upon this atheromatous change in the arteries themselves. The arteries are very smooth elastic tubes. They twist and yield with every pulsation of the heart. They shrink and open. They are governed by a set of nerves which control the muscular movements of the walls. They enlarge or diminish in consequence of the needs of the part to be supplied with blood. When the part or limb is in violent exercise and the person running rapidly, an additional blood-supply is sent. The arteries enlarge; they beat more rapidly and expand also; therefore it is essential to the life of a part that the artery should be compressible, elastic, distensible. When the condition, or change, which is called atheroma takes place, the artery becomes diminished as to its calibre and stiffened as to its walls; loses its elasticity; cannot carry any more blood at one time than at another time. The consequence is, in elderly people, when the atheromatous condition is well pronounced, that the blood-supply to the feet and distant parts is not only insufficient, but is incapable of being increased. Let such a part be exposed to cold and the blood cannot come. The result is, frequently, in the elderly, the gradual occurrence of senile mortification of the foot in consequence of a slight bruise, or a little lameness, or ingrowing nail; exposure for a few hours in riding; anything of that kind will gradually bring on stoppage of the circulation; starvation of the part and mortification; senile gangrene of the limb. That is one of the consequences of atheroma.

Another is that it not only stiffens the walls of the vessels, but leads to ulcerations, deposits of calcareous salts and thinning of their walls and formation of aneurisms. Without going into detail we can make plain in a few words how this takes place. Given a very smooth elastic tube which has got to carry a certain amount of blood, and is constantly in motion by the pumping of the blood through it, the first thing that takes place usually is the loss of brilliancy and smoothness of the innermost coat. Now the innermost coat of the artery is nourished mainly by imbibition of the blood which runs through. One stage of the degeneration which results when the coat is not perfectly nourished is the formation of fat. Fat cells form. It loses its smoothness, becomes slightly roughened and softened. What takes place when in ordinary cases a current of blood that is being pumped through a smooth tube meets with an obstruction? What takes place when we cut an artery, or vein, and allow the blood to flow upon some surface? Immediate deposition of fibrin, and the blood separates into its clot and serum and fibrin. The result of this slight roughness-inside of the vessels is that slow deposition of fibrin takes place; more obstruction ensues; the current of blood beats with irregularity upon the wall of the vessel, and the inner coat, being deprived more and more of its nutrition, finally gives way. The result is a slight ulceration. The result of the ulceration is a pocket of greater or less size in the wall of the vessel. In this pocket gradually become deposited the lime salts in the form of plates.

Given a point in the vessel where there happens to be a meeting and crossing of two or three currents, where the circulation is not so perfect, having to cross, as it would in a single tube, here let an atheromatous change take place with a little ulceration and you can see how readily that pocket will deepen, that ulceration will increase, and the coat of the artery will be stretched more and more, and finally we have a sac or

pouch formed in which the blood must go round and round, and be delayed in its progress. This is the way the ordinary true aneurism is formed.

The moment the sac is formed, blood delayed in it and the circulation impeded, nature goes on to another process, which tends to cure it; and that is by the formation of large coagula in the sac, which shall resist the impulse of the blood; be buffers as it were against the danger, and lead almost to a state of repair. The layers of fibrin which are deposited from the coagula on the inside of the sac become pressed down thinner and thinner, and those which lie next to the wall of the sac become very white, thin and firm; the next less so, and the next less so; so that you can see, in cutting into a fresh aneurism, a long series of concentric layers like the layers of the bark of a tree; those nearest the sac white and hard, next a little darker, and the central ones more and more soft. Nature makes an aneurism by ulceration of the inner coat. She tries to cure this aneurism by the coagulation of the blood inside the sac itself. As these coagula form more and more, the current of blood must go more and more slowly and imperfectly through the sac. Finally the blood, instead of being forced through, trickles through, and the aneurism may be almost cured. This is nature's process. Now it seems to me that this process indicates precisely the course we should endeavor to pursue in curing an aneurism; that is, to imitate nature as nearly as we can; to slow the current, and encourage the deposition of coagula by gradual compression and by rest.

Original Articles.

AN INVESTIGATION OF AN EPIDEMIC OF TYPHOID FEVER IN THE CITY OF SPRINGFIELD, MASSACHUSETTS, DUE TO INFECTED MILK.¹

BY W. T. SEDGWICK, PH.D.,

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ABOUT the first of August, 1892, it was noticed that typhoid fever was unusually abundant in a particular district of the city of Springfield. This city (of about 47,000 inhabitants) covers a large area extending north and south along the Connecticut River, and upon somewhat higher land to the eastward. Its soil is chiefly sandy or gravelly, and the situation is regarded as salubrious. The particular district in which typhoid fever began to appear in such abundance as to excite comment, and at length alarm, is known as the "Mc-Knight district," and lies upon a gravelly plateau of wide extent, such as often characterizes the terraces of the Connecticut valley. It is included between State Street and St. James Avenue. The district has been comparatively recently "developed" by enterprising real-estate activity, and may fairly be described as having a refined and attractive suburban character; the houses, mostly of wood, standing somewhat back from the street, are provided with grassy yards or lawns and sometimes with gardens. The sanitary arrangements are in keeping with the exterior; in brief, the district forms an inviting, whole-

¹ From the forthcoming Report of the State Board of Health of Massachusetts, for 1892.

some and excellent suburban community. There are other parts of the city, similarly situated, some as good, some better, than this; but most of the city is far less favorably situated, less inviting, less clean, and in parts, especially along the river, crowded with tenement-houses; still other portions consist chiefly of shops or stores or offices, amongst which dwellers of a lower grade are crowded. But in none of these except the McKnight district did typhoid fever make its appearance in July, 1892.

The perplexity of the people, therefore, was great, and, as is usual in such cases, various theories were advanced to account for the epidemic. Some of these were manifestly untenable; others, although resting only upon vague conjecture, were soberly propounded and seriously discussed among the citizens and in the newspapers. Even physicians and the local sanitary authorities were deeply perplexed. Attention was first drawn to well-water as a possible cause of the disease, some of the people in the McKnight district having resorted largely to well-water in preference to the city water during the hot months. But it was naturally urged as a sufficient objection to this hypothesis that many, indeed most, of the victims had used only the public water-supply for drinking purposes. A similar hypothesis was advanced in respect to certain spring-waters widely sold in the district, but the same objection was effectively raised in this case. Some turned to the drainage and some to the sewerage of the district as the probable source of the trouble. But it was immediately pointed out that the houses affected were mostly new and the plumbing was generally in good condition. With respect to the sewers, a stench from the man-holes in the neighborhood of Yale Street was said to be noticeable at times, and we found that this was a fact; but the superintendent of sewers showed that this was an incident of the hot season; that the smell was no worse this year than in previous years when there had been no fevers; that the fall of the sewers was usually good, and the system of flushing them excellent. Moreover, many of the houses nearest to the man-holes had no typhoid fever cases; so that the sewer-gas theory, also, proved to be inadequate to account for the outbreak.

The officers of the local Board of Health began work upon the impure-water theory, and in conjunction with a local chemist proceeded to examine, chemically, the numerous wells of the district. They found several wells containing large amounts of chlorine, and many which gave evidence of more or less remote sewage contamination. But in spite of their results it remained an insuperable objection to the theory of well-water contamination as the cause of the trouble that some of the cases had had no access to well-water.

Still new cases of fever continued to appear, and the local perplexity increased. It was observed by some of the citizens and made known, that many of the families affected were served with milk by the same milkman. The city physician, therefore, communicated with the latter, and on August 8th, by which time there were known to be twenty or more cases of fever in the district, visited, under the guidance of the milkman himself, the several farms from which he derived the milk furnished to his patrons in different portions of the city. All of the farms were thus visited by the city physician except one, which, he was informed, had already been visited by a well-known and competent physician of Springfield, and

found to be in good condition. He was further informed by the milkman that all of the milk distributed to the McKnight district, had come invariably from two farms in Agawam, a town adjoining Springfield, and these he found to be excellent farms in good condition, with no history of any typhoid fever upon either of them. It was learned, also, that the milkman's cans were washed and steamed only at the Springfield Co-operative Milk Association's headquarters, and that there was no reason to suspect that the origin of the fever was in any way connected with the water thus used; for the same water, under the same system, at the same place, was used for many other dairymen's cans, and no typhoid fever had appeared upon their routes. The conclusions drawn from the results of investigation of the milk-supply was, therefore, as stated in a local newspaper on August 9th, that the milk-infection theory was "entirely set aside."

In the mean time it had been suggested that the comparative proximity of a neighboring cemetery might be the hidden cause of the epidemic, and a cemetery theory was fully discussed in all its bearings. This received a severe blow when it was found that a well in the cemetery itself contained less ammonia than the wells in the McKnight district, but it continued for some time to hold a place among the favorite theories, in spite of the fact that there was not a particle of evidence in its favor, and every reason to reject it. It was hard pressed by the sewer-gas theory, especially on those streets with odoriferous man-holes; but both soon after lost some adherents, who went over to the infected-vegetable theory, namely, the theory that green foods, such as lettuce, tomatoes, celery, having been splashed by liquid manure previously infected, had been eaten uncooked, possibly in salads, and had thus produced the disease. This theory, however, like most of the theories advanced, failed to explain why the people in this district only were affected, or why, among all the families in this district, the particular families affected had been smitten. Last in the series, the theory of ice infection was brought forward as the probable cause of the outbreak; but inasmuch as the ice-supply of this district was in no respect different from that of the rest of the city, and the affected families had been served by the same carts as many families totally unaffected, this hypothesis also seemed to be untenable.

It is interesting to bring together, as more or less typical of the vague and often wholly unsupported speculations as to the cause of particular epidemics of typhoid fever, those which were propounded in the present case and were deemed worthy of mention in the public prints. They were as follows: (1) impure well-water; (2) impure "city" water; (3) defective drainage or plumbing; (4) defective sewerage, or sewer-gas; (5) infected milk; (6) influence of a cemetery, probably upon the well-water supply; (7) infected vegetables; (8) impure ice. These were not all of the theories advanced, but they suffice to show the usual condition of public opinion in the presence of an outbreak of typhoid fever.

All of these theories, if such they may be called, were propounded and discussed at much length, both in private and in the public prints, within the first week after attention had been drawn to the epidemic. During the second week the local debate was actively continued, but no new theories were advanced, the State Board of Health was not notified, no thorough

investigation was made, and no just conclusion was reached. The anxiety and alarm of the citizens remained undiminished. Finally, in the third week of the debate, the State Board of Health was appealed to, and one of us (W. T. S.) was sent to the aid of the local Board of Health, arriving in Springfield on August 14th.

On August 15th, the author began a joint investigation of the cases affected, for the purpose the blank already described in connection with the epidemic in Lowell. After nineteen houses in the infected district had been visited and forty-six cases, examined, it became clear that all theories hitherto advanced were untenable except the milk theory. No other common bond of connection whatsoever could be found, but *all of these families except one had been taking milk from the same milkman*, as had already been alleged but not proved. This milkman (F. D. K.) was by no means the only milkman who sold milk in the McKnight district, but we soon discovered that he was the only one upon whose service there was any typhoid fever. In the exceptional case mentioned above, we afterwards found that the family got milk regularly from another dealer (upon whose route there was no other case of typhoid fever), but that almost as regularly this family bought milk from a grocery supplied by F. D. K. We therefore concluded provisionally that the epidemic was probably due to infected milk; but inasmuch as it seemed to be plain that one of us (W. H. C.) had hitherto been misled, we did not immediately announce our conclusions, although we straightway acted upon them, and proceeded to interview and cross-examine more closely F. D. K., the milkman who had served the infected houses with milk.

By him we were informed that all of the milk which had been supplied to the infected houses had come from the two farms in Agawam already referred to above. Upon this point he was positive and explicit. On the next day, therefore, we visited Agawam, in the hope of finding the source of the infection. As has been said above, these farms had already been visited by one of us (W. H. C.) on August 8th, in company with F. D. K. himself, and found to be in good condition; but to our surprise we now discovered on one of them, on the 16th, a well-marked case of typhoid fever, which had apparently developed since the visit on the 8th just referred to. The most careful cross-examination of the family (which was that of a well-to-do farmer) gave no indication of any previous case of typhoid fever on the farm, and this one appeared to have contracted the disease in Springfield, thus sharing, rather than explaining as a cause, the outbreak there. It was possible, however, that the local well which, as is usual in such cases, was not far from the privy, had somehow got infected, had conveyed the disease to the milk, through washing of the pails or otherwise, and had thus infected in turn not only those in the McKnight district served with the milk, but also the farmer's son, who might have got the disease either in this way or directly from drinking the water of the well, his parents, who were beyond the most susceptible age, having escaped. Much perplexed, we therefore took samples from the farmer's well for chemical and bacteriological examination in the laboratories of the State Board of Health in Boston. Bacteriologically the water proved to be unobjectionable, and chemically showed an excellent purification.

The inquiry was interrupted by the enforced absence of one of us, but was resumed on August 19th.

The samples from the farmer's well in Agawam having shown no evidence whatever of infection, the problem seemed as puzzling as ever, when we were suddenly put upon what proved to be the right track by information showing that we had been grossly deceived by the milkman, and that in truth the Agawam milk was not the milk regularly served to the infected houses in the McKnight district.

It has been stated above that the milkman took one of us (W. H. C.) to all of the farms from which the milk that he sold "on the hill" came, *except one*. We have since discovered that the milkman, probably in pursuit of a well-formed plan, took pains to drive the city physician first to the farms remotest from the one really to blame, and then to others in succession, until the latter grew weary of the apparently fruitless visitation of excellent farms. At last the milkman remarked to him that there was still one farm lying far to the westward and much out of the way homewards, from which he got some milk; but that "Dr. H. had been out there, and everything was all right." In the belief that this was true, the milk theory, which up to that time had had no better basis than any other, was abandoned by W. H. C.

We now learned, however, that the latter had been deceived, and that the milkman, before the public had become very seriously alarmed, had told Dr. H., who was his family physician, that the milk which he was serving to the infected houses in the McKnight district was coming from the one farm to which he did not take the city physician on his round of inspection; and thus we had positive proof both of his duplicity and of the true source of the infected milk. We therefore immediately proceeded to the farm in question, which was located in Feeding Hills, and were rewarded by the discovery that upon this farm there had been one, and probably more than one, case of typhoid fever several weeks earlier. The location of this farm, which we have every reason to believe was the source of the disease in Springfield, is shown upon the accompanying figure (see next page).

The farm was owned by a well-to-do farmer, who raised, among other things, tobacco, and kept a dairy. By inquiry we found that the farmer's daughter had had in the spring a case of "bilious typhoid fever." There was also a history of others upon the place "obliged to go to bed with slow fever," and it only remained to trace some possible connection between these cases and the infected milk. This we did not succeed in doing to our entire satisfaction, but we did find two possible avenues of contamination.

Most producers of milk for sale in cities cool the milk by allowing the cans freshly filled to stand in "coolers," surrounded by ice or iced water. In the present case the farmer had no ice, and therefore was in the habit of lowering the cans by means of ropes into a well adjoining the cow-yard. But unlike some of his neighbors, who hung cans in their wells just above the water level, this farmer *submerged* his cans, and allowed them to rest upon the bottom of the well, so that they were covered by from two to four feet of water. Here the morning's milk stood all day and into the evening, the evening's milk remaining if at all only a very short time before all was "collected" and carted off to arrive in Springfield, some six miles away, about midnight or a little later, being distributed at

dawn, by the milkman referred to above (F. D. K.), to the consumers in the McKnight district.

At the time of our first visit to the farm we discovered the cans of morning's milk quietly reposing entirely out of sight on the bottom of the well. This was in most respects an ordinary dug well, but of unusually large diameter. It was covered with a platform of old and badly worn planks loosely laid on, and with rounded edges bordering on wide cracks. To allow the cans to be sunk and lifted, the planks were loose and separate. The cans were lifted by worn ropes, each of which ran through a hole in a plank and ended above in a large knot. On one side of the well was a chain pump, the spout of which overhung the platform, so that careless pumping easily washed matters on the planks near by through the wide cracks into the well. On the planks lay lumps of manure evidently left there by the dirty boots of the men. A little pumping proved that these were easily washed into the well; and, indeed, ordinary stepping about

sunk in it might have become so. But how could the well have been connected with the cases in the house? A plausible hypothesis was the following: the excreta of the patients went into the privy, and there is reason to believe that they were not disinfected. The contents of the privy, shortly before the infection reached Springfield, were spread upon the tobacco field. From this field the workmen frequently passed to the well to get water and to work about the milk. It is not difficult to believe that in doing so they may have carried upon their boots masses of faeces, originally from the privy, from the field to the well into which pieces fell through the cracks while the men trod upon the irregular planking. Whether or not this theory is true we shall probably never learn. An alternative hypothesis, moreover, remains. Upon most farms of this sort the "help" is constantly changing. Hired men only a few grades better than tramps come and go. There was a history of much of this kind in the present case, and it may easily have been that some such person

acting for the time being as milkman was suffering from incipient or "walking" typhoid fever. In such a case a self-infection of the fingers, such as can only too easily happen, may have led to a heavy infection of the warm milk, such as must have existed in the milk which was served by F. D. K. to the McKnight district in Springfield.

The milkman (F. D. K.) for a time maintained with bold assurance that the milk from this particular farm had never gone to the infected houses; and therefore, in order to have independent evidence, we undertook a minute and systematic study of the somewhat intricate system of milk-supply in Springfield. The problem was complicated by the fact that this particular milkman delivered from two separate wagons, and loaded

upon the planks to handle the milk cans or to pump must have cleaned the boots of the men at the expense of the water in the well.

On lifting the cans, on one of our visits, we found, by drawing them up and inverting them, that out of nine four leaked milk around the wooden stoppers with which they seemed securely plugged. Moreover, not one of them was *completely* full. On shaking the cans, the splashing of the milk inside was plainly heard. It was clear that if milk would leak out when the cans were inverted in the air, water would leak in when the same cans were submerged under water. Thus by submersion the milk was not only cooled in temperature but to some extent augmented in volume. The well water was plainly dirty, and bacterial analysis showed it to contain *B. coli communis* in abundance, a form which testifies to the presence of faecal contamination, at least of animal origin. There was no question in this case of pails or cans washed in infected water, for the former were washed in the house in mountain tap water, and the latter were steamed in Springfield.

This well, however, was at some distance from the house, and not used there for drinking. It was easy to see how, if the well were contaminated, the milk

these with milk from several dairies at two distinct points. But after many vexatious researches, including a visit by one of us (W. H. C.) to all of the dairies selling him milk, for the sake of obtaining documentary and statistical evidence of the dates and amounts of milk supplied by the several farms, delivered by the carriers and loaded upon each of his wagons, with the time of starting and the route of each, as well as the actual purchases of his wholesale customers, to whom he now affirmed that all of the Feeding Hills milk had always gone (thus contradicting flatly his original statement to Dr. H.); after interviewing his assistant, or "striker," who had delivered the milk; after having had the aid, also, of the able inspector of the Board, Mr. McCaffrey, — we at last obtained positive evidence from wholly independent data that the milk which went to the infected houses must have come, beyond a peradventure, from the farm in Feeding Hills. In all of this we were very greatly aided by the officers of the Springfield Co-operative Milk Association, who courteously gave us access to their books, and in many ways afforded us invaluable assistance.

It now remains to describe somewhat more fully the

epidemic itself. It must not be forgotten that many other milkmen besides the one concerned served other houses in this district, which is thickly settled, but in none of these was there any fever. The correspondence of the cases of typhoid fever with their milk-supply is plain, although, as would be expected, some houses served by this milkman had no fever. There is good reason to believe that the infected milk was not the only kind that he carried, and that a different milk was sometimes delivered, for example, in the Ingersoll Grove district.

It will be observed that there were a few cases of typhoid fever in other parts of the city. A very few of these were imported. Of the others, those on Tenth and Essex Streets deserve special comment. After the milkman became alarmed, he is known to have refused, for a time, to take milk from the dairy in question. We have positive evidence that milk from this dairy afterwards went to Essex Street; and that here, also, the fever appeared, is one of the strongest links in our chain of intrinsic evidence. Similarly, seven cases of typhoid fever suddenly appeared about August 20th, in an hotel in the heart of the city; and while no positive evidence was found that milk from the infected dairy went to this hotel, we did discover that, at the time when this milk was under a cloud and was held by the Association, one can of reserved milk (ten quarts) was sold by them to that hotel, that this was an unusual occurrence, and at the very time required to have conveyed the disease to the hotel. As for the rest of the city, it was throughout the epidemic period almost wholly free from typhoid fever. The annual autumnal wave had not yet begun to rise.

The whole number of cases discovered and investigated was one hundred and fifty, and the whole number of deaths belonging to the epidemic was twenty-five. The intensity of the epidemic may be seen upon the accompanying diagram of monthly mortality from typhoid fever, which shows well also the limits of the epidemic period. A study of the death-rate from typhoid fever in Springfield, by months for the twelve years, 1881-92, shows a marked improvement since 1888, and an enormous excess in August, 1892, at the height of the epidemic. The death-rate from typhoid fever during this month was by far the highest during any month of the entire twelve-year period.

Out of the whole number of cases, one hundred and fifty, one hundred and one had milk sold by the same milkman (F. D. K.), while one hundred and thirty-five may have had access to the same milk.

For aid in the preparation of the map and diagram, we are indebted to Mr. R. D. Chase.

A LONDON surgeon recently completing a laparotomy, gave his needle a flourish that took out the lens from the eye of an unfortunate assistant.

AN INVESTIGATION OF AN EPIDEMIC OF TYPHOID FEVER IN SOMERVILLE, MASSACHUSETTS, DUE TO INFECTED MILK.¹

BY WILLIAM T. SEDGWICK, PH.D.,
Biologist of the State Board of Health of Massachusetts.

TOWARDS the end of August, 1892, the attention of the Somerville Board of Health was drawn to a sudden and nearly simultaneous appearance of a number of cases of typhoid fever. The physicians reported the cases with commendable promptness, ten having been reported on August 23d alone, and an inquiry set on foot by the local Board of Health immediately revealed the fact that most, if not all, of the cases were served by one and the same milkman. Thereupon the Somerville Board reported the outbreak to the State Board of Health, and I was instructed to make an investigation. In view of recent experience in the Springfield epidemic, described in a previous paper, which I was

still studying, I was able to work rapidly, and began by verifying the data already in hand. It afterwards appeared that during the three weeks, August 20th to September 10th there were in the entire city of Somerville thirty-five (35) cases of typhoid fever. Of these one was imported, one was plainly a secondary case, a third was a very old case tardily reported. Thirty-two (32) cases were apparently primary and indigenous and remained to be accounted for. Thirty (30) of these had been served with, or had had access to, milk supplied by one and the same milkman. Of the other two cases, one was an old case of which the diagnosis was uncertain, though there was also a possibility that it was itself secondary to an earlier one; the other was synchronous with the epidemic period, and was that of a young woman who was in the habit of buying milk at

¹ From the forthcoming Report of the State Board of Health of Massachusetts, for 1892.