FRI BRIEFINGS

White Paper on Human Illness Caused by *Salmonella* from all Food and Non-Food Vectors

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INTRODUCTION

Salmonella spp. have been recognized as human and animal pathogens for over a century. Numerous serotypes have been described, but seven of these (Enteritidis; Typhimurium; Newport; I 4,[5],12:i:-; Javiana; Heidelberg; Montevideo) were responsible for 61.6% of human cases in the U.S. in 2007. According to recent data from FoodNet, the incidence of salmonellosis has not diminished significantly over the past ten years but some serotypes have increased or decreased in importance (*114*). Most serotypes are not host-specific, but a few species are restricted to one kind of animal such as *S.* Pullorum in chickens and *S.* Typhi (causative agent of typhoid fever) in humans. With the exception of typhoid and paratyphoid fevers, cases of salmonellosis generally involve mild to moderate symptoms of gastroenteritis lasting for about five days. However, the very young, the old, and the immunocompromised may contract more severe infections (*207*). Salmonellae may also cause urinary tract infections and sometimes migrate out of the intestine and cause septicemia and reactive arthritis (*257;401;437;477*).

Several large outbreaks of salmonellosis have occurred during the past year. *S.* Typhimurium present in municipal tap water affected over 400 people in Colorado (*56*) and *S.* Typhimurium, believed to be carried in pork, has made more than 1000 people ill in Denmark (*175*). Perhaps the most noteworthy outbreak in 2008 was the nationwide illness caused by *S.* Saintpaul that extended for several months while investigators sought to pinpoint the fresh produce vehicles of infection (*113*).

Salmonella spp. are estimated to cause about 1.4 million non-typhoidal infections in humans per year in the U.S., and it has been estimated that 95% of these cases were due to consumption of contaminated food (*315*). Additionally, 300–400 cases of typhoid fever are reported yearly in the U.S. (*116*). Although salmonellosis is typically not fatal, the large number of cases that occur annually does have a significant economic impact on individuals, the health care system, and businesses associated with outbreaks.

Salmonellae naturally live in the intestines of humans and other animals; therefore, fecal material is the ultimate source of these bacteria. Of the ten *Salmonella* serotypes detected most frequently in human infections, six are also among the most common isolates from swine and poultry. *Salmonella* serotypes in farm animals have changed over time as husbandry practices have become more intensive and as the international trade in feed has increased (*185*).

Not all animal sources are farm animals even though consumers frequently think of salmonellae as associated with poultry. Several kinds of meat-producing animals, baby poultry, many pets (particularly reptiles but also cats and other mammals), and wild animals such as hedgehogs have been reported as vehicles for salmonellosis. Fecal material from infected humans and animals may be transferred directly by contact to humans or may contaminate meat during slaughter, fresh produce in the field, foods during preparation, and drinking water.

EPIDEMIOLOGY OF SALMONELLAE

Outbreaks and Cases

A majority of *Salmonella* cases are never linked to outbreaks. In fact, at FoodNet sites in 2007, *Salmonella* isolates from outbreaks comprised only 5.4% of the total *Salmonella* cases identified; the remaining 94.6% of cases were sporadic with no known connection to other cases (*114*). CDC estimates that the true incidence of *Salmonella* infections in the U.S. is about 38-fold greater than the number of cases actually reported. This is because most people experience moderate symptoms and do not seek medical care. Even if a doctor is consulted, clinical samples may not be sent for analysis unless symptoms are severe or a recognized outbreak is in progress. Although most reported cases of salmonellosis are sporadic and not specifically related to an identified outbreak, this review emphasizes disease outbreaks because there is more epidemiological information available about potential sources and transmission of salmonellae.

Salmonellosis is typically not fatal, but about 15,000 cases annually in the U.S. require hospitalization and over 400 deaths occur (*464*). The Economic Research Service of the USDA estimates that 87.6% of people contracting this disease do not seek medical care but some people miss one or more days of work. The relatively large number of cases makes salmonellosis a high profile disease. Even though illness caused by salmonellae is, on average, less severe than that caused by *E. coli* O157:H7, the fact that about twenty times more cases of salmonellosis occur results in a five- to six-fold greater economic cost. See Table 1 (*see p. 3*) for some estimates from the ERS website's Foodborne Illness Cost Calculator (www.ers.usda.gov/data/foodborneillness/).

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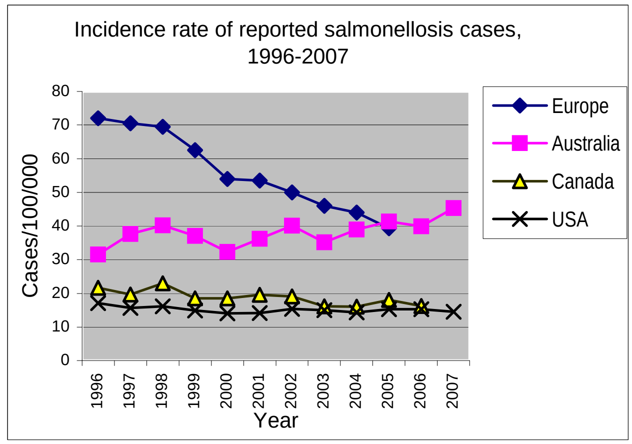
Table 1. Comparison of estimated total cases of foodborne illness, morbidity, mortality, and economic costs due to non-typhoidal Salmonellae and *E. coli* O157:H7 annually in the U.S.

	Salmonella spp.	*E. coli* O157:H7
Total cases	1,397,187	73,480
% not visiting doctor	87.6%	78.5%
% hospitalized	1.06%	2.95%
% fatal	0.03%	0.083%
Average cost/case overall	$1821.00	$6256.00
Total estimated cost	$2,544,394,334.00	$459,707,493.00

Nearly 500 salmonellosis outbreaks in the U.S. and other countries, most occurring during the past ten years, have been tabulated chronologically in Appendix 1 (*see p. 44*). Information on these outbreaks was gathered from scientific journal articles, websites, and publications from several national governments. Not all outbreaks are investigated thoroughly and not all are described in accessible literature, but these outbreaks indicate trends in infections and changes in the importance of some serotypes and vehicles of infection.

Data from the European Union, Australia, Canada, and the CDC in the U.S. from 1996 to 2007 demonstrate a marked decrease in salmonellosis in Europe, an increase in Australia, and slight decreases in Canada and the U.S. (*see chart, right*) (*11;116*) (www9.health.gov.au/cda/Source/CDA-index.cfm) (dsol-smed.phac-aspc.gc.ca/dsol-smed/ndis/index_e.html). A few points should be considered in interpreting this graph. In comparing different geographical areas, the relative incidence rates may not be true differences but rather may reflect more or less intensive surveillance systems. Australia instituted a more comprehensive national surveillance system in 2000 and this may partially account for the observed increase in salmonellosis. The European Centre for Disease Prevention and Control reports that despite the overall decreasing trend for Europe over the last ten years, some individual countries have reported increases in salmonellosis cases. Japan reported a significant decrease in number of salmonellosis cases from 2003 to 2005. During this time, its total population decreased. However, Japan does occasionally experience very large outbreaks of salmonellosis which would alter their incidence rates (*25*).

Large outbreaks (greater than 200 cases) of salmonellosis during the past ten years are presented in Table 2 (*see p. 25*). The largest reported outbreak was a waterborne typhoid fever outbreak in Nepal in 2002. Of the next ten outbreaks, vehicles included chicken, pork, eggs, fresh produce, dried squid, cheese, and cake. Three outbreaks in Japan, associated with "boxed lunch" or "school lunch," were caused by *S.* Enteritidis. One or more of these outbreaks may have been due to contaminated eggs or chicken but the exact food vehicle is unknown. The Canadian cheese outbreak was caused by contaminated cheese in a commercial lunch pack product. A fresh produce (pepper, possibly tomato) outbreak occurred in 2008 in the U.S.



Reservoirs of Salmonellae

Farm Animals

Farm animals are considered to be a primary reservoir for important *Salmonella* serotypes associated with human infections. There are several *Salmonella* serotypes that cause diseases in domestic animals. Generally these are not as much of a concern to human health either because they do not cause illness in humans or because these serotypes cause animals to exhibit symptoms. Sick animals should not be sent to slaughter. *S.* Typhimurium and *S.* Enteritidis, the most common serotypes causing human infection, are frequently detected in farm animals as are other serotypes known to be human pathogens (Table 3, *see p. 4*) (*185*).

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Table 3. Four most common *Salmonella* serotypes reported in meat-producing animals (*26;27;32;33;185*).

Country/Region	Cattle	Chickens	Swine	Turkeys
USA	Typhimurium, Newport, Cerro, Agona	Heidelberg, Kentucky, Typhimurium, Enteritidis	Typhimurium, Derby, Heidelberg, Choleraesuis	Hadar, Senftenberg, Saintpaul, Typhimurium
Europe	NA	Enteritidis, Infantis, Typhimurium, Mbandaka	Typhimurium, Derby, Infantis, Bredeney	Bredeney, Hadar, Derby, Saintpaul

Pets

Turtles are the most commonly identified pets that are vehicles for human salmonellosis. However, in recent years a variety of other reptilian pets as well as some mammals have been found to carry salmonellae and pass them on to their human caretakers. It has been estimated that 6–7% of all sporadic *Salmonella* infections (and 11% of infections among young people aged <21 years) in the U.S. can be attributed to contact with reptiles and amphibians (*316*). Although some turtle-rearing facilities have treated turtle eggs with antibiotics to kill surface bacteria, this has not completely eliminated the bacteria and has selected for antibiotic-resistant strains (*154*).

Captive green iguanas, like other reptiles, shed salmonellae intermittently or continuously, and shedding appears to increase when animals are stressed (*78*). Investigations at a green iguana farm in El Salvador demonstrated that salmonellae were not present in the reproductive tract of females but were present on surfaces of eggs after laying and in soil samples (*322*).

Pet snakes at a breeding facility were found to be frequent carriers of *S.* diarizonae (*412*). Aquaria housing tropical fish have also been vehicles for human salmonellosis. Salmonellae were found in more than 50% of aquaria from homes, wholesale facilities, and pet shops that were tested during a survey to determine incidence of *S.* Paratyphi B (which had caused human illness) (*196;322;334*).

Pet rodents (hamsters, mice, and rats) purchased at retail stores have been found to carry multidrug-resistant *S.* Typhimurium (*428*). Cats and dogs may also carry salmonellae and have been implicated in some cases and outbreaks (*95;125;458*). Hedgehogs kept as pets have also been found to be a vehicle for human salmonellosis (*366*).

In nearly all cases of pet-associated human cases of salmonellosis, the animals themselves did not appear sick. Salmonellae may be part of their normal flora or transient non-pathogenic residents of the animals' digestive tracts.

Wild Animals

Salmonellae are present in a variety of wild animals, including birds and rodents that may transport these bacteria around and between farms and human environments. Mammals and birds serve as reservoirs for salmonellae and may also be vehicles of infection for humans. Salmonellosis is known to be a significant cause of mortality in some species of wild birds, and humans have acquired salmonellosis from infected birds (*221*). In New Zealand during the winter of 2000, hundreds of small birds died from infection with a virulent *S.* Typhimurium strain. Human cases also occurred in the same areas, and *S.* Typhimurium isolates from birds and humans were indistinguishable (*9*). Other studies of serotypes of salmonellae isolated from birds captured on a dairy farm in California (*270*) and in Norway and the UK indicated that many strains commonly detected in birds are seldom isolated from farm animals or humans, suggesting that some avian strains are host adapted and may not pose a health threat to humans (*246;340*).

An unusual outbreak of *S.* Typhimurium occurred among students and teachers in Minnesota in 2001. As part of an after-school activity, students dissected owl pellets (regurgitated bones and other indigestible material) to determine what the owls had been eating. Apparently they had consumed some salmonellae along with rodents and small birds (*419*).

Salmonellae also colonize small mammals that can pass infections to humans or farm animals. Investigation of outbreaks of *S.* Typhimurium 4,5,12:i:1,2 in humans in Norway in 2000 revealed that the identical serotype was present in a high percentage of hedgehogs that came to feeding stations (*226*). Hedgehogs apparently are a reservoir for some salmonellae and most likely constituted the primary source of infection for humans during these outbreaks. Identical or very similar strains of *S.* Enteritidis were detected in mice and rats associated with layer houses and in eggs from these houses, indicating that these rodents may be reservoirs that maintain infections in these houses (*193;282*).

Numerous other wild animals harbor salmonellae and in some cases appear to be the source of human infections (*40*). A recent survey of raccoons in Pennsylvania found that about 7–9% were asymptomatic carriers of salmonellae. *S.* Newport, one of the most common human isolates in the U.S., accounted for 22% of the raccoon isolates (*130*). *Salmonella* have been detected in white tail deer but prevalence appears to be low (*395*).

Surveys of wild turtles and other reptiles and amphibians in the U.S. have yielded mixed results. In some cases, multiple serotypes are identified in many animals and in other studies very few salmonellae were isolated. In recent studies, approximately 50% of 132 individuals of several species of turtles in Texas were found to carry salmonellae in cloacae/feces or in biofilms growing on their shells. Isolates of known human pathogens included *S.* Newport, *S.* Rubislaw, *S.* Thompson, and *S.* Gaminara (*190;191*).

Insect Transport Hosts

Several *Salmonella* serotypes have been isolated from flies and beetles on farms and poultry rearing facilities (*44;353;354*). These insects frequent fecal deposits where they could encounter salmonellae and may transport these bacteria to foods, feed and drinking water for farm animals. *S.* Enteritidis was detected both on and in houseflies present in rooms with hens carrying these bacteria. In experimental studies, about a third of unexposed hens that were fed contaminated flies developed gut infections but the presence of contaminated insects flying around in a room did not appear to induce infections in hens (*238*). Salmonellae, inoculated on darkling beetles and their larvae, were found to persist for at least one week (the usual time that poultry facilities are kept empty between rearing cycles in the Netherlands), indicating that they may be a vector for salmonellae between successive broiler flocks. Consumption of inoculated beetles by chicks resulted in colonization with salmonellae (*229*).

Serotypes

Salmonella taxonomy has undergone changes during the past 10 years as new analytical methods have provided more information on the relatedness of different strains. The international Kauffmann-White scheme for designating *Salmonella* serotypes was adopted by the CDC in 2003 in order to better coordinate and compare information among countries. There are now two species of *Salmonella*: *S. enterica* and *S. bongori*. *Salmonella enterica* is further divided into six subspecies. Most of the salmonellae that are important in foodborne disease belong to subspecies I, *S. enterica enterica*, and most of these serotypes are named (e.g. Typhimurium, Enteritidis). Some serotypes in the other *S. enterica* subspecies (II, IIIa, IIIb, IV, and VI) also have names but many are known by numbers. One example is I 4,[5],12:i:-, which caused an outbreak associated with pot pies in 2007. These numbers refer to the O and H antigens on the surfaces of cells of different serotypes. Subspecies I serotypes can also be designated by number but are usually referred to by their common name. A more complete description of this serotyping scheme, including lists of serotype names that have been changed, was presented in a Salmonella surveillance summary (*115*). The WHO Collaborating Centre for Reference and Research on *Salmonella* maintains and updates the correct nomenclature for salmonellae and validates new serovars (www.pasteur.fr/sante/clre/cadrecnr/salmoms/WKLM_2007.pdf).

S. Typhi is the most virulent salmonella and still causes large, often waterborne, outbreaks in developing countries, including one in Nepal in 2002 affecting nearly 6000 people (*290*). Such large outbreaks do not occur in more developed countries with chlorinated drinking water, adequate sewage treatment facilities, and pasteurized milk. The most recent large outbreak (over 200 cases) in the U.S. occurred in a migrant labor camp in Florida in 1973 (*356*). Nevertheless, 321–377 cases of typhoid fever have been reported annually in the U.S. during the past 10 years (*116*). Most recent cases are imported by travelers returning from abroad but some have been traced to imported foods (*262*) or to food handlers who may have recently immigrated.

S. Paratyphi A causes another serious enteric fever with symptoms that are often clinically indistinguishable from typhoid fever. Paratyphoid fever used to be considered less common and less serious than typhoid fever. However, the frequency of this disease has increased in the past few decades in some parts of South and Southeast Asia and also in the U.S. among imported cases. During a one-year period (2005–2006), 149 paratyphoid fever cases were confirmed in the U.S. (as compared to 378 cases of typhoid fever). Most of the patients reported recent travel to South Asia, and 87% of *S.* Paratyphi A isolates showed a decreased susceptibility to ciprofloxacin (*216*).

Over 2500 non-typhoidal *Salmonella* serotypes have been described but relatively few are important causes of foodborne disease. Serotypes associated with outbreaks described in the literature during the past ten years are listed in Table 4 (*see p. 26*) along with their associated vehicles, if known. Some serotypes have been found in or on a variety of foods while others appear to be more restricted in their habitat. For example, some serotypes are known to be more tolerant of dry conditions and are the more likely ones to be identified in foods with a low water activity. The relative importance of different serotypes in causing outbreaks is depicted in Figures 1 and 2 (*see p. 20*). *S.* Typhimurium and *S.* Enteritidis are usually the most commonly identified serotypes but other strains, including *S.* Hadar, S. Newport, *S.* Saintpaul and *S.* Oranienburg, have caused large numbers of cases. Figures 3 and 4 (*see p. 21*) illustrate the vehicles associated with infection by *S*. Enteritidis and *S*. Typhimurium. Meat, eggs, and fresh produce are the most important vehicles for both serotypes but eggs are relatively more important for *S*. Enteritidis and meat for *S*. Typhimurium.

The importance of *Salmonella* serotypes is also measured by the severity of disease. A series of 46,639 salmonellosis cases in FoodNet sites from 1996–2006 was examined to determine whether certain serotypes were more often associated with hospitalization, invasive disease, or fatalities. Overall, 22% of cases required hospitalization, 6.7% had invasive disease outside the gastrointestinal tract, and 0.5% died. *S.* Typhimurium, *S.* Enteritidis, *S.* Newport, *S.* Javiana, and *S.* Heidelberg were the most frequently encountered serotypes among the 687 identified. However *S.* Dublin and *S.* Choleraesuis caused the highest rates of invasive disease and hospitalization. Highest case-fatality rates were recorded for *S.* Dublin, *S.* Muenster, and *S.* Choleraesuis (*257*). A large series of 956,786 cases reported to Enter-net in Europe from 1994–2004 (*478*) and a smaller series of 6797 cases in Michigan (1995–2001) (*37*) also demonstrated that *S.* Dublin and *S.* Choleraesuis caused more severe illness than other serotypes. Different virulence factors are present in different serotypes, and these likely affect the potential for intracellular survival and invasiveness. In interpreting data on pathogenicity of different strains, it is important to look at some of the outbreak populations. Salmonellae infecting persons in hospitals or other institutions may cause more severe illness because these people have compromised immune systems.

According to data from the CDC, during the past ten years the most common *Salmonella* serotype isolated from humans in the U.S. has usually been *S.* Typhimurium, with *S.* Enteritidis often coming in a close second. These two serotypes account for between a third and half of the isolates while *S.* Newport and *S.* Heidelberg usually account for another 11–20% of the serotypes identified. Preliminary FoodNet data from 2007 indicated that *S.* Enteritidis isolates exceeded those of *S.* Typhimurium in the active surveillance areas (*114*). *S*. Enteritidis is most commonly associated with eggs (43% of outbreaks, 30% of cases) (Figure 3, *see p. 4*). Eggs may also have been the source of these bacteria in some outbreaks/cases associated with bakery goods and lunches.

S. Typhimurium is also consistently the most frequently isolated serotype in Australia. *S.* Enteritidis is much less common, with an estimated 380 cases annually of approximately 8400 total reported salmonellosis cases. Only about 50 cases/year are acquired locally and the rest are associated with overseas travel. *S.* Enteritidis is often associated with laying hens in other countries but the predominant phage type identified in Australia is absent in commercial egg-layer flocks (*272*). *S.* Saintpaul, the same serotype causing the 2008 U.S. outbreak associated with peppers and tomatoes, was associated with a large Australian outbreak involving melons in 2006 (*369*).

Until 1988, *S.* Typhimurium was the most frequent *Salmonella* isolate in Japan. Since that year, *S.* Enteritidis has taken over the top spot, accounting for about half the isolates in most years (*25*). This serotype has caused several very large outbreaks in Japan associated with boxed lunches, school lunch, and cakes (Table 3, *see p. 4*). *S.* Enteritidis is also the overwhelming cause of salmonellosis in Europe, accounting for 64–85% of isolates serotyped each year. *S.* Typhimurium usually comes in second, associated with 10–13% of outbreaks, with other serotypes occasionally responsible for important outbreaks (*11;150*). *S*. Enteritidis is the most frequently reported serotype from Africa, Asia and Latin America, with *S*. Typhimurium and *S*. Typhi ranking second and third in those regions (*192*).

Antibiotic Resistance and Human Illness

Antibiotics are not usually needed for treatment of the gastrointestinal symptoms caused by salmonellae, but they are critical for treatment of invasive disease occasionally caused by these bacteria. Increasing numbers of *Salmonella* isolates are resistant to one or more antibiotics and this increases the difficulty and cost of treating seriously ill patients. In the 1990s, *S.* Typhimurium DT104, resistant to five antibiotics (ampicillin, chloramphenicol, streptomycin, sulfonamides, and tetracycline) emerged in Europe and has since spread to many other countries. Infections with this multiresistant strain in the U.S. are most often sporadic but outbreaks have also occurred, including one linked to commercial ground beef in 2003–2004 (*146*). Multidrug-resistant *S.* Newport has become more common recently (*261;460*). Some recent review articles on antibiotic resistance in salmonellae provide more details on emerging patterns and mechanisms of resistance (*7;185*).

Increasing rates of antimicrobial resistance have been reported in countries around the world, and global trade in a wide variety of foods has highlighted the potential problem of importation of antibiotic-resistant human pathogens on foods. Two recent studies demonstrated this. One depicted dissemination of a multi-drug resistant strain of *S.* Schwarzengrund from chickens to humans in Thailand and also internationally on chicken exported from Thailand (*1*). Analyses of all *Salmonella* isolates from poultry in Denmark from 1998–2002 revealed that resistance to naladixic acid was twice as frequent in strains from imported as compared to domestic meat. Significantly higher proportions of salmonellae on imported meats were resistant to one or more antibiotics (58% imported; 26% domestic) and were multidrug resistant (28% imported; 4% domestic) (*418*).

Infection with antibiotic-resistant salmonellae has been reported to result in higher rates of invasive disease, hospitalization, and death. Among outbreak cases of salmonellosis reported to CDC from 1984 to 2002, 22% of those infected with resistant salmonellae were hospitalized while only 8% of those infected with susceptible strains required hospitalization (*459*). Risk for hospitalization was 4.6-fold higher for those infected with strains resistant to five antibiotics (*461*). Resistance to antibiotics may make treatment of serious infections more difficult and early empirical treatment may fail. Treatment with antimicrobial compounds (for conditions other than gastroenteritis) prior to infection with salmonellae appears to increase risk for infection with antibiotic strains, according to a case control study of infections with susceptible and resistant strains of *S*. Typhimurium in the U.S. (*205*).

But is there also a connection between antibiotic resistance and invasiveness in *Salmonella*? Or, do increased rates of hospitalization and death reflect failures in treatment? A registry-based study in Denmark found that people infected with a susceptible strain of *S*. Typhimurium had a 2.3-fold higher mortality rate as compared to the general population of people with similar age, gender, and residence. Those infected with antibiotic-resistant strains, including multiply resistant strains, had 4.8- and 13.1-fold higher rates of mortality, respectively (*233*). Another Danish study found a 3.2-fold higher risk for invasive illness or death in those infected with quinoline-resistant *S*. Typhimurium compared to those infected with susceptible strains (*232*). These data suggest that *Salmonella* that have acquired resistance to one or more antibiotics may cause more serious illness than susceptible salmonellae (*335*).

Two possible mechanisms for this connection between resistance and virulence have been proposed and there is some experimental evidence supporting them (*185*). Many genes encoding resistance are located on plasmid DNA, which is readily transmitted among related bacteria. Plasmids also encode some virulence factors that are important for pathogenicity. Analyses of field isolates of *S*. Typhimurium containing plasmids encoding antibiotic resistance genes revealed that these plasmids could recombine with a virulence plasmid and then transfer both antibiotic resistance and virulence to other *Salmonella* cells (*244*). One mechanism of antibiotic resistance involves an active efflux pump (AcrAB-TolC) that prevents bacterial cells from accumulating toxic amounts of antibiotics. These pumps are also involved in resistance to detergents and to bile salts in the intestine. Recent experiments demonstrated that the TolC outer membrane channel is important to the type III secretion system that transports bacterial proteins into host cells, thereby allowing invasion of intestinal cells. It appears that this same channel that is involved in export of harmful chemicals out of antibiotic resistant salmonellae is also involved in transport of important bacterial proteins into intestinal cells during invasion (*463*).

Routes or Vehicles of Human Infection

Salmonellae are shed in feces of infected humans and other animals and may be present on a person's hands, an animal's body, or the environment where an animal lives. In addition, manure from infected animals may wash into nearby bodies of water, including wells, water storage tanks, and irrigation systems. Manure may also be added to soil as fertilizer, thereby potentially contaminating crop plants. The various vehicles of infection reported for *Salmonella* outbreaks in the past decade are listed in Table 5 (*see p. 28*) along with the responsible serotypes and numbers of cases. Relative importance of different vehicles is depicted in Figures 5 and 6 (*see p. 22*). Over 40% of these outbreaks were traced to eggs, with meat and fresh produce also recognized as significant vehicles. "Lunch" and combination foods (such as pot pies) were associated with 9% of outbreaks and 21% of cases. Eggs or meat included in these foods may have been the real source but investigations did not prove this. More details on vehicles of infection are included in the following sections.

Direct Contact

Person-to-person spread of salmonellae has been the primary mode of infection in outbreaks in day cares and hospitals and other institutions, particularly where there have been lapses in hygiene. In other outbreaks, some individuals who consumed contaminated food or water and developed diarrhea, passed the infection directly to others in their families. An unusual case of person-to-person transmission in 2002 involved infection of newborn twins who were exposed to *S*. Typhi-

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murium DT 104 through their mother's milk (*391*). Another unusual outbreak occurring in 2000 involved the sexual transmission of typhoid fever among nine homosexual men who had relations with one asymptomatic *S*. Typhi carrier (*394*).

An outbreak occurring in 2006, best described as a result of direct contact, involved 21 employees of a company producing poultry vaccines. Following a spill of culture material containing about 10^{10} cfu/ml of *S*. Enteritidis, clean up materials were brought to another room for sterilization before disposal. The affected workers reported performing duties in this room and apparently acquired the infection from touching contaminated areas in the room (*110*).

Pets and farm and wild animals shedding salmonellae may pass infections to humans who handle them or materials contaminated with their feces. Such outbreaks have included contact with: young chicks and ducklings at schools or on farms (*122;317*), cats at veterinary clinics (*95*), fish aquaria (*196;334*), pet rodents (*428*), and, of course, pet turtles and other reptiles (*101;123*).

Humans have also been infected with salmonellae by handling pet food. A prolonged outbreak due to *S.* Schwarzengrund in the U.S. has been traced to a manufacturing plant that produced dry pet food. Despite cleaning after it was first determined as the source of the infection, the same facility produced more contaminated dog and cat food during a two-year period (2006–2008) (*117*). Outbreaks of *S.* Infantis and *S.* Thompson in the U.S. and Canada have been traced to pet treats, including those made from or containing seafood, beef, and pigs' ears (*106;127*). Testing of pet treats around the times of these outbreaks indicated that approximately 40–50% of treats contained salmonellae with as many as 24 serotypes identified. A recent survey of pet treats in Canada found that only about 4% were contaminated with salmonellae but many bacterial isolates were resistant to multiple antibiotics (*182*)

A multistate outbreak of *S.* Typhimurium, originally ascribed simply to handling of infected snakes, was eventually traced to a Texas facility that produced rodents to feed snakes and other carnivorous pets. The implicated strain of *S.* Typhimurium was detected in frozen feeder mice and in environmental samples from the production plant (*189;285*).

Salmonellosis occurring in wild hedgehogs in Norway was passed to humans who maintained feeding stations (*226*). Salmonellae have also caused numerous incidents of avian wildlife mortality. Of a series of outbreaks occurring over a 20-year period, 64% were definitely or possibly associated with bird feeders or feeding areas. Thus bird feeders may also be a source for human salmonellosis (*221*).

Contaminated Food

Meat. The importance of different categories of meat in reported outbreaks and cases of salmonellosis is illustrated in Figure 7 (*see p. 23*). Poultry and pork together were responsible for 63% of the outbreaks and 79% of the cases included here. FSIS presents data on their website indicating the importance of different meats as vehicles for human salmonellosis. An estimation of the percentage distribution of salmonellosis cases in 1998–2003 due to different types of meat stated that ground beef accounted for 19%, poultry for 26%, and pork for 2%. Cases attributed to ground beef and pork decreased by about one-half from 1998 to 2003 while cases related to consumption of chicken increased by 1.6-fold (*215*). Attribution data, elicited from 17 experts contacted by FSIS and from CSPI (Center for Science in the Public Interest) estimated that beef accounted for about 19–21% of cases, poultry for 51–64% of cases, and pork for 7–18% of cases (*445*).

Different sets of data were used to generate all these estimates but all indicate that contaminated poultry is the most common source of human salmonellosis. CSPI and FSIS considered data only from the U.S. while the outbreaks included in this review were international in scope. Several large outbreaks in Europe and Australia due to contaminated pork increased the importance of this vehicle from an international perspective.

Processed meats, such as ham, salami and sausage accounted for about 6% of the meat outbreaks. In addition, a small number of cases and outbreaks were traced to other meats, including lamb, pigeon, rabbit, horse, and turtle. A number of outbreaks were attributed to "meat" which may indicate a mixture of meats or cross-contamination in a butcher shop or kitchen where it was impossible to identify the original source of the salmonellae.

Eggs. Eggs are an important vehicle for salmonellosis, particularly for *S.* Enteritidis. This serotype can pass through egg shells after eggs are laid and can also infect the reproductive systems of hens and be deposited in the egg contents prior to egg shell formation. Despite antimicrobial compounds in egg albumen, *S.* Enteritidis can grow well in eggs stored at 21ºC (room temperature) (*124*).

Seafood. Seafood is not usually considered an important vehicle for salmonellosis. However, shellfish harvested from inshore areas may be exposed to runoff from human sewage or animal manure or droppings from seagulls that contain salmonellae (*6*). Shellfish, such as oysters, are filter feeders and concentrate bacteria (and also red tide toxins) from surrounding waters. A survey of oysters from the Atlantic, Pacific, and Gulf coasts of the U.S. found that an average of 7.4% contained salmonellae, with *S*. Newport most frequently isolated (*68*). Trace back of salmonella-contaminated frozen mussels in Spain revealed that mussels coming into the processing plant were free of salmonellae but tested positive for *S*. Senftenberg after passing through a brine pool. Investigators believed that the salmonellae may have entered the plant on the inexpensive sea salt used to make the brine and then persisted in several inaccessible sites in processing machinery, including in grease used for lubrication (*303*).

Investigations of salmonellosis attributed to shrimp on a cruise ship (*92*) and to smoked eel in Germany (*179*) revealed that both vehicles of infection were grown on farms. Eel were apparently contaminated prior to arrival at the smokehouses and the hot smoking procedure did not inactivate all the *S*. Blockley. Shrimp were also contaminated before delivery to the ship, most likely in ponds in Southeast Asia where they originated (*277*). Aquaculture ponds involved in these outbreaks may have been contaminated by runoff from manure or sewage containing salmonellae.

Other seafood salmonellosis outbreaks have been associated with contaminated egg used in preparation (*213*) and fish dried in the open under the sun, presumably contaminated by bird and/or rodent droppings (*293*). A very large outbreak of *S*. Oranienburg in Japan was traced to dried cuttlefish produced by a single company, but the mechanism of contamination was unknown (*224*).

Fruits and Vegetables. Fresh produce has become an important vehicle for foodborne infections in recent years. Figure 8 (*see p. 24*) illustrates the significance of different categories of produce (fruits, greens, sprouts, and tomatoes/peppers) in causing reported outbreaks and cases of salmonellosis. Tomatoes/peppers caused the largest number of outbreaks whereas sprouts caused the greatest number of cases. Recurrent outbreaks associated with alfalfa sprouts started occurring in 1995; outbreaks related to mung bean sprouts were first reported in 2000 (*324*).

There are many potential routes for contamination with salmonellae—from the farm field through harvest, cleaning, storage, and retail sale. Salmonellae can attach to leaves and fruits, and experiments have shown that some virulence factors, including fimbriae and some extracellular polymers (important for causing illness in humans) also aid in attachment to plant tissues (*47;48*). Two recent review articles discuss fitness of enteric pathogens on foods, and many factors and conditions related to preharvest contamination of fresh produce. Survival on the surface of many plant parts may be difficult for salmonellae because of the lack of nutrients and moisture, drastic changes in temperature, and ultraviolet radiation from the sun. However, plant surfaces are not uniform and there are protected areas where salmonellae may thrive (*59;67*).

Several *S. enterica* serotypes grow on and adhere to alfalfa sprouts better than *E. coli* O157:H7 and remain attached after repeated washing steps (*46*). If surfaces of fruits or leaves are damaged, either mechanically or through attack by other pathogens, such as molds or insects, salmonellae can penetrate into the plant, where it is impossible to remove by washing (*396*). Both acid-adapted and unadapted salmonellae are capable of growing in stem scar and pulp tissue of tomatoes stored at 12 and 21ºC and would likely persist throughout the expected shelf life (*60*).

Pre-harvest contamination of fruits and vegetables with salmonellae can occur from soil that has been fertilized with manure, from fecal material from wild and domestic animals deposited in fields, and during irrigation. *S*. enterica can survive in soil for up to six weeks, and salmonellae in soil can contaminate plants such as tomatoes (*49*). Although it is known that aerosols containing bacteria and insects carrying bacteria can spread pathogens around a farm, it is not known whether these routes can cause significant contamination of crops in the field.

Irrigation water may contaminate crops either by spraying directly on plants or through contamination of soil. Trace back of tomatoes from outbreaks in 2002 and 2005, caused by *S*. Newport, to a farm in Virginia identified a contaminated pond used for irrigation as the source of the bacteria (*210*). A survey of 170 sources of irrigation water in Texas found that 16 contained salmonellae (*159*).

After harvest, fruits and vegetables are often cleaned before packing and shipping. Unchlorinated water used for cleaning has been determined to be a source of *Salmonella* contamination. Trace back of mangoes, involved in a 1999 outbreak, to a South American farm revealed that mangoes were dipped in hot water (47ºC) for 75–90 min to kill fruit fly larvae and then cooled in 21ºC water for 6–10 min. Toads, birds, and bird droppings were observed in or near the open water tanks. Chlorine was added only to the cool water tank, and this water was changed once a week. Subjecting warm fruit to a cooler environment causes gases inside the fruit to contract, drawing water and bacteria into the fruit. In experiments simulating this disinfection process, salmonellae were internalized into mangoes, most frequently at the stem end of the fruit (*384;417*). Washing of tomatoes in inadequately chlorinated, cool water is also believed to be the cause of some tomato outbreaks because salmonellae can penetrate through the stem scar (*230*).

Other Foods. Contaminated frozen pot pies were the vehicle for a nationwide outbreak of salmonellosis causing 401 cases in 2007. There were some indications that the bacteria may have originated in the poultry used in the pies but there was not enough evidence to pinpoint the exact source. Nevertheless, the immediate cause of illness in humans appeared to be confusion about instructions for cooking these pies in microwave ovens. Recommended cooking times varied with wattage of microwave ovens but most case patients interviewed did not know the wattage of the oven they were using. Others did not follow directions for standing time after microwaving or reported different sets of directions on different locations on the package (*112*).

A 1993 outbreak in Germany caused by a contaminated spice, paprika, demonstrated the potential impact of such a vehicle. A total of 94 different serotypes were isolated from the paprika and about 1000 case patients, although three serotypes, Saintpaul, Rubislaw, and Javiana, accounted for about 42% of isolates. Quantitative analysis of samples of spices indicated that the infectious dose for this outbreak was between 4 and 45 organisms. Such low numbers of bacteria may have been sufficient because the spice was used to coat potato chips, a high-fat product. Fat is known to exert a protective effect for bacteria as they pass through the acidic stomach. The original source of the bacteria was not determined, but these bacteria were able to survive in this dry spice for extended periods of time (*286*).

Another dry product that was an unexpected vehicle for salmonellosis was raw almonds from California, implicated in outbreaks in 2000–2001 and 2003–2004. *S*. Enteritidis was determined to be the cause, with different rare phage types identified for the two outbreaks. Although these bacteria were isolated from almond orchard soil, there was no history of use of manure as fertilizer, so the ultimate source of these bacteria was not determined. Research indicated that salmonellae could survive for long periods in the soil, could grow on nutrients available in almond hulls, and could penetrate the almond hull into the kernel under wet conditions (such as rainfall) (*140;141;250;450*).

Dairy products are occasionally identified as vehicles for salmonellosis. Raw milk and raw milk cheese (*87;120*) and milk contaminated after pasteurization (*359*) have caused outbreaks. The most notorious dairy-related outbreak occurred in 1994 when ice cream, made from a pre-mix that was transported in tanker trailers that had previously carried unpasteurized eggs, caused illness with *S*. Enteritidis in an estimated 224,000 persons (*234*).

In the 2006–2007 outbreak of *Salmonella* Tennessee associated with peanut butter, at least 628 persons in 47 states became ill with about 20% requiring hospitalization. A massive recall of peanut butter products was undertaken and lawsuits were filed against the manufacturer (*108;116*).

Food handlers. Investigation of some outbreaks associated with restaurants or other large gatherings indicates that cases occurred over an extended period or that case patients reported consuming a wide variety of foods. In such outbreaks, food may have been contaminated by an infected food handler rather than contaminated in the field or during processing. A recently described large outbreak of *S*. Enteritidis, extending over a six-week period at a convention center in Texas, was apparently caused by one or more food handlers who were excreting salmonellae even though they exhibited no signs of illness (*53*). Another prolonged outbreak associated with a restaurant in Europe was traced to a food handler excreting *S*. Typhimurium (*173*). In most cases shedding of salmonellae does not exceed four weeks from the time of infection, but some individuals may continue to excrete salmonellae for nine weeks, and salmonellae may be present in feces of asymptomatic people (*185;216*).

Contaminated Water

Water used for drinking has been reported as the vehicle of infection for nine outbreaks, including one in Spain attributed to bottled water (*376*). For the other outbreaks, wells or water storage containers were probably contaminated with fecal material from infected domestic and/or wild animals, although it is often difficult to pinpoint the exact source or site of contamination. Examination of the 2008 Colorado outbreak identified an underground cement-lined water storage tank as the site of contamination: incoming water was coliform-negative while outgoing water was positive. There were some cracks in the tank, and it was theorized that runoff from melting snow may have washed contaminants into the tank (*56*).

RESPONSES TO SALMONELLA OUTBREAKS

Surveillance

Human Illness

For many people in developed countries, diarrhea from foodborne illness is an unpleasant experience but not life-threatening. However, the World Health Organization (WHO) estimates that over a billion diarrheal episodes occur in children younger than five years of age and that over two million people in the world die from diarrhea annually. In many cases the etiological agents are foodborne, and WHO, in 2007, launched a new initiative led by a Foodborne Disease

Burden Epidemiology Reference Group to gather information and strengthen the capacities of countries to investigate and document their burden of foodborne disease. A global report and global atlas of foodborne disease will be produced (www.who.int/foodsafety/foodborne_disease/ferg/en/print.html). In addition, WHO created WHO Global Salm-Surv in 2000 to enhance the capacity of countries to detect, respond to, and prevent salmonellosis. Data on the distribution of different serotypes and emergence of antibiotic resistance strains is being gathered and published (*192*) (www.who.int/salmsurv/general/documents/GSS_STRATEGICPLAN2006_10.pdf). Another group, the *Salmonella* Network, includes researchers from a number of Mediterranean and developing countries who are collaborating and training personnel to investigate salmonellosis (www.oloep.org/salmnet.asp).

FoodNet (Foodborne Diseases Active Surveillance Network) is a collaborative active surveillance project in the U.S. to track foodborne illness and involves CDC, USDA, FDA, and ten states in the Emerging Infections Program (CA, CO, CT, GA, MD, MN, NM, NY, OR, and TN). FoodNet began collecting information from five sites in 1996 and has now expanded to monitor about 15% of the U.S. population. In the ten states, public health officials frequently contact directors of over 650 laboratories testing stool samples to find new cases of foodborne disease and report these to CDC. Goals of FoodNet include determining the burden of foodborne illness in the U.S., monitoring trends in specific foodborne illness, determining specific foods and settings associated with foodborne illness, and developing and assessing interventions to reduce foodborne illness. Data from 2007 FoodNet sites indicate that the incidence of salmonellosis has not changed significantly in recent years (*114*).

Reports of foodborne illness from U.S. clinical laboratories are reported by all state health departments to CDC under The National Notifiable Diseases Surveillance System (NNDSS). However, there is some variation among states in the priority and funding given to investigation of foodborne illness and notifiable illnesses and their aggressiveness in tracking down causes of outbreaks and sporadic cases. Many persons with foodborne illness are not seriously ill and do not seek medical care, and it is likely that only a fraction of cases is reported to CDC by passive surveillance systems. Reports of notifiable diseases are published by CDC (*116*).

The National Salmonella Surveillance System is coordinated by CDC with input from state health departments. Annual surveillance summaries detailing serotypes identified from human and non-human sources and comparing isolates from different regions and years are published (*115*). Trends in frequency of isolation of different serotypes can be observed over time (*355*).

Enter-Net is the surveillance network tracking the human enteric pathogens *Salmonella*, VTEC, and *Campylobacter* in Europe (http://ec.europa.eu/health/ph_projects/2003/action2/docs/2003_2_20_frep.pdf). Data from different countries are compared and coordinated to quickly identify outbreaks and follow trends in the rise and fall of different pathogens and changes in antimicrobial susceptibility. Cases of salmonellosis have been declining in Europe but Enter-Net has documented some dramatic changes in prevalence of different phage types of *S.* Enteritidis (*184*). Enter-Net data on major serotypes was correlated with GIS information to produce maps showing spatial distribution of different Salmonella serotypes (*254*). In 2005, the European Centre for Disease Prevention and Control was established (http://ecdc.europa.eu/en) and now issues quarterly reports on food- and waterborne diseases (*11;150*).

A national integrated enteric pathogen surveillance program, C-EnterNet, conducts surveys of human isolates, retail meat (pork, chicken, beef), food animals (broilers, swine, dairy and beef cattle), and untreated surface waters in Canada to estimate levels of human exposure to pathogens from food, animal and water sources and to detect changes occurring over time (www.phac-aspc.gc.ca/c-enternet/pdf/sr2007-eng.pdf) (www.phac-aspc.gc.ca/publicat/2007/c-enternet06/areport06-eng.php).

Two major outbreaks of salmonellosis (typhoid associated with a restaurant worker, and *S.* Bredeney in infant formula) occurred in 1977 in Australia and almost overwhelmed the public health system. This led to establishment of a national, laboratory-based system for collecting and disseminating information on enteric pathogens, National Enteric Pathogens Surveillance Scheme. Isolates from human and nonhuman sources are identified and typed, allowing recognition of outbreaks, geographical differences in predominant serotypes, and trends in serotypes in different foods or over time (*186*). In 2000, Australia established an active surveillance program for foodborne disease, OzFoodNet, which is similar to FoodNet in the U.S. Annual and quarterly reports are published with discussions of trends and significant outbreaks (*272;370*). Salmonellosis is also a notifiable disease in Australia, and this surveillance data is published on the web (www9.health.gov.au/cda/Souce/CDA-index.cfm).

Animals

FSIS tabulates annual results of its *Salmonella* testing program to track progress in controlling this pathogen in cattle, hogs, broilers and, more recently, turkeys.

Prior to 2006 some testing, called "A" set tests, were collected at establishments randomly selected from among eligible establishments, with a goal of scheduling every eligible establishment at least once a year. From 2006 and beyond, testing was targeted at establishments that appeared to be having difficulty in controlling salmonellae. Therefore, results from pre-2006 surveillance are not comparable to later results. In 2005, results from "A" set testing indicated salmonellae were present in 16.3% of broilers, 3.7% of hogs, 1.3% of cows/bulls, and 0.6% of steers/heifers tested (www.fsis.usda.gov/Science/Progress_Report_Salmonella_Testing/index.asp).

Prevalence of *Salmonella* Enteritidis was measured in 200 layer house environments and in house mice in 129 layer houses in 15 states throughout the United States. Overall, swabs from 7.1% of layer houses and 3.7% of mice tested positive. Presence of *S*. Enteritidis in layer houses was associated with age/molting of hens and number of rodents trapped. Cleaning and disinfecting houses between flocks appeared to reduce risk (*193*).

A survey of cows in 97 dairy herds in 21 states in 2002 revealed that 31% of herds had at least one cow positive for salmonellae, although the overall incidence for all cows was 7.3%. *S.* Meleagridis*, S.* Montevideo, and *S.* Typhimurium were the most frequently isolated serotypes (*61*). Fecal samples (*n*=1,026) from another survey of cull dairy cows indicated that a similar percentage, 6.7%, were carrying salmonellae (*155*). Shedding of salmonellae from cattle has been found to vary geographically and seasonally (*50;398*).

An integrated food chain active surveillance system for *Salmonella, E. coli*, and *Campylobacter* was established in 2002 in four representative states in Mexico. Samples from ill and asymptomatic persons, animals and retail pork, chicken, and beef are examined to determine prevalence of important serotypes of salmonellae and their resistance to antimicrobial compounds. Isolations of salmonellae from intestines of swine, cattle, and chicken (obtained at slaughterhouses) were 42.1%, 20.9%, and 16.9%, respectively. *S*. Typhimurium, *S*. Enteritidis, *S*. Agona, *S*. Anatum, and *S*. Meleagridis were the most common serotypes detected, and the highest incidences of antibiotic resistance were detected in isolates from ill humans and swine (*483*).

The European Union has conducted several large baseline surveillance studies to estimate prevalence of salmonellae and common serotypes in broilers, layers, hogs, and turkeys (Table 3, *see p. 4*). A survey in 2006–2007 of over 19,000 slaughter pigs in 25 European countries indicated that, on average, 10% of pigs were infected with salmonellae. Rates of infection did vary widely among countries, from 0% to 29% (*32*).

A survey in 2006–2007 of 539 breeding turkey flocks and of 3769 fattening turkey flocks in European countries indicated a salmonella prevalence of 13.6% in breeding flocks and 30.7% in fattening flocks. Rates of infection varied among countries, from 0% to 83%. *S.* Typhimurium and/or *S.* Enteritidis were detected in over half the flocks. Prevalence of salmonellae was greater in larger flocks and in those which were unvaccinated (*29;33*).

A baseline survey in Europe in 2005–2006 examined prevalence of *Salmonella* spp. in 7,440 commercial broiler flocks having at least 5000 birds. The overall incidence rate was 23.7% (0%–68.2% in different countries) with 11% of broiler flocks positive for *S.* Enteritidis and/or *S.* Typhimurium (*26*). An earlier European baseline survey (2004–2005) found the overall prevalence of salmonellae in 5310 commercial holdings containing at least 1000 laying hens was 30.8% (*27*). This varied from 0% in Sweden, Norway, and Luxembourg to over 70% in Portugal, Spain and Poland. An epidemiological study of travelers returning to Sweden found a direct correlation between salmonellosis following travel to European countries and prevalence of *Salmonella* in laying hen flocks in those countries (*143*).

NARMS (National Antimicrobial Resistance Monitoring System) has been tracking resistance to antimicrobial drugs in enteric bacteria from USDA isolates from slaughterhouses. Data from 2006 indicate that isolates from cattle, swine, and turkeys are most often resistant to tetracyclines, streptomycin, and sulfonamides, whereas isolates from chickens are most frequently resistant to tetracyclines, streptomycin, and ampicillin. Tabulated data from 1997 to 2006 indicate that the incidence of isolates with multidrug resistance has increased in chickens, turkeys, and cattle but decreased in swine. It is also evident that there is an increasing trend for resistance to cephalosporins (www.ars.usda.gov/Main/docs.htm?docid=17320). Other data on antibiotic resistance of *Salmonella* isolates from commercial turkey farms (*405*) and from raw retail turkey in the U.S. (*266*) demonstrate a high rate of antibiotic resistance.

Food

Using available data on the occurrence of *Salmonella* Enteritidis in U.S. layer flocks and eggs it was estimated in 2002 that approximately one in every 20,000 eggs produced annually in the U.S. would contain salmonellae (*160*).

FSIS publishes annual results of its *Salmonella* testing program for this pathogen in beef and poultry. Prior to 2006, some testing, called "A" set tests were collected at establishments randomly selected from among eligible establishments. After 2006, testing targeted establishments that appeared to be having difficulty in controlling salmonellae. Therefore, results from pre-2006 surveillance are not comparable to later results. Baseline data, collected in 1995 for ground chicken and turkey and in 1993–1994 for ground beef is used to gauge progress in controlling salmonellae in processing plants. See Table 6 (*see below*) for some testing results for these ground meats. *S*. Enteritidis in broiler chicken carcass rinses has increased from 2000 to 2005 according to results from USDA inspections (*10*). Data from these surveys can be used to identify companies or types of establishments that have greater numbers of animal carcasses contaminated with salmonellae so that interventions can be instituted to reduce bacteria that may enter the human food chain (*161*). Further information is available at the FSIS web site (www.fsis.usda.gov/Science/Progress_Report_Salmonella_Testing/index.asp). While these data sets are not strictly comparable, they do indicate that *Salmonella* contamination of chicken meat remains a significant issue.

Data from the Canadian EnterNet program testing retail meats indicated that in 2007, 1% of beef, 3% of pork, and 33% of chicken samples were positive for salmonellae (www.phac-aspc.gc.ca/c-enternet/pdf/sr2007-eng.pdf).

Data from the Mexican surveillance system indicated that 36.4% of pork, 29.9% of beef, and 21.3% of chicken were contaminated with salmonellae (*483*).

In New Zealand, a national survey of *Salmonella* in retail meats in 2003–2005 found that the overall prevalence of *Salmonella* was 1.1%. Low prevalences were observed in all types of meat: 3% in chicken, 1.3% in lamb and mutton, 0.5% in unweaned veal, 0.4% in beef, and 0% in pork (*479*).

Although beef is less commonly a vehicle for salmonellosis than other meats, several outbreaks have been traced to ground beef. Bovine lymph nodes associated with lean and fat trimmings that may be incorporated into ground beef are a potential source for these salmonellae. A recent survey of 1140 lymph nodes obtained from commercial beef processing plants found that only 1.6% contained salmonellae, with a somewhat higher prevalence in cull cattle than in fed cattle (*39*).

Regulations

Federal regulations for various aspects of food handling and processing are promulgated by FDA (Food and Drug Administration) and USDA (U.S. Department of Agriculture); EPA (Environmental Protection Agency) is in charge of clean water regulations. Many of these regulations are not specific for controlling salmonellae but are intended generally to ensure the microbial safety of foods and drinking water. In addition, many state and local agencies have regulations that impact food, drinking water, and agricultural fairs and petting zoos. Many regulations were established after significant human disease outbreaks and deaths and/or broad media coverage highlighted shortcomings in handling of food, water, or animals. OSHA (Occupational Safety and Health Administration) and the Grain Inspection and Packers and Stockyards Administration are also involved at the national level in ensuring the safety of meat and other foods. Laws enforced by FDA are described on their web page (www.fda.gov/opacom/laws/), and foods that may be irradiated are listed separately (www.cfsan.fda.gov/~dms/irrafood.html).

Table 6. Percent positive *Salmonella* tests in the PR/HACCP verification testing program.

Time period	Ground beef	Ground chicken	Ground turkey
1st quarter 2008	2.0%	31.7%	16.0%
2007	2.7%	26.3%	17.4%
2006	2.0%	45.0%	20.3%
1998–2005 (“A” samples)	1.6%	25.5%	19.9%
Baseline (1993–1995)	7.5%	44.6%	49.9%

Meat

The Federal Meat Inspection Act (FMIA) and the Pure Food and Drug Act for non-meat products were passed in 1906 and the Poultry Products Inspection Act (PPIA) was enacted in 1956. FMIA and PPIA require mandatory inspection of livestock before slaughter and mandatory post-mortem inspection of all carcasses, establish sanitary standards for slaughterhouses and meat processing establishments, and authorize USDA to inspect meat processing and slaughtering operations. Only unadulterated carcasses are approved for further distribution to customers. In 1967, the Wholesome Meat Act updated FMIA to require inspection of all meat processed and sold within the same state. The Wholesome Poultry Act of 1968 instituted similar requirements for intrastate processing of poultry. In addition, at least twenty-eight states have their own meat and/or poultry inspection programs covering small and very small establishments. These programs are run cooperatively with FSIS.

The Food Safety and Inspection Service (FSIS) of USDA inspects all meat sold in interstate commerce. Inspection rules are published in the Code of Federal Regulations, Title 9, Volume 2, Chapter III, Parts 301–417 (www.access.gpo.gov/nara/cfr/waisidx_08/9cfrv2_08.html#301).

Other regulations by FSIS intended to improve meat safety include:

- **1994**: FSIS Directive 7235.1 required the placement of safe handling labels on packages of raw meat and poultry. These labels address storage, cooking, and holding practices to minimize or prevent growth of pathogenic bacteria (www.fsis.usda.gov/OPPDE/rdad/FSISDirectives/7235.1.pdf).
- **1996**: HACCP (Hazard Analysis and Critical Control Point) systems were mandated as a systematic procedure for determining critical points during processing when meat could be contaminated and instituting appropriate controls to prevent contamination. This rule establishes a testing program and requires all plants to incorporate an antimicrobial process and have in place sanitation standard operating procedures (SSOPs) (www.fsis.usda.gov/OPPDE/rdad/FRPubs/93-016F.pdf) (Fed. Register 61(144):38806–38989).
- **1998**: FSIS Directives 6150.1, rev 1 and 6420.1 told inspectors to enforce zero tolerance for visible fecal, ingesta and milk contamination of poultry and livestock carcasses at slaughter. This directive was revised in **2004** to include head, cheek and wesand meats because these may be included in ground beef (www.fsis.usda.gov/OPPDE/rdad/FSISDirectives/6420.2.pdf).
- **1998**: FSIS Directive 10,010.1 revised policy for sample collection and testing to emphasize establishments perceived to be a greater risk. Establishments using validated pathogen reduction interventions on carcasses and that had not identified a positive sample within the previous six months would not need to be tested by FSIS (www.fsis.usda.gov/OPPDE/rdad/FSISDirectives/10.010.1.pdf).
- **1998**: Performance standards for lethality and stabilization for cooking of meat were updated (9CFR 318.17).
- **1999**: USDA issued rules allowing irradiation of refrigerated or frozen/uncooked red meat and meat products to destroy pathogenic bacteria (64 FR 72150) (www.fsis.usda.gov/OPPDE/rdad/FSISDirectives/7700.1Rev1.pdf).
- **2002:** FSIS directed producers of ground beef to reassess HACCP plans including improvements in analytical tests, conditions in feedlot pens, and contamination of carcasses from material on hides and in feces. Implementation of critical controls was required (Fed. Register 67(194):62325).
- **2003**: USDA banned all downer cattle from the human food chain. This was intended to prevent possible transmission of BSE but may also have decreased the prevalence of foodborne bacteria (www.usda.gov/news/releases/2004/01/0457.htm).
- **2005:** Directive 7700.1, FSIS revised and updated instructions regarding irradiation of meat and poultry products in official establishments, including off-site irradiation of product (www.fsis.usda.gov/OPPDE/rdad/FSISDirectives/7700.1Rev1.pdf).

Fresh Produce

Following several outbreaks of salmonellosis traced to tomatoes in 2005–2006, the FDA Federal Food Code was amended in 2007 to require that cut, sliced, or processed tomatoes be refrigerated because they are a “time/temperature control for safety due to their high water activity >0.99 and relatively high pH ≥4.2” (*109*). FDA also issued a Guidance for Industry (with nonbinding recommendations): Guidance to Minimize Microbial Food Safety Hazards of Fresh-cut Fruits and Vegetables. This document discusses procedures related to personnel, buildings and equipment, sanitation, production and process controls, documentation and trace back that should aid in preventing contamination of fresh produce and in dealing with an outbreak of illness if it occurs (www.cfsan.fda.gov/~dms/prodgui4.html).

FDA has issued final rules approving irradiation of alfalfa and other seeds for sprouting at doses up to 8 kGy (www.fda.gov/ohrms/dockets/98fr/103000b.htm) and fresh spinach and iceberg lettuce at doses up to 4 kGy (www.cfsan.fda.gov/~lrd/fr080822.html).

The prolonged outbreak of *S.* Saintpaul during the summer of 2008 was difficult to address because of the challenging nature of trace back investigations of fresh produce. FDA held two public meetings to discuss improvements to ensure more efficient tracking of fresh produce so that vehicles of infection can be identified more quickly, thereby preventing more cases of illness.

FDA has published regulations requiring current good manufacturing practices (GMPs) for food processors under its jurisdiction. However, these regulations do not include "establishments engaged solely in the harvesting, storage, or distribution of one or more raw agricultural commodities." FDA will, however, issue special regulations if it is necessary to cover these excluded operations (21U.S.C. §321(r)). Despite this exclusion, FDA can still regulate fresh produce as "food" subject to the adulteration provisions of the Food, Drug, and Cosmetic Act. A food shall be deemed to be adulterated "if it has been prepared, packed, or held under unsanitary conditions whereby it may have become contaminated with filth, or whereby it may have been rendered injurious to health." Therefore, FDA can take enforcement action against an agricultural producer if it determines that food is being produced under unsanitary conditions.

Juice

Following a multistate outbreak of disease linked to *E. coli* O157:H7 in unpasteurized apple juice, FDA published a final rule (Federal Register 63(130):37029–37056) requiring a warning label on fruit juices that have not been processed to prevent, reduce, or eliminate pathogenic microorganisms. Following another juice-borne outbreak of *Salmonella* in orange juice in 2000, another final rule published by FDA in 2001 required all juice manufacturers to develop and implement a HACCP plan to prevent contamination of juices with dangerous pathogens. Treatments should reduce pathogen levels by 5 logs (Federal Register 66(13):6138–6201).

Eggs

In 2000, FDA issued final regulations requiring shell egg cartons to bear safe handling instructions and requiring that eggs be placed promptly under refrigeration conditions (≤45ºF) upon delivery at retail establishments. Irradiation of fresh shell eggs was also approved in 2000 at doses (up to 3 kGy) that will reduce numbers of salmonellae in eggs but not completely eliminate them. FDA also proposed regulations in 2004 to prevent *S.* Enteritidis from contaminating eggs. These regulations would include requirements for refrigerated storage of eggs on farms, procurement of chicks from *S.* Enteritidis monitored breeder flocks, biosecurity measures, pest and rodent control cleaning and disinfection, and producer testing for *S.* Enteritidis under some conditions (www.cfsan.fda.gov/~dms/fs-eggs6.htm). Regulations for egg inspection and handling can be found in 9CFR, chapterIII, part 590. For liquid processed eggs, USDA has prescribed egg pasteurization standards with minimum process temperatures and holding times for different categories of processed egg products.

Seafood

The National Shellfish Sanitation Program issued a Guide for the Control of Molluscan Shellfish in 2007. Although it is primarily concerned with *Vibrio* spp., its recommendations will also help reduce other pathogenic bacteria such as salmonellae (www.cfsan.fda.gov/~ear/nss4-44.html). Irradiation of shellfish at doses up to 5.5 kGy was approved in 2005 to reduce populations of *Vibrio* spp. and other foodborne pathogens (www.cfsan.fda.gov/~lrd/fr05816b.html). FDA operates an oversight compliance program for fishery products with regulations promulgated under the Federal Food, Drug and Cosmetic Act and operates the Low-Acid Canned Food program, based on the HACCP concept, focusing on thermally processed, commercially sterile foods, such as canned tuna and salmon. FDA conducts in-plant inspections and takes samples for analysis of microbial pathogens and other contaminants (www.cfsan.fda.gov/~lrd/sea-ovr.html).

Water

The Clean Water Act and Safe Drinking Water Act of 1974 are administered by EPA. Revised National Primary Drinking Water regulations are published in the Code of Federal Regulations (40CFR141.1). EPA requires public water systems to monitor for coliform bacteria, which are indicators of contamination with animal waste or human sewage (www.epa.gov/safewater/sdwa/index.html).

Bottled water is regulated by FDA as a food. Standards of quality are listed in the Code of Federal Regulations (21CFR165.110); these include allowable limits for turbidity, color, odor, coliforms, radioactivity, and for 70 chemicals.

EPA also has issued regulations regarding reuse of water for agricultural purposes with limits on the number of coliforms that may be present in water used for irrigation (www.epa.gov/ord/NRMRL/pubs/625r04108/625r04108.pdf).

Animal Feed

Human infections with salmonella present in treats and food for animals have prompted FDA in October 2008 to issue a nationwide assignment for personnel in the Center for Veterinary Medicine to collect and analyze samples of "direct-human-contact feeds" for *Salmonella*. If any feed samples are found to be contaminated, warning letters should be sent to the responsible companies and steps should be taken to prevent interstate sale and distribution (www.fda.gov/cvm/SalAnalyzeOct08.htm).

Turtles

In response to numerous cases of salmonellosis linked to pet turtles, which were inexpensive and easily purchased by and for children, a law was passed in 1975 in the U.S. prohibiting the sale or distribution of small turtles (carapace <4 inches long). This resulted in a substantial decline in human infections associated with turtles. However, because this law allows exceptions such as sales for educational purposes and is not always strictly enforced, human–turtle-associated cases continue to occur. Center for Veterinary Medicine of FDA is responsible for administering this law. Several recent cases of turtle-associated salmonellosis were reported to CDC by state and local health departments since September 2006, including a fatal case in an infant (*123*). Public education campaigns aimed at preventing reptile-acquired *Salmonella* infections are helpful, but prohibiting the sale of small turtles may be the most effective public health action to prevent turtle-associated salmonellosis.

Fairs and petting zoos

Fairs and petting zoos are regulated by state and county agriculture or public health departments. During the past several years, regulations requiring more hand-washing stations, warning signs, disinfecting of handrails, etc., and cleanliness in animal enclosures have been enacted in a number of states. The CDC has published a compendium of standardized recommendations to prevent disease associated with animals in public settings. The single most important recommendation was proper washing of hands (*54*).

Industry Initiatives and Interventions

Meat

Poultry. Intervention strategies for controlling salmonellae in poultry have been described in several recent reports. If chickens are already infected when they arrive at the slaughterhouse, salmonellae may be present on feathers as well as in the crop and intestines, making it difficult to prevent cross contamination among bird carcasses. Preharvest control methods include obtaining chicks from *Salmonella*-free breeders, feeding young chicks competitive exclusion cultures to prevent establishment of *Salmonella* infections, vaccination, sanitation practices and pest control, biosecurity practices to control movement of equipment and personnel, and microbiologically clean drinking water for birds. Prior to slaughter, feed is often withdrawn to reduce levels of fecal contamination during transport, but birds may then scratch in litter and consume some *Salmonella*-contaminated material. Acidification of drinking water at this time can kill salmonellae. Chlorate decreases *Salmonella* in both chickens and turkeys when administered prior to feed withdrawal (*80;327*). A longer term strategy may be to breed chickens that are resistant to *Salmonella* colonization (*158;194*). Processing of birds in the slaughterhouse also requires attention to sanitation and employee hygiene practices. A number of strategies for reducing salmonellae during processing of ready to cook chicken are described in an extension publication (www.pubs.caes.uga.edu/caespubs/pubcd/b1222.htm).

Cattle. Preventing the contamination of beef carcasses with salmonellae begins before the animals enter the slaughterhouse. A survey to determine on-farm risk factors for fecal shedding of salmonellae by dairy cattle found that herds in southern states and herds containing > 100 animals were twice as likely to shed salmonellae as compared to smaller herds and those in northern states. Other factors associated with *Salmonella* shedding were feeding brewers' products and the use of flush water systems to clean gutters. The brewer's products had higher moisture levels than other feed, which may have increased survival and growth of salmonellae, and the flush systems sometimes use recycled water, which may spread salmonellae. One suggested strategy for large herds is to divide the animals into smaller groups, which may help control spread of salmonellae (*259*).

Several studies have demonstrated that prevalence of *Salmonella* is greater on hides of cattle in lairage and just before slaughter than it is in cattle at feedlots and on farms. Factors related to this increased prevalence may include exposure to environmental dust as cattle are loaded into trucks (*321*) but prevalence was apparently not related to cleanliness of the transport trailers or the location of cattle in the trailers

(*393*). Cattle that were agitated during loading and that were transported for longer distances had a significantly increased risk for *Salmonella* contamination of the hide. Cleanliness of lairage pens was also identified as a significant risk factor (*153*).

An investigation to determine whether conditions in feedlots or in lairage pens were important in contamination of cattle carcasses tracked the specific strains of salmonella in these locations and compared them to isolates found on carcasses. Only 0.7% of cattle were found to have *Salmonella* on their hides when sampled at the feedlot, whereas a majority of animal hides were *Salmonella*-positive when tested at the processing plant. According to PFGE (pulsed field gel electrophoresis) analyses, none of the *Salmonella* isolates found on carcasses or hides at slaughter were similar to those detected at the feedlot. Large plants may process over 3000 animals per day, and successive groups of animals are kept in lairage pens for 2–4 hours before slaughter. Data from this study indicate that a large proportion of bacteria on the hides of these cattle was acquired in the lairage pens just before slaughter. It also calls into question whether preharvest interventions on individual farms will be effective if cattle hides become contaminated with salmonellae primarily in lairage pens just before slaughter (*38*).

The emergence of *E. coli* O157:H7 as an important foodborne pathogen prompted industry initiatives to reduce contamination and improve food safety. From 1996–2000, the Economic Research Service of USDA estimates that the meat and poultry industry spent about $180 million/year on improvements in food safety. Research led to commercialization of several processes to reduce pathogens on carcasses during processing. These interventions, including procedures for cleaning hides by steam pasteurization and rinsing with hot water and mild organic acids as well as improved management systems (HACCP), also effectively reduce *Salmonella* contamination (*71*). Two processing plants that used hide wash cabinets were found to have no detectable salmonellae on cattle carcasses, while another plant that did not use hide wash cabinets had 8% of carcasses contaminated with salmonellae and none of these isolates matched those found in feedlots. Hide wash cabinets appear to be effective in removing contaminating bacteria acquired in the lairage environment (*38*). A recent study using hides inoculated with *Salmonella* found that high pressure washing with chlorinated water reduced bacterial populations by 1.7 log/cm^2. If hides were sprayed with sodium hydroxide or sodium sulfide prior to the water treatment, *Salmonella* populations were decreased by >4 log/ cm^2 (*86*).

Swine. Several intervention strategies have been implemented to reduce salmonellae on swine carcasses and pork. As with cattle, there is evidence that a significant amount of the *Salmonella* detected on carcasses at slaughter is acquired during the hours or days spent in holding pens at the abattoir. Even a two-hour holding period was found to increase percentage of pigs carrying salmonellae (*283*). Cleaning and disinfection of floor boards from these pens did decrease the amount of *Salmonella* cultured from floor swabs but did not consistently reduce salmonellae in pigs using these facilities (*411*). Resting pigs on the trailers that transported them to the abattoir rather than in holding pens resulted in significantly lower prevalence of salmonellae in pig carcasses (40.7% vs. 13.3%) (*403*).

Salmonella is commonly present in swine herds, with nearly 70% of 146 midwestern herds testing positive for salmonellae in ileocolic lymph nodes (*43*). Seroprevalence for *Salmonella* was lower in conventionally raised swine than in swine raised outdoors without regular administration of antimicrobials (*197*) although resistance to most antimicrobials was significantly greater for *Salmonella* isolates from conventionally reared swine (*198*). Transmission of salmonellae among pigs on a farm apparently occurs primarily over short distances within the same pen or room according to analyses of thousands of samples from pigs, other mammals, birds, insects and the environment on 18 farms. Therefore, intervention strategies that restrict access to different farm buildings or otherwise maintain spatial barriers may limit spread of salmonellae (*470*).

Reducing *Salmonella* colonization of pigs has been achieved by feeding sodium chlorate (*13;382*), by feeding competitive exclusion bacterial cultures (*199*), and by vaccination (*413*). Several recent reviews discuss intervention techniques for reducing *Salmonella* during pork production (*149;348;352*).

Eggs

Commercial processing methods at three plants were found to significantly decrease microbial contamination on egg shell surfaces. Salmonellae and other microbes were detected on incoming egg shells but prevalence of enterobacteriaceae decreased from 60% on incoming eggs to 10% on post-processing samples (*333*). Various methods have been used to reduce populations of salmonellae on and in eggs. These include directional microwave technology (*280*), ozone and UV radiation (*399*), electrolyzed water (*379*), several cleaning and sanitizing compounds (*422*), and thermoultrasonication (*81*).

Fresh Produce

Good Agricultural Practices (GAP) and Sanitation Standard Operating Procedures (SSOPs) are primary strategies to reduce contamination of fresh produce with pathogens. These include protecting crops from water and fertilizer that may contain high concentrations of *Salmonella* or other pathogens, attention to hygiene practices of farm workers, and washing of fruits and vegetables in potable water containing chlorine, organic acids, and/or other antimicrobial compounds. Outbreaks associated with fresh produce have been traced to lapses in these practices. In April 2006, representatives of trade associations for growers and marketers of fresh produce published a document to aid their members in implementing safeguards during growing, harvesting, value-added operations, distribution, retail, and food service operations: Commodity Specific Food Safety Guidelines for the Lettuce and Leafy Greens Supply Chain (www.cfsan.fda.gov/~acrobat/lettsup.pdf).

SUMMARY AND DISCUSSION

Over the past ten years, since the review by Mead on foodborne illness and death in the U.S., coverage of the active surveillance system for foodborne infections has increased from approximately 5% to 15% of the U.S. population (*315*). Incidence of salmonellosis cases/100,000 persons was estimated at 16.0 (13.7) in 1996 (1997), the baseline period, and, according to the most recent figures, was 14.9 (14.8) in 2007 (2006) (http://www.cdc.gov/foodnet/reports.htm). Hospitalization rates for salmonellosis were 21–22% in 1996–1997 and were somewhat higher, 26%, in 2004 (the last year with complete published data). However, the case-fatality rate was similar in 1997 (0.589%) and in 2004 (0.584%). Overall, the picture of salmonellosis in the U.S. has not changed greatly in the past decade.

However, there have been some changes in important serotypes and vehicles of infection. *S.* Typhimurium has declined as a percentage of serotyped Salmonella isolates from FoodNet sites from 29–32% in 1997–1998 to 16–19% in 2006–2007. *S.* Enteritidis isolates accounted for about 16–17% of serotypes identified during this decade although there was some yearly variation. *S.* Newport was an infrequent isolate in 1997–1998 (about 3.5%), but since 1999 has averaged about 11% of identified *Salmonella* isolates (http://www.cdc.gov/foodnet/reports.htm). Extrapolating from data provided by FoodNet to the U.S. population can be problematic because FoodNet sites are not representative of the whole population. Data from peer-reviewed articles in scientific journals are also not truly representative because only a small fraction of reported outbreaks, usually those that affect many people or are unusual or interesting in some way, are subsequently described in scientific literature. This may skew perceptions on the importance of certain serotypes or the frequency of different vehicles of infection.

Nevertheless there are some trends in the data and some contrasts between the U.S. and other countries that are of interest and suggest the need for further research and interventions.

Serotypes

- *S.* Enteritidis is by far the most common serotype in Europe and Japan whereas *S.* Typhimurium is the most common in Australia. In the U.S., *S.* Enteritidis and *S.* Typhimurium appear to have a similar prevalence. The reason that *S.* Enteritidis is uncommon in Australia is apparently due to the fact that it has not become established in chickens in that country. Are some serotypes better adapted for surviving in our food and agricultural production and processing systems?
- Case-fatality rates for different serotypes vary 100-fold, with *S.* Choleraesuis and *S.* Dublin being significantly more virulent than many other serotypes. Investigation of factors that increase pathogenicity of certain serotypes may yield information useful in preventing or treating infections.
- Salmonellosis outbreaks traced to mung beans were first recorded in 2000. All mung bean outbreaks in the U.S. were caused by rare phage types of *S.* Enteritidis. In some of the incidents, mung bean seeds were known to have been imported from China. Did these rare phage types originate in China or were they previously unrecognized phage types already present in North America?

Antibiotic Resistance.

- Antibiotic resistance remains a concern, as data from NARMS indicate that prevalence of antibiotic sensitivity in *Salmonella* isolated from turkeys, swine, and cattle has decreased between 1999 and 2006 while that of chicken isolates has remained about the same. More than 65% of isolates from turkeys and swine are resistant to at least one antibiotic whereas 30–40% of isolates from chickens and cattle exhibit some level of resistance. Resistance to multiple antibiotics has increased over time.
- *S.* Typhimurium DT104, resistant to five or more antibiotics, appears to have decreased in prevalence in recent years in the U.S., but there are increasing reports of significant antimicrobial resistance in *S.* Newport and *S.* Paratyphi. Additionally, antibiotic-resistant strains of salmonellae

are being disseminated internationally along with global trade in food.

- There is some evidence that antibiotic-resistant strains are more virulent. This should be examined more closely.

Vehicles of Infection

- Outbreaks and cases of many foodborne pathogens have increased as people consume more fresh fruits and vegetables and as production and processing of these commodities has become more concentrated. Some serotypes are more often associated with these outbreaks than others. How are they adapted for attaching to and surviving on plant surfaces?
- Importation of foods from underdeveloped countries carries the risk that sanitary practices may not be adequate to produce safe and healthy foods.
- Some European countries have undertaken well organized, nationwide programs to control *Salmonella* in poultry and swine. Some of their practices may be useful in improving U.S. production systems.

FEBRUARY 2009 UPDATE

A large multistate outbreak of salmonellosis traced to peanut butter and peanut paste, sold in large containers to institutions and to manufacturers of products containing peanuts, began in September 2008 and was still ongoing at the end of February 2009. As of 22 February, 666 cases had been reported from 45 states, with 23% of cases requiring hospitalization and nine deaths. One case was detected in Canada; this person obtained peanut products in the U.S. (*484;485*).

The outbreak strain of *Salmonella* Typhimurium PT3 has been isolated from unopened 5-lb containers of peanut butter, from peanut butter crackers, and possibly from dog biscuits containing peanut paste. The implicated peanuts, peanut butter, and peanut paste were processed at plants in Georgia and Texas and were widely distributed and used in the manufacture of cookies, crackers, cereal, candy, ice cream, pet treats, and other foods. More than 2100 products in 17 categories have been voluntarily recalled by more than 200 companies.

Investigations of the peanut production facilities in Georgia in January 2009 by FDA revealed numerous violations of good manufacturing practices, including mold on walls, a leaky roof, a lack of or inadequate cleaning of machinery and the production environment, storage of finished product next to incoming raw peanuts, and roasting machines that were not calibrated to ensure proper temperatures were reached (http://www.fda.gov/ora/frequent/483s/pcaamend483red.pdf). The plant had received 12 positive tests for *Salmonella* since 2007 but did not do a thorough cleaning after these tests and shipped out product after receiving negative results from a second test. A criminal investigation is proceeding. The plant in Texas had never been inspected by state or FDA officials since it opened in 2005 and also had inadequate controls to prevent contamination of finished products.

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Figure 1. Vehicles responsible for reported outbreaks of salmonellosis (1997–2008).

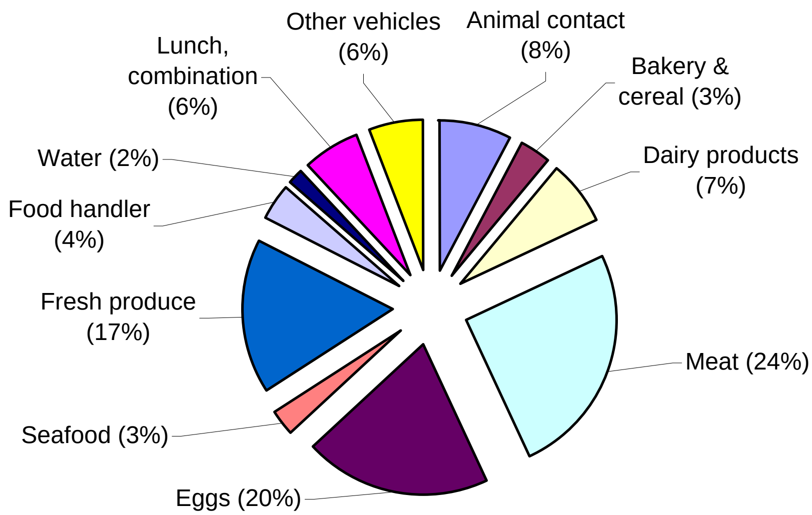


Figure 2. Vehicles responsible for reported cases of salmonellosis (1997–2008).

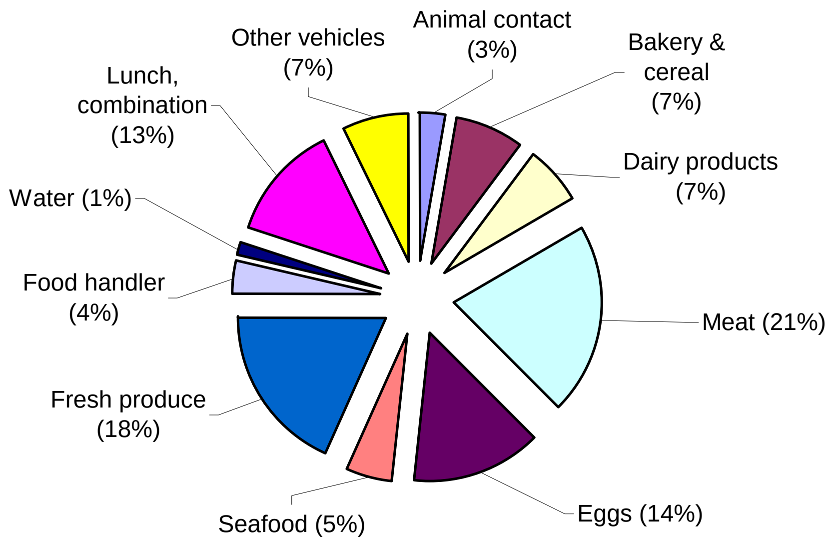
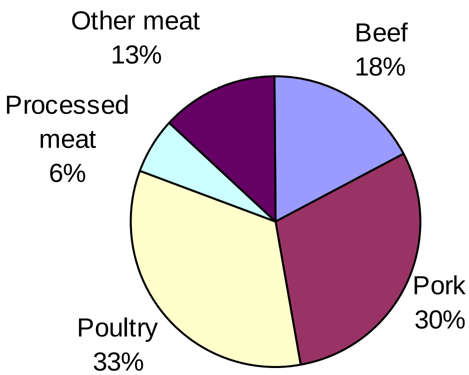


Figure 3. Outbreaks (**A**) and cases (**B**) of salmonellosis associated with different types of meat.

A. Outbreaks



B. Cases

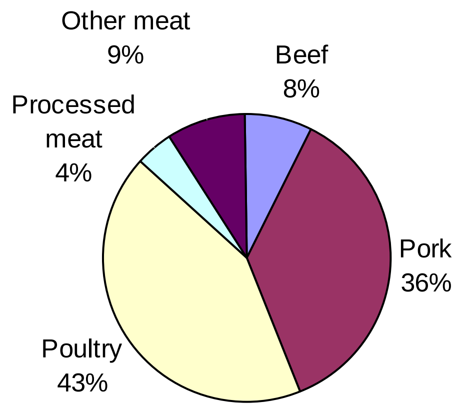
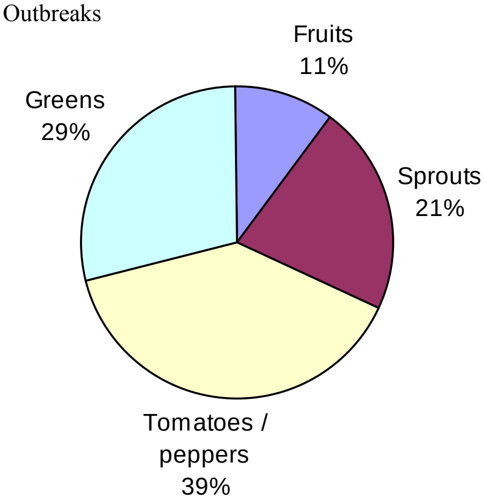


Figure 4. Outbreaks (**A**) and cases (**B**) of salmonellosis associated with different types of fresh produce.

A. Outbreaks



B. Cases

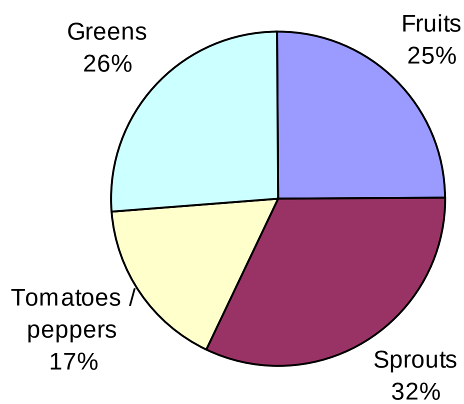


Figure 5. *Salmonella* serotypes reported as causes of outbreaks of human illness.

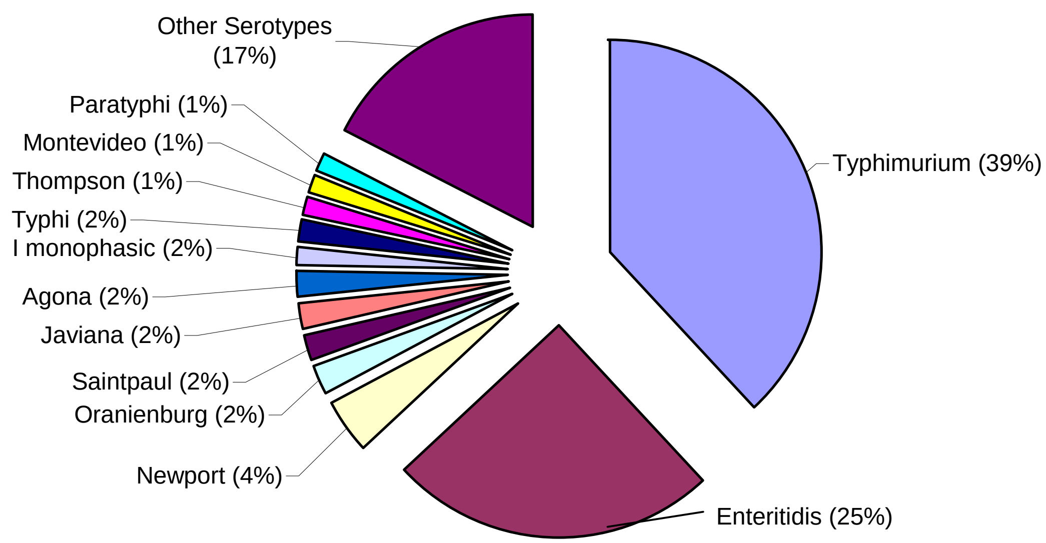


Figure 6. *Salmonella* serotypes reported as causes of cases of human illness.

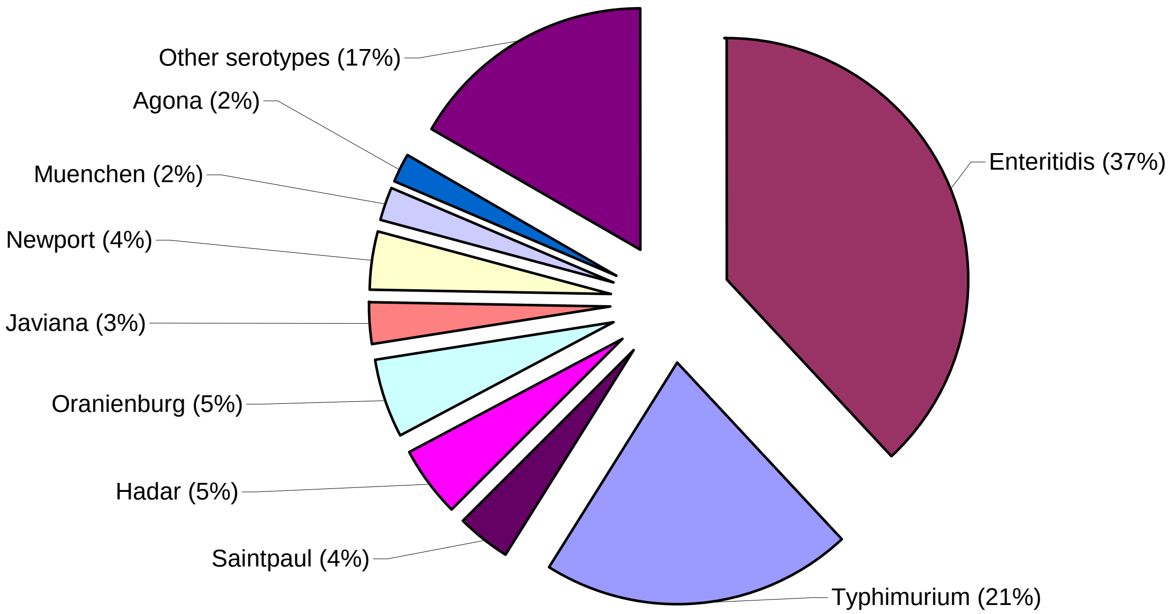
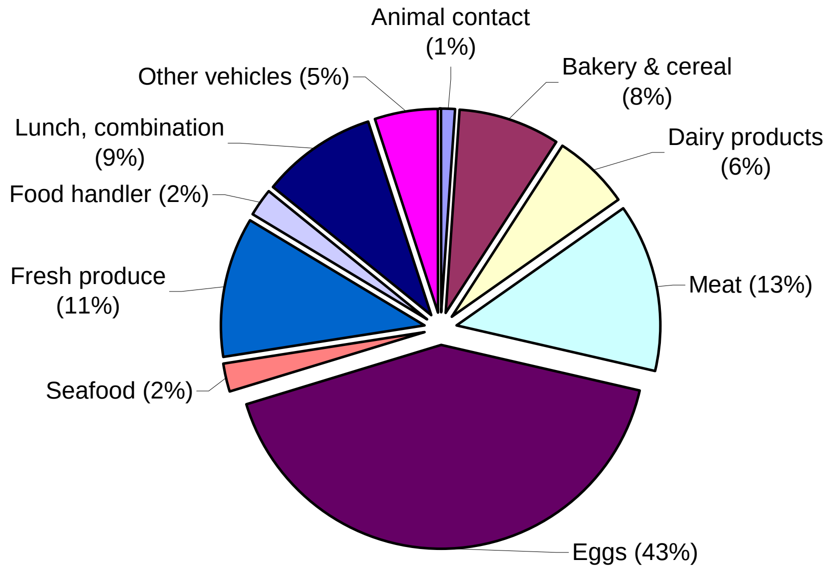


Figure 7. Vehicles associated with outbreaks (**A**) and cases (**B**) of *Salmonella enteritidis*.

A. Outbreaks



B. Cases

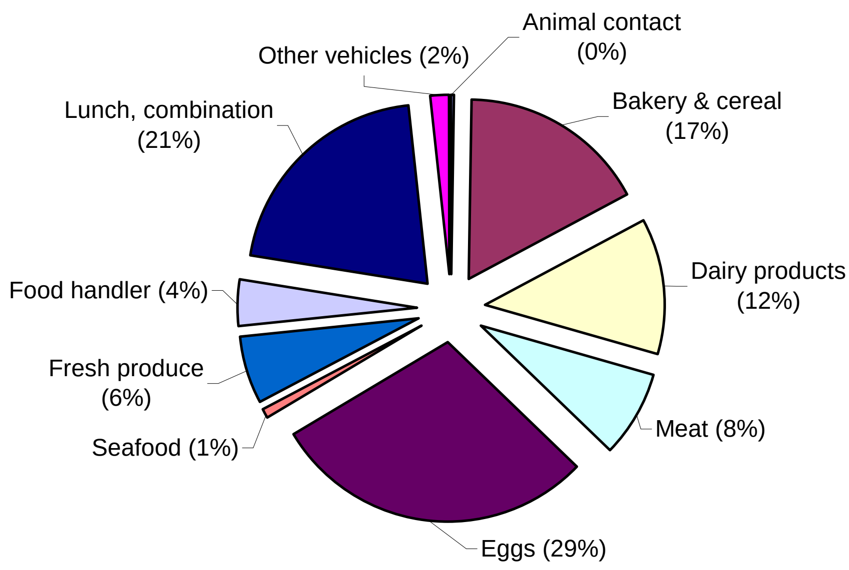
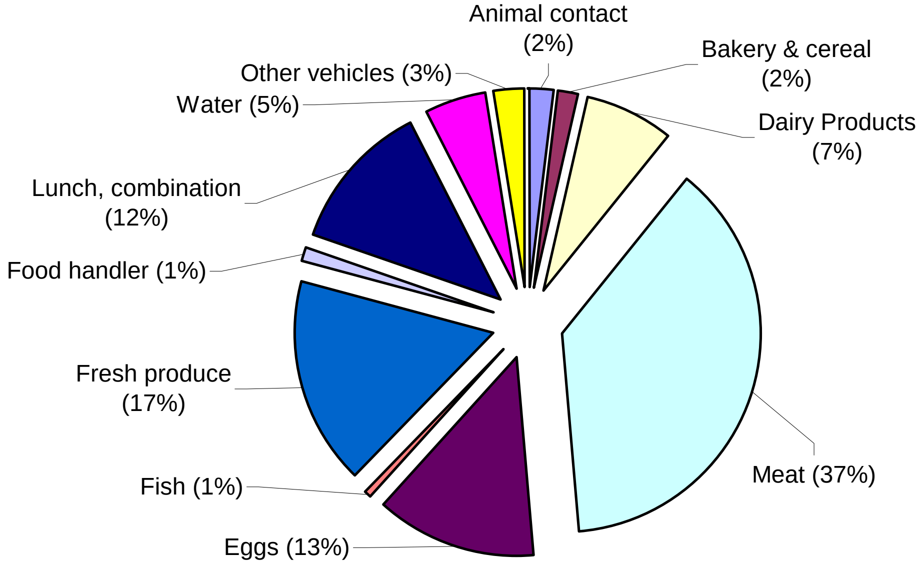


Figure 8. Vehicles associated with outbreaks (**A**) and cases (**B**) of *Salmonella typhimurium*.

A. Outbreaks



B. Cases

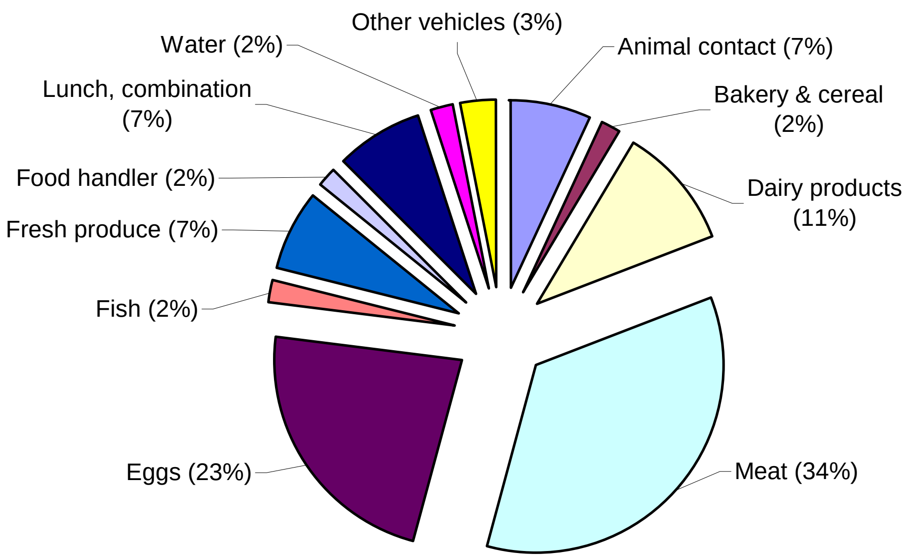


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Table 2. Large outbreaks of *Salmonella* occurring from 1997 to 2008 (>200 cases).

Year	# Cases	Serotype(s)	Location; Vehicle(s)	Reference(s)
2002	5963	Typhi	Nepal; drinking water	(*290*)
2005	2138	Hadar	Spain; chicken, precooked	(*287*)
1998	1871	Enteritidis	Japan; cake	(*30*)
1999	1634	Oranienburg	Japan; dried squid	(*30*)
2008	1442	Saintpaul	U.S.; peppers, tomatoes?	(*113*)
2002	1435	Enteritidis	Spain; pastry with eggs	(*84*)
2007	1148	Enteritidis	Japan; boxed lunch	(*30*)
2008	1054	Typhimurium	Denmark; pork	(*175;176;391*)
2002	905	Enteritidis	Japan; boxed lunch	(*30*)
1999	904	Enteritidis	Japan; school lunch	(30)
1998	>800	Enteritidis	Canada; cheese	(*3;392*)
2002	725	Enteritidis	Japan; boxed lunch	(*30*)
2001	688	Enteritidis	U.S.; eggs	(*100*)
1998–2002	671	Brandenburg	New Zealand; sheep	(*45*)
2008–2009	667	Typhimurium	U.S., Canada; peanut butter	(*484;485*)
2002	644	Enteritidis	Japan; cream puff	(*30*)
2006–2007	628	Tennessee	U.S.; peanut butter	(*108*)
2005	592	Enteritidis	Canada; sprouts	(*401*)
1998	558	Enteritidis	Japan; eggs	(*30*)
2003	540	Javiana	U.S.; food handler	(*167*)
2004–2005	525	Bovismorbificans	Germany; pork	(*204*)
2002	510	Newport	U.S.; tomatoes	(*210*)
2002	475	Enteritidis	U.S.; food handler	(*53*)
2005	448	Typhimurium	Australia; dips	(*130*)
2001–2002	439	Oranienburg	Europe; chocolate candy	(*471*)
2004	429	Multiple	U.S.; tomatoes	(*104*)
2008	411	Typhimurium	U.S.; tap water	(*35;56*)
1998	409	Agona	U.S.; cereal	(*89;427*)
2007	401	I 4,[5],12:i:-	U.S.; pot pies	(*112*)
2000	396	Typhimurium	Europe; lettuce	(*136*)
2000	372	Typhimurium	UK; salad vegetables	(*18;20*)
2004	372	Newport	UK; lettuce	(*202*)
2000	361	Typhimurium	UK; lettuce	(*243*)
2003	358	Typhimurium	Japan; lunch food	(*431*)
1999	309	Paratyphi B	Europe; unknown	(*291*)
2001	303	Enteritidis	Europe; chicken	(*214*)
2003–2004	>300	Typhimurium	Austria; eggs	(*330*)
2007	294	Typhimurium	Australia; pork/chicken rolls	(*372*)
1998	284	Enteritidis	Mallorca; mousse	(*76*)
2000	264	Baildon	U.S.; salad	(*256*)
2004	250	Enteritidis	Spain; egg glaze	(85)
2005	238	Enteritidis	Japan; boxed lunch	(*263*)
2000	234	Newport; Java; Lexington	U.S. cruise ship; shrimp	(*92*)
2007	228	Java	Europe; spinach	(*151*)
2002	224	Enteritidis	UK; eggs	(*346*)
2001	215	Enteritidis	France; cheese	(*220*)
2003	213	Typhimurium	Australia; pork rolls	(*367*)
1999	207	Muenchen	U.S., Canada; orange juice	(*91*)
1999	206	Enteritidis	Japan; cream buns	(*449*)
2001	203	Typhimurium	Europe, Australia; sesame seed candy	(*2;73;295;363*)

Table 4. Salmonella serotypes and associated outbreaks, cases, and vehicles (1997–2008).

Serotype	Outbreaks	Cases (total)	Vehicle(s)
"i" monophasic	8	647	chicken, iguana, pork, pot pies, turtles, young poultry
Agona	7	822	aniseed tea, cereal, cooked sandwich meat, infant formula, young poultry,
Ajiobo	1	103	unknown
Anatum	5	546	chicken, infant formula, orange juice, tomatoes
Baildon	2	350	salad, tomatoes
Bareilly	2	301	bean sprouts, egg sandwiches
Berta	1	29	watermelon
Blockley	1	13	smoked eel
Bongori	1	8	unknown
Bovismorbificans	3	576	lettuce, pork
Braenderup	3	228	chicken, tomatoes
Brandenburg	3	685	pork, lunch food, sheep (occupational)
Bredeney	2	180	chicken, meat
Chester	2	62	tap water, turtle meat
Coeln	1	26	beef (minced)
Cubana	1	16	alfalfa sprouts
Derby	1	16	meat (lightly grilled)
Enteritidis	109	17,503	almonds, bean sprouts, beef, bread, cake, cheese, chicks, chicken, cream, cream cheese, eggs, fish, food handler, lasagna, "lunch," mayonnaise, meat, mousse, pastries, occupational exposure, pudding, salad, sesame prawn toast, spaghetti, turkey
Give	3	155	infant formula, pork
Goldcoast	2	192	sausage
Hadar	2	2167	chicken, rabbit meat
Hartford	1	43	refried beans
Havana	1	18	alfalfa sprouts
Heidelberg	5	186	chicken, eggs, food handler, pig roast
Hvittingfoss	1	42	unknown
Indiana	1	17	mayonnaise
Infantis	3	124	meat, pig ear dog treats, young poultry
Java	4	491	coconut, shrimp, spinach
Javiana	7	1209	amphibians, food handler, tomatoes
Kedougou	2	83	powdered infant formula, salami
Kiambu	1	35	unknown
Kingabwa	1	6	lizard contact
Kottbus	2	78	alfalfa sprouts, bottled water
Lexington	1	234	shrimp
Litchfield	2	77	cantaloupe, paw paw
Livingstone	2	76	eggs, processed fish, person to person
London	3	60	infant formula, person to person, pork
Madelia	1	44	tortellini with pesto sauce
Manhattan	2	84	pork
Marina	1	4	iguana contact
Mbandaka	1	89	alfalfa sprouts
Menston	1	7	person to person
Mgulani	1	42	unknown
Montevideo	6	203	"lunch," sausage gravy, tacos, tahini, young poultry

Serotype	Outbreaks	Cases (total)	Vehicle(s)
Muenchen	5	1049	alfalfa sprouts, melons, orange juice, pork, tomatoes
Newport	19	1817	cheese, ground beef, ham, horse meat, lettuce, mangoes, peanuts, pig roast, pork, salad, sandwiches, shrimp, tomatoes
Nima	1	1	snake
Ohio	1	4	young poultry
Oranienburg	9	2397	alfalfa sprouts, beef (ground), cantaloupe, cheese, chocolate candy, gelato, melons, squid (dried)
Othmarschen	1	72	food handler?
Panama	1	109	chicken
Paratyphi	6	496	alfalfa sprouts, beef (minced), fish aquarium, turtles
Pomona	2	26	turtles
Poona	5	180	cantaloupe, iguana
Potsdam	1	17	mayonnaise
Rubislaw	1	2	lizard exposure
Saintpaul	8	1683	bean sprouts, cantaloupe, enteral formula, mangoes, peppers, tap water, tomatoes?, well water
Sandiego	1	3	turtles
Saphra	1	24	cantaloupe
Schwarzengrund	2	90	dry pet food, person to person
Senftenberg	3	170	alfalfa sprouts, fresh basil, person to person
Singapore	1	13	sushi
Stanley	4	275	alfalfa sprouts, cheese, peanuts
Stourbridge	1	52	unpasteurized goats' cheese
Telelkebir	1	8	turtle exposure
Tennessee	2	629	bearded dragon, peanut butter
Thompson	6	623	beef, bread, cilantro, lettuce, pet treats, tomatoes
Typhi	9	6108	chicken, drinking water, food handler, fruit, person to person, pork, salad, sandwiches
Typhimurium	166	10822	alfalfa and clover sprouts, anchovies (dried), baked beans/chili, bakery products, beef, Caesar salad, cake, cats, cheese (raw milk), cheesecake, chicken, Chinese food, coleslaw, cordial-like drink, cream and custard cakes, custard, dips, drinking water, eggs, farm animals, fish, food handler, fried rice, ham, hamster contact, hedgehogs, ice cream, lamb liver, lemon dessert, lettuce, lunch, mango pudding, mayonnaise, meat, milk (raw and pasteurized), mousse, owl pellets, peanut butter, person-to-person, pigeon meat, pigs ear salad, pizza, pork, pork/chicken rolls, prawn soup, pudding, ravioli, rice salad, rodents, salami, sausage, sesame seed candy, tap water, Thai salad, tiramisu, tofu, tomatoes, turkey (RTE), turtle contact, turtle meat, well water, young poultry
Uganda	1	20	pork
Virchow	4	180	bean sprouts, chicken, garlic, tomatoes, sushi
Wandsworth	2	115	veggie booty snack
Weltevreden	2	71	alfalfa sprouts, "food"
Worthington	1	49	powdered milk

Table 5. Reported vehicles and associated outbreaks, cases, and serotypes (1997–2008).

Vehicle	Outbreaks	Cases	Serotype(s)
Almonds, peanuts, peanut butter	6	1616	Enteritidis, Newport, Stanley, Tennessee, Typhimurium
Animal contact (cats, chicks, ducklings, farm animals, hedgehogs, owl pellets, sheep)	17	999	I 4,[5],12:i:-, Agona, Brandenburg, Enteritidis, Infantis, Montevideo, Ohio, Typhimurium
Animal contact (amphibians, fish aquaria, reptiles)	17	255	I 4,[5],12:i:-, IV 44;z4x23;-, Javiana, Kingabwa, Marina, Nima, Paratyphi, Pomona, Poona, Rubislaw, Sandiego, Telelkebir, Tennessee, Typhimurium
Bakery products (biscuit, bread, buns, cake, rolls)*	12	2948	Enteritidis, Thompson, Typhimurium
Beef	18	732	Coeln, Enteritidis, Newport, Oranienburg, Paratyphi, Thompson, Typhimurium
Candy and snacks (chocolate, dessert, drinks, gelato, sesame candy, tea, veggie booty)	7	882	Agona, Oranienburg, Typhimurium, Wandsworth
Cereal	2	437	Agona
Chicken and turkey (meat)	36	4012	Anatum, Braenderup, Bredeney, Enteritidis, Hadar, Heidelberg, "i" monophasic, Panama, Typhi, Typhimurium, Virchow
Combination foods (baked beans, Chinese food, dips, fried rice, lasagna, pizza, pot pies, ravioli, refried beans, sandwiches, sesame prawn toast, spaghetti, spring rolls, tacos, tortellini)	18	1561	I 4,[5],12:i:-, Enteritidis, Hartford, Madelia, Montevideo, Newport, Typhi, Typhimurium
Dairy products (cheese, cream, ice cream, milk)	32	3011	Enteritidis, Newport, Oranienburg, Stanley, Stourbridge, Typhimurium, Worthington
Eggs and egg dishes (custard, mayonnaise, meringue, mousse, omelet, pudding, salad, sandwiches, sauces, tiramisu)	83	6410	Bareilly, Enteritidis, Heidelberg, Indiana, Potsdam, Typhimurium
Fish and seafood (anchovy, bass, cod, eel, fish, prawns, shrimp, squid, sushi)	12	2283	Blockley, Enteritidis, Java, Lexington, Livingstone, Newport, Oranienburg, Singapore, Typhimurium, Virchow
Food handler	10	1535	Enteritidis, Heidelberg, Javiana, Othmarschen, Typhi, Typhimurium
Formula, infant and enteral	5	215	Agona, Give, Kedougou, London, Saintpaul
Fruit (cantaloupe, coconut, grapes, mamey, mango, melons, orange juice, paw paw)	18	892	Anatum, Berta, Java, Litchfield, Muenchen, Newport, Oranienburg, Poona, Saintpaul, Saphra, Typhi
Greens (basil, cilantro, coleslaw, lettuce, salad, spinach)**	19	2442	Baildon, Bovismorbificans, Java, Newport, Senftenberg, Thompson, Typhi, Typhimurium
Lunch, boxed, “foods”	12	4450	Brandenberg, Enteritidis, Montevideo, Typhimurium, Weltevreden
Meat, general and other (horse, kebab, lamb, pigeon, rabbit, turtle)	14	833	Agona, Bredeney, Chester, Derby, Enteritidis, Hadar, Infantis, Newport, Typhimurium
Meat, processed (ham, salami, sausage)	10	406	Goldcoast, Kedougou, Montevideo, Newport, Typhimurium
Miscellaneous (occupational exposure, tahini, tofu)	3	109	Enteritidis, Montevideo, Typhimurium
Person-to-person	7	124	Livingstone, London, Menston, Schwarzengrund, Senftenberg, Typhi, Typhimurium
Pet food/treats	4	128	Infantis, Newport, Schwarzengrund, Thompson
Pork	32	3482	I 4,[5],12:i:-, Bovismorbificans, Brandenberg, Give, Heidelberg, London, Manhattan, Muenchen, Newport, Typhi, Typhimurium, Uganda
Sprouts (alfalfa, bean, clover)	23	1774	Bareilly, Cubana, Enteritidis, Havana, Kottbus, Mbandaka, Muenchen, Oranienburg, Paratyphi, Saintpaul, Senftenberg, Stanley, Typhimurium, Virchow, Weltevreden
Tomatoes, peppers	12	3249	Anatum, Baildon, Braenderup, Javiana, Muenchen, Newport, Saintpaul, Thompson, Typhimurium, Virchow
Water (bottled, drinking, tap, well)***	8	6557	Chester, Kottbus, Saintpaul, Typhi, Typhimurium
Total	437	51,342	

*Some outbreaks may be due to contaminated eggs.
**Some outbreaks may be due to dressing rather than greens.
***Includes a large outbreak of typhoid in Nepal (5963 cases).

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Appendix : Chronological List of Salmonella Outbreaks

Date	Serotype	Location	Cases	Hosp.	Deaths	Vehicle	Reference(s)
1992 (a)	Typhimurium DT124	UK: Wales	28	2	1	Ham	(*297*)
1992 (b)	Enteritidis PT 8	US: MA	74			Sandwiches (eggs)	(*397*)
1992 (c)	Enteritidis PT 14b	US: MA	32			Sandwiches (eggs)	(*397*)
1993 (a)	Braenderup	Switzerland	215	16	0	Meat pies, commercial	(*453*)
1993 (b)	Javiana, Rubislaw, Saintpaul	Germany	1000			Paprika & paprika-powdered potato chips	(*286*)
1994 (a)	Bovismorbificans	Finland	210	21		Sprouts, alfalfa	(*307*)
1994 (b)	Enteritidis PT 8	US: 41states	593		0	Ice cream estimated 224,000 cases	(*234*;*465*)
1994 (c)	Hadar PT26	Italy	448			Meat salad	(*178*)
1994 (d)	Berta	Canada	79	15		Cheese, unpasteurized, soft	(*165*)
1994–95	Typhimurium	US: WI	158	17	0	Beef, raw	(*400*)
1995 (a)	Hartford, Gaminara, Rubislaw	US	62			Juice, orange, unpasteurized	(*131*;*378*)
1995 (b)	Senftenberg	UK: England	5			Cereal, baby	(*404*)
1995 (c)	Typhimurium PT 193	Italy	83	21		Salami	(*387*)
1995 (d)	Typhimurium DT170	UK: Wales	52	6	0	Lamb and yogurt relish	(*177*)
1995 (e)	Enteritidis	US: NV	7	2	1	Eggs, turkey	(*88*)
1995 (f)	Typhimurium PT 9	Australia	22	1	0	Pork, deboned	(*148*)
1995–96 (a)	Montevideo	UK: England	10			Chicken, cooked	(*439*)
1995–96 (b)	Newport	US: OR; Canada	133	13	0	Sprouts, alfalfa	(*456*)
1996 (a)	Enteritidis PT 34	US: GA	44	8		Eggs	(*313*)
1996 (b)	Enteritidis PT "untypeable"	UK; Europe	19			Lasagna (eggs)	(*345*)
1996 (c)	Thompson	US: SD	52	0	0	Beef, roast	(*415*)
1996 (d)	Enteritidis PT 8	US: CO	65	8	0	Animal environment (reptile) contact	(*187*)
1996 (e)	Enteritidis PT B14	Saudi Arabia	228	228		Mayonnaise	(*4*)
1996 (f)	Hartford	US: NY	56	1		Water, well	(*90*)
1996 (h)	Mbandaka	Australia	15			Peanut butter	(*407*)
1996 (g)	Typhimurium	Australia	52		1	Egg sandwiches	(*309*)
1996 (i)	Enteritidis	Mexico	83			Chiles rellenos (eggs)	(*414*)
1996 (j)	Agona	UK	9	3	0	Turkey, cooked	(*429*)
1996–2000	Schwarzengrund	US: OR	11			Person to person	(*357*)
1996–97	Anatum	UK; France	19			Formula, infant dried	(*440*)
1997 (a)	Typhimurium DT12 atypical	France	113	11	0	Cheese, soft, unpasteurized	(*145*)
1997 (b)	Enteritidis PT 4 & 7	US: CA	13			Cheesecake (raw egg whites)	(*93*)
1997 (c)	Enteritidis PT 8	US: DC	43	3	0	Lasagna (commercial, eggs)	(*93*)
1997 (d)	Enteritidis PT 13A	US: NV	91	15	0	Sauce, hollandaise (eggs)	(*93*)
1997 (e)	Saphra	US: CA	24	5	0	Cantaloupe	(*325*)
1997 (f)	Enteritidis PT 4	Belgium	88			Beef, ground; possibly eggs	(*416*)
1997 (g)	Typhimurium DT104b	US: CA	79	13	0	Cheese, raw milk	(*128*)
1997 (h)	Typhimurium DT104b	US: CA	31	14	0	Cheese, raw milk	(*128*)
1997 (i)	Typhimurium DT104	US: WA	54	5	0	Cheese, raw milk	(*462*)
1997 (j)	Typhi	France	26	26		Pork, food handler	(*388*)
1997 (l)	Enteritidis PT 4	UK	73			Eggs — dessert	(*476*)
1997 (m)	Bredeney	Ireland	10	1	0	Chicken	(*326*)
1997 (n)	Enteritidis	Japan	143			Cakes (eggs)	(*337*)
1997–98 (a)	Virchow PT8	Australia	32	12	1	Tomatoes, dried and garlic	(*55*)
1997–98 (b)	Newport	Finland	70			Ham	(*301*)
1997–98 (c)	Senftenberg	US: 2 states	52			Sprouts, clover, alfalfa	(*434*)
1998 (a)	Enteritidis PT 4	UK: England	186	7	0	Chicken liver, chopped	(*16*)
1998 (b)	Agona	US: 10 states	409	47	1	Cereal, toasted oat (Malt-O-Meal)	(*89*;*427*)
1998 (c)	Bongori	Italy	8	7	0	Unknown (infants)	(*338*)
1998 (d)	Blockley	Germany	13			Eel, smoked	(*179*)
1998 (e)	Enteritidis	Mexico	155	18		Meat, egg covered	(*126*)
1998 (f)	Enteritidis PT 6A	US: AZ	58	11	0	Chiles rellenos (eggs)	(*93*)
1998 (g)	Typhimurium DT104	UK: England	86	4		Milk, defective pasteurization	(*14*)
1998 (h)	Typhimurium DT104	Denmark	25	11	2	Pork; Occupational exposure	(*336*)
1998 (i)	Enteritidis PT 34a	UK	54	3		Mousse, chocolate	(*294*)
1998 (j)	Enteritidis PT 8	Canada	>800			Cheese; commercial prepack lunches	(*3*;*392*)
1998 (k)	Enteritidis	Greece	60	20		Mayonnaise	(*218*)
1998 (l)	Enteritidis	Italy	9			Mascarpone (cream cheese)	(*377*)
1998 (m)	Enteritidis	Italy	36			Cake, iced (eggs)	(*138*)
1998 (n)	Enteritidis PT 21	UK	67	1		?	(*469*)
1998 (o)	Coeln	France	26	15	0	Beef, minced	(*219*)
1998 (p)	Marina (IV 48:g,z51:-)	US: ND	4	2	0	Iguana contact	(*101*)

Date	Serotype	Location	Cases	Hosp.	Deaths	Vehicle	Reference(s)
1998 (q)	Typhi	France	27	21	0	Chicken, rice	(*455*)
1998 (r)	Enteritidis	US: WI	3	0	0	Eggs	J. Archer
1998 (s)	Enteritidis	US: WI	18	3	0	Unknown	J. Archer
1998 (t)	Typhimurium RDNC A045	Australia	38			Chicken	(*70*)
1998 (u)	Oranienburg	Australia	102			Gelato	(*17*)
1998 (v)	Enteritidis	Spain	101	13	0	Spaghetti, eggs	(*206*)
1998 (w)	Typhimurium PT 20	Netherlands	37			Ham	(*318*)
1998 (y)	Tel-el-kebir	Ireland	8			Turtle exposure	(*300*)
1998 (z)	Oranienburg	Canada	21			Cantaloupe	(*147*)
1998 (aa)	Manhattan	Denmark	15			Pork	(*183*)
1998 (bb)	Infantis	US: LA	63	9	0	Meat-based rice-dressing mix	(*276*)
1998 (cc)	Havana	US: CA, AZ	18	4	1	Sprouts, alfalfa	(*41*)
1998 (dd)	Enteritidis PT 4	UK	47	0	0	Eggs	(*163*)
1998 (ee)	Enteritidis PT 4	US: HI	38	3	0	Eggs	(*79*)
1998 (ff)	Enteritidis PT 21	UK	100	4		Eggs	(*15*)
1998 (gg)	Enteritidis PT 13a	Scotland	40		3	Eggs	(*134*)
1998 (hh)	Enteritidis PT 1	Mallorca	284	25		Mousse	(*76*)
1998 (ii)	Enteritidis	Spain	22		9	Unknown food	(*212*)
1998 (jj)	Enteritidis	Japan	558			Eggs	(*30*)
1998 (kk)	Enteritidis	Germany	17	0	0	Chicken, beef	(*319*)
1998 (ll)	Enteritidis	Japan	1871			Cake	(*30*)
1998 (mm)	Cubana	US: 3 states	16			Sprouts, alfalfa	(*434*)
1998 (nn)	Chester	Australia	36	6		Meat, turtle	(*350*)
1998 (oo)	Bredeney	US: AL	>170			Meat	(*252*)
1998–2002	Brandenburg	New Zealand	671	78	2	Sheep, occupational contact	(*45*)
1998–99 (a)	Java PT Dundee	UK: England	18	7		Coconut, dried	(*468*)
1998–99 (b)	Typhi	Nauru	50	32	0	Food handler	(*358*)
1998–99 (c)	Typhi	US: FL	16			Fruit (mamey), imported, frozen	(*262*)
1998–99 (d)	Baildon	US: 8 states	86	16	3	Tomatoes	(*137*)
1998–99 (e)	Typhimurium PT 9	Australia	54			Custard	(*467*)
1998–99 (f)	Typhimurium	US: MN	33	3	0	Chicken, frozen products	(*420*)
1999 (a)	Mbandaka	US: 4 states	89		0	Sprouts, alfalfa	(*201*)
1999 (b)	Enteritidis	Germany	102			Pudding	(*273*)
1999 (c)	Muenchen	US; Canada	207	21	0	Juice, orange, unpasteurized	(*91*)
1999 (d)	Typhimurium DT104	US: WA	3	0	0	Cats, contact with	(*95*)
1999 (e)	Typhimurium DT104	US: MN	7	1	0	Cats, contact with	(*95*)
1999 (f)	Typhimurium	US: Idaho	10	0	0	Cats, contact with	(*95*)
1999 (g)	Thompson	US: CA	41	3	0	Cilantro	(*83*)
1999 (h)	Anatum	US: FL	4			Juice, orange, unpasteurized	(*278*)
1999 (i)	Typhimurium	US: MO	40	3		Poultry young	(*94*)
1999 (j)	Paratyphi B	France	8		0	Beef, minced	(*219*)
1999 (k)	Enteritidis	Japan	206			Cream buns sold by peddler	(*449*)
1999 (l)	Serogroup C	Taiwan	96			Eel kabayaki	(*248*)
1999 (m)	Typhimurium	US: CO	112			Sprouts, clover	(*74*)
1999 (n)	Give	US: WI	27	0	0	Unknown	J. Archer
1999 (o)	Enteritidis	US: WI	5	3	0	Eggs	J. Archer
1999 (p)	Enteritidis	US: WI	4	2	0	Unknown	J. Archer
1999 (q)	Muenchen	US: WI	157	6	0	Sprouts, alfalfa	(389)
1999 (r)	Enteritidis	US: WI	33	0	0	Eggs, pasta dough	J. Archer
1999 (s)	Saintpaul	Australia	28			Water, drinking	(*436*)
1999 (t)	Typhimurium PT 40	Sweden	2	2		Cats, contact with	(*435*)
1999 (u)	Typhimurium PT 1	Canada	27	7	0	Ice cream pie	(*240*)
1999 (v)	Paratyphi B Java	Canada	51			Sprouts, alfalfa	(*425*)
1999 (w)	Paratyphi B	Europe: 9 countries	309			Unknown food or water in Turkey	(*291*)
1999 (x)	Oranienburg	Japan	1634			Squid, dried	(*341*;*444*)
1999 (y)	Oranienburg	Austria	16			Cheese	(*8*)
1999 (z)	Newport	US: 13 states	78	15	2	Mangoes	(*417*)
1999 (aa)	Infantis	Canada	35			Pig ear dog treats	(*127*)
1999 (bb)	Enteritidis PT 4	Ireland	110	35		Egg, fried rice	(*135*)
1999 (cc)	Enteritidis	Japan	904			Lunch, school Ref:2057	(*30*)
1999 (dd)	Enteritidis	Brazil	8		3	Eggs in enteral diet	(*306*)
1999 (ee)	Enteritidis	Spain	42			Bread, fried	(*480*)
1999–2000 (a)	Infantis	US: MI	26	5	0	Poultry, young	(*474*)
1999–2000(b)	Mgulani	Australia	42			Unknown	(*288*)

Date	Serotype	Location	Cases	Hosp.	Deaths	Vehicle	Reference(s)
1999–2005	Senftenberg	US: FL	67			Person to person	(*264*)
2000 (a)	London	Korea	31	31	0	Formula, infant	(*380*)
2000 (b)	Enteritidis PT 5c & 6a	UK: Scotland	70	11	1	Chicken from restaurant	(*133*)
2000 (c)	Typhimurium DT104	UK	361		1	Lettuce	(*243*)
2000 (d)	Thompson	US: CA	43	9	0	Bread, infected food handler	(*269*)
2000 (e)	Typhimurium DT104L	Singapore	33	17	0	Fish, dried anchovy	(*293*)
2000 (f)	Typhi	US: NY	7	4	0	Food handler	(*482*)
2000 (g)	Typhimurium DT104	France	35	25	3	Beef, minced	(*219*)
2000 (h)	Tennessee	US: FL	1	0	0	Bearded dragon	(*101*)
2000 (i)	Sandiego	US: OH	3	0	0	Turtles	(*101*)
2000 (j)	Typhimurium PT 21	US: PA, NJ	38	6		Milk, pasteurized	(*359*;*360*)
2000 (k)	Enteritidis PT 13	US: IL	36	10	1	Egg filling for salmon	(*132*)
2000 (l)	Baildon	US: TN	264	12	0	Salad	(*256*)
2000 (m)	Montevideo	US: WI	4	3	0	Tacos	J. Archer
2000 (n)	Typhimurium	US: WI	26	6	0	Coleslaw	J. Archer
2000 (o)	Typhimurium PT 135	Australia	54	0	0	Ice cream (eggs)	(*406*)
2000 (o)	Typhimurium PT 44	Australia	11			Pork?	(*448*)
2000 (p)	Typhimurium PT 126	Australia	72			Chicken	(*363*)
2000 (q)	Typhimurium	Norway	37			Hedgehogs, contact with	(*226*;*430*)
2000 (r)	Typhimurium DT204b	Europe: 5 countries	396	61		Lettuce	(*136*)
2000 (s)	Typhimurium DT120	UK	372	7	1	Salad vegetables	(*18*;*20*)
2000 (t)	Typhi	US: OH, KY	8			Person to person	(*394*)
2000 (u)	Rubislaw	UK	2		1	Lizard exposure	(*19*)
2000 (v)	Poona	US: 5 states	47	11	0	Cantaloupe	(*96*)
2000 (w)	Paratyphi B Java	Canada	7			Water, fish aquarium	(*195*)
2000 (x)	Indiana	UK	17			Mayonnaise	(*304*)
2000 (y)	Enteritidis PT 8	Canada	62	5		Eggs — baked goods	(*426*)
2000 (z)	Enteritidis PT 4b	Netherlands	27	4	0	Sprouts, mung bean	(*457*)
2000 (aa)	Enteritidis PT 4b	Netherlands	25			Sprouts, bean	(*180*)
2000 (bb)	Enteritidis PT 33	US: 4 states	75	3	0	Sprouts, mung bean	(*324*)
2000 (cc)	Enteritidis PT 11b	Canada	12			Sprouts, mung bean	(*227*)
2000 (dd)	Enteritidis	Tanzania	7	7	5	Unknown	(*454*)
2000 (ee)	Enteritidis	Saudi Arabia	57	44		Mayonnaise	(*267*)
2000 (ff)	Enteritidis	Turkey	60	16	0	Eggs	(*433*)
2000 (gg)	Enteritidis	UK	32	4	0	Chicks, ducklings	(*21*)
2000 (hh)	Newport, Java, Lexington	US: cruise ship	234	7	0	Shrimp	(*92*)
2000–01	Enteritidis PT 30	US; Canada	168			Almonds	(*250*)
2001 (a)	Saintpaul	US: WA	11	11	0	Formula, hospital enteral	(*63*)
2001 (b)	Enteritidis PT 1	Japan	96	12	0	Buns, dessert (eggs)	(*305*)
2001 (c)	Goldcoast	Germany	44			Sausage, raw, fermented	(*69*)
2001 (d)	Kottbus	US: 4 states	32	3		Sprouts, alfalfa	(*99*)
2001 (e)	Muenchen	Germany	198			Pork	(*77*)
2001 (f)	Enteritidis PT 8	France	215			Cheese, Cantal; raw milk	(*220*)
2001 (g)	Livingstone	Norway; Sweden	60	22	3	Fish, processed, "gratin"	(*213*)
2001 (h)	Enteritidis PT 14b	Norway; Sweden; Finland	303			Chicken	(*214*)
2001 (i)	Enteritidis PT 2, 13a, 23	US: SC	688	0	0	Eggs	(*100*)
2001 (j)	Enteritidis PT 13a	US: NC	53			Eggs	(*100*)
2001 (k)	Newport & Stanley	Australia; Canada; UK	109			Peanuts, Asian style	(*271*)
2001 (l)	Nima	US: CA	1	0	0	Snake contact	(*101*)
2001 (m)	Brandenburg & Corvallis	Japan	7		0	Lunch food prepared by a company	(*223*)
2001 (n)	Javiana	US: MS	66			Animals (amphibians?)	(*423*)
2001 (o)	Braenderup	US: WI	21	0	0	Chicken	J. Archer
2001 (p)	7 serotypes	US: WI	56	0	0	Sauce, spaghetti	J. Archer
2001 (q)	Javiana	US: WI	4	0	0	Unknown	J. Archer
2001 (r)	Thompson	US: WI	80	0	0	Beef	J. Archer
2001 (s)	Typhimurium PT 135	Australia	18	3		Eggs, raw	(*446*)
2001 (t)	Typhimurium PT 135a	Australia	11	4		Tiramisu, raw eggs	(*222*)
2001 (u)	Typhimurium PT 64var	Australia	28	0	0	Food handler, mango pudding	(*247*)
2001 (v)	Typhimurium PT 126	Australia	9	1	0	Custard filled pastries	(*320*)
2001 (w)	Typhimurium PT 99	Australia	50			Beef	(*362*)
2001 (x)	Virchow PT34	Australia	11			Chicken, beef, barbecued	(*365*)
2001 (y)	Typhimurium PT 99	Australia	19	2	0	Lamb liver	(*211*)
2001 (z)	Saintpaul	US: 7 states	26			Mangoes	(*52*)
2001 (aa)	Enteritidis	Taiwan	34	27		Egg-covered bread	(*298*)

Date	Serotype	Location	Cases	Hosp.	Deaths	Vehicle	Reference(s)
2001 (bb)	Wandsworth	Australia	50			Unknown	(*364*)
2001 (cc)	Uganda	US: IL	20			Pork	(*255*)
2001 (dd)	Typhimurium PT 64	Australia	29			Ice cream, fried	(*363*)
2001 (ee)	Typhimurium PT 170	Australia	14			Beef	(*364*)
2001 (ff)	Typhimurium DT160	New Zealand	119	17	0	Unknown -multiple exposures	(*438*)
2001 (gg)	Typhimurium DT104	Australia; Germany; Norway; Sweden	203			Sesame seed candy (helva)	(*2*;*73*;*295*;*363*)
2001 (hh)	Typhimurium	Australia	29			Water, well	(*364*)
2001 (ii)	Typhimurium	US: MN	44			Owl pellets (dissection)	(*419*)
2001 (jj)	Poona	US: 5 states	50	9	2	Cantaloupe	(*96*)
2001 (kk)	Poona	US: CA	23	4	0	Cantaloupe	(*96*)
2001 (ll)	Panama	US: TX	109	9	0	Chicken	(*142*)
2001 (mm)	Newport	UK	9			Salad, prepackaged	(*347*)
2001 (nn)	Heidelberg PT 1	Australia	12			Egg, raw drink	(*364*)
2001 (oo)	Enteritidis PT 913	Canada	84	5	0	Sprouts, mung bean	(*242*)
2001 (pp)	Enteritidis PT 913	US: FL	33			Sprouts, mung bean	(*324*)
2001 (qq)	Enteritidis PT 1	US: HI	22			Sprouts, mung bean	(*324*)
2001 (rr)	Bovismorbificans	Australia	36	6		Lettuce, commercial iceberg	(*363*;*424*)
2001 (ss)	Newport	US: CT	26	8	0	Cheese, soft	(*311*)
2001–02 (a)	Oranienburg	Germany; Europe	439			Chocolate candy	(*471*)
2001–02 (b)	Enteritidis PT 5	Austria	70		1	Eggs	(*57*)
2002 (a)	Agona	Australia	7			Poultry, young	(*317*)
2002 (b)	Newport	US: 5 states	47	17	1	Beef, ground	(*97*)
2002 (c)	Enteritidis PT 6	Spain	1435	117		Pastry with vanilla cream (eggs), commercial	(*84*)
2002 (d)	Typhimurium PT 135a	Australia	28	4		Cake, cream, from bakery	(*351*)
2002 (e)	Javiana	US: FL	159	3		Tomatoes	(*98*)
2002 (f)	Poona	US: CT	2	1	0	Iguana contact	(*101*)
2002 (g)	IV 44:z4z23:-	US: WI	2	2	0	Iguana contact	(*101*)
2002 (h)	Montevideo	Japan	23			Lunch prepared by caterer	(*225*)
2002 (i)	Hartford	US: WI	43	0	0	Beans, refried	J. Archer
2002 (j)	Enteritidis	US: WI	44	0	0	Chicken	J. Archer
2002 (k)	Typhimiurium	US: WI	14	3	0	Unknown	J. Archer
2002 (l)	Newport	US: WI	10	0	0	Sandwiches, submarine	J. Archer
2002 (m)	Enteritidis	US: WI	4	2	0	Unknown	J. Archer
2002 (n)	"i" monophasic	US: WI	16	0	0	Chicken	J. Archer
2002 (o)	"i" monophasic	US: WI	12	0	0	Unknown	J. Archer
2002 (p)	Typhimurium	US: WI	20	0	0	Beef, raw	J. Archer
2002 (q)	Typhimurium PT 135a	Australia	16			Eggs	(*310*)
2002 (r)	Typhimurium PT 99	Australia	22	7	1	Cakes from 1 bakery	(*447*)
2002 (s)	Typhimurium PT U290	Australia	10			Cream filled cakes (1 bakery)	(*442*)
2002 (t)	Potsdam	Australia	17	2	0	Mayonnaise?	(*451*)
2002 (u)	Newport	US: 26 states	510			Tomatoes	(*210*)
2002 (v)	Typhimurium PT 9	Australia	132			Baked beans/chili	(*366*)
2002 (w)	Typhimurium PT 8	Australia	78			Salad, Caesar	(*366*)
2002 (x)	Typhimurium PT 170	Australia	6			Hedgehog	(*366*)
2002 (y)	Typhimurium PT 135a	Australia	10			Egg/salmon patties	(*366*)
2002 (z)	Typhimurium PT 135	Australia	12			Spring rolls	(*366*)
2002 (aa)	Typhimurium PT 135	Australia	20			Pork rolls	(*366*)
2002 (bb)	Typhimurium PT 135	Australia	19			Chicken, roast	(*366*)
2002 (cc)	Typhimurium PT 126	Australia	21			Salad, Thai	(*366*)
2002 (dd)	Typhimurium PT 126	Australia	32			Pork/chicken rolls	(*366*)
2002 (ee)	Typhimurium PT 102	Australia	12			Egg dish	(*366*)
2002 (ff)	Typhimurium DT 120	Denmark	41	10	0	Turkey, RTE	(*231*)
2002 (gg)	Typhi	Nepal	5963		4	Water, drinking	(*290*)
2002 (hh)	Poona	US; Canada	58			Cantaloupe	(*96*)
2002 (ii)	Newport PT 14	Canada	5	1	0	Beef, pet treats	(*386*)
2002 (jj)	Madelia	Germany	44	2	0	Tortellini with pesto sauce	(*228*)
2002 (kk)	Livingstone	Tunisia	16	11	2	Person to person	(*64*)
2002 (ll)	Enteritidis PT 913	US: ME	15			Sprouts, mung bean	(*324*)
2002 (mm)	Enteritidis PT 34a	UK	38	2	0	Eggs	(*42*)
2002 (nn)	Enteritidis PT 14b	UK	224		2	Eggs	(*346*)
2002 (oo)	Enteritidis	Japan	905			Lunch, Boxed	(*30*)
2002 (pp)	Enteritidis	Japan	725			Lunch, Boxed	(*30*)

Date	Serotype	Location	Cases	Hosp.	Deaths	Vehicle	Reference(s)
2002 (qq)	Enteritidis	Japan	644			Cream puff	(*30*)
2002 (rr)	Berta	US: WA	29			Watermelon, grapes	(*65*)
2002 (ss)	Typhimurium DT104	US: WI	2			Milk, breast	(*391*)
2002tt	Enteritidis PT 8	US	475		0	Food handler	(*53*)
2002–03 (a)	Typhimurium DT170	US: OH, IN, IL	62			Milk, raw	(*120*;*308*)
2002–03 (b)	Agona	Germany	42	21	0	Tea, aniseed herbal	(*275*)
2002–03 (c)	Montevideo	Australia; New Zealand	68	7		Tahini (Sesame seed product)	(*452*)
2003 (a)	Typhimurium	US: OR	18	2	0	Salad, egg, commercial	(*102*)
2003 (b)	Newport	France	14	11	0	Meat, horse	(*170*)
2003 (c)	Typhimurium DT104	Japan	358			Lunch food prepared by a company	(*431*)
2003 (d)	Enteritidis	US: WI	3	0	0	Eggs	J. Archer
2003 (e)	London	US: WI	26	0	0	Pork, ham sandwiches	J. Archer
2003 (f)	Agona	US: WI	47	8	0	Unknown	J. Archer
2003 (g)	Typhimurium	US: WI	38	3	0	Chicken	J. Archer
2003 (h)	Enteritidis	US: WI	9	3	0	Unknown	J. Archer
2003 (i)	Newport	US: WI	25	0	0	Pork	J. Archer
2003 (j)	Oranienburg	US: WI	4	0	0	Beef, ground	J. Archer
2003 (k)	Newport	US: WI	12	0	0	Beef, ground	J. Archer
2003 (l)	Enteritidis	US: WI	2	0	0	Eggs, raw cookie dough	J. Archer
2003 (m)	Javiana	US: WI	4	0	0	Unknown	J. Archer
2003 (n)	Typhimurium PT U307	Australia	19			Pork?	(*390*)
2003 (o)	Typhimurium PT 4	Australia	6	1	0	Cheesecake (raw egg whites)	(*181*)
2003 (p)	Typhimurium PT UT5	US: AK	47	2	0	Beef, ground	(*312*)
2003 (q)	Typhimurium PT U302	Europe: 4 countries	77	23		Food handler, buffet items	(*173*)
2003 (r)	Typhimurium DT193a	UK	47	12		Ham	(*62*)
2003 (s)	Typhimurium DT 108 (170)	Sweden	120	8		Pork	(*236*)
2003 (t)	Typhimurium	Australia	20	3		Tofu	(*367*)
2003 (u)	Typhimurium	Australia	18	3		Sauces made with raw eggs	(*367*)
2003 (v)	Typhimurium	Australia	11	1		Salad, rice	(*367*)
2003 (w)	Typhimurium	Australia	33	4		Rice, fried	(*367*)
2003 (x)	Typhimurium	Australia	213	22		Pork rolls	(*367*)
2003 (y)	Typhimurium	Australia	20	0		Pork roast	(*367*)
2003 (z)	Typhimurium	Australia	12	0		Pork roast	(*367*)
2003 (aa)	Typhimurium	Australia	20	0		Pigs ear salad	(*367*)
2003 (bb)	Typhimurium	Australia	61	5		Pigeon meat	(*367*)
2003 (cc)	Typhimurium	Australia	29	6		Foods, mixed	(*367*)
2003 (dd)	Typhimurium	Australia	52	4	0	Eggs, raw	(*367*)
2003 (ee)	Typhimurium	Australia	47	16		Egg, raw	(*367*)
2003 (ff)	Typhimurium	Australia	19	0		Drink, cordial-like	(*367*)
2003 (gg)	Typhimurium	Australia	20	2		Chicken	(*367*)
2003 (hh)	Typhimurium	Australia	12	0		Chicken	(*367*)
2003 (ii)	Typhi	France	5	5		Salad	(*152*)
2003 (jj)	Muenchen	US: 9 states	58	15	0	Melon, Honeydew	(*65*)
2003–04 (a)	Typhimurium DT104	US: 9 states	58	11	0	Beef, ground	(*146*)
2003–04 (b)	Typhimurium DT120	US: 10 states	28	6	0	Rodents, pets, contact with	(*103*;*428*)
2003–04 (c)	Enteritidis PT 9c	US: 12 states; Canada	29	7	0	Almonds	(*265*)
2003–04 (e)	Paratyphi B Java	Australia	18	8		Fish aquaria	(*334*)
2003–04 (f)	Typhimurium DTU29	Austria	>300			Eggs	(*330*)
2004 (a)	Typhimurium	US: 9 states	31	9	0	Beef, ground	(*107*)
2004 (b)	Javiana, Typhimurium, Anatum, Thompson, Muenchen	US: 9 states	429	129	0	Tomatoes, Roma, fresh	(*104*)
2004 (c)	Braenderup	US: 16 states	125	25	0	Tomatoes, Roma fresh	(*104*;*217*)
2004 (d)	Javiana	Canada	7	1	0	Tomatoes, Roma, fresh	(*104*)
2004 (e)	Enteritidis PT 1	Japan	98			Chicken with harusame (bean-jelly)	(*441*)
2004 (f)	Enteritidis PT 13	Czech Republic	39			Chicken	(*245*)
2004 (g)	Typhimurium DT104A	Italy	63			Salami (pork)	(*299*)
2004 (h)	Typhi PT C1	Germany	6	3		Sandwich with herb dressing	(331)
2004 (i)	Brandenburg	US: WI	7	0	0	Pork	J. Archer
2004 (j)	Enteritidis	US: WI	66	8	3	Unknown	J. Archer; (*66*)
2004 (k)	Java	US: WI	11	1	0	Unknown	J. Archer
2004 (l)	Enteritidis	US: WI	6	1	0	Eggs	J. Archer
2004 (m)	Enteritidis	US: WI	19	5	0	Fish, Chilean sea bass	J. Archer
2004 (n)	Newport	US: WI	13	2	0	Unknown	J. Archer
2004 (o)	Typhimurium	US: WI	21	2	0	Chicken	J. Archer

Date	Serotype	Location	Cases	Hosp.	Deaths	Vehicle	Reference(s)
2004 (q)	Typhimurium	US: Wyoming	2	2	0	Turtles	(*105*)
2004 (r)	Enteritidis	China	199	70		Bread, Cake (eggs)	(*296*)
2004 (s)	Singapore	Australia	13	0	0	Sushi	(*51*)
2004 (t)	Typhimurium PT 9	Australia	90	7		Pizza	(*368*)
2004 (u)	Typhimurium PT 36	Austria	36			Eggs	(*330*)
2004 (v)	Typhimurium PT 197	Australia	12	2		Fish	(*368*)
2004 (w)	Typhimurium PT 170	Australia	27	1		Pork roast	(*368*)
2004 (x)	Typhimurium PT 170	Australia	12			Person to person	(*5*)
2004 (y)	Typhimurium PT 170	Australia	17	1		Chinese food	(*368*)
2004 (z)	Typhimurium PT 170	Australia	13	3		Chicken	(*368*)
2004 (aa)	Typhimurium PT 135	Australia	43	17		Custard	(*368*)
2004 (bb)	Typhimurium PT 12a	Australia	28	3		Rolls, gourmet/red onion	(*368*)
2004 (cc)	Typhimurium PT 126	Australia	11	5		Eggs	(*368*)
2004 (dd)	Typhimurium PT 12	Australia	141			Chicken	(*368*)
2004 (ee)	Typhimurium PT 108	Australia	13	5		Cream cakes	(*368*)
2004 (ff)	Typhimurium DT 104	UK	69			Food from shop	(*475*)
2004 (gg)	Thompson	Norway	21			Lettuce, rucola	(*344*)
2004 (hh)	Stanley	Australia	33	4		Unknown	(*368*)
2004 (ii)	Newport	UK	372	33		Lettuce	(*202*)
2004 (jj)	Menston	India	7			Person to person	(*466*)
2004 (kk)	London	Korea	3			Person to person	(*481*)
2004 (ll)	Heidelberg	Canada	45	6		Food handler	(*241*)
2004 (mm)	Give	Germany	115			Pork, raw minced	(*253*)
2004 (nn)	Enteritidis PT 14b	UK	42			Sesame prawn toast	(*239*)
2004 (oo)	Enteritidis	Spain	250			Biscuit with raw egg glaze	(*85*)
2004–05 (a)	Agona	France	141	51	0	Formula, infant	(*75*;*172*)
2004–05 (b)	Bovismorbificans PT 24	Germany	525		1	Pork	(*204*)
2004–05 (c)	Thompson	US: WA; Canada	9	1	0	Pet treats	(*24*;*106*)
2004–05 (d)	Pomona	US: WI	6	1	0	Turtles	(*105*)
2005 (a)	Typhimurium DT104B	Finland	60			Lettuce	(*432*)
2005 (b)	Typhimurium PT 197	Australia	43	13		Liver, lamb	(*235*)
2005 (c)	Braenderup	US: 8 states	82	18	0	Tomatoes	(*109*)
2005 (d)	Goldcoast	Europe: 8 countries	148	5		Unknown, visit to Majorica	(*289*)
2005 (e)	Hadar	Spain	2138	234	1	Chicken, precooked, vacuum packed	(*287*)
2005 (f)	Newport	US: 16 states	72	8	0	Tomatoes, fresh	(*109*)
2005 (g)	Manhattan	France	69	3	0	Pork	(*342*)
2005 (h)	Stourbridge	Europe: 7 countries	52	7		Cheese, goat's unpasteurized	(*171*)
2005 (i)	Worthington	France	49			Milk powdered	(*23*)
2005 (j)	Typhimurium DT104	Netherlands	169			Beef, raw	(*274*)
2005 (k)	Typhimurium DT12	Denmark	26		1	Pork	(*443*)
2005 (l)	Typhimurium NST	Sweden; Norway; Italy	30			Salami (pork)	(*237*)
2005 (m)	Typhimurium DT104	Norway	4			Beef, minced	(*251*)
2005 (n)	Typhimurium DT104	Denmark	31	11	0	Beef, raw (carpaccio)	(*174*)
2005 (o)	Enteritidis PT 21	Austria	85	14	0	Salad, cross contamin. with eggs	(*409*)
2005 (p)	Enteritidis PT 1	UK	195	29		Food handler?	(*12*)
2005 (q)	Anatum	Japan	7	0	0	Chicken, lightly roasted	(*162*)
2005 (r)	Derby	Japan	16	0	0	Meat, lightly grilled	(*162*)
2005 (s)	Enteritidis	Greece	133		2	Chicken, cheese	(*200*;*229*)
2005 (t)	Enteritidis PT 13	Canada	592			Sprouts, bean	(*401*)
2005 (u)	Enteritidis PT 8	US: travel to Jamaica	48			Eggs	(*129*)
2005 (v)	Enteritidis	US: WI	9	1	0	Eggs	J. Archer
2005 (w)	Heidelberg	US: WI	25	2	0	Pig roast	J. Archer
2005 (x)	Montevideo	US: WI	6	2	0	Sausage gravy	J. Archer
2005 (y)	Typhimurium DT104	UK	5			Animals, farm	(*22*)
2005 (z)	Typhimurium PT U302	Canada	45	9	0	Salami, ham	(*339*)
2005 (aa)	Typhimurium PT 135	Australia	61			Chicken	(*314*)
2005 (bb)	Hvittingfoss	Australia	42	7		Unknown	(*361*)
2005 (cc)	Typhimurium PT 9	Australia	13	5		Sauce, hollandaise (eggs)	(*130*)
2005 (dd)	Typhimurium PT 9	Australia	40	29		Pudding, bread and butter	(*130*)
2005 (ee)	Typhimurium PT 9	Australia	14	5		Mousse, chocolate	(*130*)
2005 (ff)	Typhimurium PT 9	Australia	16	0		Eggs, raw	(*130*)
2005 (gg)	Typhimurium PT 64	Australia	81			Chicken, Bread roll	(*323*)
2005 (hh)	Typhimurium PT 44	Australia	23	22		Prawn soup	(*130*)
2005 (ii)	Typhimurium PT 197	Australia	13	7		Egg-based bakery products	(*130*)

Date	Serotype	Location	Cases	Hosp.	Deaths	Vehicle	Reference(s)
2005 (jj)	Typhimurium PT 197	Australia	448	25		Dips	(*130*)
2005 (kk)	Typhimurium PT 170	Australia	20	1		Pork	(*130*)
2005 (ll)	Typhimurium PT 135	Australia	11	2		Sauces made with raw eggs	(*130*)
2005 (mm)	Typhimurium PT 135	Australia	77	2		Mayonnaise & tartar sauce	(*130*)
2005 (nn)	Typhimurium PT 135	Australia	107	6		Bakery products	(*130*)
2005 (oo)	Oranienburg	Australia	125	11		Sprouts, alfalfa	(*130*)
2005 (pp)	Kingabwa	US: 5 states	6	2	0	Lizard exposure	(*209*)
2005 (qq)	Heidelberg	US: MN	4	1	0	Chicken, frozen products	(*420*)
2005 (rr)	Enteritidis PT 8	Italy	124			Unknown	(*402*)
2005 (ss)	Enteritidis PT 4	Austria	35	2	0	Pasta dish containing eggs	(*408*)
2005 (tt)	Enteritidis PT 14b	Japan	30			Omelet, crab	(*260*)
2005 (uu)	Enteritidis	Japan	238			Boxed lunch	(*263*)
2005 (vv)	Chester/Saintpaul	Australia	26	2		Water, tap	(*130*)
2005–06 (a)	Enteritidis NST 3+	Sweden	15			Almonds	(*284*)
2005–06 (b)	Enteritidis	US: MN	27	6	0	Chicken, frozen products	(*420*)
2005–06 (c)	Typhimurium	US: 4 states	21	1	0	Snakes and their rodent food	(*189*)
2006 (a)	I 4,[5],12:i:-	US: OH, TN	4	1	0	Turtles	(*123*)
2006 (b)	I 4,[5],12:i:-	US: MI	21	7		Poultry, young	(*122*)
2006 (c)	Montevideo	US: 21 states	56	8	0	Poultry, young	(*122*)
2006 (d)	Ohio	US: OR	4	1	0	Poultry, young	(*122*)
2006 (e)	Oranienburg	US; Canada	41	7	0	Melons	(*281*)
2006 (f)	I 4,[5],12:i:-	Luxembourg	133	24	1	Pork	(*329*)
2006 (g)	Ajiobo	UK	103	6		Unknown food	(*203*)
2006 (h)	Bareilly, Virchow	Sweden	115	13	0	Sprouts, bean	(*144*)
2006 (i)	Newport	US: 19 states	115	8	0	Tomatoes, fresh	(*109*)
2006 (j)	Typhimurium	US; Canada	190	24	0	Tomatoes, fresh	(*109*)
2006 (k)	Kedougou	Norway	54		1	Salami	(*169*)
2006 (l)	Kottbus	Spain	46	most		Water, bottled	(*376*)
2006 (m)	Montevideo	UK	46	3	0	Unknown	(*166*)
2006 (n)	Typhimurium DT208	Norway; Denmark	10			Sausage, cured	(*343*)
2006 (o)	Enteritidis PT 4	UK	15	3	1	Tiramisu (eggs)	(*82*)
2006 (p)	Enteritidis var Jena	Latvia	23	15	0	Mayonnaise (eggs)	(*72*)
2006 (q)	Enteritidis	Latvia	49			Egg, raw & pork dish	(*383*)
2006 (r)	Enteritidis PT 13a	UK	49	1		Mayonnaise	(*328*)
2006 (s)	Enteritidis PT 8	US: ME	21	0	0	Spill in vaccine-producing facility	(*110*)
2006 (t)	Enteritidis PT 4	Germany	46			Food handler	(*302*;*473*)
2006 (u)	Saintpaul	Australia	115	9	0	Cantaloupe	(*332*)
2006 (v)	Typhimurium PT 9	Australia	15	1		Egg, bakery products	(*369*)
2006 (w)	Typhimurium PT 44	Australia	10	1		Mousse filling for cake	(*373*)
2006 (y)	Typhimurium PT 197	Australia	17	0		Unknown	(*373*)
2006 (z)	Typhimurium PT 170	Australia	47	32		Mousse, white chocolate	(*373*)
2006 (aa)	Typhimurium PT 170	Australia	13	0		Eggs	(*373*)
2006 (bb)	Typhimurium PT 108	Australia	23	7		Ravioli	(*373*)
2006 (cc)	Typhimurium	US: MN	3	2	0	Chicken, frozen products	(*420*)
2006 (dd)	Saintpaul	Australia	11	1		Sprouts, bean	(*373*)
2006 (ee)	Oranienburg	Australia	15	2		Sprouts, alfalfa	(*373*)
2006 (ff)	Litchfield	Australia	17	4		Paw paw	(*373*)
2006 (gg)	Kiambu	Australia	35	2		Unknown	(*373*)
2006 (ii)	Bovismorbificans	Australia	15	4		Pork (capocollo)	(*373*)
2006–07 (a)	Tennessee	US: 47 states	628	125	0	Peanut butter	(*108*)
2006–07 (b)	Pomona	US: 11 states	20	1	1	Turtles	(*123*)
2006–07 (c)	Newport	US: IL	85	36	0	Cheese, unpasteurized, aged	(*87*)
2006–08	Schwarzengrund	US: 21 states	79	12	0	Dry pet food	(*111*;*117*)
2006–07 (d)	Stanley	Switzerland	82	23		Cheese, soft	(*381*)
2007 (a)	Wandsworth	US: 20 states	65	6	0	Veggie Booty Snack	(*121*)
2007 (b)	Newport	US: WI	11	1	0	Pig roast	J. Archer
2007 (c)	Unknown	US: WI	8	3	0	Beef	J. Archer
2007 (d)	Typhimurium	US: PA	29	2	0	Milk, cheese, raw	(*292*)
2007 (e)	Java	Europe: 11countries.	228	47		Spinach, baby	(*151*)
2007 (f)	Senftenberg	Europe: 4 countries	38	3	0	Basil, fresh	(*385*)
2007 (g)	Stanley	Sweden	51			Sprouts alfalfa	(*472*)
2007 (h)	Enteritidis PT 21	Europe: 6 countries	56	3	0	Spaghetti, food handler	(*164*)
2007 (i)	Weltevreden	Norway; Denmark; Finland	45			Sprouts, alfalfa	(*168*)
2007 (j)	I 4,[5],12:i:-	US: 41 states	401	108	0	Pot Pies	(*112*)

Date	Serotype	Location	Cases	Hosp.	Deaths	Vehicle	Reference(s)
2007 (k)	Enteritidis PT 8	Hungary	31	23		Chicken	(*279*)
2007 (l)	Othmarschen	Korea	72	72	0	Food handler, unknown food	(*268*)
2007 (m)	Enteritidis	Romania	117	102	0	Unknown	(*249*)
2007 (n)	Weltevreden	Reunion Island	26	0	0	Food unknown	(*139*)
2007 (o)	"B": Monophasic "i"	US: WI	58	2	0	Unknown	J. Archer
2007 (p)	Enteritidis	Japan	1148			Lunch, boxed	(*30*)
2007 (q)	Enteritidis PT 1e	UK	17			Mousse (eggs)	(*28*)
2007 (r)	Saintpaul	Australia	24			Water, well	(*372*)
2007 (s)	Typhimurium	Japan	8			Turtle meat	(*188*)
2007 (t)	Typhimurium PT 135a	Australia	20			Eggs	(*372*)
2007 (u)	Typhimurium PT 197	Australia	21			Eggs	(*372*)
2007 (v)	Typhimurium PT 44	Australia	16			Chicken, raw eggs	(*374*)
2007 (w)	Typhimurium PT 44	Australia	27			Cream cheese cake	(*374*)
2007 (x)	Typhimurium PT 44	Australia	11			Egg, raw, (triffle)	(*372*)
2007 (y)	Typhimurium PT 44	Australia	10			Egg, Tiramisu	(*372*)
2007 (z)	Typhimurium PT 44	Australia	13			Eggs	(*374*)
2007 (aa)	Typhimurium PT 44	Australia	45			Pork rolls	(*371*)
2007 (bb)	Typhimurium PT 44	Australia	15			Salad, Caesar	(*372*)
2007 (cc)	Typhimurium PT 9	Australia	12			Ice cream, fried	(*371*)
2007 (dd)	Typhimurium PT 9	Australia	294			Pork and chicken rolls	(*372*)
2007 (ee)	Typhimurium PT 9	Australia	30			Water, well	(*372*)
2007 (ff)	Typhimurium PT U302	Australia	34			Kebabs and crepes	(*372*)
2007 (gg)	Typhimurium PT U307	Australia	75			Salad, Caesar	(*372*)
2007 (hh)	Virchow	Australia	22			Sushi	(*369*)
2007–08 (a)	Paratyphi B var Java	US: 33 states	103	24	0	Pet turtles	(*58*)
2007–08 (b)	Anatum	UK	87			Unknown	(*31*)
2008 (a)	Typhimurium	US: CO	411	18	1	Water, tap	(*35;56*)
2008 (b)	Litchfield	US; Canada	60	16	0	Cantaloupe	(*118*)
2008 (c)	Agona	US: 15 states	28	8	0	Cereal, rice, wheat (Malt-O-Meal)	(*119*)
2008 (d)	Enteritidis	Estonia	94	5	0	Chicken soup	(*156*)
2008 (e)	Typhimurium PT U292	Denmark	1054	184	9	Pork?	(*176;175*)
2008 (f)	Saintpaul	US; Canada	1442	286	2	Peppers, tomatoes?	(*113*)
2008 (g)	Agona	Europe: 6 countries	148	14	1	Meat, cooked sandwich	(*349*)
2008 (h)	Kedougou	Spain	29			Formula, powdered infant	(*421*)
2008 (i)	Enteritidis PT 12	UK	78	10	0	Unknown	(*34*)
2008 (j)	Enteritidis	Canada	87		1	Cheese	(*36*)
2008 (k)	Typhimurium PT 126	Australia	41			Eggs	(*375*)
2008 (l)	Typhimurium PT 135a	Australia	78			Eggs	(*375*)
2008 (m)	Typhimurium PT 135a	Australia	18			Foods, mixed	(*375*)
2008 (n)	Typhimurium PT 170	Australia	18			Chicken	(*375*)
2008 (o)	Typhimurium PT 170	Australia	17			Custard cake	(*375*)
2008 (p)	Typhimurium PT 44	Australia	12			Desert, lemon	(*375*)
2008 (q)	Typhimurium	Switzerland	72			Pork ?	(*410*)
2008 (r)	Typhimurium	France	112			Unknown	(*208*)
2008 (s)	Typhimurium U288	Denmark	37			Kebabs	(*175*)
2008 (t)	Typhimurium DT104	Netherlands	152	31		Pork Products	(*157*)
2008 (u)	Typhimurium DT15a	Netherlands	27			Cream cheese	(*157*)
2008 (v)	Give	France	13	5		Formula, infant	(*258*)
2008–09	Typhimurium	US: 45 states; Canada	667	153	9	Peanut butter	(*484;485*)