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TYPHOID FEVER AND MUSSEL POLLUTION.

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1 Chart.

CONTENTS.

THIS paper deals with the evidence which has accumulated in Birmingham between June 1st, 1904 and June 1st, 1909, both dates inclusive, as to the relationship between the consumption of mussels and the occurrence of typhoid fever. In Birmingham when a case of typhoid fever is notified careful enquiries are made by trained inspectors as regards, among other matters, the date of onset and the origin of the disease, and the results obtained are verified by the Assistant Medical Officer of Health who visits the house subsequently. These later visits

are of importance as they enable householders to give information which either they had forgotten or were not in possession of at the time of the first visit. By this method of enquiry, which has been instituted by Dr John Robertson, the Medical Officer of Health, it may fairly be claimed that little of etiological importance in connection with the cases of Typhoid Fever which occur in the City escapes attention. During the five years under review 946 cases of typhoid fever, exclusive of cases occurring in public institutions, commenced. Of this number 855 were primary and 91 secondary cases in households.

The etiology of the 855 primary cases in households may be summarised thus:

Cases probably due to personal contact ...	33
Cases probably due to mussels	124
Cases probably due to other shell-fish ...	32
Cases probably due to watercress	5
Cases of unknown origin	661
Total	855

Histories of mussel infection.

In all cases investigated the question of personal contact was first considered. Enquiries were then made as to whether or not mussels or other shell-fish or watercress had been consumed within four weeks of the onset of the illness. In this way a history of mussel eating as the probable source of infection was obtained in 124 out of 855 or 14·5 % of primary cases in households investigated.

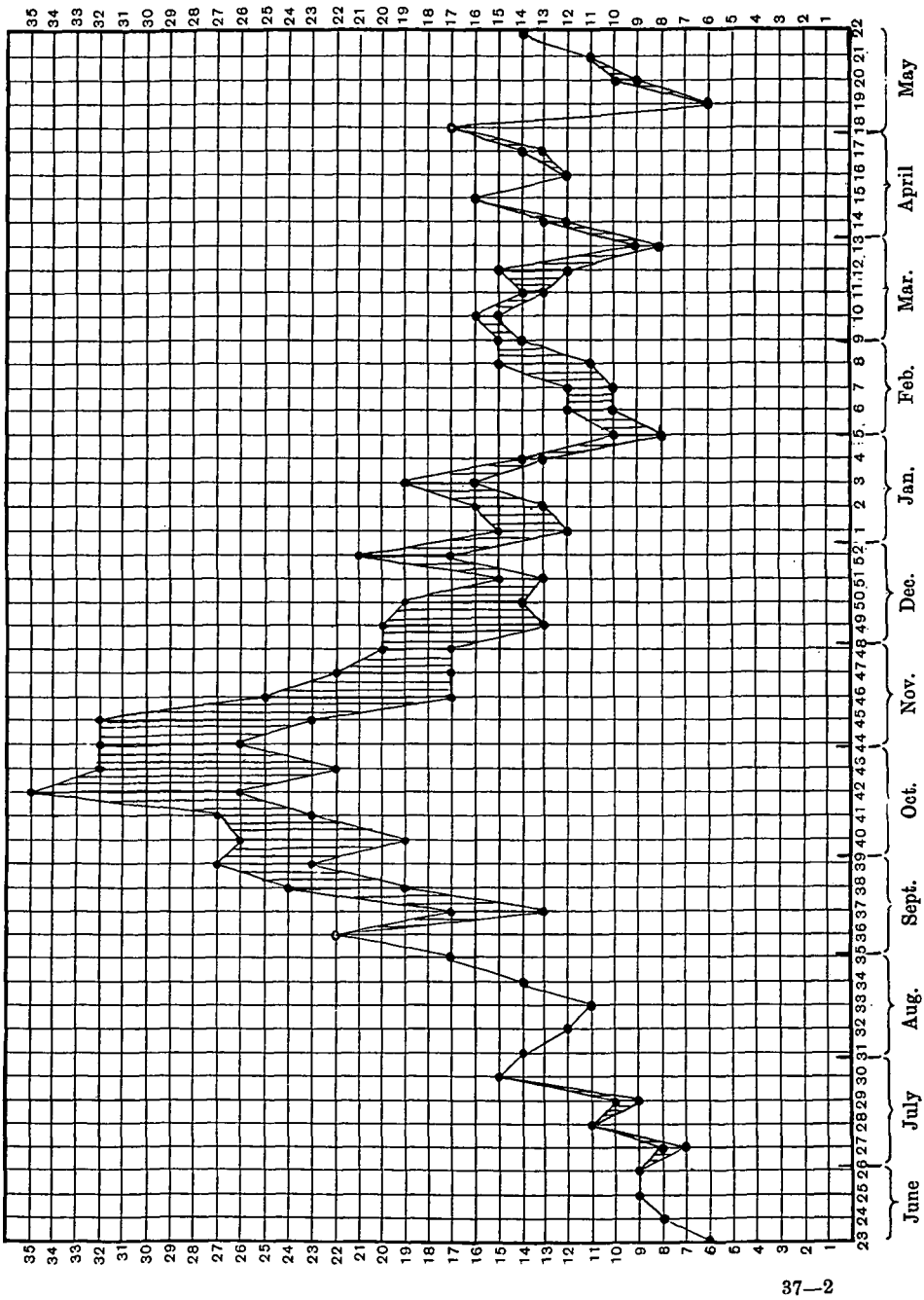
In several cases the histories of the attacks were particularly striking and practically conclusive of mussel infection:

1. It was thrice found that two persons eating mussels from the same batch at the same time fell sick of typhoid fever subsequently within a few days of each other.

2. In six instances persons eating mussels became ill suddenly with vomiting and diarrhœa shortly thereafter, remained unwell, and shewed the signs of typhoid fever a few days later.

3. A boy ate mussels at a watering place. He brought some home to his mother who immediately after eating them was seized with colic and diarrhœa which lasted three days and left her very weak for some time. The boy developed enteric fever.

Chart shewing the 855 *primary cases of enteric fever in households in Birmingham commencing between June* 1, 1904 *and June* 1, 1909, *both dates inclusive, arranged according to their weeks of onset. The cases of mussel infection are shaded.*



4. Upon two occasions it was found that only one person in a family ate mussels and only that person took typhoid fever.

5. In two instances during the close season mussels were gathered from a foreshore known to be polluted and partaken of by holiday makers who fell ill of typhoid fever a few days afterwards.

Curve of mussel-typhoid cases.

Further evidence is adduced in favour of the consumption of polluted mussels as a cause of typhoid fever by considering the curve of enteric fever in Birmingham during the five year period now under consideration. For this purpose the 855 primary cases of typhoid fever in households, whose onsets occurred between June 1st, 1904 and June 1st, 1909, have been plotted out according to their weeks of commencement, the 53rd week in the year 1907 being omitted. By summation of the cases commencing in corresponding weeks the enteric curve of the primary cases in households for the five year period 1904—1909 is obtained as shewn in the accompanying chart. The cases due to mussels have been shaded in and it will be noted that two cases occurred in the 27th and 29th weeks during the close season for mussels. These are the cases above referred to. They may be reckoned as accidental and without bearing on the general features of the chart. The first cases due to mussels have their onset in the 37th week about a fortnight after the beginning of the mussel season on September 1st. Thereafter the number of mussel cases commencing in any one week rises rapidly to a maximum about the 43rd week, remains fairly constant to about the 50th week and thereafter slowly declines. The last case occurs in the 20th week about a fortnight after the mussel season closes. This curve tallies closely with the number of mussels imported into Birmingham. After rapidly rising to a maximum at the commencement of the season the importation of mussels is fairly constant till before Christmas and thereafter gradually falls till the close of the mussel season on April 30th. A glance at the chart will shew that mussel infection certainly accounts for a not inconsiderable portion of the autumnal rise of enteric fever.

Sources of the Birmingham mussel supply.

The value of the statistical evidence which has been detailed associating a certain proportion of cases of typhoid fever occurring in Birmingham with the eating of mussels is enhanced by enquiries which

were made into the sources of the Birmingham mussel supply. Several of them are known to be polluted and in point of fact the sale of mussels gathered from certain layings from which these shell-fish are sent to Birmingham has been prohibited in the London market by the action of the Fishmongers Company.

The contamination of shell-fish layings around our coast has been investigated by Bulstrode (1894—95, pp. 1—108) and Browne (1904, pp. 1—82), and the conclusion that these workers have arrived at on topographical grounds is that there is a number of shell-fish layings which are exposed to pollution gross in amount and also a further considerable number the purity of which is open to doubt.

The probability of sewage becoming at times charged with infective bacilli has been recognised for some time. Recently acquired knowledge as to "bacillus carriers" forces us to conclude that this probability is greater than was originally supposed. About 2—5 per cent. of typhoid convalescents become "chronic carriers" of the infection, discharging the specific organism of the disease in the urine or faeces or both. It would therefore appear that sewage must contain more or less constantly in greater or lesser numbers living typhoid bacilli which may be taken up by mussels placed in proximity to sewer outfalls, and such mussels may obviously produce typhoid fever under favourable conditions in the consumer.

The bacteriological investigation.

In Birmingham it was impossible for various reasons to trace the sources and to obtain for examination samples of the mussels which were held to be responsible for the 124 mussel cases of typhoid fever recorded. It was therefore decided to obtain samples of mussels as they arrived in the Birmingham market and ascertain by bacteriological analyses the amount of pollution, if any, which they contained. This was done from time to time between February 14th, 1908 and March 17th, 1909 and in this way 65 samples of mussels from 22 different known sources were examined by me.

Method of examination of mussels.

Ten fresh living mussels were selected from each sample and opened with a sterile knife after thorough cleansing of the mussel shells in running Birmingham tap water. Care was taken not to lose any of the liquor which was poured into a sterile cylinder of 1000 cubic centimetres

capacity. The bodies were cut into very small pieces over the mouth of the cylinder and allowed to drop in. Note was made of the volume of the shell contents in every case. Sterile water was then added in small quantities at a time with stirring and emulsification and the volume made up to 1000 cubic centimetres. Varying quantities and dilutions of this emulsion were used for the tests employed.

The bacteriological tests employed.

These included the following:

1. An enumeration of the organisms capable of growing on nutrient gelatine (reaction + 1 %) at 20°—22° C. in 3 days.
2. An enumeration of the organisms capable of growing on nutrient agar (reaction + 1 %) at 35°—37° C. in 2 days.
3. An estimation by decimal methods of the number of *glucose-fermenters* present, and an investigation of the nature of these organisms by the use of Bile-Salt Lactose Agar medium and Houston's (1907, pp. 48—52) Quintuple Preferential Method.
4. An estimation by decimal methods of the number of spores of *Bacillus enteritidis sporogenes* present.
5. An estimation by decimal methods of the number of *Streptococci* present and a microscopical examination of these organisms.

The advantage of the method of examination and the bacteriological tests employed in this enquiry may be stated as follows:

1. The volume of the shell contents is recorded for each sample of ten mussels.
2. The entire contents of the shell are submitted to analysis: this is important from the etiological point of view, as a consumer, especially of raw mussels, makes no selection of liquor, body or internal juices.
3. The analysis is quantitative and the results may be expressed per mussel or per cubic centimetre of a mussel.
4. The analysis is also qualitative as regards certain organisms known to be indicative of sewage pollution.

Mussel bulk.

The total volume of the 650 mussels examined was 8750 cubic centimetres equal to 13·46 cubic centimetres per mussel. The smallest volume of a sample of 10 mussels noted was 53 c.c. and the largest

250 c.c., and it may be said at once that no relationship could be traced between the size of the mussels, their bacteriological content and the period of the season at which they were gathered.

The number of organisms in the samples examined.

For these counts it was necessary to dilute the emulsion of mussels and sterile water prepared as stated. One c.c. of the emulsion was put into 9 c.c. of distilled water and thoroughly shaken and 1 c.c. of this mixture was diluted and re-diluted in a similar manner six times. The 4th and 6th dilutions, in which 1 c.c. equalled respectively ·000001 and ·00000001 of a mussel, were examined in every case for these enumerations.

Gelatine count. This count varied greatly for the different samples examined. The smallest count obtained was 2,000,000—upon two occasions—and the highest more than 13,700,000,000 bacteria per mussel and recorded as "innumerable"—also upon two occasions. Excluding these unnumbered counts the average number of bacteria per mussel for the remaining 63 samples was found to be 1,172,000,000. This average is accounted for mainly by the samples yielding more than 1,000,000,000 colonies per mussel, viz. 14, excluding which gives an average count for the remaining 51 samples of 139,000,000 bacteria per mussel.

Agar count. This was nearly always less than the corresponding gelatine count. The smallest count with this test was 2,000,000 obtained upon four occasions and the highest more than 5,000,000,000 and called "innumerable." Excluding this count we find that the average agar count for the remaining 64 samples is 411,000,000 bacteria per mussel. In eight instances a count of 1,000,000,000 or more was recorded. If these eight samples are excluded the average count for the 57 remaining samples is 86,000,000. The following table classifies the results of the counts.

	Gelatine count	Agar count
No. of samples yielding between 1 million and 10 million organisms per mussel	12	14
No. of samples yielding between 10 million and 100 million organisms per mussel	20	30
No. of samples yielding between 100 million and 1000 million organisms per mussel	19	13
No. of samples yielding over 1000 million organisms per mussel	14	8
Total	65	65

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The above classification shews that all the samples of mussels examined as they arrived in the Birmingham market contained a large number of micro-organisms. The most likely number for any sample of mussels to contain was between 10 million and 100 million per mussel and this must be considered high. It is certain that samples shewing a larger number than this are polluted and in those cases where the number is over a total of 1000 million per mussel gross pollution undoubtedly exists. It is indeed a question if all the samples examined were not dangerous from the point of view of the public health, but this is a matter which cannot be definitely settled until we possess full information as to the bacterial content of mussels cultivated in regions remote from all possibility of contamination.

The nature of the organisms in the samples examined.

The next part of the investigation was concerned with the estimation of the numbers of certain organisms known to be indicative of sewage pollution.

Glucose-fermenters. After definite quantities of the mussel emulsion had incubated in Glucose Bile-Salt Broth at 35°—37° C. for 48 hours plates were made on Bile-Salt Lactose Agar from those tubes shewing the formation of acid and gas with the smallest quantity of mussel emulsion. The characters of the colonies growing on Bile-Salt Lactose Agar medium were noted and five colonies, red in colour if possible, were selected from each plate and their reactions tested by Houston's Quintuple Preferential Method for fermentation of glucose, lactose and saccharose and production of indol and fluorescence. For the simpler classification of these results a numerical value was assigned to each test in accordance with the following scheme:

Fermentation of glucose = 2
Fermentation of lactose = 1
Production of indol = $\frac{1}{2}$
Production of fluorescence = $\frac{1}{4}$
No change in saccharose = $\frac{1}{8}$

This method has the advantage that by its means the results are easy to classify and at the same time the value assigned indicates clearly the reactions of the organisms, as well as the importance of the organism as regards pollution. Thus *Bacillus coli communis* would have the highest possible value $3\frac{7}{8}$ and the more nearly an organism resembled

this bacillus the more nearly would its value approximate $3\frac{7}{8}$ and the stronger would be the evidence derived from its presence in favour of recent pollution by matter of excremental origin.

The following is a classification of the results on this basis:

No. of samples	No. of glucose-fermenters per mussel	*Numerical value assigned to organism isolated
5	Between 10,000 and 100,000	$3\frac{7}{8}$
3	,, 1,000 ,, 10,000	$3\frac{7}{8}$
5	,, 100 ,, 1,000	$3\frac{7}{8}$
1	,, 1 ,, 10	$3\frac{7}{8}$
1	,, 10,000 ,, 100,000	$3\frac{3}{4}$
4	,, 1,000 ,, 10,000	$3\frac{3}{4}$
4	,, 100 ,, 1,000	$3\frac{3}{4}$
3	,, 10 ,, 100	$3\frac{3}{4}$
1	,, 1,000 ,, 10,000	$3\frac{1}{2}$
5	,, 100 ,, 1,000	$3\frac{1}{2}$
2	,, 10 ,, 100	$3\frac{1}{2}$
1	,, 1,000,000 ,, 10,000,000	$3\frac{3}{8}$
1	,, 100,000,000 ,, 1,000,000,000	$3\frac{1}{4}$
1	,, 1,000,000 ,, 10,000,000	$3\frac{1}{4}$
2	,, 100,000 ,, 1,000,000	$3\frac{1}{4}$
2	,, 10,000 ,, 100,000	$3\frac{1}{4}$
3	,, 1,000 ,, 10,000	$3\frac{1}{4}$
2	Between 100 and 1,000	$3\frac{1}{4}$
1	,, 10 ,, 100	$3\frac{1}{4}$
1	,, 1 ,, 10	$3\frac{1}{8}$
1	,, 1,000,000 ,, 10,000,000	3
1	,, 10,000 ,, 100,000	3
1	,, 1,000 ,, 10,000	3
1	,, 100 ,, 1,000	3
3	,, 10 ,, 100	3
1	,, 10 ,, 100	$2\frac{7}{8}$
1	,, 100,000 ,, 1,000,000	$2\frac{1}{2}$
1	,, 100 ,, 1,000	$2\frac{3}{8}$
1	,, 1,000,000 ,, 10,000,000	$2\frac{1}{4}$
1	,, 10,000 ,, 100,000	$2\frac{1}{4}$
2	,, 1,000 ,, 10,000	$2\frac{1}{4}$
2	,, 10 ,, 100	$2\frac{1}{4}$
1	,, 1,000 ,, 10,000	2

* In some cases more than one dilution was examined, but for the purposes of this classification only that giving the organism of highest value is taken into account.

From the foregoing classification it is seen that 26 out of 65 samples examined contained *glucose-fermenters* of higher value than $3\frac{1}{2}$. As these organisms indicate recent sewage pollution it is clear that their presence in a sample of mussels must be regarded with grave suspicion from the public health standpoint. In 22 of these 26 samples there were more than 100 of these organisms per mussel, in 13 the number exceeded 1000 per mussel, and in six the number per mussel was over 10,000. In five of the six samples with more than 10,000 *glucose-fermenters* of higher value than $3\frac{1}{2}$ per mussel the organism isolated was actually *B. coli communis*, and bearing in mind the close relationship between this organism and *B. typhosus* as regards habitat it would seem a fair conclusion that specific pollution of mussels with the latter microbe must occasionally occur.

In considering the degree of pollution of the remaining samples it is important to note that not only the value of the organism isolated but

also the number present must be taken into account. It is impossible to say what increase in number makes up for a diminished value in the isolated organism according to the present classification. For the matter of the finer issues it is necessary that this should be defined and as a sequel the "permissible degree of biological impurity" referred to by Houston (1904, p. 170). But even without this knowledge a scrutiny of the classification submitted leaves no room for doubt as to the objectionable nature of the larger number of the samples examined.

It has been urged by Houston (1904, p. 307) that shell-fish (oysters) placed on the market for sale should not be hastily condemned for the following reasons:

(1) Coli-like microbes may multiply in the oyster,

(2) Coli-like microbes may diminish in number in the oyster, and

(3) The oysters may have become contaminated after removal from the fishery.

Johnstone (1909, p. 438) expresses the same opinion for reasons (1) and (3) as above numbered. It would of course be unwise and indeed impossible to condemn a mussel laying on the results of the bacteriological examination of shop samples but such an examination clearly reveals the danger to which the consumer is exposed. The sixty-five samples examined in the present enquiry were obtained upon their entry to the Birmingham market and the large proportion which the test under discussion proves to be grossly polluted indicates the need for restrictions as to layings and subsequent storage before transit.

Bacillus enteritidis sporogenes. The spores of this organism were sought for in every case with the following results:

		No. of spores of *B. enteritidis sporogenes* per mussel
5	samples shewed between	1,000 and 10,000
24	,, ,, ,,	100 ,, 1,000
31	,, ,, ,,	10 ,, 100
4	,, ,, ,,	1 ,, 10
1	sample ,,	none

In dealing with this organism it is to be remembered that it occurs in sewage along with *B. coli communis* usually in the proportion of 1 of the former to 100 to 1000 of the latter, and this proportion should always be borne in mind in estimating the nature of the pollution of any batch of mussels. As we have already indicated that mussels with 1000 *glucose-fermenters* of high value or organisms of the colon group

are dangerous it is clear that mussels with more than 10 spores of *B. enteritidis sporogenes* must be looked upon with grave suspicion. Only five out of the 65 samples contain less than this number of spores per mussel, and this fact is further evidence of the gross sewage contamination of the mussels examined.

Streptococci. The investigation as regards this class of organism has been already outlined. Frequent endeavours were made to isolate *Streptococci* seen microscopically but only on three occasions were the attempts successful. The results of the microscopic examination are as follows:

		No. of *Streptococci* per mussel		
2	samples shewed between	100,000,000	and	1,000,000,000
2	,, ,, ,,	10,000,000	,,	100,000,000
5	,, ,, ,,	1,000,000	,,	10,000,000
2	,, ,, ,,	100,000	,,	1,000,000
10	,, ,, ,,	10,000	,,	100,000
8	,, ,, ,,	1,000	,,	10,000
7	,, ,, ,,	100	,,	1,000
4	,, ,, ,,	10	,,	100
25	,, ,, less than 10			

The above table shews that *Streptococci* were not found in as much as 1 mussel in 25 instances although on other grounds 14 of these samples were bad. These facts combined with our scant knowledge of the nature and importance of *Streptococci* make it impossible to lay down any definite guide with regard to them. But it is clearly established that mussels may contain these organisms in large numbers and so far as they indicate contamination a large proportion of the 65 samples of mussels examined must be considered grossly polluted.

Conclusions based on the bacteriological results.

All the five tests which have been applied have been carried out so that the results could be expressed quantitatively. It is interesting to note that these tests corroborate each other and shew clearly that mussels as they arrive in the market are grossly polluted by sewage organisms. The risk to the consumer has been shewn and as it is impossible in the practical work of administration to use Sections 116—119 of the Public Health Act, 1875 to protect him, the need for further legislation to prevent mussels from polluted sources being sent into the market becomes apparent.

Cooking of mussels.

Various experiments have been carried out in connection with the cooking of shell-fish. Clark and Gage (1905, pp. 427—457) have pointed out that *B. coli* was found in as large a proportion of clams after 15 minutes steaming as in uncooked clams, and that *Streptococci* were found after 30 minutes steaming. The same observers conclude: "The cooking experiments with both clams and oysters shew that some of the common methods of cooking cannot be depended upon to destroy the bacteria of the sewage type found in shell-fish; that is, to do this, a degree of heat or a period of cooking is required in many instances that destroys or impairs the palatability of both oysters and clams. It is, of course, evident that neither should be eaten in the raw condition except from unpolluted and certified sources."

I have been able to confirm these views and at the same time to shew how difficult it is to sterilise mussels.

In the following experiments the mussels used were fresh and the shells were cleansed with a sterile nail-brush in running Birmingham tap water immediately before each experiment was begun.

(1) *Boiling in a saucepan.*

Mussels cleansed as above described were put into a saucepan with Birmingham tap water which was quickly heated to the boiling point. A mussel separated from the shell was taken out immediately the water boiled and put with sterile precautions into a large sterile broth tube and incubated at 35° to 37° C. Boiling was allowed to continue and the process of removing and incubating a mussel was repeated at regular intervals. Growth occurred in all incubated tubes. The following table gives the times of boiling and incubation before growth appeared in nine experiments conducted in this way:

No. of minutes boiling before incubation							No. of hours incubated at 35°—37° C. before growth appeared						
Exp. 1	Exp. 2	Exps. 3 & 4	Exp. 5	Exp. 6	Exps. 7 & 8*	Exp. 9†	Exp. 1	Exp. 2	Exps. 3 & 4	Exp. 5	Exp. 6	Exps. 7 & 8*	Exp. 9†
0	0	8	16	30	40	60	24	24	48	48	48	48	72
4	4	16	26	45	60	80	24	24	48	48	72	48	72
8	6	24	36	60	80	100	48	48	48	48	72	72	96
12	8	32	46	75	100	140	48	48	48	72	72	72	96
16	10	40	60	90	120		48	48	48	72	72	72	
				105							72		
				120							72		

* Exp. 8. After 120 minutes boiling a mussel shell was incubated and proved sterile.

† Exp. 9. After 140 minutes boiling a mussel shell was incubated and proved sterile.

(2) *Heating in steam steriliser at* 100° *C.*

Each of five cleansed mussels with shells were put into sterile broth tubes and steamed in a steam steriliser at 100° C. The tubes containing the mussels and shells were taken out at intervals, cooled and allowed to incubate at 35°—37° C. A growth always resulted. A broth tube was put on in each experiment as a control and remained sterile after heating and incubating. The following is a statement of the times of heating and incubation before growth appeared in five experiments conducted in this way:

No. of minutes in steam steriliser at 100° C. before incubation			No. of hours incubated at 35°—37° C. before growth appeared		
Exps. 10 & 11	Exps. 12 & 14	Exp. 13	Exps. 10 & 11	Exps. 12 & 14	Exp. 13
30	60	120	48	48	72
40	90	180	48	72	72
60	120	210	48	72	72
80	150	240	72	72	72
100	180	270	72	72	72

All these experiments shew that mussels are not sterilised after heating for considerable periods. After heating for a short time—from 6 to 8 minutes—growth appears in nutrient broth after 48 hours incubation and no better results as regards sterility are obtained by heating for a much longer period. This may mean that heating for these periods kills surface organisms but not deep-seated organisms or spores, or kills surface and deep-seated organisms but not spores especially if these are deep-seated.

In the event of *B. typhosus* being present in the intestinal tract or other deep-seated region of a mussel it may be fairly concluded from the foregoing experiments that the usual method of cooking by no means dispels the risk of infection to the consumer. Klein (1905, p. 46) has arrived at the same conclusion from another standpoint, and Thresh (1906, p. 253) has been able to trace cases of typhoid fever to cockles steamed under pressure for three to five minutes.

Remedies suggested.

The foregoing evidence from the statistical and experimental aspects clearly associates typhoid fever with polluted mussels. Various remedies have been suggested:

(1) Purification of sewage before its discharge into tidal waters. This has been considered by the Royal Commission on Sewage Disposal

(1904, p. xx) and shewn to be impracticable as purified effluents contain large numbers of organisms of intestinal derivation.

(2) Seizure and destruction of unwholesome shell-fish under Secs. 116—119 of the Public Health Act, 1875. The provisions contained in these sections are from an administrative standpoint useless for preventing the sale of contaminated shell-fish as there is nothing in the appearance to distinguish the polluted from the clean.

(3) Removal of the source of pollution. This is a possible method under certain circumstances.

(4) Cleansing polluted shell-fish. The following varying results of observers in this field hold out little hope that this method can be utilised.

(*a*) Foote (1894, pp. 197—199) recovered *Bacillus typhosus* from experimentally infected oysters kept in a cool room 30 days from the date of infection.

(*b*) Klein (1894—95, pp. 116—120) was able to recover *B. typhosus* from experimentally infected oysters kept in the laboratory in clean sea water changed daily 17 days after infection.

(*c*) Chantemesse (1896) added typhoid bacilli to sea water in which oysters were placed for 24 hours. He recovered the organism from the body of the oyster 24 hours after its removal from the water. He recommends a period of several weeks for cleansing.

(*d*) Herdman and Boyce (1899, p. 46) state that when experimentally infected oysters were subjected to a running stream of clean sea water there was a great diminution or total disappearance of *B. typhosus* in from one to seven days.

(*e*) Mosny (1899—1900, p. 1098) is of opinion that a period of eight days in pure sea water is sufficient for the disappearance of typhoid organisms from oysters.

(*f*) Hewlett (1903, p. 166) shewed that typhoid bacilli remain and multiply in cockles placed in sea water.

(*g*) Houston (1904, p. 299) re-laid polluted oysters in sea water remote from sewage pollution and found *B. coli* still present in considerable numbers after 26 days.

(*h*) Klein (1905) shewed that oysters infected with huge numbers of *B. typhosus* kept in clean sea water frequently changed were able to clean themselves in six days: that oysters infected with human faecal matter and thereafter kept in sterile sea water frequently changed were able to rid themselves of *B. coli* in eight days; that cockles infected with typhoid organisms and thereafter kept in clean sea water

frequently changed allowed the bacilli to multiply; that in mussels similarly treated the bacilli were still plentiful after seven days.

(*i*) Johnstone (1909, pp. 436—438) found that mussels taken from polluted beds and placed in sea water half-a-mile from the nearest outfall sewer were able to rid themselves of 93 per cent. of intestinal bacteria in four days, and that a further period of eight days did little if anything to effect a further reduction.

(5) Sterilisation of shell-fish. The results obtained by the experiments conducted during the present enquiry and those of Clark and Gage already quoted shew that this is not reasonably possible.

(6) Control of waters and pits, ponds, layings and beds. This was the remedy suggested by the Royal Commission on Sewage Disposal (1904, p. xxi) and it seems to me the only practical method as none of the other remedies which have been mentioned can be relied upon with certainty to protect the consumer from the risk of infection. Legislation on these lines would have the added advantage that it would ensure the stability of trade interests by the practical guarantee involved that mussels exposed for human consumption were obtained from clean sources.

My thanks are due to Dr John Robertson, Medical Officer of Health for the City of Birmingham, for permission to publish this paper and to Professor R. F. C. Leith, University of Birmingham, in whose laboratory the bacteriological work was carried out.

SUMMARY.

(1) 855 primary cases of typhoid fever in households in Birmingham were investigated.

(2) In 124 or 14·5 % of these cases a history of mussel eating within four weeks of the onset of the disease was obtained.

(3) In 17 instances the histories were conclusive of mussel infection.

(4) The curve of mussel-typhoid cases arranged in their weeks of commencement tallies closely with the importation of mussels into Birmingham.

(5) Mussel infection is one of the causes contributing to the autumnal rise of enteric fever.

(6) Some of the sources from which mussels are sent to the Birmingham market are known to be exposed to dangerous sewage contamination.

(7) 65 samples of mussels obtained on entering the Birmingham market from 22 different known sources were analysed bacteriologically.

(8) The results in terms of (*a*) the total number of organisms, (*b*) the number of *glucose-fermenters*, (*c*) the number of spores of *Bacillus enteritidis sporogenes*, and (*d*) the number of *Streptococci* shew that pollution to a dangerous degree of a large proportion of mussels placed on the market for human consumption exists.

(9) 14 experiments were carried out in relation to mussels subjected to moist heat at 100° C.

(10) These shew that the ordinary method of cooking mussels does not remove the risk of typhoid infection and that mussels may be heated in a steam steriliser at 100° C. continuously for as long as four and a half hours without sterilisation.

(11) Legislation is necessary to prohibit the gathering of mussels for human consumption from mussel beds exposed to sewage contamination.

REFERENCES.

BROWNE, T. J. (1904). On an enquiry into the conditions under which oysters and certain other edible molluscs are cultivated and stored on the coast of Ireland, with special reference to the question of the pollution of the shell-fish layings by sewage matter. *Report of the Local Government Board for Ireland* (Cd. 1900), pp. 1—82.

BUCHAN, G. F. (VII. 1908). On mussels and typhoid fever. *City of Birmingham Health Reports.*

BULSTRODE, H. T. (1894—95). On an enquiry into the conditions under which oysters and certain other edible molluscs are cultivated and stored along the coast of England and Wales. *24th Annual Report of the Medical Officer of the Local Government Board*, pp. 1—108.

CHANTEMESSE (1896). Transmission de la fièvre typhoïde par les huîtres. *Bull. Acad. de Méd.*, Paris, Séance du 2 Juin.

CLARK, H. W. and GAGE, S. De M. (1905). On the pollution of shell-fish. *37th Annual Report of the State Board of Health of Massachusetts*, pp. 427—457.

FOOTE, C. J. (1894). On a bacteriological study of oysters with special reference to them as a source of typhoid infection. *18th Annual Report of the State Board of Health of Connecticut*, pp. 189—199.

HERDMAN, W. A. and BOYCE, R. (1898—99). On oysters and disease. *Lancashire Sea-Fisheries Memoir I. Thompson-Yates Laboratories—Reprints and Reports*, Vol. II.

HEWLETT, R. T. (1903). On shell-fish and typhoid fever. *Journal of State Medicine*, Vol. XI. pp. 163—166.

HOUSTON, A. C. (1904). On bacteriological examinations. *Royal Commission on Sewage Disposal*, 4th Report, Vol. III. 1904.

—— (1907). On the quintuple preferential *Bacillus coli* test. *Reports on the Metropolitan Water Supply*, 1907, January, pp. 48—52.

JOHNSTONE, J. (1909). On shell-fish examination. *Journal of Hygiene*, Vol. IX. pp. 412—440.

KLEIN, E. (1894—95). On his bacteriological researches. *24th Annual Report of the Medical Officer of the Local Government Board*, 1894—95, pp. 109—151.

—— (1905). On experiments and observations on the vitality of the bacillus of typhoid fever and sewage microbes in oysters and other shell-fish. Published by the Fishmongers Company, London, 1905.

MOSNY (1899—1900). Des maladies provoquées par l'ingestion des mollusques. *Revue D'Hygiène*, 1899, pp. 1057—1105; 1900, pp. 12—62, 102—142, and 193—212.

Royal Commission on Sewage Disposal (1904). On the pollution of tidal waters, with special reference to contamination of shell-fish. *4th Report*, Vol. I. 1904.

THRESH, J. C. (1906). On unsound food—shell-fish. *Preservatives in Food and Food Examination* by Thresh, J. C. and Porter A. E. Published by J. and A. Churchill, London, 1906, pp. 247—255.