birds on 42
commercial and 11 backyard premises in the Fraser Valley
were declared infected with HPAI. Although not proven, it is
thought that LPAI was introduced into the older flock on the
index farm by wild waterfowl and that the virus then mutated
to HPAI strain, which subsequently infected younger poultry
on the same farm and spread to other farms. To control this
outbreak, approximately 17 million commercial poultry were
depopulated at a total cost of $80.7 million in Canadian dollars.

It is estimated that the poultry industry in British Columbia
suffered losses of between 222 and 252 million in Canadian
dollars in sales and production margin losses. The virus in this
outbreak also caused human disease. Although a number of
exposed or potentially exposed individuals reported symptoms
of influenza-like illness and/or conjunctivitis, only two of
these individuals were ultimately confirmed as being infected
with the H7N3 strain of avian influenza. In late September
of 2007, HPAI (H7N3) was detected on a broiler hatching-
egg operation in southern Saskatchewan. The affected poultry
operation was located in a major wild bird breeding area
related to the Central and Mississippi flyways. A freshwater
dugout located on the premises was used as a secondary water
source for the poultry. It was hypothesized that the influenza
virus in this outbreak was introduced through contaminated
drinking water from the dugout, or through farm workers and wild animals. Poultry operations are widely distributed in this area, and the infection remained confined to the index farm. No zoonotic infections were reported in this outbreak.

U.S. and Canadian Efforts to Exclude H5N1 and Other HPAI Viruses

Like other countries, the U.S. and Canada are concerned that the Asian strain H5N1 viruses could enter domesticated poultry flocks or wild birds. In the U.S., APHIS has re-examined its HPAI prevention and eradication plans in light of that epidemic. All imported birds must now be quarantined and tested for avian influenza viruses before they enter the country. In addition, APHIS has placed trade restrictions on the importation of poultry or poultry products from countries that have reported cases of HPAI. APHIS has alerted the U.S. Department of Homeland Security to be particularly vigilant in its agricultural inspections of passengers and cargo from Asia, and has increased its surveillance of domestic markets for illegally imported poultry products. The U.S. Fish and Wildlife Service, together with APHIS and state wildlife agencies, is conducting surveillance for HPAI viruses in wild birds. In addition, the USDA is working with the OIE, the United Nations’ Food and Agriculture Organization (FAO), and World Health Organization (WHO) to help affected countries and their neighbors with disease prevention, management, and eradication to reduce the global threat from this virus.

Canada is closely monitoring global avian influenza developments, particularly the spread of the Asian H5N1 strain. The Canadian Food Inspection Agency (CFIA), in collaboration with other government agencies, has put in place safeguards to limit the introduction and spread of avian influenza. These safeguards include enhanced surveillance, enhanced biosecurity, import controls, and emergency preparedness. Canada has two surveillance programs, one targeting wild birds and the other domestic poultry. In 2006, over 12,000 birds were tested through the wild bird surveillance program; there were no findings of HPAI including the Asian strain of H5N1. In light of the increased risk of avian influenza, the CFIA has focused attention on protecting domestic poultry through effective use of on farm biosecurity measures. In the case of commercial flocks the CFIA promotes best practices and provides technical advice to ensure that the most effective and uniform practices are used across the industry. In cooperation with the provinces and territories, the CFIA has created an awareness campaign to inform smaller producers of the best biosecurity practices. Canada now prohibits trade in poultry, poultry products, and birds from any country until domestic poultry in that country are proven free of HPAI. New quarantine and inspection requirements have also been implemented for countries recognized free of HPAI. In addition to the processes in place to prevent introduction of avian influenza, Canada has also enhanced its efforts towards responding to an outbreak. These enhancements include the formation of dedicated emergency response teams, development of detailed procedures for response in the case of an outbreak, use of avian influenza scenarios and exercises, development of partnerships with other levels of government and external bodies, and identification of personnel and equipment that could be required to provide surge capacity in the case of an outbreak.

H3N8 and the Canine Influenza Virus

While there is no sign that avian H5N1 viruses are becoming adapted to replicate among humans, an H3N8 equine influenza virus recently made a successful jump into dogs. This is the first canine influenza virus that has ever been reported.

In January 2004, 22 racing greyhounds at a Florida racetrack became ill with an unknown respiratory disease. Fourteen of the dogs developed a fever, followed by a persistent cough that lasted for 10 to 14 days. These dogs recovered. Eight other dogs died suddenly with signs of severe hemorrhagic pneumonia. Using lung tissue samples from the dead dogs, researchers discovered an influenza A virus that was very similar to an H3N8 equine influenza virus that circulates in horses. No influenza virus had ever become established in dogs before. Serology using paired acute and convalescent sera demonstrated that the recovered dogs had also been infected by this virus.

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Although canine influenza continued to be reported among greyhounds in a number of states, this virus did not seem to
be a threat to other breeds of dogs at first. Experimentally infected beagles developed a fever, but no respiratory signs. However, since that time, cases of H3N8 canine influenza has been reported in a variety of breeds at veterinary clinics, animal shelters, pet stores, and boarding kennels in the U.S. All dogs regardless of breed or age are now considered to be susceptible. One study suggests that canine influenza is rare, if it exists at all, in Canada. In the province of Ontario, a survey found antibodies to the H3N8 virus in only one of 225 dogs in 2006. This dog was a greyhound that had come from a racetrack in Florida, and may have been infected there. It had no recent history of respiratory disease, and there has been no additional evidence of canine influenza in Ontario or elsewhere in Canada.

Canine influenza is an emerging disease in dogs, which are not expected to have any immunity to influenza viruses. In kennels, the infection rate may reach 100 percent, and clinical signs often occur in 60-80 percent of the dogs infected. Most dogs are expected to develop a relatively mild form of the disease, which is characterized by a cough that may persist for weeks in spite of treatment. Many dogs recover spontaneously. Occasionally, the cough is accompanied by a fever and/or a nasal discharge that appears to be caused by secondary bacterial invaders, and responds to antibiotics. A few dogs develop more severe disease with signs of pneumonia or bronchopneumonia. Peracute deaths with evidence of hemorrhages in the respiratory tract have been reported among racing greyhounds, but this syndrome seems to be rare or nonexistent in pets. The mortality rate is thought to be 1-5 percent, and deaths mainly occur in dogs with the more severe syndromes. Secondary bacterial infections appear to contribute significantly to these deaths. In 2009, a USDA licensed vaccine for canine influenza became available in the US.

There is no evidence that any other species, including humans, can be infected by the new canine influenza virus. However, some experts are concerned that, due to their close associations with humans, dogs might become a source of novel influenza virus transmission to humans. As a precaution, physicians, veterinarians, and others have been asked to report any cases of human influenza that seem to be linked to exposure to canine influenza.

**The H1N1 Swine Origin Influenza Virus**

Although there has been some concern that the canine influenza virus might be able to reassort with human influenza viruses, as well as significant fear that the next human influenza pandemic might be caused by an avian H5N1 virus or a reassortant of this virus, the first pandemic of the 21st century came from a different source – a novel H1N1 virus that was produced by reassortment between two or more swine influenza viruses.

Influenza pandemics (widespread epidemics) can occur in the human population when a virus with a hemagglutinin protein to which people have little or no immunity emerges and spreads efficiently from person to person. In the 20th century, pandemics were caused by an H1N1 virus in 1918 (Spanish flu), an H2N2 virus in 1957 (Asian flu), and an H3N2 virus in 1968 (Hong Kong flu). All three viruses contained at least some genes from influenza viruses found in animals, and in all three cases, the hemagglutinin genes originally came from avian influenza viruses. The Asian flu and Hong Kong flu viruses were reassortants that had recombined with human influenza viruses.

On April 21, 2009, the CDC reported that H1N1 swine influenza infections had been found in two children in California. The cases were diagnosed as the result of routine surveillance for influenza viruses, when isolates that were untypeable as any known human influenza virus were forwarded to specialized laboratories for further analysis. Although both children had mild symptoms, the infections concerned public health officials. Neither child had any history of contact with pigs, which suggested that they might have been infected by person-to-person transmission. Other members of their families had also been ill with influenza-like illnesses. Soon afterward, six more confirmed infections with this virus were reported in California and Texas.

At about the same time, it became apparent that an ongoing outbreak of respiratory disease in Mexico was caused by the same virus. In April, reports of an unexpected number of respiratory illnesses, including serious atypical pneumonia, began to concern Mexican officials. Mexican authorities sent clinical samples with an unusual influenza virus to the Public Health Agency of Canada (PHAC). On April 23, the PHAC reported the isolation of a swine-origin H1N1 virus from these samples. A retrospective survey revealed nearly 2,000 human cases that may have been caused by this virus between March 1 and April 30. The illness appeared to be widespread throughout Mexico.

At first, surveillance in other countries focused on travelers who had been to Mexico. The novel H1N1 virus was identified in the U.S. and Canada, and soon afterward, among travelers in other countries. As surveillance increased, cases of person-to-person spread were also revealed. By May 13, this virus had been officially reported in 33 countries, with at least 5,700 known cases and 61 deaths. Most of the first cases were reported from North America, with the vast majority of the deaths in Mexico. The virus spread quickly, and in June, the World Health Organization declared a pandemic. By September, more than 29,000 laboratory-confirmed cases in countries around the world and at least 3400 deaths had been reported to the WHO. Many additional mild infections have probably occurred. Overall, the rate of serious illness from this virus, as of Fall 2009, appears to be similar to human seasonal influenza. However, severe or fatal cases have been reported in some healthy young people, as well as pregnant women and individuals with underlying health conditions. Some populations, including aboriginal communities in Canada, have been disproportionately affected by the novel H1N1 virus.
Where Did the New H1N1 Virus Come From?

The novel H1N1 virus contains gene segments from three swine influenza viruses - a Eurasian H1N1 virus, a North American H3N2 triple reassortant virus, and the H1N1 ‘classical’ swine influenza virus. This particular combination of gene segments has not been found previously among pigs or people, except those affected by the 2009 outbreak. Genetic analysis suggests that this virus was probably transmitted to people as either a single event or as multiple events involving very similar viruses, and that it probably occurred fairly recently. It is possible that the ancestors of this virus are circulating among pigs in some part of the world; however, as of October 2009, these viruses have not been detected in any country where surveillance for swine influenza viruses is conducted regularly.

Swine influenza viruses are very common in pigs throughout the world. Pigs seem to acquire new influenza viruses fairly readily, but all of these viruses do not become established in swine populations, and some disappear after a time. Many swine influenza viruses have gene segments from human or avian influenza viruses, acquired by reassortment. Some human and avian influenza viruses have also been transferred “whole” into pig populations. Some of the most changeable viruses in pigs are triple reassortant H3N2 swine influenza viruses, which appeared in North America late in the 1990s through reassortment between a human H3N2 influenza virus, an avian influenza virus, and the classical H1N1 swine influenza virus. The latter virus had been circulating among pigs for decades with relatively little change in its genome, and is related to H1N1 human influenza viruses. The triple reassortant H3N2 viruses tend to recombine fairly readily with other viruses, producing new variants with a different hemagglutinin and/or neuraminidase.

Infections with various swine influenza viruses are reported sporadically among people who have contact with pigs. Many cases are clinically indistinguishable from human seasonal influenza, but a few fatal infections have been reported in people who were not expected to be at high risk for severe disease. Although swine influenza viruses have occasionally been transmitted to a few close contacts, there is usually no sustained transmission of these viruses in people. One incident with more extensive person-to-person transmission occurred in the 1970s during an outbreak at a military base in Fort Dix, New Jersey, raising fears of a human pandemic with a swine influenza strain. However, the virus in this outbreak disappeared from the military base and never spread to the general population.

The Swine Origin H1N1 Virus in Pigs, Turkeys and Other Animals

Early evidence suggests that pigs have limited immunity to the novel swine-origin H1N1 virus. The novel H1N1 virus has sporadically entered pig farms since the human outbreaks began and surveillance was initiated in swine. In a number of cases, these viruses seem to have been transmitted to pigs from people. Outbreaks in pigs have been characterized by mild respiratory disease but a few pregnant animals have aborted. The morbidity rate has been as high as 90 percent in some herds, but deaths have been rare.

Turkeys are infected fairly often with swine influenza viruses. Turkeys infected with these viruses usually develop respiratory disease, have decreased egg production, or produce abnormal eggs. The novel H1N1 virus has been reported in turkeys on a few farms in Chile, Canada and the U.S. Decreased egg production was the principal sign of disease. In Chile, approximately 61 percent of the flock was affected, but no birds died. Mild to severe illness has also been recognized in a few ferrets, cats and dogs, as well as a cheetah in a zoo. Some cases in cats and ferrets were fatal.
What Does the Future Hold?

Severe pandemics such as the 1918 Spanish flu can occur in waves as the virus adapts to humans. Whether such waves will occur, and whether more virulent strains of the novel H1N1 influenza virus will emerge is unknown. Most people appear to have little or no immunity to this new virus. A human vaccine is expected to help interrupt transmission. Similarly to previous pandemic viruses, the swine-origin H1N1 virus will probably continue to circulate among human populations, at least for a time. As such viruses become well established among people, they become typical seasonal human influenza viruses and are controlled by annual flu vaccines. Several swine herds have also been infected, suggesting that this virus is readily transmissible in pigs and a panzootic is possible in this species. There seems to be little or no threat to humans from this source, particularly as the virus is already being transmitted widely among people. In addition, influenza viruses are readily killed by cooking, and transmission via properly handled and prepared pork products is highly unlikely. The outbreak in turkeys raises concerns, particularly if birds were to be infected with this virus in countries where the Asian strain H5N1 avian viruses circulate.

Given the changeability of influenza A viruses, it is certain that these viruses will continue to provide surprises. Whether the Asian strain H5N1 avian influenza viruses will be among those viruses that adapt to new species is still unknown. However, surveillance systems and pandemic plans that had been established for a potential human pandemic with this virus helped ensure a rapid response to the swine-origin H1N1 virus. Responses to influenza viruses illustrate how good preparedness and awareness of unusual cases can help detect a new pathogen, even if its origins are unexpected.

Information Sources for this chapter can be found at: http://www.cfsph.iastate.edu/EEDATextbookReferences/