HUMAN *SALMONELLA* *TYPHI* *MURIUM* INFECTION DUE TO DUCK EGGS

WITH SPECIAL REFERENCE TO FLOCKS OF
DUCKS

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In recent years increasing interest has been shown in the role of the duck in human *Salm. typhi murium* infections. That ducks may be symptomless faecal excretors of this organism and that their eggs, if ingested, may cause acute gastro-enteritis are well-recognized and accepted facts. Although duck-egg infections have often been reported, the suspected eggs have less frequently been traced to the appropriate flocks of ducks and the necessary measures been taken to control or to eradicate the infection.

The purpose of this paper is to describe two fatal and two severe cases of food-poisoning attributed to the eating of duck eggs, in three of which the incriminated eggs were traced to the appropriate flocks of ducks by means of bacteriophage typing of the strains of *Salmonella typhi murium* and by agglutination tests on ducks' sera. From the public health point of view this must be regarded as an important investigation.

Case 1

A fit and active man aged 58, who had had few illnesses in his lifetime, ate a raw duck egg on May 30, 1949, and within less than 24 hours developed severe abdominal pain and diarrhoea and, later, sickness and vomiting. During the next four days his symptoms became more severe. On June 3 he was acutely ill, with raised temperature, persistent and uncontrolled diarrhoea, and severe muscle cramps. He was profoundly shocked and dehydrated. His extremities were cold and blue. He was admitted to hospital on June 3 and died the following day. The cause of death appeared to be acute septicaemia, probably due to salmonella infection.

The necropsy examination, conducted less than 24 hours after death, revealed the signs of acute septicaemia: both lungs showed scanty subpleural petechial haemorrhages and their substance acute passive congestion. The heart showed clusters of petechial haemorrhages, mainly on the left auriculo-ventricular groove; the right side was dilated and engorged. The mucosa of the jejunum and ileum was intensely congested and Peyer's patches were enlarged and prominent. Both kidneys were small, with adherent capsules, and had the appearance of chronic nephritis. A post-mortem specimen of blood contained 253 mg. of urea per 100 ml. The probable cause of death was acute septicaemia and uraemia.

Cultures of post-mortem specimens of faeces, of stomach and small-bowel contents, and of urine gave heavy growths of *Salm. typhi murium* which belonged to Vi phage Type 2.

Source of Infection.—The patient suspected the duck egg to have been the cause of his illness, although he thought it was perfectly fresh when he ate it. No portion of the suspected egg remained, and there were no more eggs in the house. As a result of inquiries it was learned that he had obtained half a dozen hen and duck eggs from a friend four days before his illness. The time of the laying of these eggs is unknown. The flock which had produced the incriminated egg consisted of seven white Aylesbury ducks—six in lay and one not in lay—and one drake. They were all well-nourished healthy birds. There was no history of recent deaths or of illnesses among the ducks or among the

hens. The duck eggs, after being cooked, had been eaten regularly by the family, which included children, without complaints or harmful results.

Investigations

Bacteriological Examination of Two Layings of Duck Eggs.—The technique of the duck-egg examination employed was a modification of the method of Gordon and Buxton (1945). The first laying of six eggs from the six ducks in lay were not incubated before examination. One of the six eggs examined yielded a scanty growth of *Salm. typhi murium*, the positive culture being obtained from a mixture of white and yolk, while the cultures from the yolk and the white alone, and also from the shell, gave negative results. The second laying of eggs from three ducks were examined after six days' incubation at 37° C. One of the three eggs gave a scanty growth of *Salm. typhi murium*. Again the positive culture was obtained from a mixture of the yolk and white, but not from the yolk and white alone nor from the shell. Both strains of *Salm. typhi murium* belonged to Vi phage Type 2. Blood samples for agglutinins to *Salm. typhi murium* were not obtained from the ducks either before or at the time of the layings.

Post-mortem and Bacteriological Examination of Ducks.—On July 12 the whole flock of seven ducks and one drake were killed and specimens of blood withdrawn from the neck veins of each bird to test for agglutinins to *Salm. typhi murium*. The blood samples were examined for O and H specific agglutinins and also for salmonella group H agglutinins, using suspensions obtained from the Standards Laboratory at Colindale. The results in the Table show

Summary of Investigation of a Flock of Seven Ducks and One Drake. Egg Layings and Post-mortem Specimens

Duck:	1	2	3	4	5	6 (drake)	7	8
Cultures during life:								
1st laying of 6 eggs (1*)								
2nd laying of 3 eggs (1*)								
Cultures post mortem:								
(a) Faeces ..	+	—	—	—	—	—	+	+
(b) Ovaries ..	—	—	—	—	—	(Testes)	—	—
Agglutination titres (P.M. sera):								
<i>Salm. typhi murium</i> H (i)	1:250	Nil	1:50	Nil	1:1,250	Nil	1:500	1:1,250
<i>Salm. typhi murium</i> O	1:50	1:25	Nil	1:250	1:250	1:25	1:25	1:25
<i>Salm. group H</i>	1:125	1:25	1:125	1:250	1:250	1:250	1:250	1:250

Nil = no agglutination at 1:25 and upwards. + = *Salm. typhi murium* isolated. — = no salmonellae isolated.

* Positive to *Salm. typhi murium*.

positive reactions in the sera of five ducks, while the drake and two ducks were negative. Post-mortem examinations were performed on each of the ducks and on the drake. The entire ovaries together with specimens of faeces were removed from the seven ducks, and a specimen of faeces and of the testes from the drake. Specimens of the other abdominal organs were not examined. The entire ovaries and the testes were cut into small portions with sterile scissors and placed in 100-ml. quantities of selenite F and tetrathionate broth, which after 24 and 48 hours' incubation at 37° C. were plated out on desoxycholate citrate agar. *Salm. typhi murium* was identified by biochemical tests and by slide agglutinations with the specific sera, and was confirmed in each case by serial tube agglutinations to titre.

Salm. typhi murium was isolated from the intestinal tract of one duck, from one ovary of a second duck, and from the intestinal tract and the ovary of a third duck (see Table). Cultures of the specimens from the remaining four ducks and also from the drake gave negative results. This investigation may be summarized as follows: The same Vi phage type of *Salm. typhi murium* was isolated from two out of

nine eggs laid by six ducks, from the intestinal tract of one duck, from the ovary of a second duck, and from both the intestinal tract and the ovary of a third duck.

Case 2

A woman aged 30 suffered a severe attack of acute gastro-enteritis on October 2, 1949, a few hours after eating a fried duck egg for breakfast. Her husband, who also ate a fried duck egg cooked at the same time as his wife's, suffered no ill effects. On further inquiry the patient stated that her own egg was probably underdone. The illness continued for about one week, with high temperature, severe abdominal pain, vomiting, and diarrhoea. In about a fortnight she was convalescent. Bacteriological examination of specimens of faeces yielded heavy growths of *Salm. typhi murium* which belonged to Vi phage Type 4.

Source of Infection.—The incriminated duck egg was traced to a farm with a flock of 50 ducks. Their eggs were normally delivered to a packing station. The sanitary inspector considered the duck premises satisfactory. The birds drank from troughs, which were emptied and cleansed daily, and they had cabins to lay in. There was no history of deaths or of recent illnesses among the ducks.

An interesting sidelight was thrown on the potential infection in this flock of ducks by an incident which took place in the farmer's home. On September 10 the farmer and his sister, who were the sole occupants of the farm, became ill after eating ice-cream composed of goat's milk, sugar, cornflour, and duck eggs; it was prepared in the following way: On the evening of September 9 the milk was boiled and sugar and cornflour were added. No attempt was made to hasten the cooling, and while the mixture was still warm four duck eggs were added and the mixture was left to cool overnight. Next morning the "mix" was cooled with ice in a double-jacketed container. Within an hour of eating this ice-cream the farmer complained of vomiting, abdominal pain, and diarrhoea. His sister had a similar attack of acute gastro-enteritis the following day. Specimens of faeces had not been examined either during these attacks or immediately after, but at the time of this investigation, about a month later, the farmer, who still suffered from bouts of diarrhoea, was found to be a faecal excretor of *Salm. typhi murium*. Cultures of faeces from the farmer and his sister gave profuse growths of *Salm. typhi murium*, both strains belonging to Vi phage Type 4.

Investigations

Bacteriological examination of two layings of duck eggs at an interval of seven days was carried out. The eggs from six ducks on each of two layings (12 eggs in all) were examined for salmonellae, with negative results.

The examination of cloacal swabs from 39 ducks, all of which were taken on the same day and about the time of the laying of the eggs, produced one culture of *Salm. typhi murium*, which belonged to the same Vi phage type as the strains isolated from the farmer and his sister, and also from the patient.

The results of testing blood samples from each of the 50 ducks showed that almost the whole of the flock was infected. Only one duck serum gave negative readings against the three standard suspensions. The serum of the duck which had produced a positive cloacal culture showed titres of H 1:250, O 1:125, Group H 1:250.

Case 3

A woman aged 56 ate a lightly poached duck egg on November 29, 1949. In less than 48 hours she complained of abdominal pain, diarrhoea, and sickness; her condition gradually worsened and she was admitted to hospital on December 5, dying the same day. She had suffered a fulminating attack of gastro-enteritis of about four days' duration. It is interesting to note that the other members of her family had eaten hard-boiled duck eggs at the same meal without suffering ill-effects.

The necropsy examination performed about 12 hours after death revealed signs of toxæmia. The meninges showed intense congestion and the lungs passive congestion; the heart appeared normal; the stomach and small and large intestines showed marked peritoneal and mucosal injection; the liver showed acute passive congestion and diffuse fatty change; the kidneys were congested. A post-mortem specimen of blood contained 160 mg. of urea per 100 ml. The remainder of the abdominal organs appeared to be normal. Post-mortem specimens of faeces and of stomach and small-bowel contents yielded heavy growths of *Salm. typhi murium*, Vi phage Type 4.

Examination of faecal specimens from the remainder of the family showed that one of the children was a symptomless faecal carrier of *Salm. typhi murium* which belonged to the same Vi phage type.

Source of Infection.—The duck eggs consumed by the family had been obtained from a small farm which kept a flock of 24 ducks. The sanitary inspector reported favourably on the duck premises. There had been no illnesses or deaths among the birds.

Investigations

Bacteriological examination of two layings of duck eggs, produced at an interval of ten days, was carried out. The eggs from 6 and 17 ducks examined for salmonellae after seven days' incubation at 37° C. gave negative results.

Blood samples taken from each of the 24 ducks and from each of 9 ducks, ten and three days respectively before the first laying of eggs, were examined for agglutinins to *Salm. typhi murium*. The results showed positive reactions in 17 sera, while 7 were negative in the dilutions used. The titres of 9 sera repeated at an interval of one week showed no significant differences.

Cloacal swabs taken from 24 ducks on the same day as the first blood samples were obtained gave negative results for *Salm. typhi murium*.

Although the duck eggs and the cloacal swabs produced negative findings, the agglutination tests showed that practically the whole flock was infected. About two months later the 24 birds were killed, but permission for post-mortem examinations was withheld.

Case 4

A man aged 43 consumed a raw duck egg in milk on November 28, 1949. He had not eaten a raw duck egg before. The following morning he complained of general malaise, of cold and shivering, and of headache, and in the evening of abdominal pain, sickness, and diarrhoea. Two days later he was admitted to hospital with a very severe attack of gastro-enteritis, which lasted for about three weeks. He made a slow convalescence. Cultures for faeces gave heavy growths of *Salm. typhi murium* which belonged to Vi phage Type 4.

Source of Infection.—Investigations revealed that the incriminated duck egg was one of four purchased from an egg-packing depot which received both hen and duck eggs from many sources, but for the period in question from three main sources, all of which were investigated. It is interesting to note that the three remaining eggs were used for a home-made cake which was eaten by the man's wife and daughter without ill effects.

Investigations

This investigation proved to be more difficult than the previous ones. Two of the flocks were of a reasonable size, but the third numbered some 3,000 ducks. It was decided, therefore, to investigate the whole of two flocks and a proportion of the third flock.

The examination of cloacal swabs from 47 ducks, which composed one flock, gave negative results. The examination of 12 eggs, laid by 12 ducks, after seven days' incubation at 37° C., also gave negative results. The examination of duck sera for agglutinins to *Salm. typhi murium* showed

that 18 were positive reactors, the remainder being negative in the dilutions used. Both the bacteriological and the serological examinations were carried out within a few days of each other.

The second flock comprised 27 ducks. Cloacal swabs from each of these and four eggs from four ducks were negative for salmonellae. The examination of blood sera from the 27 ducks showed that all were negative reactors in the dilutions used.

From the large flock eggs only were examined: 24 eggs from 24 ducks gave negative results for *Salm. typhi murium*. Two of the egg-shells, however, gave profuse growths of *Salm. thompson*.

Discussion

Many writers since Le Coq (1906) have shown that duck eggs can cause human infections due to *Salm. typhi murium* and *Salm. enteritidis* of Gaertner. Scott (1932) investigated three cases of acute gastro-enteritis due to *Salm. typhi murium*—one in each of three families—which followed the consumption of a duck egg. In each case he isolated the same organism from the patient and from the eggs laid by the corresponding flock of ducks. All the ducks (nine) in one of the flocks were infected, *Salm. typhi murium* being isolated from post-mortem specimens of spleens, ovaries, and intestinal contents.

Since then Gordon and Buxton (1945) have produced still more convincing evidence showing that the duck egg is a potential source of human gastro-enteritis. They reported a fatal case of *Salm. typhi murium* infection in a man aged 49, following the consumption of a fried duck egg, which they were able to trace with certainty to a particular flock of ducks. They isolated the same Vi phage type of *Salm. typhi murium* from three of sixteen eggs laid by four ducks, from the ovaries of two ducks, and from the intestinal tract of a third duck, comprising the flock from which the suspected egg was obtained.

The findings in the first and second investigations in the present article are as convincing as those of Gordon and Buxton. In the third investigation the evidence must rest on the presence of agglutinins to *Salm. typhi murium* demonstrated in the sera of 17 of the 24 ducks.

The findings in these investigations stress not only the potential dangers of the duck egg as a source of salmonella infection in man but the diagnostic significance of the agglutination tests in detecting infected ducks. The results of single blood tests taken from most of the flocks may not be reliable, because, as Warrack and Dalling (1933) point out, the agglutinating titres fluctuate from high to considerably low figures over the short periods (four months) during which repeated tests were performed. However, the same authors (1932) also state that repeated agglutination tests done on two small flocks of 12 and 18 birds during observation periods of one and twelve months showed that negative reactors remained negative and positive reactors remained positive. They expressed the hope of cleaning up an infected flock by eliminating positive reactors and keeping negative reactors under subsequent observation.

This brings the agglutination tests in ducks into line with the long-accepted tests of pullorum and gallinarum in chickens (Felix, personal communication, 1950).

Regarding the agglutinating reactions in avian sera, the titres accepted as significant are usually those accepted for human sera. Specific H agglutinin may be accepted in a dilution of less than 1:100, probably 1:25 or even 1:20. Sera reactions to B O suspensions prepared by the Standards Laboratory are usually found in dilution greater than 1:100. Although salmonella group H agglutinins in avian sera are not in themselves significant, they become no less significant than specific H agglutinins if present in a flock which is known to be infected. In the second flock of ducks the employment of group H suspensions helped to pick out 10 or 11 positive reactors, which otherwise would have been missed.

Although irrelevant to this discussion, the isolation of *Salm. thompson* from the shells of two of the eggs laid by two ducks is a finding of some interest. This salmonella has been isolated much more frequently from hens and chicks than from ducks and ducklings. Buxton (1948) isolated it from three diseased ducklings.

Summary

The investigations which followed two severe and two fatal cases of *Salm. typhi murium* infection, attributable to the eating of duck eggs, are reported.

In the first and second cases the incriminated eggs were successfully traced to two flocks of ducks. The flock to which the third egg was traced was the probable source, but the attempt to trace the source of infection in the fourth case was unsuccessful.

In the first infection the same Vi phage type of *Salm. typhi murium* was isolated from two out of nine eggs laid by six ducks, and from the ovary of one duck, from the intestinal tract of a second duck, and from both the ovary and the intestinal tract of a third duck—these composing the flock from which the suspected egg was obtained. The agglutinating titres showed that five out of six ducks were positive reactors.

In the second investigation *Salm. typhi murium* Vi phage Type 4 was isolated from the patient, from the farmer and his sister, and also from one cloacal swab obtained from the flock of ducks to which the suspected egg was traced. Practically all the ducks in this flock were positive reactors.

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An article in *New Era*, the magazine of the World Veterans Federation (27, Rue de la Michodière, Paris, 2^e), describes a machine for reading to the blind, invented by Walter Blum, a German electrical engineer, which is said to be an advance on any hitherto constructed. It consists of a moving tube with a light and a lens which moves along each line of print in turn in a book and forms an image successively of each letter in the row on a little window at the back, close to a photoelectric cell but separated from it by a kind of shutter, a disk rotating at 600 r.p.m. This disk has cut out of it all the letters of the alphabet. When the image of the printed letter falls through its own cut symbol on the disk the photoelectric cell is activated, and this is the signal for the machine to "speak." It does this by selecting from its library of sounds recorded on a magnetic tape (like a B.B.C. recording), which is moved in step with the whirling disk. Thus when the letters o, n pass successively under the machine, its loudspeaker plays its recording of someone saying "on" rather mechanically. The machine is suitable for reading German or Italian, which are written much as spoken, but is useless at English. It can also be used for printing a Braille version from ordinary printed matter, without the intervention of an operator.