Epidemiology of Salmonellosis

"The Epidemiology of Salmonellosis" was the discussion topic for the Conference of Public Health Veterinarians, American Public Health Association, held during the annual meeting in Miami Beach, Fla., on October 17, 1962. Selected papers by the experts who served as panel members are presented on the following pages.

Salmonella 1885–1962

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Salmonellae first came into prominence in the 1880's, soon after the isolation of the "hog cholera bacillus" by Salmon and Smith (*1*). The genus name was given to the group in honor of Dr. D. E. Salmon, and the first organism of the group isolated was named *Salmonella chlerae-suis*. This organism was believed to be the cause of hog cholera, but it was shown later that the disease was caused by a virus and that *S. cholerae-suis* was an important secondary invader. During the next two decades, salmonellae were found by numerous investigators in a variety of diseases in animals. *Salmonella abortus-equi* was isolated in 1893 from the vagina of an aborting mare by Kilbourne (*2*). The causative organism of "fowl typhoid," *Salmonella gallinarum*, was found in 1889 (*3*). A few years later, Loeffler (*4*) isolated the "mouse typhoid bacillus" which was later given the name *Salmonella typhimurium*.

In some instances, however, errors in etiology were made, for example when Nocard (*5*) isolated a member of the *Salmonella* group, later called "*Salmonella psittacosis*," from cases of psittacosis during an outbreak in Paris in 1893 and considered it to be the causative agent. The organism was believed to be the cause of psittacosis until the pandemic of 1929–30 in Europe and the United States, when other investigators found that a virus could be recovered regularly from such cases but failed to find Nocard's organism. *S. psittacosis* was later found to be identical with *S. typhimurium*. This was another example of a *Salmonella* as a secondary invader in a viral disease.

In 1909 (*6*), Dr. Leo F. Rettger isolated *S. pullorum*, the cause of "bacillary white diarrhea," or pullorum disease in young chicks. However, except in the case of pullorum disease in poultry and limited studies in other animals, little progress was made in the study of *Salmonella* infections in the United States until a few years after White and Kauffman established the present method of antigenic analysis of the *Salmonella* group, and the occurrence of numerous diverse serotypes was recognized. In 1934, the National Salmonella Center was set up by Dr. P. R. Edwards at the Kentucky Agricultural Experiment Station, Lexington, Ky., and a few years later a similar center was established at the Beth Israel Hospital in New York City. Much of the information on the occurrence and distribution of serotypes in this country has resulted from the work of these centers.

During World War II salmonellae became important as a food industry problem, particularly in dried egg products being exported to Europe. The production of liquid egg products increased in the United States from 46 million pounds in

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1922 to 1,575 million pounds in 1944. Nearly two-thirds of the latter amount was used to produce dried egg powder. In 1947 the Medical Research Council of Great Britain reported evidence of the relation of salmonellae in North American egg powder to the increase in cases of food poisoning in the United Kingdom. During this same year Edwards moved the U.S. National Salmonella Center to the Communicable Disease Center, Public Health Service. A year later, the Communicable Disease Center, in cooperation with the Florida State Board of Health and the Armed Forces Epidemiological Board, established a veterinary public health laboratory in Jacksonville and commenced epidemiologic investigations on salmonellosis in animals in Florida and later on *Salmonella* contamination in human and animal foods. These studies revealed that salmonellae were widely distributed in normal dogs, swine, and in the environment of abattoirs. Further studies revealed that approximately 20 percent of the fresh pork sausage samples examined were contaminated with salmonellae and that more than 25 percent of the dehydrated dog meal sampled contained salmonellae.

In 1959, with the establishment of a veterinary public health laboratory at the Communicable Disease Center in Atlanta, investigations on salmonellae in meat products, swine, in the environment of abattoirs, and in rendered animal byproducts used in animal feeds were undertaken in the Atlanta area. These studies confirmed earlier work and again emphasized the need for the development of control measures to reduce the spread of infection among food-producing animals and the subsequent contamination of their products.

In 1962 the National Salmonella Surveillance Program was developed at the Communicable Disease Center in cooperation with the State health departments. It is anticipated that this program will provide more adequate information as to the true prevalence of salmonellosis in man, animals, and their foods in the United States and that subsequent investigations will lead to the development of better methods to control the problem.

During the period of more than three-fourths of a century since *S. cholerae-suis* was first isolated, salmonellosis has not only been recognized as a problem in the United States, but extensive studies in the United Kingdom, Germany, the Netherlands, and many other countries have shown that its scope is worldwide.

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Salmonellosis in Livestock

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Although domestic fowls are considered the greatest single reservoir of salmonellae both in this country (*1*) and abroad (*2,3*), these notoriously ubiquitous organisms are widely distributed in our domestic and wild animal population as well as in many reptiles and wild birds. For this reason, attention and emphasis on control measures must include all of these reservoirs.

In recent years a significant increase in prevalence of salmonellosis has occurred in the large meat animals. For example, of 9,272 cultures from animal and poultry sources identified by Edwards and co-workers (*1*) during the 14 years from 1934 to 1947, only 71 (0.7 percent) were from cattle. In contrast, of the 7,471 cultures submitted to the enteric bacteriology laboratory, Communicable Disease Center, during the 5 years from 1957 to 1961, 516 (7 percent) were from cattle (*4*). During the same periods there was also a 7 percent increase in cultures

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identified from fowls. Similarly, reported cases of salmonellosis in human beings have increased (*5*). In spite of the incompleteness and inadequacy of reports in the United States, a fourfold increase has been noted in the human cases reported in the weekly Morbidity and Mortality Reports during the past decade (see table).

Investigations have shown that variable numbers of salmonellae are present in a high percentage of human and animal foods (*6–10*). These contaminated foods include not only those derived from animal sources but also such products as desiccated coconut (*11*), cereals (*12*), and certain vegetable meals used in animal feeds (*13*). Many reports have emphasized the importance of foods as a source for the spread of salmonellosis.

In a study in Florida (*14*) the relative prevalence of the most common *Salmonella* types isolated from man, hogs, and dogs was similar. Concurrent studies on fresh pork sausage and dog meals showed that the distribution of *Salmonella* serotypes was also similar to those obtained from man and animals. These studies suggested that infections in man and animals in Florida were spread from one to the other or that they were derived from the same sources.

Swine

Data obtained on the prevalence of salmonellae in swine on farms and in abattoirs in Florida clearly indicated that an increase in infection occurred in these animals during transportation and while they were being held for slaughter (*15*).

The spread of the infection during transportation to the abattoir and in the holding lot was again demonstrated in the Atlanta area. Rectal swab cultures were obtained from hogs at a sale barn in Kentucky, when they arrived at the Atlanta abattoir, and after they were slaughtered. Salmonellae were isolated from 9 percent of the samples collected in Kentucky; isolations increased to 26 percent in the samples taken at the abattoir before slaughter and to 80 percent in samples taken after slaughter (*16*).

Subsequent studies of swine on farms and in the abattoirs in the midwestern part of this country (*17*) and in the United Kingdom (*18*) have shown a similar increase in infected animals as they move to the slaughter plant. Although farms selected were those known to have sent infected pigs for slaughter, Newell and associates (*19*) were unable to demonstrate, with rectal swabs, an increase in *Salmonella* infections in farm and slaughter pigs in Northern Ireland. However, an increase was obtained when caecal swabs were taken after slaughter. The investigators suggested that these differences may have been due to differences in sampling or in isolation technique. They found the same predominant *Salmonella* types in the pigs and in their feed. Each infected animal is a possible source of spread of salmonellae in the abattoir; therefore, the finding of salmonellae in up to 37 percent of fresh pork sausage samples in the retail markets is not surprising. Contaminated sausage, although usually cooked sufficiently to kill salmonellae, is a source of contamination in the kitchen not only for the cooked but for uncooked foods that may be prepared in the same area.

Cattle

Until recent years, salmonellosis in cattle was not considered a serious problem in the United States. The most prevalent *Salmonella* type was *S. typhimurium* found primarily in cases of enteritis, usually in young animals. Infec-

Typhoid, paratyphoid fever, and other salmonelloses, total reported cases in the United States, 1951–61

Year	Typhoid	Paratyphoid and other salmonelloses
1951	2, 128	1, 733
1952	2, 341	2, 596
1953	2, 252	3, 946
1954	2, 169	5, 375
1955	1, 704	5, 447
1956	1, 700	6, 704
1957	1, 231	6, 693
1958	1, 043	6, 363
1959	859	6, 606
1960	816	6, 929
1961	814	8, 542
Total	17, 057	60, 934

SOURCES: National Office of Vital Statistics and Communicable Disease Center, Morbidity and Mortality Weekly Report, Annual Supplements, 1951–61.

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tions with the host-adapted type, *Salmonella dublin*, have been confined entirely to the western part of the country. In 1952, a limited survey was made of dairy cattle in Florida (*15*). Fecal cultures were obtained by rectal swabs from 1,196 animals in 7 dairy herds. Cultures from 596 of these animals in 5 herds were all negative. Two carriers of *Salmonella give* and *Salmonella bareilly* were found in 1 herd of 50 cows. In another herd of 550 animals, salmonellae were isolated from 12. Eight of these cultures were from an isolated group of 26 calves in which diarrhea had occurred. Cultures from one of the positive cows, a normal healthy animal, were found to contain *S. give* persistently for 5 months. From an additional 147 rectal swab cultures taken from cattle immediately after slaughter, salmonellae were isolated from 17 (12 percent). This finding was in distinct contrast to the 51 percent of isolations obtained from hogs after slaughter.

Recent reports indicate that salmonellosis among dairy and beef cattle is becoming a major problem. During 1959 and 1960 Ellis (*13*) reported 40 isolations of *Salmonella* types from cattle with enteritis in Florida. Eighteen of these were from calves; *S. typhimurium* was the predominant type. Moore and associates (*20*) reported the isolation of salmonellae from 78 necropsied cattle in Michigan during 1960. Thirty of these animals were 1 year of age or older. In considering possible sources of infection in a large animal clinic, these authors suggested two epizootiologic hypotheses: (*a*) that the source of infection was in the hospital and (*b*) that the incoming patient was a chronic carrier and clinical illness was stimulated by nutritional, metabolic, or surgical stress. Subsequently, these assumptions were strengthened by the finding of 6 *Salmonella* carriers among 16 experimental cattle wintered in the hospital and another 6 carriers in 44 bovine admissions. Nottingham and Urselmann (*21*) also considered the possibility that other infections or metabolic disorders predispose animals to *Salmonella* infection. They examined fecal samples from 104 dairy cows diagnosed as having a variety of disorders and found *S. typhimurium* in 12.

It is interesting, and perhaps significant, that 80 percent of the isolations from cattle with fatal enteritis were *Salmonella newport*. This type has been associated with occasional severe infections in cattle for years. In 1948 Edwards reported the isolation of *S. newport* in a severe outbreak of enteritis in heavy steers. During 1953 the same type was isolated at necropsy from the intestinal contents of a dairy cow with severe diarrhea in a herd of 358 cows in Florida (unpublished data). Five months later 10 new cases of diarrhea developed and, again, *S. newport* was recovered. Two cases terminated in the death of the animals, and salmonellae were isolated from the liver, kidney, heart, and intestine of one cow and from the liver and intestine of the other. Rectal swab cultures were taken on the entire herd, and *S. newport* was obtained from 10 cows, *Salmonella inverness* from 1, and *Salmonella gaminara* from 1. The remaining ill animals recovered in about 10 days.

The Wisconsin Department of Agriculture reported in its September 1962 *Newsletter* that salmonellosis was being diagnosed in cattle with increasing frequency. Most of the Wisconsin cases were caused by *S. typhimurium*, but several cases were associated with *S. newport*. The disease occurred in that State between September and March with the highest incidence in October. This seasonal distribution would indicate that exposure is greatest when the animals are housed together in barns during the winter months.

The effect of transportation and holding on prevalence of *Salmonella* infection in calves carried to abattoirs was studied in New Zealand (*21*) and in England (*22*). As with swine, a buildup in infection rates was observed in calves between farm and slaughterhouse. On the farm, Anderson and co-workers (*22*) estimated the mean infection rate in calves at less than 0.5 percent. In contrast, after being held for 2 to 5 days in collecting centers, 35.6 percent of the slaughtered calves were found infected.

Horses

Nearly one-half of the 70 cultures reported from horses in Edwards' 1948 summary were *Salmonella abortus-equi* obtained from the genital tract of mares after abortion. The remaining cultures, with two exceptions, were *S.*

typhimurium. More recently, severe outbreaks of salmonellosis with high mortality have been reported with increasing frequency in Florida (*13*) and in Georgia (personal communication from Dr. M. W. Hale, Port Salerno, Fla., 1959). Although *S. typhimurium* is still predominant, *Salmonella enteritidis* is reported more commonly, and at least 12 other serotypes have been found. In one instance, the same type was isolated from fatal enteritis in horses and from lots of cottonseed meal fed to these animals.

While contaminated feeds may be responsible, in part, for the introduction of infected animals into the processing plant, this is not the entire problem. For example, in Argentina, horses are on range and have no contact with processed feeds, yet Hobbs (*23*) has found salmonellae in more than 50 percent of the horse meat imported into England from the Argentine.

Singer and Brandly (*24*) reported the isolation of 13 *Salmonella* types from samples taken from a slaughter plant that processed horses in this country. Prior to this study, Caraway and co-workers (*25*) studied a severe outbreak of salmonellosis in sentry dogs in Louisiana. All the dogs had been fed frozen horse meat processed in the same plant. Five of the 13 types obtained from horse meat samples in the plant were isolated from the dogs. During the survey in the processing plant, it was found that samples obtained from animals slaughtered on the first 3 days of the week contained salmonellae more frequently than those obtained from animals slaughtered on Thursday and Friday. They suggested that this finding might be caused by the spread of infection among horses kept in the holding lots during the weekend.

Since salmonellae are known to survive in soil for long periods, a single carrier animal on a farm may contaminate the premises and serve as a source of spread to other animals. In New Zealand (*21*) soil samples were examined from farms that had supplied infected animals to abattoirs. *S. typhimurium* was isolated from 10 of 20 soil samples from 1 farm where acute salmonellosis had occurred in the cows during the previous 9 months. Mair and Ross (*26*) in England were able to demonstrate survival of *S. typhimurium* in garden soil exposed to ordinary weather conditions for 251 days.

Significance of Sampling and Culturing

In any study the findings will be greatly influenced by the method of sampling, the types of samples, and the procedure used to examine the samples.

Numerous studies have been undertaken to compare various aspects, such as size and number of samples, ratio of sample to enrichment, preenrichments, and so on. Many difficulties have been encountered in the development of satisfactory procedures for isolation of salmonellae from various food products. Continued research is essential in this area.

The value of serologic typing of salmonellae as a means of following the interchange of these organisms between foods, man, and animals should be emphasized and the typing of all isolations encouraged. Another valuable tool for epidemiologic study is the use of bacteriophage typing for certain salmonellae.

Control Measures

Specific methods for the prevention and control of salmonellosis have been outlined in the American Public Health Handbook, "Control of Communicable Diseases in Man," 1960 edition. In order to break the chain of infection between food-producing animals and man, more attention needs to be given to the food sources of infection for these animals and to the processing of meats used for human food. Following are several suggested control measures.

1. Improved design is needed in rendering plants where animal byproducts used in animal feeds are processed so that complete separation of raw and finished products may be maintained. Workers should be made aware of the importance of strict sanitary measures and required to exercise these precautions.

2. Several studies have shown that dissemination of salmonellae in the environment of abattoirs and on the meat from these plants can be reduced by thorough daily cleaning of the plant and equipment. Limited studies suggested that washing of carcasses before evisceration in 165° F. water will reduce the salmonellae contamination in the plant.

3. In rendered meals, it has been shown that a drastic reduction in salmonellae occurred after storage. In one study a 90 percent reduction in

the salmonellae count was noted after 40 days' storage. Nottingham (*21*) was able to show a threefold decrease in numbers of salmonellae in calf tissue after freezing and storage for 1 week. Unfortunately, this holding period cannot always be applied to finished food products.

In summary, reported cases of salmonellosis have increased in both man and livestock during the past decade. It is well established that meat products used for human consumption and those used as a protein supplement in animal feeds are heavily contaminated with salmonellae.

Much progress has been made in the control of milkborne and waterborne infections by the establishment of strict hygienic measures and bacteriological controls. Is it not reasonable to assume that similar sanitary precautions and bacteriological controls would be equally valuable for other foods?

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Salmonellosis in Poultry

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The sources most often incriminated in food-borne outbreaks of *Salmonella* infections in the United States are poultry and poultry products. During 1961, 20 outbreaks of salmonellosis were reported from 8 States. In 11 of these poultry or eggs were believed to be the source of infection. In five outbreaks the source was not determined (*1*). The question arises as to why poultry products are so frequently incriminated in *Salmonella* outbreaks. There is no simple answer. Several factors possibly influence this, such as: (*a*) the unusual susceptibility of poultry to infection, (*b*) the use of eggs in a raw or semi-raw state, and (*c*) improper handling of poultry meats in kitchens where it is cut, washed, stuffed, or otherwise manipulated, increasing the chances of contaminating other food products.

In 1962 the Communicable Disease Center, Public Health Service, received information on at least three outbreaks of salmonellosis involving bakery products in which eggs were the probable source of contamination. Recent Canadian reports also have indicated the occurrence of salmonellae in egg products in that country. Thatcher and Montford (*2*) reported having isolated *Salmonella* organisms from commercial frozen egg products and cake mixes containing eggs. Of 114 samples of frozen eggs 27, or 21 percent, were positive for salmonellae, and of 119 samples of cake mixes containing eggs 65, or 54 percent, were positive.

Occurrence in Poultry

A comparison of the most common serotypes isolated from both man and poultry lends credence to the importance of poultry as a source of human disease. Between July 1947 and July 1958, the Enteric Bacteriology Unit, Communicable Disease Center, received for typing 11,210 *Salmonella* isolations from human sources and 7,135 cultures from chickens and turkeys. During this period, 5 of the 10 most common serotypes were shared by man and poultry, exclusive of the host-adapted types—*S. typhi*, *S. paratyphi B*, *S. pullorum*, and *S. gallinarum* (see table) (*3*). The frequency of *Salmonella* isolations obtained from poultry has indicated that domestic fowl is one of the largest single reservoirs of *Salmonella* organisms existing in nature. Thus, it is logical that efforts should be directed toward reducing infection in poultry in order to control human salmonellosis.

Salmonellosis has been recognized as a significant disease in poultry since the early 1920's. It usually occurs as an acute disease in birds less than 1 month of age. Mortality rates may vary from negligible to 80 percent or higher in severe outbreaks (*4*). Adult birds generally show no outward signs of disease but serve as intestinal carriers over long periods. Most veterinary poultry pathologists believe that the existence of the disease in a breeding flock will eventually cause serious problems, such as higher mortality in chicks hatched from this flock, lowered fertility and hatchability, and impaired egg production. The disease may

Ten most prevalent *Salmonella* serotypes identified from human and poultry sources, July 1947–June 1958

Serotype from person	Number	Serotype from poultry [1]	Number
typhimurium	1, 501	*typhimurium*	2, 035
newport	771	*anatum*	375
oranienburg	645	*heidelberg*	253
montevideo	570	*newport*	245
muenchen	343	*san-diego*	195
anatum	334	*derby*	147
tennessee	302	*oranienburg*	124
cholerae-suis var. kunzendorf.	244	*meleagridis*	123
javiana	216	*enteritidis*	118
reading	216	*montevideo*	112
Total	5, 142	Total	3, 727

[1] Turkeys and chickens only (excludes host-adapted types).

SOURCE: Enteric Bacteriology Unit, Communicable Disease Center, Public Health Service.

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cause stunting of growth and debilitation that increases susceptibility to other diseases.

There is no reliable information on the prevalence of salmonellosis in fowl; however, it can be stated that salmonellae are frequently found in the intestinal tract of fowl at autopsy and that most flocks are exposed to the organism at some time during their lives. This is readily understandable when the environments and contaminated sources which maintain the chain of infection are considered. Infection in newly hatched chicks can occur if the parent eggs are naturally infected or are contaminated in the incubators. If infection is not established by this means, it may be introduced through contaminated feed.

Morehouse and Wedman (*5*), in compiling the experiences of many investigators, illustrated the common occurrence of salmonellae in animal protein supplements which are essential components of most poultry feeds. The question arises as to whether it is possible economically to prepare poultry feeds that are free of *Salmonella* organisms. With the possible exception of fish reduction plants, rendering establishments use temperatures which should destroy pathogenic organisms. The problem is recontamination of the heated product, which can be corrected by establishing proper sanitation practices and improving plant designs. Pelleted feeds are usually free of salmonellae. This is attributed to the use of steam and the development of high temperatures by friction during pelleting. Further investigation of the value of this type of processing as a means of resterilization is needed.

Control Efforts

The approach to disease control in animals often requires radical changes in husbandry practices. Certain diseases in swine are being controlled by establishing breeding herds derived from offspring delivered by cesarean section and maintained in an environment free of pathogens (*6*). Chute (*7*), in collaboration with the U.S. Department of Agriculture, has extended the specific pathogen-free principle to include poultry. Under this system good sanitation, housing, and proper management standards are essential for successful results. Neither the program for specific pathogen-free swine nor that for poultry has included salmonellae as one of the specific pathogens to be eliminated. Nevertheless, application of strict sanitary requirements and use of both *Salmonella*-free feeds and isolation procedures would assist in the control of salmonellosis.

The poultry processor must cope with the problem of infection in fowl by improved handling practices which will assist in reducing contamination. These, of course, will not eliminate the organism until poultry can be produced free of salmonellae. Present slaughtering operations are geared to mass production. Methods of evisceration and practices of handling carcasses in common cooling tanks help to transfer bacteria from infected birds to those that are not infected. Continued emphasis on proper evisceration practices should avoid fecal contamination of the carcasses.

Increased contamination in dried egg powder and frozen egg slurries will result if holding temperatures reach a level that permit salmonellae to multiply. Inasmuch as eggs cannot be produced that are entirely free from *Salmonella* contamination, either on the surface or inside the shell, pasteurization at present is the only practical method of control. Salmonellae in bulk egg products have been generally attributed to contamination from the eggshells during breaking operations. One would expect that samples containing high coliform counts would also be more likely to be *Salmonella*-contaminated. Thatcher and Montford compared this relationship and found no direct correlation. They suggest that the chief source of salmonellae may be from within the egg (*2*).

Conclusion

If we are to eradicate foodborne disease, it is essential to provide food products free of pathogenic organisms. This philosophy was accepted when standards of milk pasteurization were established to control brucellosis and tuberculosis. It was extended even further in eradication campaigns waged against these diseases in their natural animal hosts. The key to prevention of human salmonellosis is the reduction of infection in the animal host, of which poultry is one of the most important. The first step in any disease control program is gaining the support of industry and public health authorities. The poultry industry must recognize the need for cooperative control efforts because the disease not only imposes an economic burden on the poultry industry but also creates a human health hazard.

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Five Salmonellosis Outbreaks Related to Poultry Products

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The actual incidence of salmonellae in lower animals is not known since no systematic method for reporting exists. The work of Galton, Edwards, and others and the numerous articles which are now being published in medical and veterinary journals make it clear that these bacteria are extremely common in a wide variety of animals, most of which have the ability to become carriers for relatively long periods. It is difficult to envision the possibility of elimination, or even effective reduction, of all these sources of infection to which man and meat animals are exposed.

Quist (*1*) has pointed out that there is no serologic procedure by which most salmonellae can be identified in animals. At least, there exists nothing comparable to the process by which with experience *Salmonella pullorum* and *Salmonella gallinarum* can be detected in poultry and by which flocks, through isolation procedures and destruction, can be freed from these common serotypes. Therefore, it is necessary to seek the animal sources of salmonellae through bacteriological culturing, and this is exceedingly difficult.

To illustrate the confusing nature of the *Salmonella* problem, five poultry-related outbreaks which occurred in Georgia during the past 10 years are summarized. These outbreaks are not definitive of the situation but they help describe its diffuse character. They have been arranged in order from egg to adult for the sake of convenience. It is not our aim to point an accusing finger at the poultry industry. With the exception of the practice of keeping fowl as pets, the sources of the outbreaks were eliminated by improved processing and have not recurred.

Egg Powder

The first outbreak to be described occurred in 1956. *Salmonella montevideo* recovered from an egg powder product designed for and prescribed by physicians as a special infant dietary supplement was incriminated as the causative organism. In this instance, notification from the U.S. Food and Drug Administration that several States were reporting outbreaks of diarrheal disease among infants and that *Salmonella*-bearing egg powder was believed responsible prompted examination of baby foods containing egg powder. Outbreaks in Georgia had not then been reported. Soon after the search began, *S. montevideo* was successfully recovered from one lot of powder manufactured by a well-known processor of infant foods. Isolation of the organism, however, was accomplished only with considerable difficulty because of the limited amount of the inoculum which could be placed into 10 ml. of tetrathionate broth.

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The number of organisms per gram of powder was obviously small, and some inhibitory factor in eggs seemed to contribute an additional stumbling block to successful isolation. In an attempt to dilute this inhibitory factor to innocuous levels and also to increase the amount of sample, liter flasks containing 500 ml. of tetrathionate broth were inoculated with entire cans of the infant food. As a result a greater percentage of cans was found to contain *S. montevideo* than had been originally suspected. Unfortunately, the precise bacteriological findings are no longer available.

Ultimately, 13 infants developed symptomatic *S. montevideo* infections in Georgia after consuming this egg powder dietary supplement, and a more generalized outbreak was apparently averted by quick removal of the contaminated product from the market.

Fresh Eggs

An outbreak of *Salmonella typhimurium* probably involving fresh eggs occurred in March 1961 among the clientele of a fashionable northeast Atlanta restaurant. This outbreak came to our attention when physicians practicing on the north side of Atlanta began to see an unusual number of patients with characteristic symptoms of severe diarrhea, fever, nausea, vomiting, abdominal cramps, and dehydration. Investigation revealed that all patients had eaten blue cheese dressing in the restaurant on either Friday night, Saturday, or Sunday prior to onset of illness.

Blue cheese dressing was made from a special mayonnaise base which had been prepared in the restaurant kitchen. This mayonnaise base was far richer than the ordinary commercial product because it contained approximately 22 fresh eggs per gallon. On the occasion of a St. Patrick's Day weekend, a "green cheese" dressing was thought appropriate. Since the green color was impossible to achieve, a special dressing prepared with domestic blue cheese was devised.

Samples of the mayonnaise and the blue cheese as well as the mixed dressing were available for examination. Both the mayonnaise and the blue cheese dressing were found to be positive for *S. typhimurium*. The organism was not found in the blue cheese alone.

One salad cook who may or may not have mixed the particular batch of dressing was found to be positive for *S. typhimurium*, but so were a barmaid and two waitresses. The barmaid had eaten blue cheese dressing and one of the waitresses admitted to "nibbling" as the probable source of her infection. The other waitress averred strongly that she did not like blue cheese and had not eaten any dressing, but she is a heavy smoker and quite possibly laid her cigarette down on a surface which could have been contaminated with dressing.

Since neither the barmaid nor the two waitresses could reasonably be suspected of directly infecting 77 people almost simultaneously, the logical source of contamination was the eggs in the blue cheese dressing. The mayonnaise contained about seven times the common commercial amount of eggs and was not pasteurized. The other constituents were available for culture and were negative for salmonellae.

Subsequent to the outbreak commercially prepared, pasteurized mayonnaise having a lower pH and a much lower egg content has been used for salads in the restaurant and no further difficulty has been experienced.

An attempt was made to find the laying flock which had produced these presumably infected eggs. Investigation of the source revealed that eggs from many producers are collected into shipments and carried into a large packinghouse where, in the process of grading, eggs from as many as 40 different farms may find their way into one case. It became apparent by conservative estimate that at least 250,000 chickens would have to be examined to locate the responsible flock or flocks. Since *S. typhimurium* is one of the most common salmonellae in fowl (*2*) and in poultry feeds (*3*), there would be no guarantee that the infected flock or flocks located through examination procedures would be the source of the suspect eggs. Further investigation seemed useless.

Baby Chicks

After Easter 1960, an increase of *Salmonella enteritidis* infections was noted among small children. After numerous attempts to arrive at the source of exposure it was determined that each of the more than 20 affected children had received an Easter chick. These chicks became prime suspects rather late in the investigation, and it was possible to find only one chicken remaining from those indicted. This bird had been handled by a crawling baby in a crib, had been observed on numerous occasions to soil the pad on the bottom of the crib, and had behaved generally as one would expect a small biddy to behave when being caressed, cuddled, or crushed by an infant. The child had suffered a severe illness, and *S. enteritidis* had been isolated repeatedly from stool specimens.

The chicken, however, was in excellent health, and having grown too big to be a household pet, had been carried to the farm of the child's grandparents, the fate of many chicks and ducks under similar circumstances. The young rooster was about three-fourths frying size when it was finally run to earth and brought to Atlanta for observation. The chicken was refused admission to the animal laboratory house because of the suspected infection; therefore, it was incarcerated in a backyard in a residential area. Droppings cultured over a period of about a week were uniformly negative. It was finally necessary to sacrifice the bird, since he had developed the ability to crow screechily, causing a suburban neighborhood some alarm. The viscera were negative; nevertheless, the circumstantial evidence is convincing, particularly in the light of subsequent experience.

In 1962 similar findings in children after Easter prompted an immediate search for contact with chicks or ducklings. Investigation revealed the same typical epidemiologic pattern seen in 1960. The organism isolated from eight persons was *Salmonella tennessee*.

A considerable number of birds from a variety of sources were available from the six households where clinical illness occurred. One family with five children had bought or been given a total of nine chicks. At least one chick from each of the six families could be traced to hatchery A. Eight of these birds were donated for examination; seven yielded *S. tennessee* and one yielded *S. typhimurium*.

A total of six clinical cases and two asymptomatic infections was traced to Easter chicks from hatchery A. The attack rate, calculated on the basis of clinical illness and asymptomatic carriers among those exposed, was 28.57 percent (table 1). Onset of illness occurred 5 to 39 days after chicks were introduced into the homes.

According to a representative of hatchery A, the firm sold more than 12,000 chicks during a 10-day period preceding Easter. Their own birds were not used for the Easter market, however. Instead, hatchery A had obtained, colored, and distributed leghorn cockerels from hatcheries B, C, D, and E.

None of the four hatcheries which supplied hatchery A had a recent history of trouble from salmonellae in their breeding flocks. In an effort to trace the origin of *S. tennessee*, breeder flocks totaling approximately 30,000 birds were sampled by obtaining composite droppings from units housing 2,500 to 3,000 birds. The only *Salmonella* recovered was *Salmonella worthington* from 1 house of 3,000 birds.

Mature Birds

A large outbreak of *Salmonella blockley* occurred in 1956. After a considerable search for common factors it was concluded that a prepared food must be responsible for the wide scattering of cases among both sexes, both races, and all ages of persons throughout Georgia. Finally, a clue pointed to a particular item. A patient who lived some distance from Atlanta said she had eaten packaged chicken salad, a food unusual for her, prior to onset of illness. She did not like chicken salad but had yielded

Table 1. *Salmonella tennessee* infections disseminated by Easter chicks, Georgia, 1962

Case number, sex, and age	Interval between purchase of chick and onset of illness (days)	Number persons ill or positive and total family members
1. Male, 5 months	12	1(4)
2. Male, 1½ years	6	1(4)
3. Male, 2 years	5	2(7)
4. Male, 12 years	(1)	
5. Female, 45 years	39	1(3)
6. Female, 5 years	37	1(4)
7. Female, 9 years [2]	36	1(3)
8. Male, 5 months	(1)	1(3)
Total		8(28)

[1] Asymptomatic.
[2] Also had *Shigella sonnei* infection.

to the temptation to try some from a carton which her grandson, who particularly favored this food, had bought. Approximately 4 days later she became suddenly ill while watching television, fell from her chair, and was rushed unconscious to the hospital. So severe was the electrolyte imbalance which developed that the physician in attendance stated that he did not believe Asiatic cholera could have been worse. Great numbers of *S. blockley* were found in early stool specimens.

In following this clue a large number of patients, interviewed earlier, were revisited. All had eaten chicken salad prepared by the same large Atlanta manufacturer who operated a fleet of refrigerated trucks which carried the salad to stores located throughout most of Georgia. Upon arrival at the manufacturing plant, we noted that the building was new and the trucks parked outside were also obviously new. These facts caused us to think that the plant operators would not be likely to believe that their product could be capable of causing food poisoning. However, the plant manager, who had already had numerous claims against his product, was found more than ready to surrender his burdens to the Georgia Department of Public Health.

All chicken salad then out on consignment was recalled, and samples representative of each day's run for the preceding month were cultured. *S. blockley* was isolated from all of them.

Four plant employees were found to be harboring *S. blockley*. Swabs from several pieces of mixing and grinding equipment also yielded the organism. The four persons who were carrying *S. blockley* were furloughed, and a thorough cleanup was undertaken. All equipment was disassembled, thoroughly cleaned, and sanitized.

Following the cleanup, the manager and assistant manager prepared a trial batch of chicken salad which, upon culture, was entirely free of salmonellae, and it was believed that normal production could safely be resumed. Accordingly, a new batch of roosters was made into chicken salad. (Male birds are preferred to hens for salads because they have less excess fat, and superannuated roosters from breeder flocks are accumulated for sale to salad manufacturers.) Luckily, this batch was held in bond until bacteriological examination could be completed, because all samples tested contained *S. blockley*.

The investigators observed that workers who cut up raw chickens with a machine saw and placed the meat in pressure cookers, where it was completely sterilized, also boned the cooked meat without changing aprons or even gloves. In addition, a positive culture was obtained from a hard-to-clean crevice in the last mixing machine. Routine measures were taken to separate the raw food from the cooked food operation, boned chicken was returned to the cookers for 5 minutes at 215° C., and a thorough recleaning was undertaken.

At this point the discouragement of plant personnel became so marked that, surreptitiously, the cartridges were removed from a gun kept in the plant for protection of payrolls.

All sources of contamination seemed to have been located, however, and the source of infection once more appeared to be eliminated. Another batch of roosters was purchased and chicken salad prepared in limbo, as it were, was held for bacteriological examination. All samples from this batch of chicken salad also contained *S. blockley*.

When informed of the results, one senior worker left the assembled group but returned in a few moments to inquire, with an air of innocence, if anyone knew who had unloaded the gun.

Fortunately for his peace of mind and the reputation of the investigators, a fifth worker was reported that day to be infected with *S. blockley*. She operated the last mixer and was engaged much of the time in sweeping the salad back into the bowl as it was pushed up to the edges by the mixer. Although she had worn heavy canners' gloves, which were chlorinated after each use, her method of donning these was clearly such as to allow gross contamination, and it seemed entirely conceivable that she was responsible for infecting the entire batch. This last infected worker was removed from the processing line, and another complete housecleaning was effected. The next batch of chicken salad was manufactured without *S. blockley*, and subsequently all tested batches have remained free from this organism.

S. blockley was not isolated from the frozen roosters sampled. That it is associated with chickens was demonstrated a few months later by a sizable *S. blockley* outbreak which caused unusual mortality in a number of broiler flocks in Georgia and South Carolina. Thus, the presumption that the organism was introduced into the plant through infected birds is considerably strengthened. Once inside the plant, it could easily have been carried from the raw food to the cooked food operation by workers who cut up raw carcasses and then literally had a hand in the boning of cooked meat.

It was the custom of the line workers in the plant to bring bread from home and to make sandwiches from the company's filler products for lunch. This practice may explain how 5 of 18 persons employed on the assembly line came to be infected with *S. blockley.* Once established in the plant, the organism remained for at least a month, as returned salad packages dating back 30 days were positive. One hundred and thirty-eight clinical cases of salmonellosis were confirmed by laboratory studies, and at least 200 others occurred in the families in which a positive individual was found. During a 4-week period, 30,000 cartons of chicken salad, all of it presumably infected, were distributed. On the basis of sampling interviews, it is believed that 100,000 persons were exposed and at least 3,000 symptomatic cases occurred.

Discussion

Edwards (*4*) has stated that domestic fowl probably constitute the largest single reservoir of salmonellae among animals. This is not surprising if one considers the frequency with which fowl are exposed to these organisms. Salmonellae can often be isolated from animal byproducts used as sources of protein in poultry rations as well as in other animal feeds (*3, 5, 6*). To be considered also is the ability of these bacteria to be transmitted to progeny through infected eggs (*7*). Other investigators (*8–10*) have demonstrated that it is not so much a question of the amount of salmonellae present in animals when they leave the farm as the number to be found in carcasses after the animals have been slaughtered, dehaired, defeathered, eviscerated, or otherwise processed. This has been shown to be true of pork products, of beef products, and is certainly true of poultry products. The only additional difficulty with poultry is the fact that the industry is vertically integrated, with one firm controlling every step of production and processing. If this suggests a danger, it also implies a greater opportunity for control of infection.

It would seem that when contamination can be lessened through improved management of abattoirs and of meat processing plants, efforts toward control would be more than justified. On the other hand, it would appear unreasonable to demand that either meat animals or poultry be free from salmonellae until feeds, particularly those which contain animal byproducts as sources of protein, are themselves devoid of salmonellae. Clearly, the responsibility for elimination of salmonellae from poultry does not rest with the individual producer. Instead, it would seem far more reasonable and practicable to suggest that the cook continue to be expected to accomplish this task, as she nearly always does. It is our thesis that the chicken is entitled to accept the salmonellae thrust at it and that man ought to protect the chicken, and not the chicken the man.

Table 2, based on 11 years' experience with salmonellae in Georgia, illustrates again the variety and abundance of these organisms. The five *Salmonella* serotypes most often isolated in order of frequency were *S. typhimurium*, *S. blockley*, *S. newport*, *S. oranienburg*, and *S. montevideo*. Combined isolations from these five serotypes accounted for 57 percent of the total. *S. typhimurium* alone comprised 26 percent of the total and was recovered more than 2½ times as frequently as *S. blockley*, the second most common organism in the series. With the exception of *S. blockley*, all these organisms were recovered repeatedly over the entire 11-year period. This serotype was not isolated in Georgia prior to 1955, and the 140 isolations during 1956 are a reflection of the large-scale outbreak previously described (table 2). *S. blockley* is an outstanding example of the rapidity and ease with which a serotype, previously rare or absent, may become established and even attain prominence in a given area.

During the period 1950–54 a careful *Salmo-*

Table 2. Isolations from persons of *Salmonella* by serotype, Georgia, 1950–60

Serotype	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	Total
albany	1											1
amager						1	2			2	1	6
anatum	1		5	5	7	19	14	10	2	11	5	79
atlanta		1	1	1	1	3	2	2	7	6	4	28
bareilly	1	2		1	2	3	5	4	4	3	2	27
berta								1	1		2	4
binza						1	1	1				3
blockley						2	140	15	11	25	49	242
braenderup							1			3	2	6
bredeney	1			1	1	3	3	4		1		14
california	1	2			3	3			59	4		72
carrau				1								1
cerro							1					1
chester				3	4	5	4	3				19
cholerae-suis	2	2	9	7	5	3	4	4	4	4	6	50
cubana								1	1	2	2	6
derby	3	6	4	5	2	9	8	7	1	10	11	66
enteritidis	1	3	2	1	1	1		1	6	3	20	39
florida		1				1						2
give	2	1		1	2	2	4	3	1	2	3	21
grumpensis							1					1
hartford	1					1	1			3	1	7
heidelberg				1		1	3	18	5	6	13	47
indiana						1		1	1	1	1	5
infantis				3	1	13	11	11	14	25	11	89
inverness										1		1
java										1	3	4
javiana	1		3	2		7	2	3	15	8	12	53
kentucky					3	1	1	1				6
litchfield		3	1	1	3	2	4	7	4	2	6	33
livingstone											1	1
luciana		1	1							1		3
madelia	1			1							3	5
manhattan	1	1				2	4	3	1		3	15
meleagridis		1	1	1								3
miami	1	1		3	2	3	3	3	3	5	5	29
minnesota	1							2		1		4
mission							1				1	2
mississippi					1	2			2	2		7
montevideo	6	2	13	5	11	26	16	9	13	12	6	119
muenchen	1	3	4	4		3	11	9	4	12	10	61
newington					4		2	5	1	2		14
newport	1	5	15	14	12	20	22	24	16	43	41	213
norwich				1							1	2
oranienburg	8	4	7	17	50	20	13	13	10	15	9	166
orion				1	3	1				1	2	8
oslo		1									1	2
panama		1			3		1	2		5		12
paratyphi A							1					1
paratyphi B	4	5	1	3	1	2	3	2	1	1		23
paratyphi C					2							2
pensacola	2	1				1	1	1	1	2	4	13
poona					1							1
pullorum	2		1									3
reading								10	2			12
rubislaw					2		3	1		1	3	10
saint-paul						2	8	1	1	5	6	23
san-diego			2	2	2	2	1		2	3		14
schwarzengrund				3	2	3	3	3		3	3	20
senftenberg	1	1	1			3			1			7
siegburg								1				1
simsbury											1	1
sundsvall						1						1
tallahassee							1					1
tennessee	2	2	2	5	4	4	5	3	4	1	5	37
thomasville			3								1	4
thompson				2		1	1	5	2	1	1	13
typhimurium	13	34	33	64	53	81	87	64	79	68	71	647
worthington				1	2		2		1	1	1	8
Total	59	84	109	160	190	259	401	258	280	308	333	2, 441

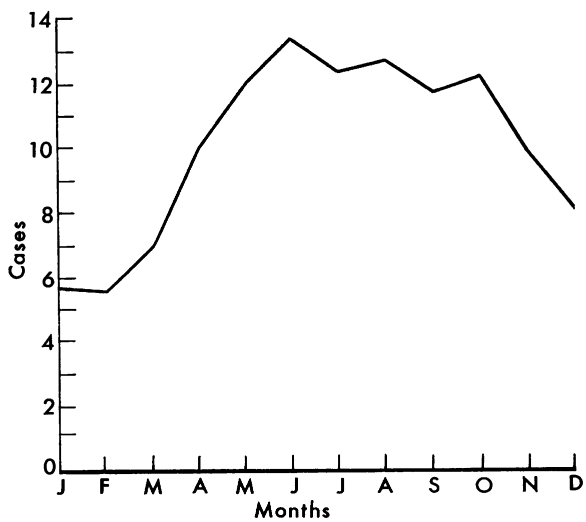
nella surveillance program was maintained and every effort was made to gather data that would be of value in determining the nature of the public health importance of these organisms in Georgia. Total *Salmonella* isolations by months show some seasonal variation, with the least number of cases being reported during December, January, February, and March (see chart). The age distribution of patients during the 1950–54 period in Georgia follows:

Age (years)	*Number of cases*	*Percent of total*
Under 1	109	20. 19
1–5	134	24. 81
5–10	50	9. 26
10–15	17	3. 15
15–20	24	4. 44
Over 20	206	38. 15
Total	540	100. 00

Age was unknown for 65 of the 605 patients for whom isolations were recorded. Of the remaining 540, 45 percent were under 5 years of age, 54 percent were under 10 years, and only 38 percent were more than 20 years.

These data, indicating human infections with such a wide variety of salmonellae, and experience derived from the outbreaks described as well as others have convinced us that it is extremely difficult, if not impossible, to trace an individual case of salmonellosis to its source. Therefore, except when multiple cases occur, it seems scarcely profitable to undertake detailed investigation.

Average number of cases of salmonellosis in persons, by month, Georgia, 1950–54 [1]



[1] Based on a 3-month moving average.

We have also been convinced for some years that it is hardly possible to develop a reliable public health program based on control of persons infected with salmonellae. It appears that if on a given occasion A is found to be carrying a *Salmonella*, he may lose the organism spontaneously before the report gets back from the laboratory. In the meantime, his associate, B, may have acquired a *Salmonella*, quite possibly an entirely different serotype from that of A. Again, before a positive report can be returned, infection may have transferred itself to C or even back to A. Also, Edwards (*4*) has stated that "the carrier state is an occupational hazard of those who continually handle uncooked meats and carcasses." Under these circumstances, examination of foodhandlers except upon initial employment would appear to be essentially a fruitless undertaking. Indeed, the solution would seem to lie not in the discovery of the whereabouts of the organism but rather in the invocation of every sanitary and hygienic measure that can be devised to lessen the spread of salmonellae in animal feeds and in the food processing industry.

Conclusions and Summary

Protection of man against *Salmonella* infections depends on proper cooking and handling of poultry, eggs, and meat by housewives, on adequate disinfection of uncanned meat by commercial processors, and on use of properly processed egg or animal products in uncooked foods. Measures to avoid the contamination of animal feeds and improved sanitary and decontamination practices in abattoirs and poultry processing plants would materially reduce the number of grossly infected animal carcasses now being marketed. Prohibiting the sale of Easter chicks and ducklings as pets for small children would also eliminate a sizable potential source of infection.

The value of such measures is illustrated in reports of five outbreaks of salmonellosis related to poultry products in Georgia. Among 2,441 *Salmonella* isolations from persons in Georgia during an 11-year period, the five serotypes occurring most frequently were *S. typhimurium*, *S. blockey*, *S. newport*, *S. oranienburg*, and *S. montevideo*. During a 1950–54 surveillance program in the State, the smallest number of cases of salmonellosis occurred in the December through March period; in 540 cases, 20 percent of the patients were under 1 year and 54 percent were under 10 years of age.

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Surveillance of Human Salmonellosis

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Human salmonellosis has been recognized as a public health problem for half a century. Early studies of this disease were primarily concerned with field investigations of isolated outbreaks and characterization of the organism in the bacteriology laboratory. Recently investigators from a variety of medical disciplines have reported that salmonellosis is more widespread among man and animals than previously recognized (*1–3*). Moreover, this evidence strongly suggests that the true incidence of this disease in man has been increasing steadily over the past two decades (*4*). Cognizant of these reports, the Communicable Disease Center, Public Health Service, and the Associations of State and Territorial Epidemiologists and Laboratory Directors have jointly established a program of surveillance of salmonellosis in the United States.

Origin of the Surveillance Program

The major theoretical indications for establishment of nationwide surveillance have been mentioned. However, the practical need for such a program was demonstrated dramatically during a recent interstate outbreak of unusually severe gastroenteritis caused by *Salmonella*.

In December 1961 the Canadian Department of National Health and Welfare reported having recovered *Salmonella thompson*, a previously rare *Salmonella* serotype, from a variety of commercial cake mixes examined during a search for the source of an outbreak of gastroenteritis. (*S. thompson* was isolated only 245 times, or 0.87 percent, from 28,000 *Salmonella* cultures from all sources serotyped at the Communicable Disease Center from 1947 to 1958.) The Communicable Disease Center relayed the Canadian report to State health departments and requested reports of recent infections caused by *S. thompson* that may have occurred in the United States.

Responses to the inquiry revealed that only Michigan had experienced an unusual incidence

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of *S. thompson* infections during 1961. Thirteen cases of severe gastroenteritis had occurred in a single Michigan county during a 48-hour period in early July 1961. A field investigation of these cases was begun in January 1962 by State, local, and CDC personnel. The 13 patients had eaten eclairs within the 36 hours prior to onset of illness, and each had purchased the eclairs at the same local bakery.

Further study was begun to determine the source of presumed contamination of the eclairs. Two possible sources appeared likely: a *Salmonella* carrier who had introduced the organism into the ingredients of the eclairs or the ingredients themselves. Fortunately, the county health department staff had cultured two stool specimens obtained from each of the bakery employees shortly after the outbreak. All specimens were free of salmonellae, and the first possible source, a human carrier, could be eliminated. Of the eclair ingredients, only cracked eggs appeared to have been a likely source of *Salmonella* organisms. Therefore, the distribution pattern of the cracked eggs was traced.

Hens had been supplied to several local farms by a poultry breeder in a nearby State. Eggs from hens on the local farms had been sold to an egg wholesaler who had sent only one shipment of cracked eggs to the bakery via a delivery agent. To test the theory that cracked eggs had been a vehicle of the infection, the breeder of the laying hens was interviewed. He reported having lost large numbers of chicks to an obscure illness which affected his flocks early in 1961. He noted further that hens supplied to farms during the remainder of 1961 were predominantly survivors of this illness. Cultures of swabs obtained from the environment of the breeder's hatchery and droppings from surviving hens grew *S. thompson*. Thus, presumptive evidence was obtained to explain the sequence of events leading to the Michigan outbreak of *Salmonella*-caused gastroenteritis.

Some of the hens that survived the outbreak in the breeder's flocks were undoubtedly intestinal carriers of *S. thompson*. Eggs laid by these hens were then contaminated either in the oviduct or cloaca. Cracked eggs, which have been shown to be especially vulnerable to such contamination (*5*), were then shipped to the bakery. Any lapse in refrigeration of the eclairs easily could have led to bacterial multiplication and subsequent human infection.

The Michigan outbreak was the culmination of a chain of events that traversed at least three States in a period of 9 months. The investigation described occupied an additional 3 months. The lessons obtained from the study of this outbreak clearly indicated the need for a central clearinghouse of information concerning *Salmonella* isolations from all sources. The proper utilization of this information could lead, perhaps, to more prompt and less circumspect investigation of the epidemiology of human salmonellosis. With the impetus of the Michigan *S. thompson* and similar interstate outbreaks, a trial period of formal surveillance was begun.

Organization and Goals

Surveillance activities were assigned to the CDC Epidemiology Branch. A Salmonella Surveillance Unit was established within the branch's Investigations and Veterinary Public Health Sections. The unit is staffed by two Epidemic Intelligence Service officers, a statistician, and a public health veterinarian. Assistance in epidemic investigations is available from the branch, and laboratory support is supplied by CDC's Laboratory Branch and Veterinary Public Health Laboratory.

The trial period of surveillance began in April 1962, when eight States reported both human and nonhuman isolations of salmonellae to the unit. By October 1962, the number of States voluntarily joining the program had increased to 22. The National Animal Disease Laboratory, U.S. Department of Agriculture at Ames, Iowa, began regular reporting of nonhuman isolations in August 1962. The 50 States, District of Columbia, and the Virgin Islands agreed to participate in a formal program which began January 1, 1963.

The unit receives regular monthly reports of *Salmonella* isolations. Those from human beings are reported by the organism's serotype, the patient's name, age, and sex, the material cultured, and the culture's county of origin.

These reports are compiled according to a variety of epidemiologic parameters and issued monthly to participating health departments and other interested agencies. They contain tables which summarize data on human isolations by serotype, geographic region, and State of origin. Data on age and sex of patients are also analyzed and recorded monthly. A separate table of the most frequently encountered serotypes and their relative incidence is included in each unit report.

Nonhuman isolations are catalogued according to serotype, source, and State of origin, and the incidence of the serotypes isolated most frequently from both human and nonhuman sources is compared in each report. This, then, is the basic orientation of the surveillance program.

The unit has five other functions: (*a*) provision of epidemiologic or laboratory field assistance to the States upon request, (*b*) solicitation of reports of investigations of *Salmonella* outbreaks among man or animals, editing these, and including them in the unit's monthly report, (*c*) encouragement of and participation in investigations of single isolations of extremely rare *Salmonella* serotypes which are easily identified and thus easily traced, (*d*) encouragement and performance of basic laboratory investigations into the characteristics of the organism and its mode of introduction and survival in a variety of foodstuffs and animal and poultry feeds, and (*e*) investigations of unusual clinical syndromes, factors contributing to host susceptibility, and the characteristics of the human carrier state.

This brief review of the organization and function of the Salmonella Surveillance Unit indicates the short-term and long-term goals of the program. Naturally, the ultimate goal is sufficient definition of the epidemiology of salmonellosis to permit effective control and prevention of the disease in man and animals. The means to accomplish this end include definition of the extent of the disease and its natural reservoirs, early recognition of epidemics, prompt transmission of available information to appropriate health authorities, and discovery of new sources of the organism and of methods to eradicate it from sources that are potential vehicles of human infection. The tasks confronting the unit are numerous, and its goals are far-reaching. However, experience derived from surveillance during the past 8 months has provided significant epidemiologic data and a firm foundation for a nationwide program.

Results of 8 Months' Surveillance

The serotyping of *Salmonella* isolations in each of the 22 participating States has been performed by the State's health department laboratory and, in New York State, by two additional laboratories, the New York City Department of Health Laboratories and the Beth Israel Hospital Salmonella Reference Center. Between April and November 1962, a total of 5,081 isolations were reported to the Salmonella Surveillance Unit. Data on the five most frequently recovered serotypes follow.

Serotype	*Number of isolations*	*Percent of total isolations*
typhimurium	2, 165	42. 6
heidelberg	401	7. 9
newport	352	6. 9
infantis	309	6. 1
enteritidis	202	4. 0

S. typhi accounted for 3.6 percent of total *Salmonella* isolations during this period. The incidence of salmonellosis in each sex was identical. An age distribution curve obtained from these data indicated the modal age group to be 1–4 years. Forty-five percent of all recoveries were from children less than 10 years of age.

From August to November 1962, 13.5 percent of all persons reported as harboring a *Salmonella* organism were found to have one or more members of their immediate family simultaneously positive for the same organism. Of course this observation is subject to numerous sources of bias, the most significant being the frequency with which specimens for culture are obtained from asymptomatic family contacts of a patient in a given investigation. However, this observation again confirms the concepts that salmonellosis is an extremely widespread disease and that asymptomatic excreters of the organism must be sought in tracing the ultimate source of the organism.

During the trial period of surveillance, 30 outbreaks of salmonellosis were investigated in the field, and CDC personnel assisted in the study of 6 of these. A single source of infection has been implicated in at least 18. These sources were desserts incorporating egg products 7, cooked turkey 5, household pets 2, cattle or bovine products 2, cooked chicken 1, and hospital-acquired infection, presumably by contact, 1.

The sources of two outbreaks were traced to products shipped in interstate commerce which were vehicles of human infection in several States. It was felt that the surveillance-reporting mechanism facilitated casefinding and eventual definition of the source of infection in both outbreaks.

The Salmonella Surveillance Unit is currently conducting several long-term investigations. Characteristics of the convalescent and chronic carrier state occurring after acute illness are being studied among a large population infected at a political rally in Kansas (*6*). A field search for the sources of contamination of a variety of animal and poultry feeds is continuing. Finally, studies have been begun to determine the incidence of salmonellosis among population groups with a high incidence of diarrheal illness not previously subjected to bacteriological analysis.

The results presented here have been, of necessity, tentative. However, they indicate that this type of surveillance can provide potentially useful data; reporting from all 50 States will provide more meaningful epidemiologic information, such as geographic distributions of specific serotypes and seasonal variations of the incidence of salmonellosis.

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Value of International Reporting of Salmonellae

KENNETH W. NEWELL, M.D., D.P.H.

Salmonellae are not spread evenly throughout the world. We know from studies in a number of countries that in animals, birds, reptiles, and man there are large variations in the proportions of the different serologic and biochemical *Salmonella* types which can be isolated during surveys and outbreaks. Considering the different ecologies in these countries, these varying proportions are perhaps not surprising. Because we believe that some countries have self-perpetuating *Salmonella* cycles, it is reasonable to expect that the *Salmonella* types most closely adapted to the local circumstances will be selected and will continue to occur in that area endemically.

Until relatively recently the comparison of type differences in man and animals, by area, appeared to be unimportant for practical purposes. *Salmonella* infections in man were thought to be relatively minor causes of illness or death, and the odd occurrence of an exotic serotype in the feces of an international traveler was the most frequent sign of international differences.

Recently there has been a marked increase in interest. This cannot be ascribed wholly to increasing human or animal transport across national boundaries but rather to four separate factors which have occurred simultaneously.

1. Recognition that "food poisoning" is an important cause of illness even in developed countries and that *Salmonella* infections make up a large proportion of these illnesses.

2. Awareness in Europe and in the United States that a large series of "new" *Salmonella* types have appeared in the respective human populations.

3. A restatement of the fact that many sal-

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monellae are true zoonotic infections and are commonly spread from animal to man.

4. Increasingly frequent identification of salmonellae in food, food products, and animal food products which cross national boundaries and have been associated with national or regional *Salmonella* outbreaks in animals and man.

Suddenly it has become urgent to find out what is happening on an international scale, to assess the significance of this transfer of known pathogens across national boundaries, and to try to do something to stop it.

It is not easy to do all these things immediately.

Already a number of *Salmonella* outbreaks have been shown to be international rather than national. High protein sources such as meat and egg products and fish, bone, and meat meals have been implicated as passive vehicles of international *Salmonella* transfer, and legislation to stop the import of infected substances has been prepared and acted upon by a number of countries.

But these have been national actions taken before developing agreed standards or methods of examination. They do not cover all possible vehicles and do not assist in discovering new sources.

To attack salmonellosis rationally we must proceed by clear, logical steps. The first is to collect more information so that we know more about the occurrence of human and animal infections by area, host, and time. It may be possible to get this information by special surveys, but, except for special purposes, these are wasteful and expensive in time and laboratory resources. It is more reasonable to suggest that the existing, continuing observations by medical, veterinary, and references laboratories be collected and made available in a meaningful fashion. Before we can do this internationally we must show how it can be done on a national basis.

I propose that the following data be included in national and international *Salmonella* reports.

1. What type of product served as vehicle and what type of animal or man served as host, including the age, sex, and occupation of human excreters.

2. Whether the host was symptomless or ill.

3. Whether the case was part of an outbreak or was sporadic.

4. The locality where the host lived when examined.

5. Time or season of the isolation.

6. Type of laboratory that made the isolation (*Salmonella* reference, regional, veterinary, hospital, or other).

Already some laboratories in a number of countries have started to report regularly some of this information. Recently the Communicable Disease Center, Public Health Service, has made a big advance in this direction. Their regular publication of *Salmonella* reports from laboratories of a number of States, combined with an advisory and followup service on an interstate basis, provides information and possibilities which have never before been available. However, in most countries the only available reports are from single reference laboratories reporting irregularly. The main source of their data is strains sent to them for identification without full details on the origin of the material. These reports do not show national patterns, but they are usable, and they can be improved. The additional collection and presentation of frequent reports from a large number of regional, veterinary, and medical laboratories would be a major step forward.

If information were available from enough countries on a regular basis, it would be possible to make some international comparisons. Comparisons of the incidence of human cases, however, would be impossible to make from this type of data.

Instead, it would be possible to compare the proportion of different salmonellae in various hosts and products, demonstrate changes if and when they occurred, and show relationships between countries with similar experiences. If a meaningful relationship were suspected, the possible vehicles which might connect the two areas and be worth detailed examination would be limited to manageable size. This accomplishment would be an enormous advantage; at present the number and quantity of possibly contaminated substances which are traded are so large that resources are insufficient to examine them properly.

The changes required to undertake this type of study nationally are small when compared with the difficulties in encouraging reporting internationally. I do not believe that international data collection will be possible until a number of large countries have proved that it is practicable on a national basis, that the final product is useful and used, and that international comparisons would make investigation and control easier and more effective.

A demonstration of usefulness could well take place in this country. The observation of regional outbreaks within the United States and the association of these outbreaks with infected vehicles distributed on a multistate basis mirrors almost exactly what we suspect happens internationally. This line of investigation could result in the identification of new vehicles and yield a model of an organization to deal with them.

Even without an international reporting mechanism, a number of observations have demonstrated the potentialities of international pooling of information. Best known was the identification of North American dried egg products as the vehicle of the wartime *Salmonella* outbreaks in England and Wales. The postwar world experience with *S. heidelberg* is another good example. Human and animal infections with this serotype, now one of the most important in this country, have shown wide differences in time, place, and the sort of person infected. Without a wider knowledge of the world distribution, it might be suspected that the increase in the proportion of *S. heidelberg* isolations in the United States has been a purely national phenomenon. We know that this is not true. If an international clearinghouse of *Salmonella* data had existed in the early 1950's, the vehicle of intercountry transfer might have been identified and countered.

The reasons for advocating the international reporting of salmonellae differ from those which justify the reporting of diseases included in the International Sanitary Regulations collected and distributed by the World Health Organization. Maybe WHO is too official a body to welcome this new responsibility. As an alternative, it might be possible to interest an international *Salmonella* center, a national epidemiologic unit, or a university group to start this project as a research venture, even if the number of countries initially covered was limited.

International reporting of *Salmonella* isolations is already justifiable on logical and experimental grounds. At present all that is required is a standard method of presentation, development of national reporting, use of already accepted field techniques, and a body willing and able to undertake this responsibility.

Control by the FDA Of Foodborne Salmonellae

GLENN G. SLOCUM, Ph.D.

The Federal Food, Drug, and Cosmetic Act is an important instrument for the control of salmonellae in food products in interstate commerce. Section 402(a) of this act defines a food as adulterated if it bears or contains any poisonous or deleterious substance which may render it injurious to health; ". . . if it consists in whole or in part of any filthy, putrid, or decomposed substance, or if it is otherwise unfit for food; if it has been prepared, packed, or held under insanitary conditions whereby it may have become contaminated with filth or whereby it may have been rendered injurious to health; if it is in whole or in part, the product of a diseased animal or of an animal which has died otherwise than by slaughter." . . .

These are the general requirements of the act on which the control of salmonellae in foods must be based. There are no requirements or regulations which specifically name the salmonellae or other pathogenic organisms, but Section 404 titled "Emergency Permit Control" provides:

"Whenever the Secretary finds after investigation that the distribution in interstate commerce of any class of food may, by reason of contamination with micro-organisms during the manufacture, processing, or packing thereof in any locality, be injurious to health, and that such injurious nature cannot be adequately determined after such articles have entered interstate commerce, he then, and in such case only,

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shall promulgate regulations providing for the issuance . . . of permits to which shall be attached such conditions governing the manufacture, processing, or packing of such class of food, for such temporary period of time, as may be necessary to protect the public health;" . . .

This procedure has not been invoked to date.

Direct epidemiologic implication of food products in interstate commerce in outbreaks of salmonellosis has been rare during the past 30 years I have been associated with the U.S. Food and Drug Administration. In the past decade we have experienced four such outbreaks involving canned egg-yolk powder for infants, a dry baby-formula product, yeast powder, and hollandaise sauce, all in interstate commerce. In these episodes, the *Salmonella*-infected foods were seized on charges that they contained poisonous or deleterious substances which might make them injurious to health.

Three additional outbreaks of salmonellosis are of interest: (*a*) the 1956 outbreak of typhoid fever in several midwestern States, (*b*) a nationwide outbreak of 325 known cases of *S. reading* infections in 1957, and (*c*) in 1962 the occurrence of an unusual number of cases of *S. hartford* infections in several States. These outbreaks appeared to have characteristics indicating possible interstate sources. Unfortunately, epidemiologic studies failed to discover the origin of these episodes.

The number of cases of foodborne salmonellosis reported during this period (*1*) has fluctuated from about 500 to 2,000 annually, with an average of about 1,200 cases. However, the annual summaries of specific disease categories by the National Center for Health Statistics show a rather steady rise in the number of cases of salmonellosis, excluding typhoid fever, from 882 in 1948 to 6,929 in 1960. It seems unlikely that this increase reflects solely improved investigation and reporting; more probably it indicates a true increase in the disease. The source of infection is rarely established in the majority of these cases and remains speculative. It appears logical to conclude that a large proportion of these cases are foodborne infections. Since it is generally recognized that the reporting of such cases is grossly incomplete, it is evident that we need vastly improved systems for the epidemiologic investigation and reporting of salmonellosis to identify the food products and establishments in need of application of control measures. The Salmonella Surveillance Program initiated in 1962 by the Communicable Disease Center, Public Health Service, is an important step in that direction.

The list of food commodities shown to contain salmonellae is constantly growing as the scope of the search widens. Food derived from animal sources such as meat, poultry, and egg products lead the list. Meat and poultry products in interstate commerce are exempt from application of the Food, Drug, and Cosmetic Act to the extent that the provisions of the Meat Inspection and Poultry Products Inspection Acts apply, and generally they are not receiving regulatory attention by FDA.

The experiences in England and Sweden with dried eggs imported for direct consumer use during World War II led to investigations demonstrating frequent infection of egg products with salmonellae. Although the presence of many *Salmonella* serotypes in frozen and dried eggs has been amply confirmed, sound epidemiologic evidence implicating such products in outbreaks of salmonellosis in the United States was slow to develop. More recent evidence from well-authenticated outbreaks in this country and others in England and Canada has led FDA to conclude that increased attention should be given to the problem since salmonellae in egg products must be regarded as poisonous or deleterious substances which may render the products injurious to health within the meaning of section 402(a)(1). We are embarking upon an active regulatory program to control traffic in frozen and dried products containing salmonellae.

Reports of outbreaks of salmonellosis in Australia and England traced to dried coconut led us to begin examination of import shipments about 2 years ago. Viable salmonellae were found in a substantial number of shipments which have been denied entry into the United States. We are not aware of cases of illness in this country traced to coconut.

Recently, we have started the routine testing for salmonellae of all food samples collected during sanitary inspections of food establishments. This program may disclose unsuspected food sources of salmonellae not previously revealed by epidemiologic investigation of known outbreaks.

Food is defined in the act as "articles used for food or drink for man or other animals. . . ." Animal feeds in interstate commerce are within the jurisdiction of the act, and we are concerned with the safety and health aspects of feeds and ingredients containing salmonellae. Since funds and facilities have not permitted direct study of the problem we have followed the work of other groups and researchers with avid interest. Appropriations for 1963 provided for the appointment of one bacteriologist to initiate work in this area. Certainly we are convinced that the elimination of reservoirs in domestic food animals is an essential step in eliminating the ubiquitous salmonellae.

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Summary

PHILIP R. EDWARDS, Ph.D.

In summarizing a symposium, it is inevitable that most of one's thoughts already have been voiced. However, there are some points which will bear comment.

The Salmonella Surveillance Program of the Communicable Disease Center, Public Health Service, not only indicates an increased awareness and concern in regard to salmonellosis, but it is also revealing a greater incidence of the condition than previously was apparent from morbidity and mortality reports. As this study is expanded, the reported incidence of salmonellosis will increase, but it must also be remembered that only a fraction, and probably a small fraction, of the cases are reported. At present we have no method of assessing accurately the actual incidence of the disease.

Today, the great majority of reported incidents of salmonellosis are classified as sporadic cases. Yet it seems unlikely that many cases of salmonellosis are truly sporadic and not connected with other occurrences. Lack of demonstrated relations in such cases can be attributed only to the difficulties encountered in establishing causative connections among them. Among these difficulties may be the lapse of time in establishing etiological identity of cases, lack of rapid collection of data on etiologically identical cases, the multiple pathways of infection to be investigated, and the lack of sufficient properly trained personnel to undertake the intensive investigations required. National and international reporting of salmonellosis on a current basis, as described by Sanders and Newell, should solve some of these difficulties, and it is hoped that interest generated by such programs eventually would aid in the solution of others.

The occurrence of salmonellae in poultry and other animals, in animal feeds, and in foods for human consumption and the incidence and epidemiology of salmonellosis in man were discussed, but some facets of these discussions should be emphasized. The changing food habits of man and animals must be considered. Both man and his domestic livestock now consume foods which are mass produced and which frequently contain multiple ingredients prepared by a variety of subsidiary suppliers. This situation has resulted in a greater degree of contamination of food products with salmonellae than existed when foods and feeds were prepared in the individual kitchen and on the individual farm. This fact is amply confirmed by many reports in the literature. Galton, in particular, has spoken of increased incidence of salmonellosis in herbivorous animals and our experience supports this conclusion. This incidence seems to be directly connected with the presence of the bacteria in feeds, since salmonellae of identical serotype and phage type have been found in infected animals and in the feeds they consumed.

The role of the human carrier, which has not been stressed in this discussion, should not be ignored. The isolation of such organisms as shigellae, *S. typhi* and *S. paratyphi A* from foods illustrates this role. Some years ago, Felsenfeld and Young in reviewing the literature found that 26 of 56 outbreaks of salmonellosis caused by nonhost-adapted serotypes were

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traced to human carriers. As McCroan mentioned, one must be careful to distinguish between culprits and victims in reviewing the carrier status of food handlers. Yet there would seem to be little doubt that the presence of salmonellae in the foods and carcasses with which the food handler is in continuous contact predispose to the carrier state. Among this class of employees the repeated ingestion of small numbers of the bacteria may lead to the production of asymptomatic temporary carriers. Further, the particular vehicle by which salmonellae gain entrance to an area of food preparation probably is of secondary importance. Their entrance by any route with resulting contamination of utensils, possible production of carriers, and the subsequent opportunities for contamination of a variety of products is of primary importance.

In the past the discrepancies in the reported percentile distribution of serotypes in man, animals, and egg products on the one hand and in foods and food ingredients on the other has been perplexing and disturbing. *S. typhimurium* is by far the predominant serotype in man, animals, and egg products, but it constitutes only a small percentage of the serotypes isolated from foods and feeds. Recently, I have been informed by Dr. E. Kampelmacher, National Institute of Health, Utrecht, the Netherlands, that if a sufficient number of samples of each lot of feed is examined, *S. typhimurium* can be found in a high percentage of the lots examined. Further, it must be admitted that little is known regarding the comparative invasiveness of the *individual serotypes* as such versus ability of *individual strains* of each serotype to produce disease. Such considerations must be taken into account in comparing the distribution of serotypes in foods and in clinical cases.

It is most encouraging that industry itself is taking a serious view of, and an active interest in, the presence of salmonellae in food and food ingredients. The efforts of Dr. G. M. Dack of the Institute of Food Research and of Dr. C. F. Niven, Jr., of the American Meat Institute Foundation have assisted materially in delineating the problems faced by the food industries of this country. They have investigated the presence of salmonellae in human foods and animal feeds and studied various sources and mechanisms of contamination. While the industries concerned are by no means insensitive to the public health aspects of salmonellae in food and food products and are motivated by the desire to market a wholesome product, it must also be admitted that the problem is not devoid of economic aspects.

When a large food processor insists that the ingredients which he purchases be free of salmonellae, a powerful incentive is provided the subsidiary supplier to produce an acceptable product. Requirements of this sort undoubtedly will be more generally adopted as the widespread distribution of salmonellae is more fully publicized and better understood. Further, there is continually more pressure brought upon the purveyor of livestock to supply animals that are thrifty and have a high livability. In many instances, flocks known to be infected are excluded as breeding stock.

Thus, one may adopt a rather optimistic outlook for future solution of many present problems. The ecology and control of the organisms are being studied more closely, and methods gradually are being devised to free food ingredients of salmonellae and to prevent contamination of the final products. These efforts, combined with those of the sanitarian and the epidemiologist, may be expected to have a salutary effect. However, it is essential to maintain and stimulate the interest which has been aroused among workers in medicine, public health, industry, and agriculture. This can be done only through continued investigation of the many aspects of salmonellosis and dissemination of the knowledge thus gained in such a manner that it is brought to the attention of all concerned.