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III. Salmonellosis

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Salmonellosis (paratyphoid) was widely recognized as a disease of economic importance in miscellaneous birds in the second and third decades of this century. Not until the middle of the century, however, did it begin to come under thorough review. This came about largely through increased awareness that disease in man had a relation to infection in poultry. Contributing also was extensive work on salmonella typing beginning in the early 1930's at the University of Kentucky under the leadership of Dr. Philip R. Edwards.

Salmonellosis in fowl is interpreted as involvement with salmonellae other than those causing pullorum disease and fowl typhoid. It became manifest early that salmonella infection was widespread in birds and mammals, including man. The disease was first reported in the United States in pigeons in 1895, in ducks in 1920, in chickens the following year, and in turkeys in 1933. That the disease was prevalent also in canaries and other birds in pet stores is evidenced by reports from New Jersey in 1926 and from Michigan in 1929. The European literature of that period contained many references to *Salmonella aertrycke* in digestive disturbances of man from ingestion of infected duck and pigeon eggs. With salmonella being ubiquitous and so many new types being continually recognized, understanding of these infections did not develop in the orderly fashion that characterized pullorum disease.

By the early 1940's, about 60 serological types of salmonellae had been recognized, including 35 isolated from fowl. In 1972, Dr. J. E. Williams of the Southeast Poultry Research Laboratory of the USDA listed 127 serotypes from chickens and turkeys. More than 800 serotypes had been identified at that time. By 1976 about 1700 known salmonella serotypes had been reported. Of these, 153 have been reported in the United States from chickens and turkeys.

Host specificity is not a common trait, and various species and serotypes have been found as common pathogens in many species of birds, domestic and wild animals, man, and reptiles. It is not uncommon to find more than one salmonella involved in a single outbreak. Lists of the most numerous or most important serotypes are continually changing, depending partly upon the reporting systems used and the zealousness of laboratories in submitting cultures to centers for typing. In 1939, Dr. W. R. Hinshaw, at the time in California, listed species from turkeys in approximate order of importance: *S. typhimurium, S. derby, S. senftenberg, S. newington, S. anatum, S. bareilly, S. bredeney, S. oranienburg, S. montevideo, S. worthington,* and *S. minnesota.* In a 1948 report by Dr. P. R. Edwards and associates, a list of the most common serotypes in chickens and turkeys included *S. typhimurium, S. anatum, S. derby, S. bareilly, S. meleagridis, S. oranienburg, S. give, S. bredeney, S. newport, S. montevideo,* and *S. senftenberg.* In 1976, Dr. J. E. Williams listed in order the more common serotypes in chickens and turkeys: *S. typhimurium, S. heidelberg, S. saint-paul, S. infantis, S. thompson, S. montevideo, S. worthington, S. johannesburg, S. enteritidis, S. anatum, S. senftenberg, S. sandiego, S. reading, S. blockley, S. newington, S. agena, S. bredeney, S. schwarzengrund,* and *S. chester.*

Problems in all species including poultry are usually most serious in the very young. Mortalities in birds of 20–50–85% and higher have been reported. Outbreaks in chickens and turkeys have behaved like pullorum disease. There generally has been less ovarian transmission. The adult asymptomatic carrier was more likely to have intestinal than ovarian infection. Contamination on the egg surface characteristically penetrates the shell. Usually there is less lung and more cecal involvement in the dying young. Salmonella infections often produce no appreciable clinical disease even in the very young. This is more characteristic in chicks than in poults. Both are highly susceptible to infection, though the turkey is more susceptible to clinical disease than is the chicken. Losses in all species have been variable. In ducks, for example, some question has been raised about the economic import, but a grower reported in 1918 to Dr. Leo F. Rettger, "Whereas two years before the fields were white with ducks, they were now green with grass."

Turkeys have borne the brunt of the financial losses from salmonellosis. And yet in 1943, Dr. R. Fenstermacher in Minnesota stated, "it is not so many years since it was thought that turkeys were not susceptible to bacterial diseases." Agglutination testing as a control procedure has proved much less satisfactory than with pullorum disease. Intestinal carriers, common in turkeys, are less likely to show demonstrable agglutinins than ovarian carriers. Even so, careful testing has aided in reducing losses in large turkey-producing areas, especially Minnesota, California, and Texas. For several years the National Turkey Improvement Plan made provision for states to issue lists of flocks known to be free of infection of a specific serotype. Initially, each laboratory tended to use antigens produced from the most prevalent type of organism(s) in the area, sometimes employing the somatic (O) antigen and at other times testing also with a flagellar (H) antigen. In 1954, Dr. J. E. Williams received from Dr. Ronald Gwatkin of Hull, Quebec, a culture of *S. typhimurium,* strain P-10. Further studies by Dr. Williams and Dr. B. S. Pomeroy, University of Minnesota, showed that their strain produced a good antigen. Dr. Pomeroy has supplied several laboratories with antigen made from strain P-10. It was widely used in official NTIP programs from 1964 to 1974. In 1974, the National Plan eliminated the salmonella control program from the Plan. At the July 1975 meeting, a modified program was instituted that is based on monitoring the salmonella status of the breeding flock through bacteriological examination of cloacal swabs and environmental sampling of the breeding pens. The latter evolved in large measure following a 1968 report of Dr. G. H. Snoeyenbos and associates at the University of Massachusetts on the spread of infection through litter. Although litter with high ammonia content is quite germicidal, bacteriological examination of samples of litter, especially when supplemented with nest material, has given better results than use of cloacal swabs. In 1976, the NTIP placed emphasis on careful handling and early fumigation of eggs in an effort to avoid shell penetration by organisms.

Testing has followed an uncertain pattern in other species. Improved sanitation has been of importance, particularly in ducks and pigeons. Found most frequently in the latter is a host-adapted member of *S. typhimurium copenhagen.* A special characteristic of this infection in the adult pigeon is involvement of the wing joint. The writer recalls the initial experience with the disease in chickens in the early 1930's. Agglutination tests were applied a few times to the survivors of the outbreak. Reactors were detected, and the organism was isolated from some of the reactors. For the next few years the flock evidenced no salmonellosis, but there was no assurance that the testing was responsible. In later years, the laboratory and others had moderate success in testing chickens. The National Poultry Improvement Plan retains a committee for consideration of salmonellosis, and it is largely up to individual states to consider each problem as it arises.

Replacement of flocks with stock which has not evidenced infection has not always succeeded because there are so many possible sources of infection. These sources have proved to be legion, and some thought has been given to the possibility that most flocks are likely to be exposed to infection at some time or other. A slightly unusual or regional example of this was identified by Dr. W. R. Hinshaw and associates in southern California and the southwest, where several kinds of reptiles were found to be frequent carriers of infection. In 1955, Dr. L. E. Erwin, in Kansas, directed attention to poultry feed as a source of infection. Since then, many investigators have found salmonellae in bone meal, meat scraps, and fish meal. The USDA made determined efforts in the late 1960's to reduce contamination of feed through a monitoring program. Alterations in operations of rendering plants were recommended to avoid recontamination after cooking of feed ingredients. Salmonellae may also be present in vegetable feed ingredients. The heat used in pelleting feeds was recognized as destructive of salmonellae, and this practice is increasing. Dr. J. E. Williams' 1969 list of the most common salmonellas in the U.S. included *S. agona*, a newly recognized type isolated from fish meal brought into this country from South America. An example of the appearance of salmonellae in new locations is the finding of six new serotypes in Great Britain following large-scale importation of dried egg powder from the U.S.A. during the second World War.

Dr. Leo F. Rettger, who made the original report on the isolation of *S. pullorum,* made initial reports in the U.S. on salmonellosis in ducks in 1920 and in turkeys in 1933. Dr. Philip R. Edwards, as a graduate student in Dr. Rettger's laboratory, did his thesis on the characteristics and relationships of what is now known as somatic O groups, B, C, and E of the salmonellae. While at Yale University, Dr. Edwards collaborated with Dr. F. R. Beaudette of New Jersey in identifying the etiology of an outbreak in canaries. Also, while a student at Yale, Edwards worked in the pullorum laboratory, which at that time was doing the official testing for Connecticut. Edwards joined the staff of the Kentucky Agricultural Experiment Station in 1925. He turned his attention, first, to a study of bacillary white diarrhea, at the time one of the most destructive diseases of poultry. It seems likely that information of this type from several sources resulted in the observation in 1939 by Dr. F. R. Beaudette that young research workers in poultry diseases were apt to start with a study of pullorum disease. In 1934, Edwards initiated a monumental work in classification of the salmonellae. His service was invaluable to the many laboratories that lacked facilities and expertise in the identification of isolated cultures. One result of that study was the establishment, in 1939, of a National Salmonella Center at the University of Kentucky, with Edwards as director and Dr. D. W. Bruner and Alice B. Moran as principal associates. In 1948, Edwards joined the staff of the USPHS Communicable Disease Center (CDC) in Atlanta, Georgia, in charge of the Enteric Bacteriology Unit. In 1962 he became Chief of the Bacteriology Section of CDC, at which time the serotyping of salmonellae isolated from animals was moved to the Animal Disease Eradication Division of the USDA at the National Animal Disease Laboratory in Ames, Iowa. Alice B. Moran became the salmonellosis project leader.

Direct transmission of salmonellae to man from live poultry has been reported occasionally. Usually, however, transfer to man has been from poultry meat and poultry by-products. A small amount of infective material may contaminate food in a processing plant and be allowed to proliferate in transit or in the kitchen through improper handling. The ensuing attacks are principally gastroenteritis. Poultry and poultry products are undoubtedly a major source of contamination but are frequently accused mistakenly and given unfair publicity. Salmonellae have been studied more extensively in poultry than in other animals, so the number of isolations is greater. It is estimated that the source of infection is determined in fewer than 15% of human cases. Many poultry processing plants have established laboratory control testing services to monitor salmonella organisms in their operations.

Drugs useful in combating salmonellosis in young poultry began to make their appearance principally after the second World War. Several groups of drugs were found useful in reducing mortality. By the early or mid-1960's, drugs were widely used in poults to prevent mortality. Drugs were also used for simultaneous control of salmonellae and arizona-group infections. The latest edition of Bergey's Manual added the arizonas to the salmonellae. This change has not been acceptable to most avian pathologists.

Creating and maintaining a breeding flock free of salmonellae has proved a complex and expensive procedure. Each step in the process of putting a satisfactory product in the kitchen has proved important. Sanitation in general has been recognized as of great importance. Decontamination of poultry houses and premises is one of the many difficult aspects of the problem. Testing over the years, particularly with *S. typhimurium* antigens, has reduced the incidence of this salmonella in many areas of the country, but other salmonellae have been encountered. The testing of cloacal swabs, litter, and nesting material has not had widespread practical evaluation. In the mid-1970's, Dr. J. E. Williams and associates were actively exploring a micro-antiglobulin test.

Many are concerned with eliminating salmonellosis on a commercial basis. As an expression of national concern, a task force was formulated in 1975 and 1976, and a committee was later formed to advise the U. S. Secretary of Agriculture on requirements for reducing the incidence of salmonellae in poultry populations and red-meat animals and their products. This came about partly because of a realization of the complexities of the problem and the difficulties of solution. In the 1960's and since there have been a series of comprehensive seminars and workshops on salmonellosis. These involved workers in many fields and collated much of the available information. The clinical manifestations of salmonellosis continue to be relatively unimportant except for occasional outbreaks, particularly in turkeys. The public-health aspect of contaminated food products continues to make the surveillance of salmonellosis of great importance.

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