Baker

TYPHOID FEVER

AND

LOW WATER IN WELLS.

BY HENRY B. BAKER, M. D., LANSING, MICH.

[REPRINTED FROM THE ANNUAL REPORT OF THE MICHIGAN STATE BOARD OF HEALTH FOR THE YEAR 1884.]

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THE RELATION OF THE DEPTH OF WATER IN WELLS TO THE CAUSATION OF TYPHOID FEVER.

BY HENRY B. BAKER, M. D., LANSING, MICHIGAN.

[Reprinted from the Annual Report of the Michigan State Board of Health for the year 1884.]

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During the last six months of the year 1881, and the first three months of 1882, sickness from typhoid fever was, I believe, much more than usually prevalent in the State of Michigan. The evidences of the truth of this statement are found in the Annual Reports of the Michigan State Board of Health; and they consist of replies by regular correspondents to questions asked by the Board,† and of tables compiled from weekly reports of sickness, made by health officers and other prominent physicians in different parts of the State.‡ Of forty-three correspondents, eleven reported typhoid fever (and nine reported typho-malarial fever) unusually prevalent in 1881, while only one reported typho-malarial fever and not one reported typhoid fever as less than usually prevalent in that year.

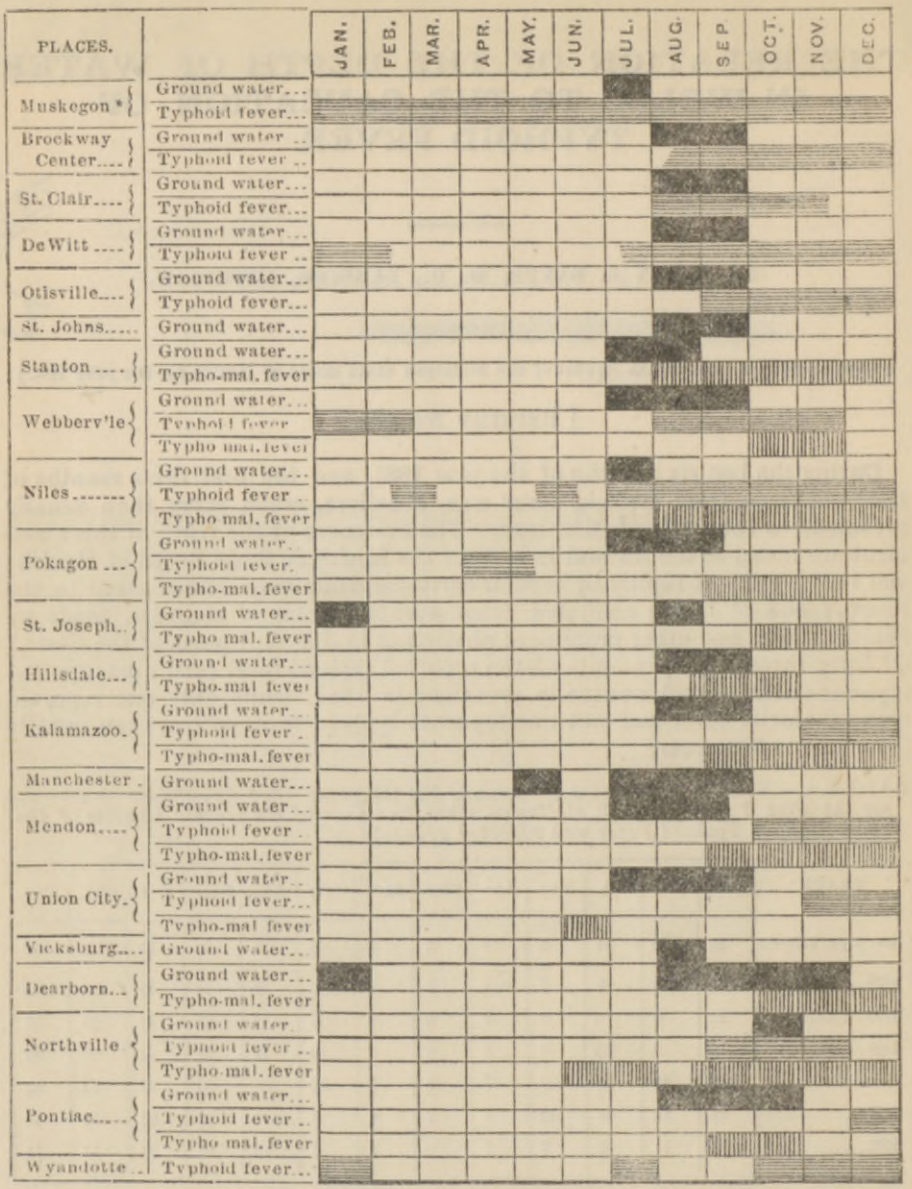
TABLE 1.—*By year and months for each of the six years 1878-83, and on an Average for the Five Years 1878-82, stating on what Per Cent of the Weekly Reports of Diseases received Typhoid Fever was reported present.*

YEARS.	Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Av. 5 yr. 1878-82	13	12	11	8	6	6	6	8	15	22	25	23	17
1878	10	12	9	7	4	7	6	6	10	13	18	11	12
1879	12	6		6	8	3	4	5	14	20	24	25	17
1880	14	8	13	7	5	6	5	10	19	26	23	22	17
1881	18	13	10	7	5	6	6	12	23	35	37	32	25
1882	14	21	16	12	8	7	9	8	11	17	23	23	16
1883	11	11	7	7	7	6	7	6	11	19	21	17	14

By the table (No. 1), which is here submitted, it may be seen that, beginning with July, 1881, the sickness reported from typhoid fever was about fifty per cent greater than the average for corresponding months in the five years 1878–1882, and it continued at this high rate until April, 1882.

* This paper was read before the American Public Health Association, at St. Louis, Mo., October 16, 1884.
† pp. 285-9, Report of Mich. State Board of Health, 1882.
‡ p. 568, Report for 1882, and p. 241, Report for 1883.

DIAGRAMATIC TABLE No. 2.—*Exhibiting Correspondence in Time and Place Between unusually Low Water in Wells and the Occurrence of Typhoid Fever, in Michigan in 1881. Data obtained from Replies by Correspondents and from Weekly Reports of Diseases.*



* Muskegon has a general water-supply from a ravine on the banks of which are privies.

For this increased prevalence of typhoid fever, a variety of supposed causes were alleged by the physicians who reported, but, taken altogether, the alleged causes seem at first sight nearly to negative each other, the number alleging excessive rainfall, wet soil, etc., at some time during the year, about equaling the number who alleged unusual drouth as the cause of the sickness. But by a careful study of the evidence relative to the condition of the soil and of the ground-water, immediately preceding and during the prevalence of sickness from typhoid fever, it is found that it was one of unusual drouth and low water in wells, in quite a number of different parts of the State, beginning with July, 1881, and that, although the rainfall later in the year was sufficient to make the surface-soil moist, the water in wells continued unusually low. It was especially low in July, August, and September, 1881. From reports by meteorological observers for the Michigan State Board of Health for the summer and autumn months in 1881 I quote as follows: Dr. J. S. Caulkins, M. D., of Thornville, says, "July has been a very hot and dry month. * * * Crops are badly injured by the drouth. August has been a dry, hot month. Vegetation has suffered beyond all record. At a short distance a pasture cannot be told from ploughed field. * * * The crops are almost a total failure." Dr. Jas. S. Reeves says, "The driest ever known here." For October, Dr. Caulkins says, "In spite of the heavy rainfall, water has not risen in the wells and springs, and below the wet there is a stratum of dry earth one or two feet in thickness." At the close of the year, Dr. Caulkins reports, "December has been a warm, open month, with scarce any snow, and very bad roads. There is no frost in the ground worth speaking of as the month closes. No ice in the lakes and streams. *Water is still low in spite of all the rains we have had.*"*

I submit herewith a diagramatic table (No. 2) in which is summarized the evidence which seems pertinent, that was contained in replies by regular correspondents of the Michigan Board of Health, relative to the months in the year 1881, in which the ground-water, as observed in wells, etc., was unusually low, and the months in that year in which typhoid fever occurred under their observation. It may be seen that in quite a number of localities observers have made records which show either a coincidence between the low water and sickness from typhoid fever, or that the fever occurred in months succeeding the low water.

I have shown that the *sickness* from typhoid fever in Michigan was unusually great in the last part of the year 1881 and first part of 1882 compared with other years, according to reports extending back to 1876. I submit herewith a table (No. 3) showing that the *deaths* from typhoid fever were also unusually numerous in the year 1881, compared with other years. The mortality statistics extend back to the year 1866.

I have compared reports of the meteorological and other conditions in the years 1881–82 with those for other years; and I find no condition, concerning which we have records, that varied in such manner as to explain the unusual prevalence of typhoid fever in those months, except the condition of the ground-water, as indicated by the lowness of water in wells. The temperature of the atmosphere was unusually high during those months; but to high temperature of the atmosphere the causation of typhoid fever has never been directly traced; the disease occurs in cold as well as in hot climates, and

* Dr. N. S. Davis reports a very dry summer in 1881, with an exceptionally high typhoid death-rate in Chicago (*Chicago Med. Jour. and Examiner*, Feb., 1882, vol. 44, pp. 113-117); and a very destructive drouth appears to have prevailed during the summer of 1881, over a large portion of the eastern United States (H. H. Clayton, Jr., in *Am. Meteorological Journal*, Aug., 1884).

TABLE 3.—*Deaths Returned as having occurred from Typhoid Fever in Michigan, in each of the 16 Years 1867-82, by Sex, and by Months.*

SEX.	MONTHS AND YEAR.														Years.
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Unknown Month.	Year.	
Total	36	28	24	22	9	13	19	21	42	60	48	37	2	361	1867
Males	21	16	13	11	3	7	9	13	22	28	24	18	1	186	
Females	15	12	11	11	6	6	10	8	20	32	24	19	1	175	
Total	36	28	24	17	14	11	18	45	72	84	31	49	1	430	1868
Males	21	16	13	8	8	7	6	27	37	43	15	29	.....	230	
Females	15	12	11	9	6	4	12	18	35	41	16	20	1	200	
Total	17	18	31	18	27	16	21	51	76	79	45	38	.....	437	1869
Males	8	10	19	11	16	8	10	25	36	40	25	20	.....	228	
Females	9	8	12	7	11	8	11	26	40	39	20	18	.....	209	
Total	10	17	33	12	17	17	34	64	106	117	94	52	1	574	1870
Males	7	11	9	6	7	6	18	32	50	59	38	27	.....	270	
Females	3	6	24	6	10	11	16	32	56	58	56	25	1	304	
Total	16	26	25	23	25	21	15	37	59	41	34	32	3	357	1871
Males	8	15	8	9	13	8	9	18	37	25	23	17	2	192	
Females	8	11	17	14	12	13	6	19	22	16	11	15	1	165	
Total	15	25	26	40	25	24	14	39	106	129	97	78	2	620	1872
Males	6	12	13	22	15	15	7	22	59	75	54	39	1	340	
Females	9	13	13	18	10	9	7	17	47	54	43	39	1	280	
Total	39	45	32	39	22	24	36	62	103	144	77	50	4	677	1873
Males	23	22	17	24	12	14	16	37	56	83	45	34	2	385	
Females	16	23	15	15	10	10	20	25	47	61	32	16	2	292	
Total	33	23	22	24	31	24	30	50	104	123	92	51	3	610	1874
Males	12	16	12	16	13	12	13	26	59	62	46	30	.....	317	
Females	21	7	10	8	18	12	17	24	45	61	46	21	3	293	
Total	30	16	21	23	17	22	22	29	55	92	63	40	3	433	1875
Males	12	10	9	16	8	15	12	15	31	50	32	22	.....	232	
Females	18	6	12	7	9	7	10	14	24	42	31	18	3	201	
Total	18	18	19	20	17	19	29	54	82	66	49	34	1	426	1876
Males	8	10	11	13	8	11	13	33	34	42	29	21	.....	233	
Females	10	8	8	7	9	8	16	21	48	24	20	13	1	193	
Total	14	13	25	18	24	9	18	54	83	85	58	43	2	446	1877
Males	8	5	10	11	11	5	11	29	44	44	32	22	2	234	
Females	6	8	15	7	13	4	7	25	39	41	26	21	.....	212	
Total	11	13	16	14	21	13	21	42	54	52	41	31	.....	329	1878
Males	3	10	7	7	14	9	9	22	28	25	25	17	.....	176	
Females	8	3	9	7	7	4	12	20	26	27	16	14	.....	153	
Total	15	24	24	23	13	11	18	48	53	61	55	52	.....	397	1879
Males	7	11	14	10	7	3	10	25	26	26	27	24	.....	190	
Females	8	13	10	13	6	8	8	23	27	35	28	28	.....	207	
Total	22	13	22	28	20	19	35	73	92	87	58	44	.....	513	1880
Males	9	6	10	17	13	11	23	38	58	43	31	26	.....	285	
Females	13	7	12	11	7	8	12	35	34	44	27	18	.....	228	
Total	20	15	23	34	27	35	45	99	150	178	149	108	1	884	1881
Males	13	9	14	21	14	23	26	49	79	83	93	67	.....	491	
Females	7	6	9	13	13	12	19	50	71	95	56	41	1	393	
Total	31	34	30	18	35	30	20	*27	52	91	53	40	2	463	1882
Males	19	20	17	11	19	15	9	13	26	54	36	28	2	269	
Females	12	14	13	7	16	15	11	13	26	37	17	12	.....	193	
Total	363	356	397	373	344	308	395	795	1,289	1,489	1,044	779	25	7,957	1867 to 1882†
Males	185	199	196	213	181	169	201	424	682	782	575	441	10	4,258	
Females	178	157	201	160	163	139	194	370	607	707	469	338	15	3,698	
Total	99	99	115	117	116	108	139	289	401	469	356	275	3	2,586	1878 to 1882†
Average	20	20	23	25	23	22	28	58	80	94	71	55	.....	517	

* Includes one "unknown sex." † Inclusive.

in cold as well as in hot seasons of the year; and although in Michigan it follows the hot weather of summer, in some other countries it follows the cold season. On the other hand, the disease has many times (hundreds of times, I suppose) been traced directly to the use of contaminated drinking-water.

There is one other closely-related physical condition that it would seem may have influence in the causation of typhoid fever, namely, the *temperature of water in wells,* and of the fluids in privies. The temperature of water in wells is recorded and reported each month from some localities in Michigan; and some study has been given that subject in the preparation of this paper; but the changes in the temperature are so slight that it is difficult to see how they can have *great* influence. Moreover, any effect this may have is so hidden in the greater changes in the quantities of water in wells, usually coincident with if not one cause of the changes of temperature therein, that it is difficult to distinguish separate influences, if such there are.

From the foregoing it appears that in Michigan there is a relation between low water in wells and the prevalence of typhoid fever; that this relation is found to hold by seasons of the year,—those months in which the water is lowest (or the months immediately following) being the months in which typhoid fever is most prevalent; and the unusual year 1881–2 when typhoid fever was more prevalent than ever known before, was also unusual because of the exceeding low water in wells.

A relation of low water in wells to the prevalence of typhoid fever being considered established, several questions arise:—

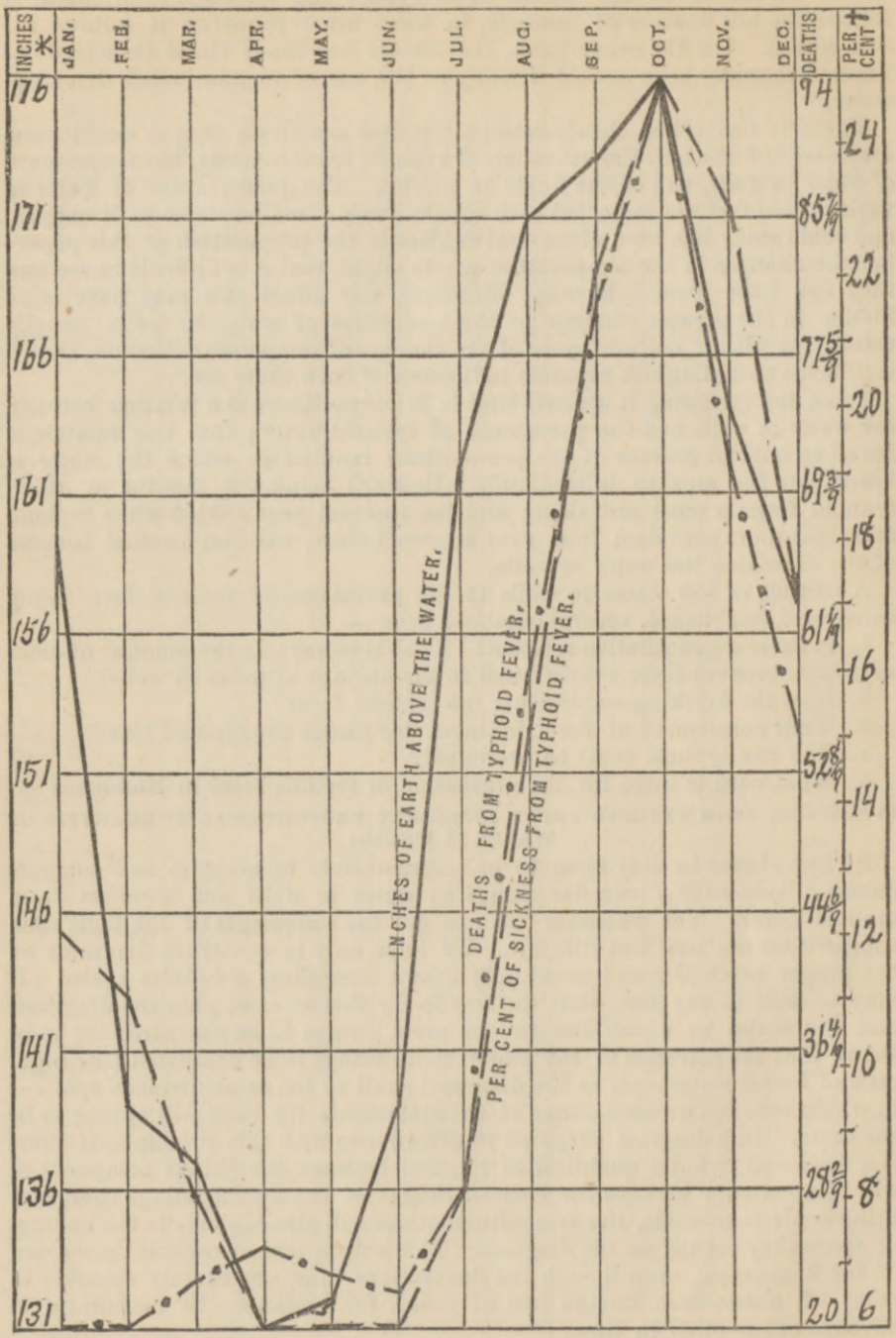
1. Is there a quantitative relation? That is to say: Is the amount of sickness from typhoid fever proportional to the amount of water in wells?
2. Does the drinking-water cause the typhoid fever?
3. What constituent of the drinking-water causes the typhoid fever?
4. How can typhoid fever be prevented?
5. What need is there for the prevention of typhoid fever in Michigan?

IS SICKNESS FROM TYPHOID FEVER INVERSELY PROPORTIONAL TO QUANTITY OF WATER IN WELLS?

At first glance in may seem to be impracticable to measure and compare quantitatively such dissimilar things as water in wells and sickness from typhoid fever. Yet whenever we can get the statements of the facts such comparisons are now not difficult. We have only to construct diagrams on the proper principle, and accurately drawn according to definite scales. It may be well to say here, that the way to do this is to so plan the diagrams and the scales by which the two or more things to be compared are to be shown that the *extremes* of the two or more things to be compared (the highest and lowest statements in the diagram) shall be the same distance apart,—in which case the greatest range of the statements for each will appear to be the same. In a diagram prepared in accordance with this principle, if there is a fixed and definite quantitative relation between the things compared, it will be apparent; because the greatest ranges of the several things compared being *made* to coincide, the minor fluctuations will also coincide in the amount of space they occupy on the diagram. This will be true as regards the *amount* of the fluctuation, even though the fluctuations may not exactly coincide in point of *time*,—even though one of them, for instance, be constantly in advance of the other in time.

This principle, just stated, has been held in mind in the preparation of the diagrams which I present to you, and which show the relation of the depth of

DIAGRAM A.—*Exhibiting, for a Period of Five Years (1878–82) the Average Monthly Oscillations of Ground-water in Michigan, the Deaths from Typhoid Fever, and what Per Cent of the Weekly Reports of Sickness Received Stated the Presence of Typhoid Fever.*



* Inches of earth above water in wells.

† Of all weekly reports received, per cent stating presence of typhoid fever.

NOTE.—The sickness-curve should rise and fall later than the curve for its cause by about the

the earth above the ground-water in wells in Michigan, and the prevalence of sickness from typhoid fever in Michigan by months in each of the years 1878, 1879, 1880, 1881, 1882, and 1883, also an average for five years,—1878–82, this diagram also including statements of the deaths in Michigan from this cause during the same five years. In these diagrams, statements of the "depth of earth" above the water in wells, have been employed; because if statements of the "depth of water" in wells were used the scale would, if upright, have to be the reverse of that used for the statements relative to the sickness, and therefore would not be as easy of comparison. In studying these diagrams, one will need to bear in mind that whenever the "depth of earth" over the water is great, the depth of the water in wells is low, and *vice versa*.

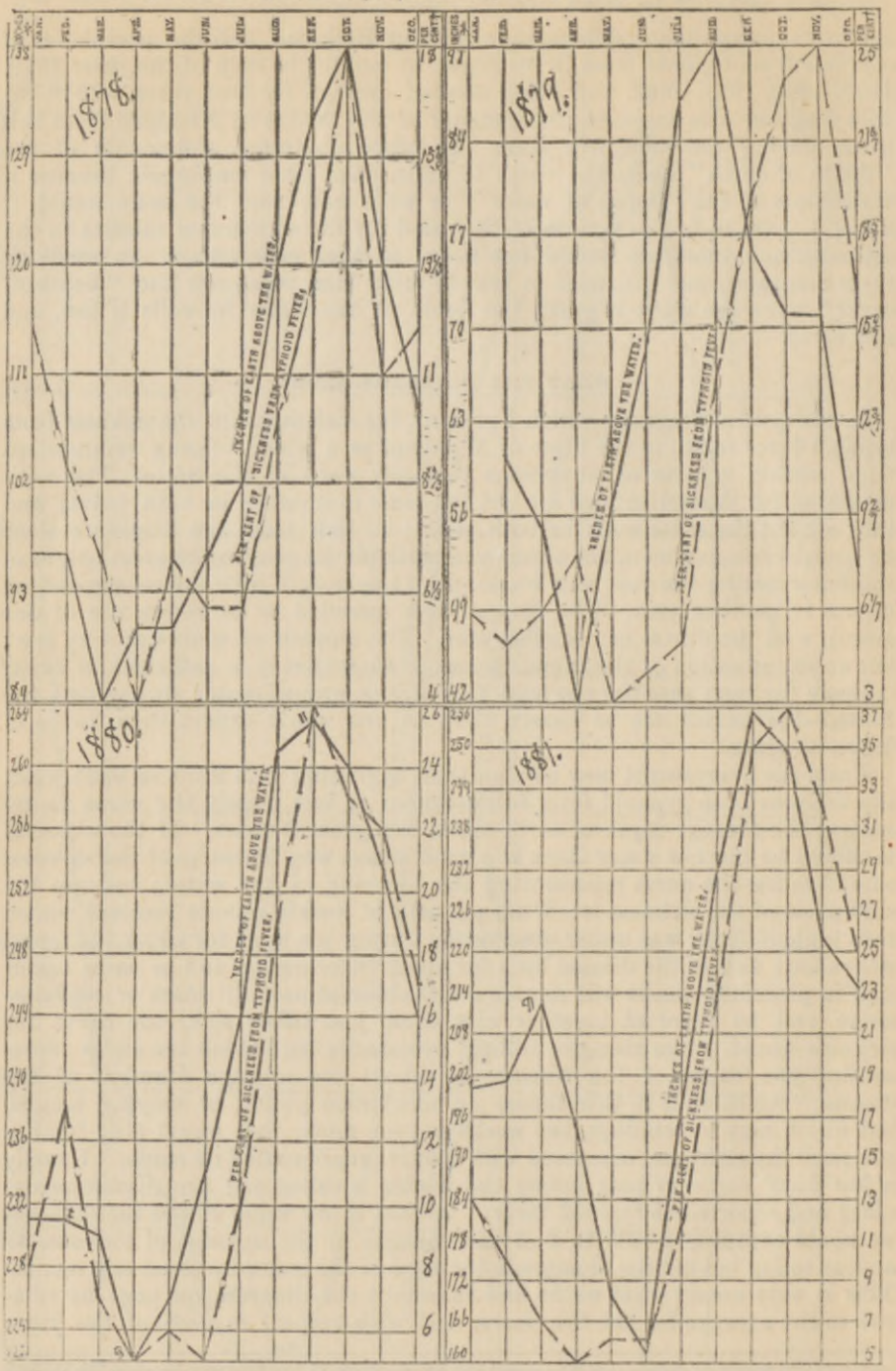
WHAT THE DIAGRAMS SHOW.

In the several diagrams which I present, the statements of the sickness from typhoid fever relate to the State of Michigan as a whole,—being summarized from weekly reports of physicians in many parts of the State. The wells measured for these diagrams are not the same in number in both years; and they are not the same wells in both years; so that from the diagrams alone no comparison can be made of one year with the other as to the exact height of the water during the year as a whole, or of one month with the corresponding month in another year. The comparisons intended to be shown are of one month with the others in the *same* year. The number of wells was very few; but an examination of the subject seems to show that it is sufficient to fairly indicate for each year the rise and fall of the ground-water throughout the State,—the curves are as nearly alike as one would expect them to be in different years.

From the diagrams it may be seen that, beginning with June in each year, the sickness from typhoid fever follows more or less closely the curve representing the average depth of earth above the ground-water. If the sickness is caused by the low water there is a good reason why the curve of the sickness should *follow* the curve representing the lowering of the water; because the statement of the sickness is: What per cent of weekly reports received stated that typhoid fever was under observation during the week for which the report was made; and as the disease lasts for about three weeks, and as cases taken sick in preceding weeks will remain under observation until death or convalescence and be reported together with those just taken sick, the curve for sickness would, when rising or falling, necessarily lag behind the curve representing the cause of the disease, by about the average duration of the disease. As there is in this disease an incubation period of varying length, but which may be ten days, two weeks or even more, this would still further postpone the sickness, compared with a curve representing its cause. Usually a few days' sickness pass before the doctor is called and the disease recognized and reported as typhoid fever. So that if low water causes the sickness, we would expect as a rule to find the changes in the amount of sickness to appear to lag behind the changes in the level of the water by about one month. This is very nearly what we do find shown by the diagram on page 94 relative to the average for the five years, and with respect to each of the years

length of the period of incubation plus about the av. duration of the disease; because the reports of sickness include all cases under observation, old cases and new cases. The time-unit of the diagram is so great (one month) that the interval between the two curves is sometimes greater and sometimes less than the interval between the supposed cause and its consequent sickness.

DIAGRAM B.—*Exhibiting the Rise and Fall of Water in Wells, and of Sickness from Typhoid Fever, in Michigan, in each of the Four Years 1878–81.*



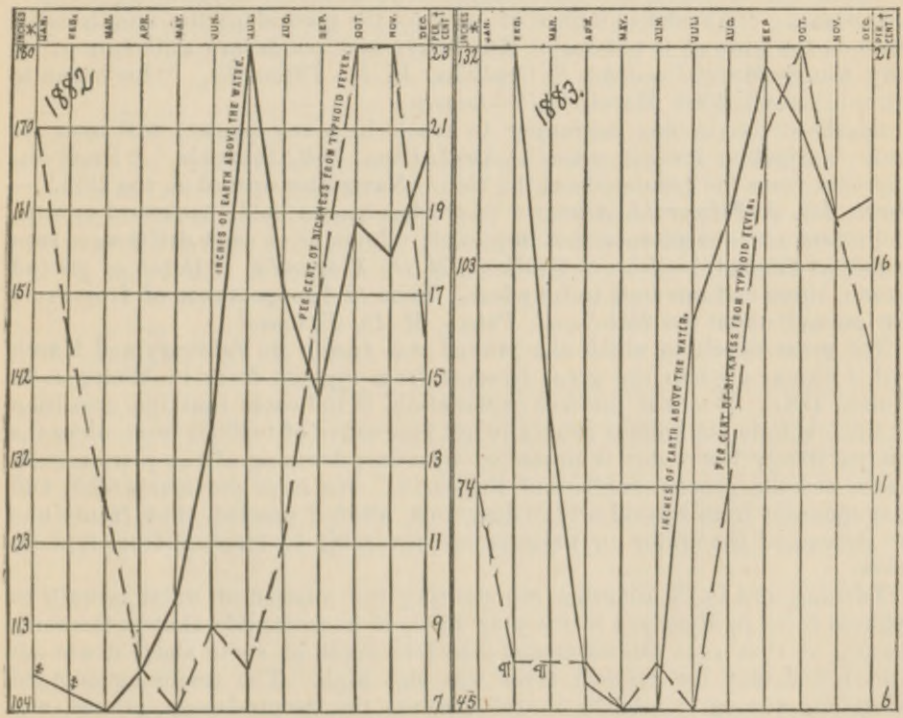
* Inches of earth above the water.
† Of all reports received for the given month, the per cent stating the presence of typhoid fever.
‡ Well-water high, but not protected by frozen ground; organic matter decomposing.
§ Depth of earth above the water least,—water highest; least sickness from typhoid fever.
‖ Depth of earth above the water greatest,—water lowest; most sickness from typhoid fever.
¶ Well-water low, but protected by frozen ground.

1878, 1880, 1881, and 1883,* namely, that the rise or fall of the disease appears to be greatly influenced in any month, after May or June, by the level of the water in that same month, but that the influence extends over into the succeeding month.

The comparison between the depth of water in wells and the sickness from typhoid fever being so close for every month after June, what is the reason for the want of correspondence in several years from January to June? By the diagram for the year 1881 it may be seen that the earth above the water increased from January to March and decreased from March until June, while the sickness seemed to decrease because of the low water in wells in March, and to increase in consequence of the rise of water in April. In considering this subject, it seemed to me that the cause of the low water in March, 1881, might be the great depth to which the ground was frozen; and that the reason why the sickness was decreased might be that the privies and other sources of typhoid contamination were also frozen, and the liquid therefrom prevented from descending to the water in the wells. The water in the wells would then be derived in greater proportion by percolation from a distance, in some cases from streams not frozen. In either case, whether the water in wells came

* If the diagrams were made by weeks instead of months it might be found that the relation is more definite and constant than appears by these diagrams; but this remains to be ascertained.

DIAGRAM C.—*Exhibiting the Rise and Fall of Water in Wells, and of Sickness from Typhoid Fever, in Michigan, by Months, during each of the Years 1882, 1883.*



* Inches of earth above the water in wells.
† Per cent of reports of sickness from typhoid fever.
‡ Well-water high, but not protected by frozen ground; organic matter decomposing.
¶ Well-water low, but protected by frozen ground.

from a distant stream above ground, or from the general level of the ground-water, the ground above being frozen deeply, the water which enters the wells would be filtered much more slowly through the deep strata of the earth than is the case when rain passes freely down to wells through foul surface-soil. To learn whether this supposed explanation accorded with the facts, I have turned to the reports by the meteorological observers for the State Board of Health of Michigan, and I find they reported relative to the weather in the first part of the year 1881, as follows:—

January.—"January was a very cold month. Ice about 25 inches thick; ground deeply frozen."—*John S. Caulkins, M. D., Thornville.* "January 1881 was the coldest, judging from its mean temperature, of any January since 1875. The mean temperature was 14 degrees."—*Sergt. Jas. A. Barwick, Alpena.*

February.—"Nights of February 23 and 24 were the coldest recorded since the first opening of the signal office in this city, minimum thermometer registering −27°."—*Sergt. Jas. A. Barwick, Alpena.* "The month has been stormy and quite variable in temperature, which is below the mean of several years."—*John S. Caulkins, M. D., Thornville.* "Ground frozen four feet deep."—*Lee S. Cobb, Winfield.* "Frost four feet deep in the cemetery, soil, sand, and gravel."—*Francis D. Parmelee, Hillsdale.* "Thickness of ice put up in ice-houses, 26 inches. Average depth of frozen earth in cemetery, 3 feet."—*Edwin Stewart, M. D., Mendon.*

March.—"Ground frozen to the depth of 18 inches."—*Sergt. Jas. J. Fitzgerald, Alpena.* "About five inches of snow on the ground as the month ends. Frost in the ground is not deep. The lakes and ponds are still frozen. A very wintry March,"—*John S. Caulkins, M. D., Thornville.* "Ice began to move in Grand River March 28."—*Lansing.*

April.—"Ice in bay beginning to crack in many places; will soon be gone; navigation not yet open."—*Sergt. Chas. Dill, Escanaba.* "Frost disappeared from the ground about the 25th. Navigation opened on the 29th."—*Sergt. Jas. J. Fitzgerald, Alpena.* "April has been a cold, backward month, and closes with the prospect not improved. Remains of snow drifts were seen as late as the 22d."—*John S. Caulkins, M. D., Thornville.* "Depth of ground frozen, three and one-half to four feet. Time of disappearance of frost from the ground, about the 25th."—*H. Peters, M. D., Tecumseh.*

The great depth to which the ground was frozen in February and March will, I think, explain the great freedom from typhoid fever in Michigan in March, 1881. If this is the true explanation, it indicates that the condition of the low water in wells is generally not productive of typhoid fever when the comparatively low water is protected by a deep freezing of the privies, cess-pools, and the general surface of the earth. We have previously seen, and it is apparent from several of the diagrams, which I present, that from June to December *low* water in wells is *not* favorable to freedom from typhoid fever.

Turning now to the diagram representing the relation of water in wells to typhoid fever in Michigan in the year *1880*, it is noticeable that in the early months of that year the water was *high* (the depth of earth above it was not great), and that the typhoid fever was also high. The reasoning adopted relative to the early months in *1881*, where the deeply-frozen ground was believed to have prevented typhoid fever, would lead us to suppose that the well-water was *not* protected by frozen ground in *1880*. Inspection of the records (in the Annual Report of the Michigan State Board of Health) shows

that this is true, that in Michigan the earth was *not* as deeply frozen as usual during the months of January and February, 1880. In January, the average temperature for 15 stations in different parts of Michigan was above the freezing point, being 34.06° F. In February, the average was 27.93°, and in March, 31.00° F. Dr. Stewart, observer at Mendon in southwestern Michigan, reported: "Considerable plowing has been done in this county during the month of January;" Dr. Caulkins, observer at Thornville, reported for January, 1880: "There is no snow, no ice in streams and ponds, and scarcely any in the ground." Dr. Peters, of Tecumseh, reported for February: "Frost all out of the ground February 28. Streams froze up and thawed out three times during winter, ice at no time more than six inches thick. Not more than half the usual amount of ice was put up." Dr. Caulkins reported for February: "The ice crop is a total failure. February has been very mild for this latitude, and so much freezing nights and *thawing days has materially injured the clover.*"

The unusual prevalence of typhoid fever in Michigan in February, 1880, is probably fairly attributable to the unusually mild weather in January and February, and to the lack of protection usually afforded by the frozen ground at that season of the year to the water in wells, which water, by reason of the injury to vegetation by alternate freezing and thawing, was probably unusually contaminated by decomposing organic matter, in addition to the leaching from privy-vaults.*

From the evidence in the tables, diagrams, and comments in this paper, it may be seen that not only in the spring of 1880, but in the early part of other years, typhoid fever was prevalent coincidently with an unfrozen surface of the ground. The year 1882 is another example of high ground-water and high rate of *sickness*, during the first few months of the year. By reference to the reports of meteorological observers for the Michigan State Board of Health it is found that February and March, 1882, were unusually mild months. The observer at Lansing records for February: "Frost Feb. 9. River opened Feb. 13, closed Feb. 21, and opened again Feb. 25. Robins came back Feb. 22." Dr. Caulkins writes at the close of February: "Nights that no ice formed, 7, 12, 13, 16, 27, 28. A warm and pleasant month for the season, with no sleighing, and noteworthy for the six days without freezing. Wheat seems not to be in the least injured by the freezing and thawing and the lack of snow, but looks excellent. As the month goes out there is not a particle of ice in sight,

*In this connection the following from the Massachusetts Board of Health Report for the year 1871 is of interest:—

"A large house in this village [Sutton] is supplied with water from a well in the front yard, three rods from the house. Connected with the house is a barn without cellar, some three rods from the well. In December, 1868, a trench three or four feet deep was dug from the well to a point near the middle of the barn, where a pump was set and a pipe connecting it with the well was laid in the trench; after which the earth, which was in large frozen chunks, was filled back into the trench. In the house was kept a boarding-school for boys, of whom there were ten or twelve. Three little girls were also there, aged twelve, eight, and three years, belonging to the family of the owner of the house; there were therefore fourteen or fifteen children who drank from the well. The oldest boy was seventeen or eighteen years old, while the others were of ages from ten to thirteen. Everything went well until after the thaws in February and March, 1869, when the water had a decided taste and smell of stable-manure. March 26, one of the boys, thirteen years old, was seized with typhoid fever; another, twelve years old, on the 31st of March; another, eleven years old, April 2; another, ten years old, April 4; and another, twelve years old, April 9. April 20, one of the little girls (eight years old) was seized. Each of these six children (all of whom finally recovered) drank water with their meals from the well in the yard. Some of the older boys drank coffee in the morning and tea at night. The manner in which these children were attacked, and the fact that this house had been free from typhoid fever for many years, and the water heretofore known to be very pure and wholesome, leads me to the conclusion that the use of the water thus impregnated was the cause of the disease occurring where and just at the time it did. My theory is that while the ground, manure, etc., under the barn were frozen, the water was all right; but when it thawed, and the previously frozen filth leached through the soft and loose earth along the track of the pipe into the well, the effect of the poison was felt most perceptibly by those who used the polluted water most freely, while those who used it less freely escaped entirely."

and little frost in the ground. Robins came back as early as Feb. 22, and blue birds soon after. Blue flies and mosquitoes have been seen." Dr. Caulkins writes again at the close of March: "March in spite of some cold weather, has been a warmish month. As it closes there is scarcely any ice in the ground. Wheat looks uncommonly well, but the last year's seeding of clover is pretty much all killed by the repeated freezings."

We thus reach the conclusion that, in Michigan at least, the relation of the depth of water in wells to typhoid fever is not the same in summer as in winter; that in summer when vegetation is active and not decaying, a lowering of the water is uniformly followed by increased prevalence of typhoid fever; with the advent of colder weather, there is a rise in the water-level which is uniformly followed by a decreased prevalence of the fever; that this decrease continues through the winter and spring, even though the level of the well water is lowered, *provided* the surface of the earth is deeply frozen; that on the contrary, *high* water-level in wells in winter and spring, coincident with ground *not* thoroughly frozen, is followed by *increased* prevalence of the fever. Briefly stated, the typhoid fever follows *low* water in summer, and *high* water at that season of the year when the ground is usually thoroughly frozen. (Although I find little evidence of it as yet, we may expect to find that high water in winter and spring may not necessarily be followed by increased prevalence of fever, if it is coincident with a deeply and continuously frozen surface of the ground.)

As regards bronchitis, pneumonia, and other diseases caused by cold weather, it does not seem to be true that they are more prevalent in a mild than in a severe winter. But as regards typhoid fever in its relations to contamination of ground-water, as herein set forth, there seems to be a partial explanation of the old saying, "A green Christmas makes a fat graveyard."

WHAT CONSTITUENT OF THE DRINKING WATER CAUSES THE TYPHOID FEVER?

Typhoid has been known to occur after the drinking of water contaminated by decomposing vegetable matter (turnips in one instance*); by decomposing *animal* matter (a turtle in one instance†); also in the autumn succeeding a hot summer in which diarrhea had been unusually prevalent; and the unusual fouling of the water-supply by the extra quantity of fecal discharges under these circumstances has been supposed to have causative relation to the typhoid fever which succeeded it. All this receives explanation if we accept the doctrine that typhoid fever is caused by bacteria; because bacteria require for their growth and multiplication a nutritive solution,—either mineral (such as Pasteur's), or vegetable, or animal, very few, if any, of the many species of bacteria being able to reproduce themselves in great numbers in *pure* water. This last statement seems to me to be evident to those who have used the microscope much; yet I may quote from a high authority as follows: Dr. Robert Koch, in his recent address on cholera, before the Imperial German Board of Health, is reported to have said: "I would not certainly assume that the multiplication of the comma-bacillus outside of the human body takes place in well-water or in river-water without any assistance, for these fluids do not possess that concentration of nutritious substances which is necessary for the growth of the baccilli."‡ Dr. Koch was, however, able to reproduce the comma-bacillus in meat juice, and other

* *Sanitary Record*, London, Jan. 29, 1876, vol. iv., pp. 81-82.
† Annual Report Mich. State Board of Health, 1876, pp. lxii-lxiv.
‡ British Medical Journal, Sept. 6, 1884, page 456.

nutritive solutions. After mentioning the growth of bacteria in stagnant water, and that "the continuous flow of water prevents the formation of a local concentration of nutritive substances in the liquid sufficient for pathogenic bacteria," Dr. Koch further says:* "The connection between the falling of the subsoil-water and the increase of several infectious diseases, I would explain as follows: that when the subsoil water falls, the current that takes place in the subsoil-water is much less significant. Besides, the quantities on the surface are much diminished, so that those concentrations, which I assume to be necessary for the growth of the bacteria must much sooner take place." I venture to suggest that the evidence we now have of the causation of typhoid fever renders it necessary that we substitute for Dr. Koch's diminished quantities of fluids "on the surface," *diminished quantities of water in wells* as more *directly* causative of typhoid fever; because that disease is *not* frequently traced to transmission through the air, but *is* frequently traced to the use of bad water; so that aside from such evidence as that which I present to you at this time,—we have good reason to believe that in some way typhoid fever is frequently caused by the drinking of contaminated water. The cases recorded are exceedingly numerous. References to a few of them are as follows:—

NEUCHATEL OUTBREAKS.

A mild, extensive epidemic of typhoid fever occurred in Neuchatel, Switzerland, in the fall of 1882. There were six hundred and twenty-three cases between September 14 and October 20, and the total cases in the period covered by the epidemic, included 5 per cent of the entire population. All classes were taken and the outbreak occurred in all parts of the city at the same time. The water drinkers suffered most, and, so far as reported, those who drank only beer escaped entirely.

The city water supply is brought by an aqueduct from the Seyon, a mountain stream, torrential in spring and during rains, but small in summer. This stream with its affluents drains the Val-de-Ruz, and on its banks above Neuchatel are many small villages. A careful investigation authorized by the government, showed the following condition: The drinking water is taken from the Seyon directly below the town of Valangin; there are twenty other little villages higher up the valley. Slaughter-houses, pig-sties, cess-pools, sewers, and privies were found in close proximity to the stream, and with liquid contents oozing in some cases directly into the stream. A public laundry much used by several villages is also situated on the banks of the stream and the wash water flows directly into it. Ordinarily the water of the Seyon is pure, but during heavy rains the filth from above mentioned sources is washed into the stream in large quantities and gives to it a turbid aspect. A committee which examined the condition of the Seyon below Valangin and above the point from which the Neuchatel water-supply is taken, immediately after a heavy rain, declared the stream to be "nothing but a vast drain, the water being absolutely unfit for alimentation." Some weeks prior to this outbreak at Neuchatel, there had been cases of typhoid in nine of the small villages above Neuchatel, and also about fifty cases of an infectious gastritis, thought by some to have been a mild typhoid. These cases were followed by a series of heavy rains, and these in turn by the typhoid outbreak at Neuchatel. In the fall and early winter of 1875 after continued heavy rain there was an analogous outbreak of typhoid fever in Neuchatel preceded some weeks by sporadic cases of the fever in the Val-de-Ruz. (L'Eau du Seyon et La Fievre Typhoide a Neuchatel. Par Dr. Guillaume. Neuchatel, 1882.)

NEUCHATEL R. R. STATION OUTBREAK.

Dr. Favarger relates (*Feuilles d' Hygiene*, November, 1879) that being called in the early part of 1878, as physician to the railroad company, to care for a series of more or less grave cases of typhoid fever (14 cases, 3 deaths), confined exclusively to the employees of the railroad station at Neuchatel, he made an investigation and found that some weeks previous the son of an engineer in charge of the water-works had been taken with the fever, and had been cared for in the building which contained the hydraulic ram used for forcing water from the lake into a reservoir from which the station eating-house and the locomotives were supplied; he found that a portion of the excreta of this boy had passed into the lake near where the water-supply was taken and had undoubtedly been pumped into the reservoir, and then consumed by the employees of the station. —(Cited by Dr. Guillaume, as above.)

* British Medical Journal, Sept. 6, 1884, page 456.

BRANHAM SCHOOL OUTBREAK.

At the college of Branham, Yorkshire, Eng., two pupils were taken with typhoid fever in Feb., 1869, the discharges being thrown into the water closet. Toward the end of the next month there was, all at once, an outbreak of 16 cases of fever in the school. Investigation showed (1) that all the pupils ate the same food, while only a part were stricken; (2) that the beer drinkers were regularly spared by the disease; (3) that the disease seemed to single out the water-drinkers. These facts threw suspicion on the drinking water. Further investigation showed that a defective soil-pipe had allowed the typhoid excreta to pass from the water-closet into a reservoir of fresh water, and that the well water had been polluted by infiltrations from this reservoir. The fact that the food was cooked in this water would go to show that heat destroyed the typhoid poison.—(Dr. Anker, as quoted by Dr. Guillaume.)

UPPINGHAM OUTBREAK.

During the month of Oct., 1875, fifty-one cases of typhoid fever occurred in a school at Uppingham, England. There had been one case of this fever (terminating fatally) in this school in the preceding June, and no sanitary precautions had been taken. The lad died at the commencement of the midsummer holidays. Two cases occurred between Sept. 21 and Sept. 28; and twenty-eight others between this date and Oct. 12, up to which time no sanitary precautions appear to have been taken. The excreta from these cases went into large, full, and extremely foul cess-pools in proximity to the wells,—afterwards shown to be polluted. The contents of some of these cess-pools was pumped upon the garden for fertilization purposes, and drained into a stream in the polluted water of which the boys were accustomed to bathe. The sewer-gas from these cess-pools, into which the typhoid excreta were thrown, penetrated almost without hindrance, not only the water-closets, but also the living and study rooms of the school. It will thus be seen that, whether the cause of the fever was gaseous or particulate, given a first case in this school there was *a priori* every reason to suppose the disease would spread as it afterwards did. This outbreak was carefully investigated by Dr. A. Haviland, Medical Officer of Health, who considered the outbreak to be the result of gross neglect on the part of the school authorities and the physician in charge.—(The Late Visitation of Typhoid Fever in the School and Town of Uppingham. London. E. & F. Spon, Publishers.)

ARMLEY OUTBREAK.

In an epidemic of typhoid fever occurring at Armley, in the Borough of Leeds, England, which was investigated by Dr. Ballard, of the Local Government Board (Reports of the Med. Officer of the Privy Council and Local Gov't Board, New Series, No. II., London, 1875, Pg. 79-91), one hundred and seven cases occurred between July 7 and Sept. 7, 1873. The milk supplied by a certain dairyman, who had himself been ill of this disease in May, was shown to be the cause of the outbreak. "The manner in in which the fever picked out the customers of the dairyman in various rows and blocks of houses, sparing other families, was indeed remarkable. * * * * As to the mechanism of the distribution of the fever from the dairyman's premises, there arises at the outset a question which it is desirable to answer, but to which, in the nature of things, a direct answer can hardly be expected. Was it water added to the milk that produced the enteric fever among families supplied from the dairy? No one knows anything of enteric fever being propagated by cow's milk *per se*, while there is very ample knowledge about the spread of such fever by means of water. The following considerations lead one to believe that it really was not through milk, but through water added to milk, that the customers of Hall Lane dairy got their infection of enteric fever. Houses occupied by families supplied from this dairy were invaded freshly, one after another, almost every day up to July 27; on that day three houses so occupied came freshly under medical notice; and from that day the epidemic, as such, was at an end. In the whole of the next week only one family dealing with the Hall Lane dairy applied newly for medical aid. This sudden cessation of the fever epidemic among this section of the community on July 27, means that the cause of the epidemic had ceased for them a fortnight or more previously, since in enteric fever there are commonly 11 days of incubation and several other days before medical advice for its symptoms is sought. July 10 would therefore be about the time when the cause of the epidemic among customers of the diary suddenly ceased to operate. Now, on July 10, Dr. Robinson had the handle of the pump at the Hall Lane dairy chained up, and thenceforth it was kept chained. There was coincidence therefore between the cessation of the fever and the cessation of the opportunity that the dairy had to supply a particular water; while there was no suggestion that the cows or their milk had undergone any change." Did subsequent investigation of the water supply (in which the milk cans were known to have been washed) show it to be contaminated? Dr. Ballard leaves no doubt on this point. He says that the entire premises were in a filthy condition. Close to the well was an old urine tub in use; a very large dung pit full of filth and manure was situated about 15 feet from the well in one direction; and the privy used by three cottages (and full of liquid excrement) was only a little farther off in an opposite direction. This well was 36 feet deep, loosely

bricked up without cement for upper 22 feet, the lower 14 feet being in shale. "For the first four feet from the top of the well the outside of the brick work was pudded with clay, but not lower. All the way down below the place where the pudding ceased there was observed an oozing of black matter between the bricks, and below the spot where the brick work ceased the oozing was considerable, as shown by the staining of the stony portions of the soil, and by a black stain, 12 inches wide, on the side next the dung-pit, reaching to the water two feet lower down. There was a deposit of mud and filth at the bottom of the well which gave off abundant bubbles of gas on being disturbed." Analysis of the well-water showed much contamination from fecal matters. There had been considerable rain in the last part of May, toward the close of the dairyman's sickness.—The excreta had been thrown into the privy and also, in all probability, owing to the slovenly habits of the family, into the dung pit and the urine tub, which were very near the well.

LAUSANNE (SWITZERLAND) OUTBREAK.

"The case in which the poison of typhoid fever mixed with drinking water was transmitted through nearly a mile of porous earth, and which was mentioned in the abstract of my discourse o the Fellows of the Chemical Society (*Nature*, Vol. xiii, p. 331), is fully described (in German) in the 6th Report of the Rivers Commission on the Domestic Water Supply of Great Britain. It will shortly appear, in English, in the Monthly Journal of the Chemical Society. Meanwhile perhaps I may be allowed to trespass upon your space with the following remarks:—The outbreak of typhoid fever occurred at the village of Lausen, near Basel, Switzerland, and it was exhaustively investigated by Dr. A. Hagler of Basel, who has given a full account of it in the 'Deutsches Archiv. f. Klin. Med. xi.' The source of the poison was traced to an isolated farm house on the opposite side of a mountain ridge, where an imported case of typhoid, followed by two others, occurred shortly before the outbreak. A brook which ran past this house received the dejections of the patients, and their linen was washed in it. This brook was employed for the irrigation of some meadows near the farm house, and the effluent water filtered through the intervening mountain to a spring used in all the houses of Lausen, except six which were supplied with water from private wells. In these six houses no case of fever occurred, but scarcely one of the others escaped. No less than 130 people, or seventeen per cent of the whole population, were attacked, besides fourteen children, who received the infection whilst at home for their holidays and afterwards sickened on their return to school.

"The passage of water from the irrigated meadows to the spring at Lausen was proved by dissolving in it, at the meadows, 18 cwt. of common salt, and then observing the rapid increase of chlorine in the spring water; but the most important and interesting experiment consisted in mixing uniformly with the water 50 cwt. of flour, not a trace of which made its way to the spring, thus showing that the water was *filtered* through the intervening earth, and did not pass by an underground channel.

"These are the main features of the case, according to the works above cited. It affords a clear warning of the risk attending the use, for dietetic purposes, of water to which even so-called *purified* sewage gains access; notwithstanding that, as at Lausen, such water may have been used with impunity for years, until the moment when the sewage became infected with typhoid poison. E. FRANKLAND." Quoted from PUBLIC HEALTH, April 14, 1876, page 266.

SYRACUSE (N. Y.) OUTBREAK.

The history of this outbreak is very clearly set forth in an article on "Typhoid-Fever Poison," (*Popular Science Monthly*, N. Y., Feb. 1879,) by Dr. Eli Van de Warker. Sixteen cases of the fever were traced to one previous case, and the subsequent defilement by excreta from this case of one of the neighborhood wells by overflow of privy during a heavy rainstorm. People living on the same block or across the street, and under similar conditions except as to the water which they drank, escaped entirely, although many of these same people were up night and day caring for the afflicted families.

GERMAN TROOPS AT WITTENBERG.

In some respects one of the most interesting outbreaks of typhoid fever ever recorded occurred in the summer of 1882, among the troops of the third Brandenburg Infantry-Regiment, garrisoned at Wittenberg, Germany.

A full and admirable report of this outbreak by Staff Surgeon Dr. Gaffky, is given in the last volume of the Report of the Imperial German Board of Health (Mittheilungen aus dem Kaiserlichen Gesundheitsamte, Band II., Berlin, 1884), pages 403-420.

Between June 11 and July 12 there were ninety cases of the fever. This outbreak occurred very suddenly, and was confined almost exclusively to the troops of one battalion of the Regiment.—Citizens upon whom part of these soldiers were quartered escaped, as did also the officers. This sudden and severe epidemic at once attracted government attention, and the investigation which followed is very characteristic of the thorough way in which the Germans do things. Dr. Gaffky was detailed to make the investigation, with the approval of the Minister of War, and under the

direction of the Imperial Board of Health. By a rigid induction, every step of which is clearly detailed, Dr. Gaffky reached the conclusion that some weeks previous to the outbreak the well in the yard at the barracks had been infected by innumerable "typhoid seeds" from a neighboring privy, and that the use of the water of this well was the cause of the sickness. The citizens, officers, and soldiers not attacked escaped because they did not use the water of this well.

Two wells supplied the water used by the troops. Chemical analysis and careful inspection showed both wells to be badly contaminated, but in different ways. One well was situated in the yard of the barracks, near a privy. The water of this well was used for dish-washing, washing canteens, and scrubbing purposes, and to some extent for drinking purposes, but was not used for this purpose by the officers nor by many of the troops because the water was not so good as that brought from the street well. Into the privy typhoid excreta had unquestionably been thrown in the months immediately preceding this outbreak. The strata between this privy and the well were for the most part coarse sand and gravel, easily permeable. The privy vault had two openings in its walls and through these its liquid contents had oozed into the surrounding soil. Its subsequent movement into the ground-water and thence into the well was facilitated by three factors, (1) the lowness of the water in the well, (2) the increased amount of water which was drawn from the well at that season of the year, and (3) the movement of the ground-water itself which was found to flow from the privy toward the well.

The other well, much used by the citizens as well as by the troops on account of the better appearance and taste of the water, is located in the middle of the neighboring Burgomaster street. No cases of fever resulted from drinking the water of this well, although it was very foul. The manner of defilement of this well was as follows:—The horse-dung and other filth and rubbish of the street was supposed to be washed by rains along a pavement gutter to the northward away from this street well; but owing to a settling of the pavement there was a sag towards this well, and during rains the wash of the street actually poured into the well, and was pumped up and drank. This was not all,—beneath the pavement there was found a well-defined little gutter leading directly into the well. This befouling of the well had apparently occurred during every rain, for a long time, and yet no typhoid fever resulted from drinking this water, *because no typhoid germs had ever found their way into this well.* If typhoid dejections had at any time been cast into the street they would in all probability have been washed into the well during the next rainstorm. The author thinks there is no reasonable doubt that in such an event an epidemic such as was traced to the well in the yard at the barracks would also have resulted from drinking the water of the Burgomaster street well.

ADRIAN OUTBREAK.

In the fall and winter of 1883-4 an outbreak of typhoid fever occurred at Adrian, Michigan, in which there were fifty-three cases, with eight deaths. Over one-third the cases were pupils at a German Lutheran school in the house of the teacher, which house had for many years been used as a hotel, and at which was a well (in use by the family, the pupils, and others) very near which (from 25 to 56 feet) were an overflowing privy-vault, several old filled privy-vaults, two other privy-vaults in use, and a barnyard; there was also a drain or sewer (laid in June, 1883) in which, six feet from the well, was a leak from which the contents of the sewer flowed toward the well, forming a little cess-pool in the gravelly soil only 3 feet from the well-wall, which was of brick laid up without mortar,* and from which cesspool the contents undoubtedly leached into the well. The well was 36 feet deep, with four feet of water at time of examination, October 24. Examination of the water with a microscope revealed vibriones and other organic matter, animal and vegetable. Analysis of the water showed sewage contamination. Twenty-one (of about eighty) pupils were sick, all of whom presumably drank of the water. Thirteen other persons who used water from the well were sick. Of the other nineteen cases eighteen were in the families of pupils or of persons who used the water and were sick, and but one was not traced thus directly or indirectly to this well, and he attended another German school in the neighborhood of this well.

The first case was a son of the teacher (about six years old), and was taken sick September 7. *Discharges from this patient were thrown into a catch-basin three feet from the well,* connecting with the drain or sewer, and into which catch-basin passed the overflow from the pump. Because of the leak above mentioned, if not otherwise, these typhoid discharges without doubt reached and infected the already foul water of the well. September 24, seventeen days after the first case was taken sick, the second case occurred. The third came down September 27, both in persons using water from this well. The fourth case attended a German school on a lot in the rear of the lot where the bad well was, and cornering with it, but it is stated did not use water from this well. He came down October 1. Cases from the fifth to the thirty-fourth, inclusive, came down from

* According to another statement, the wall of the well had been relaid in water-lime in June before the sickness, at a time when it had been found necessary to have the well cleaned, the water having been reported as bad, pieces of dead earthworms having been brought up by the pump, at which time the drain or sewer was laid. Whether all or part of the wall was relaid in water-lime does not appear.

October 2 to October 22 as follows: Two, October 2; one, October 5; one, October 6; three, October 7; six, October 8; four, October 9; one, October 10; two, October 11; one, October 14; one, October 15; one, October 16; two, October 17; one each, October 19, 20, 21, and 22; and one at a date not so definitely ascertained. Of these 30 cases 20 were pupils of the school, 9 were other persons who used water from this well, and one (a brother of one of the pupils taken sick Oct 9) was a pupil at a third German school, across the street and about 12 rods from the one where the bad well was, and was himself taken sick Oct. 9, but is said not to have drank from the bad well.

The physician who treated the first and third cases was called to the third (his second) October 4, which day, at his request, the use of the water from this well was discontinued; but before the use of the water was discontinued the 30 persons (pupils and others who used the water) who were taken sick from October 2 to October 22 had an opportunity to become infected from this water.

After October 22d there were no more new cases till November 5th; then began a second series of 19 cases, all but two of them in the families (mostly in two families) of previous cases, which 19 cases were taken sick at dates as follows: One each, November 5, 7, 8, 13, 19, 21, 24, 27, 28, December 1, 4, 13, 15, 19, 25, January 1 (1884), 4, 7, and April 1. Of these, 8 were in one family (and its near and neighboring relatives), the first case in which was one of the pupils taken sick October 7, the second case being taken sick November 24; and four were in a family, the first case in which was the pupil taken sick October 15, and the second case was taken December 1; two (taken Nov. 13 and Nov. 21) were in a family in which two cases (one of them a pupil at the bad well) were taken sick Oct. 9; three were in three families in which had been sick pupils, taken sick October 8, October 9, and October 8, and in which the second cases were Nov. 8, Nov 5, and Nov. 19, respectively; one of the other two was a near neighbor of a family in which were five cases; and one attended the German school across the street from the bad well and drank from that well. Two of the second series of cases were users of water from the bad well, one of them being a pupil at the school where that well was. Concerning these it does not appear whether they used the water after it was infected by discharges from the first case (taken Sept. 7). The interval is so great between the discontinuance of the water (Oct. 4) and the coming down of these two cases (Nov. 7 and Nov. 19) as to make it seem likely that they were infected in some other way than by water drank before Oct. 4. Concerning the two cases in the first series who are stated not to have used water from the bad well, it should be remembered that they attended schools near that well, one of them had a sister attending the school where the bad well was, and it does not seem unlikely that they may have visited the playground and drank at the bad well, as one pupil of the school across the street from the bad well is stated to have drank at that well.

Where and how the first case in this outbreak contracted the fever is not known, but typhoid fever is known to have occurred in a house near the school the year previous to this outbreak.

A longer report of this outbreak (not, however, including all the cases) is printed on pages 36–47 of the Report of the State Board of Health for 1884.

It appears to be established conclusively that in this outbreak the fever resulted from the use of foul well-water, *after it had become infected by the specific* discharges from a first case. The facts developed may be summarized as follows:

1. Filth conditions likely to contaminate this well (the nearness of the privy-vaults and the barn-yard) had existed for a long time without, so far as known, causing a case of typhoid fever. It had been found necessary to clean the well in June before the sickness. The leaky drain laid in June became another source of contamination. Unless M. H. (the teacher's son) was infected with the foul water, no case of typhoid fever resulted from the use of the foul water until excreta (containing the specific typhoid germs?) from a case (M. H., the first case) of typhoid fever were introduced into the water. Then, after about the usual period of incubation, other cases followed rapidly. If the teacher's son, M. H., was infected by water from the well, it seems strange that of the large number of persons using water from this well, no one else should have been infected at that time, and that no other case occurred till 17 days after the first, especially as so many of those subsequently infected by the water were near the age of this first case, about six years.

2. After the first case of the fever occurred (September 7), seventeen days elapsed before the second case (September 24). This may indicate that the period of incubation was, in that case, 17 days; or if we call the period of incubation 11 days, it was six days after the first case was taken sick before his discharges were capable of causing the disease; or it took six days for the discharges to reach and so infect the body of water in this well as that it could cause typhoid fever. The third case occurred September 27, and the other cases followed rapidly (thirteen of them coming down on the three days, Oct. 7, 8, and 9) until October 22.

3. The use of the well-water ceased about October 4.

4. In the first series, new cases ceased to appear about 18 days after the use of the water from the condemned well was discontinued.

5. In the first series of cases, out of about 80 members of this school 20 had the fever, and all of these are believed to have used water from the infected well.

6. In this series, fourteen other persons, not members of the school, had the fever. All but two

of these used the water of this well, occasionally or habitually; one of the two was a brother of one of the sick pupils.

7. The first series of 34 cases, with possibly one exception, *was confined to persons using the water from this infected well.*

8. The second series of 19 cases, beginning Nov. 5 and ending April 1, could not have been derived directly from the school well (a) because but two of these persons used its water, and (b) because the first case of this second series occurred Nov. 5, 32 days after the use of the well water was discontinued.

9. Most of these 19 persons *might have contracted the fever from the infection of their own wells or drinking water* (a) because this second series of cases all occurred in families whose children or near neighbors had contracted the fever at the school and had been nursed at home, and (b) because nearly all this second series of cases occurred in from 3 to 6 weeks after the first case in the family, and sufficient time after the first case in the family to allow for the infection of the home privy-vaults and the subsequent infiltration of this infection through the porous soil into the wells, which infection of the water-supply may have been continued by subsequent cases in the same family.

An outbreak at Caterham, England, and a few other outbreaks are mentioned on page 108.

TABLE 4.—*Inches of Earth above Ground water, from Observations of Wells in Michigan, by Months for the Five Years, and for each of the Five Years 1878–82, also for 1883.*

YEARS. NUMBER OF WELLS.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Av. 5 years, 1878-82...	159	139	137	131	132	139	162	171	173	176	164	157
1878, at Elsie.....	96	96	84	90	90	96	102	120	132	138	120	108
1879, at Otisville.....	.....	60	55	42	57	68	87	91	76	71	71	52
1880, Av. at 4 stations*	231	231	230	222	226	234	244	261	263	260	253	244
1881, Av. at 3 stations†	200	201	212	194	170	162	198	232	255	249	222	215
1882, Av. at 3 stations‡	108	106	104	108	116	136	180	152	140	160	156	168
1883, Av. at 2 stations‖	132	132	84	48	45	45	96	108	129	120	108	111

NOTE.—As the stations are different for different years, this table is useful rather for comparing months in the same year with each other than for comparing one year with another. The average line in Table 4 is represented in Diagram A, page 94; the lines for 1878 and 1879, in Diagram B, page 96.

* In 1880, at Thornville, Hillsdale, Mendon, and Union City. (Diagram B, page 96.)
† In 1881, at Thornville, Linden, and Dearborn. (Diagram B, page 96.)
‡ In 1882, at Brockway Center, Otisville, and Woodland. (Diagram C, page 97.)
‖ In 1883, at Brockway Center and Saginaw City. (Diagram C, page 97.)

IS THE CONSTITUENT OF THE DRINKING WATER THAT CAUSES TYPHOID FEVER, SPECIFIC? MAY THE DISEASE BE CAUSED BY MORE THAN ONE SPECIES OF BACTERIA? BY THE ORDINARY BACTERIA OF DECOMPOSITION?

The statistics show that in Michigan, typhoid fever in every year increases in prevalence in the autumn months, following the season of the year when there is most sickness from diarrhea. With the unusual prevalence of typhoid fever in Michigan in 1881, beginning in July of that year, we must note the unusual prevalence of *diarrhea* in that year, especially in June, July, and October. (There was most sickness from diarrhea in August, but compared with other years, the sickness in June, July, and October was very unusual). Then again, in the year 1882, the greatest prevalence of typhoid fever occurred rather later in the season than usual, as did also the diarrhea, and as did also the highest monthly average temperature in that year. Whether the typhoid fever is very generally caused by diarrheal discharges getting into the drinking water, and whether the diarrhea is sometimes caused by bad water under conditions the same as, or similar to those which cause the typhoid fever, are among the many interesting questions in this connection upon which further evidence is desirable.

With reference to the causation of typhoid fever by air and water contaminated with diarrheal discharges, we are indebted to Dr. W. Stewart, Honorary Surgeon to Beckett Hospital, Barnsley, for facts and suggestions as to how the fever may thus arise.* Speaking of a series of cases of typhoid fever, Dr. Stewart says:—

"After careful inquiry, I arrived at the conclusion that the cause of this outbreak was to be attributed to the fact that the slaughter-house of a butcher was situated at the end of the row, into the common sewer of which the blood from his operations was allowed to flow, there to remain and putrefy. The waste pipes from the sinks were directly connected with this drain without the intervention of any kind of trap, and the smell therefrom was often horrible. Here the putrefaction of a highly albuminous liquid, blood, in the drain, and a direct communication between it and the interior of the cottages, seemed to give rise to the fever." Dr. Stewart gives other cases, and then says: "In the experiments instituted by M. V. Feltz, and communicated to the *Academie des Sciences*, upon the effect produced upon dogs by the injection of putrid blood, and alluded to in a contemporary (Lancet, Vol. II, 1875, p. 460), the symptoms produced were very analogous to those we see in typhoid fever.

"'Putrid blood which has stood for several months was dried and desiccated in the air-bath and mixed with a certain quantity of distilled water, and injected into the crural vein of three powerful dogs. The animals immediately exhibited marked depression. After a period of incubation of from four to five days, febrile symptoms set in, accompanied by vomiting, loss of appetite, elevation of temperature, bilious and bloody diarrhea, and biliary urine;' and these symptoms were produced even when all trace of bacterial life had disappeared from the blood injected." After referring to the typhoid condition in puerperal fever, attributed to decomposing blood, and referring to other considerations, he says:—"The question may now be asked in what way is the origin of these cases, apparently arising from some component of putrefying blood, connected with the vast number of typhoid fever cases which appear to arise from the pollution of drinking-water by the excrement of human beings? In this manner, by fixing upon the serum of the blood as the essential factor of the poison, we at once see how any severe case of diarrhea would be sufficient to produce the disease, because the liquid evacuation of severe diarrhea is principally composed of serum blood, and it is drawn from a source and placed in a condition highly favorable to the development of the putrefactive process. * * * This theory of typhoid fever, arising from the decomposition of the serous evacuations of severe diarrhea, accounts in a more satisfactory manner than any other for the extraordinary prevalence of the fever at a certain period of the year. It is a fact of universal observation that enteric-fever cases reach their maximum, in point of numbers, in the months of October, November, and December; and this 'periodical disposition' to the disease is accounted for by Liebermeister (who believes that 'the real cause of every epidemic and every isolated case of typhoid fever is only the specific poison of typhoid fever' (Ziemssen's *Cyclopædia*, Vol. I, p. 61), in the following manner. He says (*ibid*, Vol. I, p. 65): 'The curves representing the frequency of typhoid correspond to the curves of average temperature, only with this difference—the different points of the typhoid curve follow those of the temperature curve by an interval of some months; and in order to account for this discrepancy, he says it takes two or three months for the changes of temperature to penetrate to the breeding places of the typhoid germs.' But, if it can be shown that typhoid fever may arise from the putrefactive decomposition of blood-serum, then the abundant prevalence of summer cholera, from the end of July to the beginning of September, affords plenty of material for the elaboration of the poison, which afterwards percolates into the wells or is washed by the autumnal rains into the sources of our water-supply." Dr. Stewart says: "I do not propose to enter into the discussion as to whether the disease can have an abiogenetic origin, although the facts upon which my theory is founded appear to favor that doctrine. Whether the fever arises only from specific typhoid germs, which (according to the advocates of this theory) have a nearly omnipresent existence, and have the property of preserving their vitality in a dormant condition for many years, ready to spring into active and vigorous life when introduced into a proper nidus for their development; or whether the poison is manufactured from the ordinary germs existing in all the putrefactive processes which take place in certain animal fluids, or is elaborated by some subtle chemical change in the properties of the substance itself, does not signify so much to those who have to deal practically with the disease, so long as we can put our finger upon the factor, element, or pabulum without which these forces would be rendered permanently impotent. It is from the conviction that this pabulum will be found in albuminous liquids, such as blood, blood-serum, and the liquid discharges from the bowels in diarrhea, and that the poison of typhoid fever is elaborated from the putrefactive changes which occur in them after their expulsion from the body and subsequent exposure to the air, that I have ventured to draw the attention of the profession to what appears to me to be a probable explanation of the origin of this disease."

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*British Med. Jour., reprinted in "Public Health," March 16, 1877, pp. 192-193.

I agree with Dr. Stewart that a great practical point is gained when we know the materials and places in which the cause of typhoid fever is reproduced; but we also need to know in what way the cause of typhoid fever usually enters the body,—whether, as he seems to think it sometimes does, with the air which is breathed, or whether it is generally with the water which is drank; and I still think the question whether or not the disease is specific is an important one to which we should seek the true answer. From the evidences of statistics, from clinical evidence, and such evidence as to coincident conditions as those relative to well-water, etc., it may not be quite possible to decide whether the cause of typhoid fever is or is not specific; because, although we *can* say that the cause is associated with decomposing organic matter, of vegetable and animal origin, in drinking-water, and that it appears to be capable of reproduction, thereby making it extremely probable that the cause is organic, and probably one or more of the bacteria,—many of such organisms are known to be able to reproduce themselves in meat juice, and other fluids consisting of water and *animal* products, also in *vegetable* infusions, and even in *mineral* solutions, not directly derived either from animals or vegetables, as for instance in Pasteur's solution. Yet it is probable that by proper effort we may soon learn the truth,—whether typhoid fever is ever caused by more than one species of bacteria, whether the cause of every case is derived from a previous case.

Bearing upon the question of a specific cause for typhoid fever, are many well-known outbreaks, especially those at Caterham and Red Hill, England; at Lausanne, Switzerland*; and Dr. Austin Flint's cases at New Boston, N. Y. The history of the outbreaks at Caterham and Red Hill is substantially as follows†: In the towns of Caterham and Red Hill, England, 352 cases and 21 deaths from typhoid fever occurred in a period of six weeks in 1879. Dr. Thorne Thorne, of the Local Government Board, made a thorough investigation, and found that the cause of the outbreak could be very clearly traced to the defilement of the common water-supply of the two towns by the typhoid excreta of a workman employed at the water-works in the construction of an adit from an old well to a new bore which was being sunk. This man worked at the bottom of the adit, 455 feet below the surface, and was at the time suffering from a mild form of typhoid fever. The excreta of this man was hauled up to the surface in a bucket, and spattered over on the sides and the bottom of the adit, into which the water-supply was soon after admitted. The outbreaks occurred about two weeks after the infection of the water, and were confined entirely to those families using water from the pipe lines. The cases at Lausanne, stated on page 103, also strongly indicate that the cause of typhoid fever is specific; and the cases recorded by Dr. Austin Flint can hardly be explained on any other hypothesis; nor can the cases reported by Dr. Gaffky. See, in this article, "German Troops at Wittenberg," page 103. The Adrian, (Mich.) outbreak, a synopsis of which appears on page 104, in this article, also supplies strong evidence that the disease was spread by the discharges from a first case infecting the drinking water.

Klein,(‡) Klebs,(‖) and many other eminent histologists have thought that typhoid fever is caused by a specific bacterium, although they have not agreed as to which of several described forms should be considered the *true typhoid bacterium*. A recent view is that the forms seen by Klein and Klebs in the

* Detailed on page 103.
† Ninth Annual Report of the Local Government Board, 1879-80, pages 78-92.
‡ Intimate Anatomical Change in Typhoid Fever: *Reports of the Medical Officer of the Privy Council and Local Gov't. Board*. London. 1875. Also, *Public Health*, June 16, 1876, page 463.
‖ Archiv fur exper. Pathologie, 1881.

diseased Peyer's glands are secondary invasions, and that the real cause of the disease is a peculiar short, thick bacillus with rounded ends, found during the fever not only in the diseased Peyer's patches but also in various other organs of the body, as the liver, spleen, and kidneys. This bacillus has been described by Eberth, Meyer, and Friedländer, and is believed by them to be specific. Koch has confirmed the statements made by these observers, and Ziegler says this bacillus is "probably the exciting cause of the disease."* The statements of Eberth, Meyer, and Friedländer have been again confirmed quite recently† by a series of very exhaustive and carefully conducted microscopic examinations by Dr. Gaffky, of the Imperial German Board of Health. These bacilli have been found by him in 27 out of 28 cadavers examined, and have never been found, either by himself or by the other investigators named, except in typhoid cases. It is believed that the failure to find this bacillus in the twenty-eighth cadaver was because death had occurred at a late stage or the disease, when the characteristic symptoms of the disease had mostly disappeared, and at which stage of the fever this bacillus is much less frequent than at an earlier stage. Dr. Gaffky cultivated this typhoid bacillus outside of the body on various nutritive substances, as nutrient gelatin, meat-broth, fluid blood-serum, boiled potatoes, and also in *vegetable solutions*, although in the latter they grew less vigorously. All Dr. Gaffky's attempts to reproduce the disease in the lower animals proved futile, but inoculations of animals with cultures of typhoid bacteria are recently reported‡ to have been successfully made by two French scientists, MM. Tayon and Mozioconacci. The description of their experiments, however, leaves much to be desired by way of explanation and confirmation.

HOW IS TYPHOID FEVER INDUCED BY LOW WATER IN WELLS?

The evidence of the causation of typhoid fever by low water in wells will not be accepted by some persons, because they do not understand, at first sight, how the disease can be thus caused. Several persons to whom I have presented some of this evidence have replied that they could understand how dilution of a *poison* would lessen its effects; but that if typhoid fever is caused by a specific organism, they failed to see how the low water in wells could cause the disease. A study of the relations of privies to wells, and the statement of certain facts may aid such persons to an understanding of how it is possible to explain such mode of causation.

Herewith I submit a diagram, page 110, showing a privy and a well under two circumstances; in one case the water in the well is low, and in the other case it is high. It would seem that when the level of the water is the same in the well as in the privy, there would not be likely to be a mingling of the water from the privy with that in the well, unless the distance between them was small. But whenever and wherever the water in the well is below the bottom of the privy not far distant, there will be a strong tendency of the fluids cast in the privy to pass downward toward the water in the well; or, if not directly to the well, to the ground-water not far distant, which will pass into the well to replace that which is drawn. The quantities of solid and liquid filth deposited in privies probably do not vary much from month to month, except that because of diarrhea in the hot months of July and August, more

* Pathological Anatomy. London, 1883, Part I, page 300.
† Zur Ætiology des Abdominal typhus; *Mittheilungen aus dem Kaiserlichen Gesundheitsamte.* Band II., 1884, pages 372-403.
‡ *Comptes Rendus*, Aug. 18, 1884, vol. xcix., pages 331-334.

fluid fecal matter probably enters them. The supposed causation of the regularly recurring increase of typhoid fever in the autumn, by discharges from persons suffering from diarrhea gaining access to the drinking water, is referred to in another part of this paper. That is only one way of rendering the water foul, or, as we might say, nutritive to bacteria; and it is quite in keeping with the other evidence referred to in this paper, as to outbreaks of typhoid fever after the use of water contaminated by decomposing animal and vege-

DIAGRAM D.—*Illustrating the Proposition that the Fluids Cast into a Privy bear a Relation to the Water in a Well Not Far Distant, which Relation is Different When the Water in the Well is High from What it is When the Water is Low.*

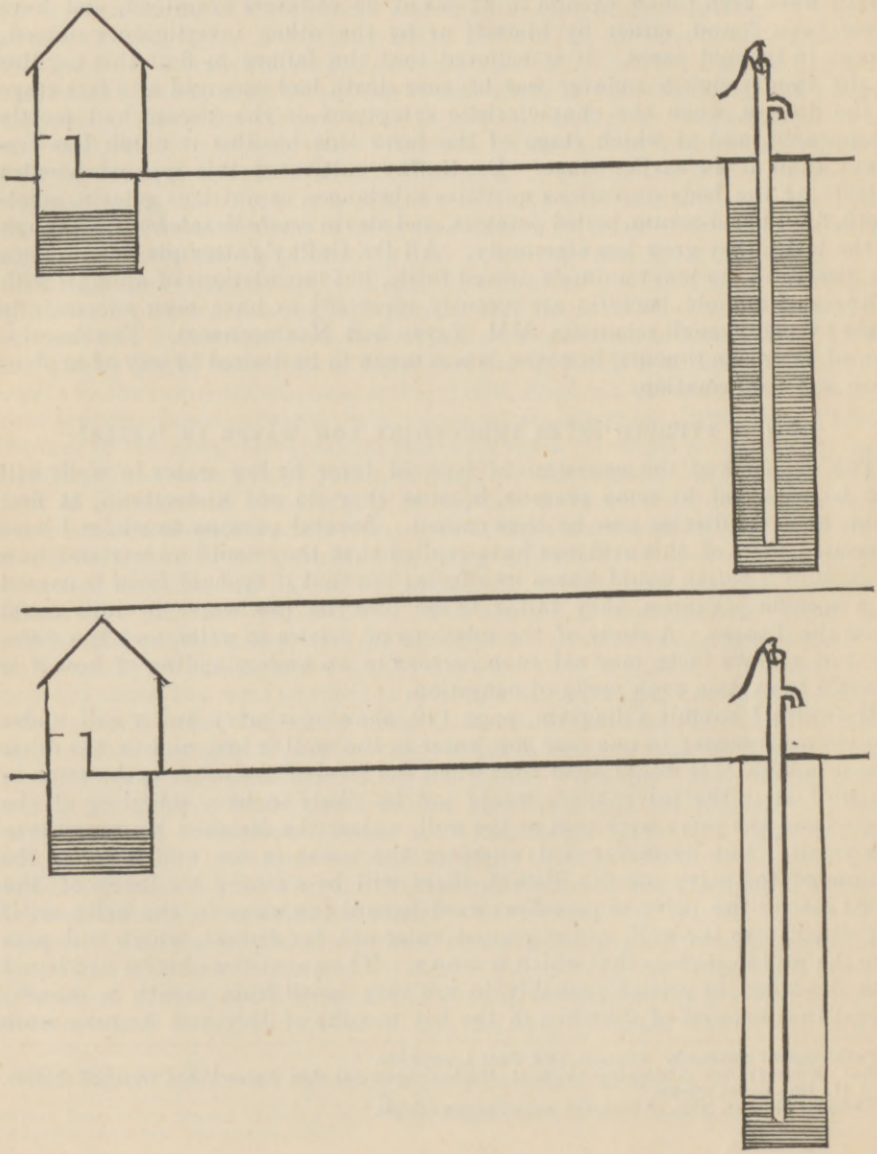

table matter. The explanation of all these lines of evidence would seem to be that either the ordinary bacteria of decomposition cause typhoid fever, or that the specific cause of the disease is quite generally distributed, *and is capable of self-multiplication outside of the body*, whenever it falls into fluids sufficiently nutritive. But even if the cause of the autumnal increase of typhoid fever is the diarrhea which precedes it, and which is itself caused directly or indirectly by the high temperature,—even then, it would seem that under present circumstances the quantities of water in wells controls the rise and fall of typhoid fever; because the relation which the curve representing diarrhea bears to the curve representing the fever is not closer than is that borne by the curve representing water in wells; and it is probable that it is only by passing into the drinking water that the diarrheal discharges help to cause typhoid fever.

In the early autumn, also, there is more than the usual likelihood of a *specific cause* being introduced into certain wells, because then surface supplies of drinking-water, wash-water, etc., are diminished to such an extent that unusually large drafts are made on the wells. This increased use of well-water would lead to the drainage of an unusually large territory around the wells, with a consequently increased danger of contamination from privies infected by typhoid excreta.

I think we may now safely assume that there is a greater dilution of the dejections from typhoid-fever patients, and of human excreta generally, when the water in wells is high than when it is low, except when the low water is caused by a frozen ground which locks up the excreta on the surface of the earth. It cannot yet be positively asserted that the specific cause of typhoid fever is reproduced outside of the body in nutritive solutions at the temperature of water in wells; yet this may be found to be possible, or, if not in wells, in the higher temperature of privy-pits, from which they may pass into the well, either at once in the form of mature bacilli, or after a time in the less perishable form of spores; and if typhoid fever is caused by the ordinary bacteria of decomposition, as many seem to believe, then we must consider that lessening the quantity of water in wells would probably (except as just mentioned) lessen the dilution of the fluid derived from privies, and consequently increase the proportion of bacteria thus introduced into a given quantity of well water; and not only this, but the proportion of albuminoid matter suitable for the rapid reproduction of bacteria would then be increased; and, bearing in mind how rapidly the reproduction of bacteria occurs under such circumstances, we can well understand how in such a "culture fluid" there would soon be something of very much greater import than simply what would result from a lack of dilution of a fluid containing some organism or poison not capable of self-multiplication. Then, again, the ordinary bacteria are known to be frequently in much greater abundance on the surface than elsewhere in a liquid, because of their requirement of air; therefore a much greater proportion of bacteria would be likely to be drawn up by a pump reaching to the bottom of a well, when the top of the water falls to near the opening into the pump.

Many years since Chauveau* performed a series of careful experiments with vaccine virus diluted with constantly increasing quantities of water, when he found that the proportion of successful vaccinations was correspondingly decreased. Under these circumstances it appeared that whenever there was a lodgement of the virus the development of the case proceeded regularly to the

* Comptes Rendus, lxviii, 1868, and lxxii, 1871.

close; but with large quantities of water the proportion of such cases of successful vaccination was very small. I suppose that no one now doubts that vaccinia is caused by specific particles which are reproduced within the body (it is now many years since vaccinia was shown to be due to a "particulate" cause, and those same experiments by Chauveau had much to do with establishing that fact; however, Dr. Burdon-Sanderson's experiments verified those made by Chauveau, and have been considered sufficient to establish this point). The two points just alluded to (the lessened chance of vaccination with diluted virus, and the fact that vaccinia is a specific disease) may serve to remind those who have not held these facts in mind, that *dilution of a fluid containing the specific cause of a disease lessens the chances of communicating that disease* when the fluid is brought in contact with the body.

An objection has been offered, that the variations in the amounts of water in wells, as shown by the diagrams, were too slight to account for so great differences in the prevalence of typhoid fever as are shown to occur in Michigan in the months of June and October. The reply is that the variations shown in the diagrams are mostly averages of several wells, and that in one of the wells included in the average for the year 1881, the amount of the variation was from twenty feet of water in the month of June, to no water whatever, in the month of September. Besides this, the wells measured are not the wells the water of which actually caused the typhoid fever in Michigan, but they are only examples of how the water rose and fell, on the average; it is probable that many wells (besides one of those observed) were nearly dry at some period during or following the extreme drouth of 1881.

An instructive inference from the evidence which I present is either that the cause of typhoid fever does not long remain in the well-water in an active form, or that the dilution is so great as to reduce very greatly the chances of its producing the disease. As the water lowers in summer, the typhoid fever cause is apparently quick to act; and as soon as the autumnal rains filter into the wells, its action quickly disappears, although it must be admitted that at no time of the year is the State entirely free from typhoid fever; and it is quite possible that the rapid subsidence of typhoid fever after the autumn rains is simply because of the extreme dilution of its cause in the wells.

THE CAUSE OF THE GENERAL ANTAGONISM BETWEEN INTERMITTENT FEVER AND TYPHOID FEVER.

It would lead us too far aside to treat fully here of the controlling cause of intermittent fever; but it may be allowable for me to say here that we now have possession of facts which in my opinion enable us to explain the general antagonism between intermittent fever and typhoid fever; and that the nature of some of these facts may easily be inferred; because *high* ground-water, with coincident high temperature of the air, is generally conducive to intermittent fever; and *low* ground-water is conducive to typhoid fever, whenever the drinking-water is liable to be contaminated by typhoid excreta. The first-named condition is most frequently found in new countries, as yet undrained; the last named in localities which have long been settled,—especially in large villages which depend upon wells for their water-supply.

WHAT NEED IS THERE FOR THE PREVENTION OF TYPHOID FEVER IN MICHIGAN?

For the five years, 1878 to 1882 inclusive, there were returned as having occurred in Michigan, 2,586 deaths from typhoid fever (Page 92.) This is

an average of 517 each year; but we have reason to believe that the deaths returned are about one-half of the number that occur; therefore we conclude that, on the average, over one thousand persons die in Michigan in each year from typhoid fever. The proportion is not greater in Michigan than in other States.*

HOW CAN TYPHOID FEVER BE PREVENTED?

If the evidence which I have presented is conclusive, the reply to the above question may be stated in four words, namely: *Stop drinking contaminated water.* This might not prevent *all* the typhoid fever; but it would appear that by far the greater proportion of it in Michigan may reasonably be expected to be thus preventable. How to prevent the contamination of the various water-supplies, cannot be so briefly stated; but if people care enough about it to take the necessary trouble to do this, sanitarians can tell them how. So far as it relates to typhoid fever, it *may* be that all that is necessary is to destroy and keep out of the water all discharges from persons suffering from typhoid fever; but the difficulty of recognizing the disease early enough in its course is so great, that in order to do this it will be necessary to keep all human excreta, and perhaps the excreta of some animals, out of the water-supply. Most people think they do this now, or probably we would not have a thousand deaths a year in one State from this cause; but I think we have reason to believe that their confidence in the purity of the water they drink is misplaced, and that consequently many of them sicken and die. The numerous instances where typhoid fever has apparently been caused by drinking-water contaminated by decomposing *vegetable* matter, indicate that, even if the cause of the disease is specific, until such time as that the specific cause shall be so restricted as not to find access to water-supplies, it is important to preserve the water from contamination by vegetable as well as by animal matter.

HENRY B. BAKER.

NOTE.—In this paper the design has been to present one line of the evidence on this subject which, during the past ten years, has been collecting in the Annual Reports of the Michigan State Board of Health, in the office and library of the Board, and in the mind and manuscript of the writer; and in doing so, much of the interesting evidence which has been contributed by prominent physicians and others in Michigan, on the general subject of the causation of typhoid fever by contaminated water, has been omitted, in order to confine the paper mainly to the subject of the relation of low water in wells from which water is drank to the causation of typhoid fever. But, although in this paper no attempt is made to give the literature of the general subject of the relation of ground water to typhoid fever, the author cannot let the paper go without a reference to the work of one whose name is foremost throughout the world in connection with this general subject. I refer to Max von Pettenkofer, of Munich. If I understand Pettenkofer's view, it was in 1869, that with the recession of the ground water the air enters deeper into the soil, and stimulates into activity and multiplication disease germs which lay dormant when under water. These germs permeate this *ground air*, and whenever the barometric pressure is low, or other conditions favor its

*There is reason to suppose that a large number of deaths attributed to other diseases than typhoid fever are caused by impure drinking-water. In a paper entitled: "Chronic Zymotic Disease Simulating Consumption," in the Annual Report of the New Hampshire State Board of Health for 1884, page 240, D. M. Currier, M. D., says: "Another instance in point where the effect lay between typhoid fever and consumption, with a decided preponderence in favor of the latter, and caused by drinking impure well-water, was reported and published in the report of the State Board of Health [N. H.] for 1883, in which the analysis of the water is given (pp. 263-269) [The water was very foul, and was declared 'neither fit for man nor beast.'] On this farm nine persons died, — two of typhoid fever, one of gall stones, and six of consumption, the last of which was the only one that I had under personal observation. A general survey of the case would give one the impression that he was suffering from tubercular deposit in the lungs, but upon thorough examination of the chest no evidence of tubercles could be found. There was equal resonance over both lungs, which were equally and fully distended by a forced inspiration. He had chronic laryngo-pharyngitis, with loss of voice. There was great and constant irritation of the stomach, as manifested by frequent nausea and vomiting of food, with progressive weakness and low vitality. This went on, and the man died, not, in my opinion, from tubercular consumption, but from what I believe to be chronic poisoning by the filthy water he drank."

upward movement, the germ-laden air rises from the soil, and enters houses, and causes typhoid fever. That there is a causal relation of low ground-water (not necessarily in wells, but underlying residences) Pettenkofer, from the great masses of statistics with which he dealt, long ago considered established, the chances being as 36,000 to 1. (Boden und Grundwasser, etc., Pettenkofer, Munich, 1869, pages 16 and 137.)

The interpretation of the most usual mode of entrance of the cause of typhoid fever into the human body, which pervades this paper, is very different from the interpretation which Prof. Pettenkofer seems to have adopted; yet, so far as relates to the fact of there being a relation of water in wells (ground-water) to typhoid fever, the evidence relative to Michigan is not materially different from the evidence relative to Munich, with which Prof. Pettenkofer dealt; except that it has been found that in Michigan a frozen surface of the ground prevents the low water from causing typhoid fever. Whether or not the interpretation which the author of this paper adopts—that the cause of the fever enters the body most frequently with the drinking water— will apply to the causation of typhoid fever in Munich at the time the subject was studied by Prof. Pettenkofer, the writer has no ready means of determining, not having at hand a reliable account of the water-supply of Munich during that period of time—1856 to 1869. But in this connection an account of the enormous reduction of typhoid fever in Munich coincidently with the construction of sewers, is interesting and suggestive. In an extract from an address by Capt. Douglas Galton, quoted from "Proposed Plan for a Sewerage System, etc.," by Samuel M. Gray, C. E., Providence, R. I., 1884, pages 7-8, it is stated that "at Munich the enteric [typhoid] fever mortality *per* 1,000,000 *of inhabitants* for quinquennial periods, was as under:—

"1854 to 1859, when there were absolutely no regulations for keeping the soil clean..... 24.2
"1860 to 1865, when reforms were begun by cementing the sides and bottoms of porous cess-pits 16.8
"1866 to 1873, when there was partial sewerage..... 13.3
"1876 to 1880, when the sewerage was complete..... 8.7"

There was thus, in Munich, coincident with sanitary work, a reduction of two-thirds of the mortality from one of the most deadly diseases. Whether this great reduction was due entirely to the work for complete sewerage, or whether that work was wholly or in part incidental, I am not now able to say; but it is reasonable to infer that during the years 1856 to 1869 when Buhl, Seidel, Pettenkofer, and others were collecting their evidence relative to ground water and typhoid fever, and when, as appears from what I have just quoted, there was little or no sewerage in Munich, there may not have been as good water supply as there was after the sewers were complete. If the water supply was in great part from wells, the evidence which Pettenkofer compiled, together with his statement of probabilities of 36,000 to 1, of the relation of low ground water to typhoid fever being a causal relation, holds as well in favor of the view that the mode of introduction into the body was with the drinking water as in favor of the view that its introduction was with the air inhaled.

At the meeting of the American Medical Association in Detroit in June, 1874, during a discussion in the Public Health section, Dr. Foster Pratt of Kalamazoo, Michigan, remarked that typhoid fever became unusually prevalent in Kalamazoo in a certain year, in the autumn about the time the water in the wells became very low, some wells being dry. Dr. Pratt's remarks at that time have had much influence toward the collection, during the past ten years, of facts bearing upon this subject, and toward the preparation of this paper.

H. B. B.