PARATYPHOID FEVER: AN EPIDEMIOLOGICAL STUDY

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The epidemiology of paratyphoid fever is usually discussed on the assumption that it is identical with enteric fever. Actually there are considerable differences and such an assumption may lead to misdirection of effort in the investigation of outbreaks of paratyphoid fever.

The present report is based upon a close study of forty outbreaks in Great Britain, utilizing also reports from America and elsewhere, together with a consideration of the various bacteriological problems which are an integral part of any such investigation. Consideration is confined to paratyphoid due to *Bact. paratyphosum* B, the usual type in this country. A tabular statement of these British outbreaks is set out in Table 1.

Symptomatology

These need not be discussed in detail in an epidemiological study. The reports bear out the accepted views that paratyphoid fever is, in general, a milder disease with a lower incidence of complications than enteric fever and with comparatively few deaths. The case mortality in these forty outbreaks was only 1·76 %. Even this does not represent the true case mortality, as in many outbreaks there is a considerable number of mild, unnotified cases which if included would still further reduce the case mortality. For example, in outbreak no. 8, Dr Shaw states: 'The number of instances in which no medical advice was sought, added to those in which a diagnosis of influenza was made and never revised, would probably reach considerable proportions.'

The case mortality from acute food poisoning due to a living *Salmonella* strain is about 1·5 %. *Bact. paratyphosum* B is a true *Salmonella*, and the close correspondence is of considerable interest, in spite of the fact that the clinical courses are so different.

There is a group of symptoms which occasionally occur in paratyphoid fever which is of great scientific interest and of epidemiological importance. In the majority of paratyphoid cases the symptoms are throughout of the enteric type lasting for several weeks. In some outbreaks a small proportion of the cases are, at onset, of the gastro-intestinal type, characterized by diarrhoea, vomiting and acute abdominal pain. In most instances, after an interval which may be almost without symptoms, the cases pass on to the typical enteric type, but sometimes they are the only symptoms present. A very few outbreaks are on record in which all the cases are of this gastro-intestinal type.

Writing at a time when, owing to the gross confusion of nomenclature, the peculiar restriction of *Bact. paratyphosum* B to paratyphoid fever was not appreciated, Bruce White and I (1925) pointed out that the paratyphoid bacillus was purely a human parasite and a cause of paratyphoid fever only. At the same time we recognized that this organism might occasionally initiate its attack with the symptoms of gastro-enteritis, and quoted the outbreak of Hamburger & Rosenthal (1918) as a case in point, as in their outbreak although forty-one cases were clinically enteric, fourteen were acute gasto-enteritis.

In our present series such clinical manifestations are reported in three outbreaks. The most interesting is the Consett 1940 (no. 30) outbreak. In this epidemic (spread by

home-made trifle) in nine cases (16%) there were gastro-intestinal symptoms only, in thirty-four (61%) the initial symptoms were gastro-intestinal followed later by the typical enteric picture, in seven, typical enteric only, while the remaining six cases showed specific infection but no symptoms. In outbreak no. 28 many of the cases showed a sudden onset with vomiting and diarrhoea, but most went on to the usual enteric type. In outbreak no. 10 some of the cases started like food poisoning.

Further examples of this special group of symptoms can be found in foreign literature. Testal (1937), in a paratyphoid outbreak of seventy cases at Möre (Norway), spread by milk, reported that while in sixty-four the cases were of enteric type, in four there was acute gastro-enteritis. Describing another outbreak at Asker, of the twelve cases most were acute gastro-enteritis and four of them were subsequently typical paratyphoid fever. In an outbreak in Schleswig-Holstein described by Henneberg (1938), seven out of the seventy-four cases showed acute enteritis symptoms. Williams (1925), reporting an outbreak spread by milk at New Rochelle (New York State), describes the cases as acute gastro-enteritis affecting infants and young children, mostly with short incubation periods. *Bact. paratyphosum* B was isolated from a temporary carrier. In one of the four outbreaks described by Feemster & Anderson (1937) in Massachusetts, some of the cases in the boys' school were apparently of this type, as eighty-two out of the 130 started with diarrhoea within 1–5 days.

This group of symptoms is of epidemiological importance as, if the possibility is not recognized, confusion with an outbreak of acute food poisoning may arise. A possible bacteriological explanation of these cases is discussed below.

Incubation period

While many of the reports yield no information on the incubation period, two facts emerge, one that the incubation period is very variable and the other that on the whole it is usually shorter than in enteric fever. Apart from the cases with initial gastro-enteritis the period mostly ranges from 7 to 24 days, but where accurately obtainable a surprising number are 10–12 days. There is evidence that the size of the dose shortens the incubation period. This is well brought out in outbreak no. 39 at Bristol due to cream. The period was accurately obtained in twenty-three cases and ranged from 4 to 19 days, with a mean of 12 days. In two cases the cream pasties were kept before consumption from 2 to 7 August, thus ensuring a massive dose, and for these the incubation period was 4 and 6 days. In an outbreak at Norwich (no. 6) the incubation period was accurately ascertained in nineteen cases and the periods were 5 or 6 days in eight cases, 7 or 8 days in four, 10 or 11 in five, one 12 days, and one 18 days. In one of the Glasgow outbreaks (no. 24) the six cases accurately ascertained were 9 days (one case), 10 days (three), 12 days (two). Most of the cases in the Newcastle (no. 12) outbreak were round about 10 days.

We are now nearer a clearer picture of what happens, in typhoid fever (and probably also in paratyphoid fever), in the body between infection and the onset of symptoms. The old conception was that the introduced bacilli multiplied in the intestine and from there invaded the body. The facts rather suggest that while the portal of entry is often through the intestinal lymphatics, a view supported by the frequent involvement of the mesenteric glands, the sites of growth during the incubation period are in the liver, spleen and glands (especially the mesenteric), and that the close of this period and the

Table 1. *British paratyphoid fever outbreaks*

No.	Place	Date: Year	Date: Months	No. of cases	Deaths	Vehicle	Suggested source of infection of vehicle	Reference
1	Leamington	1923	June–Oct.	88	2	Cream cakes	Infected employee	Goldie & Ward, 1924
2	Dover	1924	Apr.–July	52	0	Milk	Chronic carrier	McMaster, 1926
3	Chorley	1924	Sept., Oct.	52	0	Milk	Notified case	Shaw, 1925
4	—	1925	May	23	0	Cream cheese	Not ascertained	Graham-Stewart, Manson-Bahr & Goddard, 1928
5	Aberdeen	1925	Aug.	23	0	Ice cream	Not ascertained	Bowie, Kinlock & Smith, 1926
6	Norwich	1926	June, July	63	0	Ice cream	Carrier	Soothill & Leggat, 1927
7	Northants	1927	July–Nov.	23	0	Confectionery	Not ascertained	Davies, 1927
8	Herts	1927	Oct., Nov.	166	0	Milk	Undetected case	Shaw, 1928
9	West Herts	1927	Nov.	140	0	Milk	Temporary bacterial carrier	Ward, 1928
10	Egham	1928	June	11	0	Tongue	Paratyphoid case	Wilkinson, 1942
11	London and counties round	1928	July, Aug.	383 + (on 201)	5	Cream	Not ascertained	Brincker, 1928
12	Newcastle	1930	—	48	1	Milk	Not ascertained	Charles & Porteus, 1930
13	Epping U. and R.	1931	Feb., Mar.	312	8	Milk	Undetected case	Bullough, 1931
14	Wroxall	1931	May, June	14	0	Milk	Contaminated water	Carpenter, 1931
15	Consett	1931	July, Aug.	56	0	Synthetic cream	Undetected case	Walker, 1932
16	Blackwell	1932	Sept.	12	1	Watercress	Infected water	Wear, 1932
17	Ipswich	1935	June	37	0	Hospital food	Undetected case	Pringle, 1935
18	Glasgow	1936	Feb.–May	200	6	None found	Not ascertained	Brown, Gray & Adam, 1937
19	Balfron	1936	Mar.	13	0	Milk	Unrecognized case	Brown, Gray & Adam, 1937
20	Kettering and district	1936	May, June	32	3	Cream cakes	Not ascertained	Hogg, 1936
21	Liverpool and district	1936–7	Dec., Jan.	132	11	Bakery products, bread	Carrier	Frazer & Glover, 1937
22	Mersey training ship	1937	Oct., Nov.	11	0	Not determined	Unrecognized case	Peirce, 1938
23	Cardiff	1938	Mar., Apr.	21	0	Synthetic cream	Not ascertained	Wilson, 1942
24	Glasgow	1938	May	6	1	Direct infection	Carrier	Laidlaw, 1938
25	Torquay	1939	Jan., Feb.	5	0	Direct infection	Carrier	Simpson, 1939
26	Bebington	1939	Aug.–Oct.	51	1	Confectionery	Ambulant case	Hughes & Harwood, 1940
27	Glasgow	1940	Mar.	126	0	No information	No information	Anderson, 1940
28	Glasgow	1940	Mar., Apr.	400 + (on 274)	3	Not found	Not ascertained	Bloch & Peters, 1940
29	Bristol	1940	May, June	34	0	Synthetic cream	Ambulant case	Davies, Cooper, Wiseman & Davies, 1940
30	Consett	1940	June	56	1	Home-made trifle	Ambulant case or carrier	Warren, 1941
31	Kettering, etc.	1940	June–Sept.	213	1	Natural cream	Unrecognized case	Hogg & Knox, 1941
32	Birmingham	1940	July	33	0	Synthetic cream	Not ascertained	Warin, 1942
33	Exeter	1940	July, Aug.	60	0	Synthetic cream	Not ascertained	Page, 1940
34	Birmingham	1940	May–July	231	8	Synthetic cream	Not ascertained	Warin, 1942
35	Liverpool, etc.	1941	May–Sept.	883	?	Synthetic cream	Not ascertained	Holt, Vaughan & Wright, 1942
36	Brixworth	1941	July	4	0	Water	Not ascertained	*Monthly Bull.* 1942
37	Ipswich	1941	July, Aug.	12	0	Cream cakes	Unrecognized case	Hunter, 1941
38	Rhayader	1941	July–Sept.	8	0	Case to case infection	Temporary carrier	Poole, 1942
39	Bristol	1941	July–Oct.	203	2	Synthetic cream	Carrier	Davies, Cooper & Fleming, 1942
40	Birmingham	1941	Oct.	18	0	Synthetic cream	Not ascertained	Warin, 1942

onset of symptoms is marked by a bacteriaemia, soon followed by excretion of the bacilli into the intestine, in part through the gall bladder. It is then that Peyers's patches are invaded. As Teile (1934) and others have pointed out, the normal intestinal mucous membrane is a very efficient barrier against bacterial invasion from the lumen of the gut.

In paratyphoid, as in typhoid fever, the organism can be isolated from the blood in over 90% of cases during the first week, falling to some 75% in the second week and 60% in the third week. On the other hand, the bacilli are isolated from the stools in the highest proportion of cases in the second week, then rapidly falling with successive weeks.

I am unaware of any bacteriological explanation of the considerable variation in the incubation period in paratyphoid fever. No data are available from any reports I have read as to whether in cases with an incubation period of a few days and gastro-intestinal symptoms the bacilli can be isolated from the blood, or whether they behave like the other Salmonellas causing acute food poisoning which are not infections and from which the bacilli can never be isolated from the blood in the early stages but only in terminal fatal cases. The point is worth investigation.

Age and sex distribution

It would not be difficult to work out the age and sex distribution of the cases in my series of outbreaks, but to do so would be valueless. It is evident that these two factors are entirely conditioned by the vehicles and the classes of persons who consume the particular vehicles. For example, in the Norwich ice-cream outbreak (no. 6) 80% were females and included a great many children, i.e. the habitual consumers of ice cream.

Seasonal prevalence

This is usually determined on the basis of the dates of actual notifications. Dealing with the outbreaks it is of more value, to judge the influence of temperature and other factors, to consider the months of *onset* of each outbreak. These and the months over which the cases occurred are as follows (one date not available):

Month	Month of onset	Months of duration	Month	Month of onset	Months of duration	Month	Month of onset	Months of duration
Jan.	1	2	May	7	9	Sept.	2	9
Feb.	2	3	June	6	12	Oct.	3	8
Mar.	4	6	July	9	15	Nov.	1	4
Apr.	1	4	Aug.	2	12	Dec.	1	1
						Total	39	

Twenty-two outbreaks (60%) started in May, June or July showing a definite summer origin and no evidence of a special autumn incidence. Naturally the months of epidemic prevalence are a little later but still show a summer prevalence. It would appear that paratyphoid fever in its seasonal distribution approaches nearer to the seasonal distribution of *Salmonella* food poisoning than to that of enteric fever.

The vehicle of infection

The vehicles in the forty outbreaks included in Table 1 are summarized in Table 2. The striking features of these vehicles are the very high proportion of the involvement of cream (40% of the whole), that foods (excluding water) are responsible for 80%, and

compared with enteric fever the great rarity of water as a vehicle and the complete absence of shellfish.

The rarity of water and shellfish as vehicles for the spread of paratyphoid fever merits rather detailed consideration. It is not a peculiarity special to this series but generally true, and a search of the literature of other countries has revealed extremely few outbreaks.

Table 2

Cream, cream cakes, etc.	16	Water (including 1 watercress)	2
Other bakery products (bread)	1	General food infection	1
Milk	8	Direct case to case infection	3
Ice cream	2	Not ascertained	4
Other foods (cream cheese 1, tongue 1, trifle 1)	3	Total	40

Brixworth outbreak (*no.* 36). This little outbreak, with four definite cases but probably with some mild unrecognized cases, occurred in a block of five cottages with a total population of thirty-four. Of these thirty-four as many as twenty-one excreted *Bact. paratyphosum* B in their faeces mostly without any symptoms. The water supply was from a well in the centre of the courtyard with obvious sources of pollution, also shown by bacteriological analysis, while the paratyphoid bacillus was isolated from the water. The actual original source of specific contamination of the water was not ascertained.

Hippe (1938) describes a small outbreak on a farm in Schleswig-Holstein in which one case of paratyphoid fever was followed by three other cases in the same family. While the three subsequent cases may have been due to contact infection the author considers that water was responsible, as *Bact. paratyphosum* B was isolated from it. The water was derived from a local well which supplied the farm, and the sketch in the paper shows that it was liable to gross pollution.

Chalmeton (1938) describes an outbreak of forty-four cases spread over 15 days at Lozère, a small town of 3500 inhabitants. The incrimination of the water supply as the source of infection was mainly on circumstantial evidence which was far from conclusive. No source of infection of the water was ascertained or advanced.

Apart from the Lozère outbreak, in which there is considerable doubt as to the vehicle, for both the above water-spread outbreaks we have to deal with gross pollution and continued heavy pollution suggesting massive infection.

In this connexion it is of interest that the only water-borne outbreaks of paratyhpoid A which I have come across at Vindex, Maryland (Franklin & Halliday, 1937), was also localized to a small group of twenty-six houses with heavy contamination of the well-water supply from a privy collecting the discharges of an undiagnosed case.

It is true that in the very large outbreak (45·7 cases) at St Catharine's, Ontario, McKay (1932) suggests that the milk was contamined from water in a polluted stream in which the cans were cooled, but it is a supposition with no real evidence to support it.

While it is possible that infected shellfish may be responsible for individual cases of paratyphoid fever I have been unable to find an instance in which the connexion has been established, and no example of an outbreak with a number of cases with shellfish as the vehicle. The nearest is the outbreak at Portsmouth in 1924 described by Frazer (1924), in which eighty-five of the 135 guests at the Mayor's Banquet were taken ill after an incubation period of 15–40 hr. with the ordinary gastro-intestinal symptoms of acute food poisoning. All but one had eaten oysters. Three persons subsequently developed clinical paratyphoid fever. As no bacteriological examinations were made it is impossible

to unravel the outbreak and the three cases of paratyphoid fever (diagnosed on agglutination tests only) may not have been connected with the other cases or with the oysters.

Before discussing the significance of the unimportance of water as a vehicle we have to consider whether this is due to the failure of *Bact. paratyphosum* B to occur in sewage or contaminated water as compared with *Bact. typhosum*. We know that the latter organism can survive for several weeks in water, the length of survival being reduced by high temperatures or competing organisms. There are no grounds for supposing that the paratyphoid bacillus differs in these respects from the typhoid bacillus.

As regards the presence of *Bact. paratyphosum* B in sewage and sewage effluents we now have conclusive proof. Gray (1929) isolated this organism from seven out of twenty samples of Edinburgh sewage. Begbie & Gibson (1930) also isolated it from seven out of fifty-eight samples of Edinburgh sewage. Wilson & Blair (1931) isolated it from Belfast sewage, and in some experiments with sewage kept at room temperatures the typhoid bacillus was recovered up to 38 days and the paratyphoid bacillus up to 21 days. Fleming (1933) isolated the paratyphoid bacillus on two occasions from the sewage of the Hereford Mental Hospital, there being a number of cases of paratyphoid fever in the institution.

The Epping results are of particular interest (Houston, 1932; Harold, 1935, 1936, 1937). At the height of the Epping paratyphoid fever outbreak in 1931, when 5% of the population was known to be infected, the raw sewage contained 3400 *Bact. paratyphosum* B and the effluent up to 355 per ml. and it was estimated that on 13 October 1931 as many as 143,000 million paratyphoid bacilli were passing via the effluent to the brook. On 6 August 1931 the faeces of an Epping paratyphoid fever carrier was found, before sterilization, to contain 450 million paratyphoid bacilli per gram, equivalent to ninety-eight paratyphoid bacilli in every c.c. of the sewage discharged at the Northern Epping outfall. The persistence of this organism in the effluent continued, although there were no paratyphoid fever notified cases in Epping, and in spite of the installation of modern disposal works. The figures for the 5 years per ml. were approximately as follows:

	1931	1932	1933	1934	1935
Sewage	312	446	219	227	68
Effluent	—	—	16	7	2·7

These reports make it evident that *Bact. paratyphosum* B is found not only in sewage and sewage effluents some time after there has been an outbreak of paratyphoid fever in the area served, but that it continues to persist in the sewage, probably for years. This fact emphasizes the importance of unrecognized cases and carriers, temporary or permanent, as persistent potential sources of infection.

The three outbreaks with case-to-case spread were all in institutions, i.e. two hospitals and one children's home, due to the introduction of a carrier. Apart from these three outbreaks, and excluding the four with vehicle unascertained, *all* the outbreaks but one (water) were spread through food. Except the little watercress outbreak the foods concerned were almost invariably ones on or in which the paratyphoid bacillus can multiply fairly readily.

The prominence of cream, particularly some form of artificial cream, cannot be accidental, and suggests that there must be some definitely promoting factors.

Warin (1942), in his interesting paper on three outbreaks associated with synthetic cream, states that the raw materials used vary slightly, but in the main consist of flour, a vegetable oil, lecithin or egg in the form of powder or frozen liquid, sugar and water.

These materials are emulsified and homogenized by machinery. The manufacture is concentrated in the hands of a small number of firms, and their products are widely distributed. Warin gives some bacteriological findings from cream derived from five different firms. All the samples initially showed gross bacterial contamination, but samples collected towards the end of 1941, after administrative action had been taken, showed very marked improvement and a nearly sterile product.

As regards the sanitary conditions at the various bakeries and the actual opportunities for contamination the various reports are, in general, disappointingly vague or fail to mention the question at all. Also in so many of the outbreaks the local investigations were undertaken very late in the course of the outbreak, and almost certainly in the interval considerable improvements would have been effected.

In outbreak no. 29 the authors mention that the wholesale confectionery firm prepared the synthetic cream on the premises and add: 'The process of cream making appeared to offer maximal opportunities for infection.' The cream showed abundant evidence of general infection, but no paratyphoid bacilli could be isolated at the time it was investigated. In the Liverpool outbreak (no: 35) paratyphoid bacilli were isolated from two samples of synthetic cream.

On the other hand, while in outbreak no. 31 the report shows defects in bakery management, stress is laid upon the rigid exclusion of all possible infective persons as the main line of prevention.

With synthetic cream, not manufactured locally, the wide distribution of the one product over many parts of the country, only one of which showed an outbreak of paratyphoid fever, makes it fairly certain that the source of infection was local.

Information is wanting as to whether paratyphoid bacilli multiply readily in artificial cream, but it is probably a good medium when the temperature is fairly high. Little or no information is given in the reports as to the usual interval between the introduction of the cream into confectionery and their consumption, a point of interest.

The only other vehicle calling for comment is the little watercress outbreak (no. 16) of twelve cases, in which most of the cases had either eaten watercress or had associations with the family originally infected. These comprised five cases. The father hawked watercress obtained from a polluted stream from the water of which *Bact. paratyphosum* B was isolated.

VEHICLE INFECTIVITY RATE

Since in so many outbreaks the vehicle is one in which the paratyphoid bacillus can grow readily, it might be anticipated that the proportion of cases amongst persons at risk would be very high, but actual experience does not support this supposition.

In the sixteen cream epidemics the known cases in the outbreaks vary from twelve to 883 with an average of 146, in the two ice-cream outbreaks the numbers were twenty-three and sixty-three, while not all the milk outbreaks were extensive. Also the number of cases per week were often surprisingly few.

Outbreak no. 1 ran for 15 weeks, but there were never more than twelve cases a week, and infection must have been very intermittent. In outbreak no. 29 the thirty-four cases were spread over 40 days, so the outbreak was in no sense explosive although cream was the vehicle. The same point comes out in no. 6 from ice cream, when of sixty-three cases there was never more than five cases on any one day and mostly only one or two.

This intermittency of infection applies especially to the cream outbreaks but is not confined to them.

From many reports it is obvious that the official notifications form only a proportion of the persons infected, and their inclusion would probably raise materially the percentage at risk infected. This is well brought out in outbreak no. 32, where the author points out that judging from the number of very mild cases found amongst the small proportion investigated, it can be deduced that the number of mild undiagnosed cases may have been very large, while in addition there were probably an even greater number of infected persons without symptoms.

Another factor operating in some cases is the influence of temperature. In the ice-cream outbreak, no. 5, there were only twenty-three cases although about 360 customers were served each day, and here it is suggested that the refrigerator temperature at which the ice cream was kept prevented the multiplication of paratyphoid bacilli. At the opposite extreme we have outbreak no. 30, where the vehicle of infection, home-made trifle, was left overnight during a spell of particularly hot weather, and, in consequence of the heavy specific infection, no less than fifty-six out of the sixty-four who took part in the wedding feast were attacked.

A factor of importance in relation to infection is the well-authenticated fact that normal gastric juice is definitely highly germicidal to both typhoid and paratyphoid bacilli, actually in proportion to the percentage of physiologically active hydrochloric acid.

The infectivity rate is of considerable practical importance. These facts suggest that we cannot exclude these various vehicles being involved because an outbreak is not explosive in character. We also have to reckon with the possibility of many coincident infections as well as with clinical cases, and that these may tend to obscure the actual vehicle of infection.

The primary sources of infection

The actual source of infection of the vehicle raises problems of great epidemiological importance which cannot be discussed apart from the bacteriology of the paratyphoid bacillus. In typhoid infections the chronic carrier looms largely, but the prevalent assumption that it is of equal importance in paratyphoid fever cannot be accepted without critical consideration.

The carrier problem. Much confusion would be obviated if the distinction between temporary and chronic carriers was always kept in mind. The differences have been defined by Ledingham & Arkwright (1912) and more precisely by Browning, Coulthard, Cruikshank, Guthrie & Smith (1933). Browning defines as follows:

'*Temporary carriers:* Persons who in convalescence, and for short periods afterwards, excrete the specific organisms and then clear up.

'*Permanent* (*or chronic*) *carriers:* Those who continue to excrete the bacilli after a year. These will not become spontaneously cured.'

In connexion with the war of 1914–18 several studies were made on this problem. Leishman (1923) gives an analysis of the records of the central enteric depot at Addington Park, Surrey, where enteric convalescents were concentrated. A chronic carrier was so indicated if the bacilli were present 6 months after the final decline of the temperature. Of 1425 cases of paratyphoid (B) fever forty-three, or 3%, became chronic carriers, forty-two being faecal and one both urinary and faecal.

Bumke (1925–6) gives figures from the German military station at Spa of 805 paratyphoid B carriers. His findings were that some 60–70% become bacillus free during the first quarter of freedom from symptoms, and a further 10–20% are freed during the second, leaving 20–30% as persistent carriers at the end of 6 months; apparently no studies were made beyond this period.

More recently, Glass & Wright (1937), dealing with a Liverpool outbreak, point out that the disappearance of the organisms from the faeces seems to be a gradual and fairly orderly process. The rate of clearing slows down with each succeeding week, and not until the eleventh week did the figures decline to 10% while 4% were still excreting the bacilli at the fifteenth week when observations ceased.

Still more recently, Holt, Vaughan & Wright (1942) with more material have extended these observations and, omitting their age and sex figures, supply the following table:

Rate of disappearance of Bact. paratyphosum *B from the faeces*

Week of disease	Liverpool 1941, outbreak (339 cases)	Percentage excreting in faeces: Liverpool, 1937 (98 cases)	Percentage excreting in faeces: Bristol, 1940 (30 cases)	Week of disease	Liverpool 1941, outbreak (339 cases)	Percentage excreting in faeces: Liverpool, 1937 (98 cases)	Percentage excreting in faeces: Bristol, 1940 (30 cases)
1	100	—	83	8	22	33	—
2	92	100	93	9	15	19	—
3	81	93	64	10	10	15	—
4	73	88	46	11	9	9	—
5	61	84	22	12	7	7	—
6	44	67	7	13–16	6	—	—
7	31	49	7	Over 16	5	4	—

Exact percentage figures for over 16 weeks are not given but at least one was a chronic carrier after 5 years.

The reports in the outbreaks in my series give very little information apart from those quoted. In outbreak no. 21 three cases, all adult females, persisted as carriers for 5 months or more. In outbreak no. 30 two females continued to pass paratyphoid bacilli in faeces 10 months after infection. In outbreak no. 2 one female was still a carrier at 11 months.

The only general survey of a population which I have been able to find is that of Welch, Dehler & Havers (1925) in Alabama in an area with a high prevalence of typhoid fever. The persons examined numbered 1076, specimens examined 4950. Although sixteen paratyphoid carriers were found thirteen were paratyphoid A and only three paratyphoid B (0·06%), all faecal carriers. No information is given about these three carriers. The figures of Gill (1927) are sometimes quoted, but he used these same statistics, and all his new facts only refer to enteric fever.

Interesting as are these observations it will be obvious that we do not yet know the percentage of paratyphoid cases which become chronic carriers, i.e. persistence over a year after convalescence, and whether this percentage is higher or lower than for enteric fever. That some cases become chronic carriers is quite evident, and Browning (1933) in his report gives details of two cases, both females; the one aged 39 had been a carrier for 3 years, while the duration of the other could not be determined, but she was known to have infected at least eleven persons.

That a material proportion of cases continue for some time as temporary carriers is obvious from the above, and many examples are given in my series of outbreaks.

The extent to which bacterial infections occur without clinical manifestations

No one can read a series of reports on paratyphoid outbreaks without being impressed with the extent to which this is a common accompaniment. It is true that many reports mention no such cases, but, almost invariably, because they were never looked for, but where the point is both appreciated and investigated instances are common. Even in the trifle outbreak (no. 30) with such heavy infection six persons bacteriologically positive were symptomless. Further examples are the following: Outbreak no. 18 where thirty-three families in which there was a definite case were investigated and in twenty-two the faeces and in eleven the urine contained *Bact. paratyphosum* B. The great majority of these infected contacts showed no signs of illness and no history of recent ill health. In outbreak no. 27 eight similar cases are mentioned. In outbreak no. 28 twenty-one symptomless positive carriers are mentioned. In outbreak no. 31 the investigations made disclosed five ambulant bakery employees without history or symptoms, and the authors consider it likely that a number of ambulant cases were undetected. In outbreak no. 32 there were many infected symptomless cases, and the author considers that the number was probably large. In outbreak no. 39 as many as forty-one intestinal carriers without symptoms were found.

These infectious persons were ascertained because, for one reason or another, such as being on the staff of the incriminated bakery, special attention was directed to them. It cannot be doubted that if it had been practicable to have made detailed examinations by modern methods of all the persons at risk, a quite material proportion would have been found infected but without symptoms of paratyphoid fever.

One foreign outbreak may be quoted, as it is of special interest. Faxén (1938) reported a paratyphoid outbreak in a maternity hospital at Gothenberg involving twenty-four adults and fifteen new-born babies, the infection originating from a mother who had paratyphoid fever a year previously and who continued to discharge paratyphoid bacilli ever since. All but one of the infected babies were practically symptomless, without even any rise in temperature. One baby harboured the bacilli for 7 months.

Sources of infection in the present series

Excluding sixteen outbreaks for which no source of infection of the vehicle is put forward, the remaining twenty-four outbreaks fall into three groups:

A. Infection through specifically infected water. Two outbreaks. In the watercress outbreak pollution of the stream in which the cress was grown is suggested, but apart from the water being polluted no specific evidence was forthcoming. In the other outbreak (no. 14), spread by milk, the sewage and sewage effluent contained the paratyphoid bacillus, and it is suggested that this was the source of infection of the milk, particularly as a case of paratyphoid fever with continuing positive stools occurred amongst the population supplying the sewage.

B. Infection spread from a known case or an unrecognized case of paratyphoid fever. In several instances ascertained cases of paratyphoid fever were involved, but in nearly all the infection was spread from cases which were unrecognized at the time. If outbreak no. 1 is included in this group outbreaks so spread were twelve.

C. Infection spread by some type of carrier. This method is suggested in ten instances, but they cannot be accepted without critical consideration. Critical analysis of these reports suggests the following groupings. In four outbreaks (nos. 9, 25, 38, 39) the agent of infection was a person who was a temporary bacterial carrier, and there is no suggestion of a chronic carrier being implicated. In one outbreak (no. 24) in a Voluntary Hospital the infection was introduced by a carrier, but there is no clear evidence whether she was a temporary or a chronic carrier. In outbreak no. 2 the suggested carrier was only proved to be excreting paratyphoid bacilli several months after the outbreak started and he could have been himself infected from the milk. The evidence that he was a chronic carrier is partly epidemiological, but chiefly rests on the fact that he continued to excrete paratyphoid bacilli for at least a year subsequently. On the whole it is probable he was a chronic carrier. In another outbreak (no. 29) the suggested source of infection was an employee who was found at the end of the outbreak to pass paratyphoid bacilli in her stools. The stools were soon clear of these bacilli, so she was not a chronic carrier and might equally well have been an ambulant case as suggested or a victim of the outbreak. In outbreak no. 30 there is no suggestion of a chronic carrier, but the facts suggest that the maker of the trifle, who later was found to have very large numbers of paratyphoid bacilli in both faeces and urine, was an ambulant case without symptoms. In the remaining two outbreaks (nos. 6 and 21) the suggested persons responsible were only found to be excreting paratyphoid bacilli after the outbreak ceased, and both could equally well have been cases of bacterial infection from consuming the infected foodstuffs. There is no corroborative evidence either way, and no evidence at all that they were chronic carriers.

It will be seen from these remarks that in not more than two outbreaks is there any reliable evidence of a chronic carrier, and for both of them there is an element of doubt. On the other hand, the ambulatory unrecognized case or the bacterially infected person without symptoms is prominent as a means of infecting the vehicle.

The comparative rarity of the chronic carrier in this series as the source of infection of the vehicle is of great significance. There is, I believe, a real danger of investigators being over-impressed with the prevailing conception of the importance of the chronic carrier resulting in a failure, when a carrier of paratyphoid bacilli is found, to try and establish the diagnosis on a firmer footing.

Since nearly always the suggested carrier is a handler of the infected vehicle and also a potential consumer of it, it is important to consider the possibility of distinguishing between an infective carrier and a potential victim of the infection. All the following lines of inquiry should be explored:

(1) A close attention to actual dates (these are often quite ignored in the published reports). It should be ascertained from a study of the dates whether it was possible for the found carrier to have been a victim, and whether he or she was a consumer of the product. It would be helpful if these inquiries were put in hand at the earliest possible time when the chances of self-infection are less likely. Nearly always they wait upon a full certitude as to the vehicle instead of when there is only a reasonable probability.

(2) The clinical history of the suggested carrier. A definite history of previous illness, possibly paratyphoid fever, is valuable evidence, but on the other hand its absence is not of great significance, as so many persons are infected without noticeable clinical manifestations.

(3) The previous associations of the supposed carrier. If such a condition has persisted for years there is a reasonable prospect of evidence of infections in the family or amongst associated workpeople being forthcoming.

(4) The bacteriological history of the supposed carrier. In a recently infected case the specific bacilli should be fairly abundant in the faeces in the early stages, especially in the second week, and then there is usually an orderly and progressive decline in prevalence. In a genuine carrier the bacilli are usually present in far smaller numbers, and there is no quantitative decline with time.

The agglutination level is of considerable significance and value. In a chronic carrier the agglutinin level is low or may be absent and the O, H and Vi agglutinins should be separately estimated. In a victim of infection the agglutinin level is low in the second week, rises to a maximum at about the end of the third or fourth week or even later, and then falls, at first rapidly and then slowly. This sequence may not occur with an infected person without symptoms and rarely there may be no exhibition at all of agglutinins. These *quantitative* estimations are all valuable and usually throw light upon the point under discussion.

In only one outbreak (no. 31) have these criteria been used, and here Hogg & Knox (1942) make valuable use of it. For example, dealing with a suspected person they draw attention to the rising and varying agglutinin titres, and on this account rule him out as a chronic carrier.

While admittedly our knowledge is as yet inadequate to say with certitude whether a suspected person is a case or a carrier, I suggest that if all these lines of inquiry are explored it may be adequate to settle the point in an individual case.

Bact. paratyphosum B as a *Salmonella* organism

While some authorities include *Bact. typhosum* in the *Salmonella* group there is no doubt as to the paratyphoid bacillus, and this fact is an important clue to its epidemiology. Indeed, its affinities to some other *Salmonella* types, particularly *Bact. typhi murium*, are so close that much of the older literature (especially in Germany) is invalidated by the failure to distinguish the types. The confusion as to the high host specificity of *Bact. paratyphosum* B has not yet been entirely dissipated, and some aspects bear upon the problem of paratyphoid fever.

Bact. paratyphosum *B as a cause of disease in animals.* While this organism has frequently been reported as isolated from animal sources there is practically no evidence that this ever occurs when the isolated organism is accurately typed. It is possible that one or two instances are authentic, but for practical purposes this strain only occurs as a *human* parasite. There is a possible exception, as recently from Scandinavia several outbreaks have been recorded as associated with infection of dogs.

Caspersen (1937) has described an outbreak of paratyphoid fever in March 1937 in a small town in Norway. Six of the nine persons affected were all from one house, three of them were without symptoms. A dog closely associated with a number of the cases was ill for 2 weeks in February, including violent diarrhoea, recovering just before the first human cases. Blood and stools of the dog examined 6 weeks after recovery were negative as regards the paratyphoid bacillus, but her serum agglutinated this strain 1 : 320 (H) and 1 : 40 (O), and later higher agglutination figures were obtained.

Magnusson (1938) described a small paratyphoid fever outbreak of four cases in Stode (Sweden), affecting two families. Two were primary and two secondary cases. A week before the first cases a stray dog arrived and attached himself to the house of the first two cases. The dog became ill but quickly recovered. Stools of the dog yielded a bacillus identified as paratyphoid bacillus B, and the blood agglutinated this strain 1 : 250. The author does not state definitely that the human and the dog strains were identical in all respects. Gard (1938) gives details of the cultural characters of this dog strain and states that the human and dog strains agreed serologically. He called the strain *S. abortus canis*. While it seems probable that this strain was responsible for the human cases, it is not quite clear that it is identical with the ordinary *Bact. paratyphosum* B or is a variety. The possibility that cases which clinically are paratyphoid fever may be associated with a dog infection cannot be ignored.

Another outbreak in one family, but this time clinically gastro-enteritis, was also ascribed by Kauffmann & Henningsen (1939) to infection from a dog, but the organism isolated was definitely not paratyphoid B, but serologically allied to *S. newport*.

Varieties of Bact. paratyphosum *B and their epidemiological significance.* As for other Salmonellas the application of special serological tests, phase tests and the like is evolving subtypes of this strain. For example, Christensen (1937), with the help of the I antigen of Kauffmann divided 263 strains into two subtypes, i.e. seventy-seven with the I antigen and 186 without this antigen. Felix using the phase method and Vi antigen has also split the strain into a number of varieties. Time must elapse before the practical epidemiological value of these differentiations can be established.

There is one subdivision which is of considerable interest. Kristensen & Kauffmann (1937) describe an outbreak in Denmark in an asylum in which the cases were predominantly slight enteritis, and no case of typical paratyphoid fever occurred. Kauffmann (1941) reports upon twenty-five strains from Java isolated from cases which were never typhoid-like, but as a rule slight enteritis. The asylum strains and the Java strains, unlike the true paratyphoid bacillus B, failed to produce the mucous wall around agar colonies and did ferment *d*-tartrate. Kauffmann advances the view that while the typical *d*-tartrate negative with mucous wall colonies cause clinical paratyphoid fever, the *d*-tartrate positive with no wall building strains are chiefly responsible for the acute gastro-enteritidis type of case. It is not asserted that the distinction between type of strain and type of illness is clear cut. Both types are non-pathogenic to mice by feeding. I have tested a number of strains from both the clinical gastro-enteritis and the enteric type of disease from English outbreaks, but all so far have been of the normal paratyphoid B type. If this distinction can be confirmed it will help to explain one of our epidemiological difficulties.

THE EVOLUTION OF *BACT. PARATYPHOSUM* B

It will be appreciated that paratyphoid fever shows definite differences from enteric fever as regards its epidemiology, and I suggest that an appreciation of the reasons for these differences can be obtained by a recognition that *Bact. paratyphosum* B is a true *Salmonella* still in an evolutionary stage. As I pointed out in my Sedgwick Memorial Lecture (Savage, 1932) the *Salmonella* group is at the present time in a very evolutionary stage as regards its host selections and parasitic functions. *S. typhi murium* (*B. aertrycke*)

is possibly nearest to the common ancestor, catholic in its distribution, and undifferentiated in its host selections. Some *Salmonella* types have become so far differentiated as to be pathogenic only to certain domestic animals. For one of them, i.e. *Bact. paratyphosum* B, invasive powers and differentiation of function have proceeded so far, that for practical purposes this type has become parasitic to man only, causing the long-continued enteric type of disease associated with a successful establishment and growth in the body organs and a definite bacteriaemia.[1] This is in contrast to the undifferentiated *S. typhi murium* which, when it affects man, merely acts as a gastro-intestinal irritant without invasion of the tissues except in the very few instances when it does establish itself, and then usually kills its host. On the other hand, this *Salmonella* is a common disease of a host of lower animals in which it establishes itself in the tissues and persists after recovery for long periods.

A parasite which restricts its activities to one host to be successful must come to terms with its host, or as Dudley (1935) puts it: 'The balance between host and parasite must be very exact if both species are to survive.'

To retain what, for want of exact knowledge, I have called the 'irritant', properties of the ordinary food-poisoning *Salmonella* is not compatible with successful single-host parasitism, as it would operate to ensure its speedy expulsion. Yet not being completely differentiated its ancestry is shown by the occasional occurrence of cases in which these irritant properties, not completely lost, operate as shown by definite gastro-intestinal attacks. On the other hand, the 'invasive' properties for man of the paratyphoid bacillus are as yet inferior to those of the typhoid bacillus which appears to have had a much longer experience of human parasitism. The marked variations in the duration of the incubation period in paratyphoid fever are accountable when we view the bacillus as an organism in evolution with still uncertain proportions of irritant and invasive properties, it has not yet settled down to an orderly sequence.

I suggest that the lack of invasive experience offers an explanation of the marked distinction of vehicles between typhoid and paratyphoid fever. The paratyphoid bacillus requires many more bacilli for a successful invasion of the tissues and the outbreaks occur with vehicles in which the bacillus can multiply before it is introduced into the human body. The favourite vehicles of infection in paratyphoid fever approximate much more closely to the vehicles in *Salmonella* food poisoning than to those for enteric fever.

The fact that paratyphoid fever is mild, and that there are so many cases of successful infection either with no symptoms at all or ones so trivial that they are often overlooked, is more easily understandable on an evolutionary basis. As regards the persistent carrier state the evidence is inadequate for a final judgement, but I believe it will be found

[1] Every series of summaries of the bacteria isolated from acute food poisoning shows the absence of *Bact. paratyphosum* B when the classification of the strain is correct. The following table illustrates this point:

Organisms in food poisoning outbreaks

Strain	Denmark		Essen 1933–39	England (Dr Scott)
S. typhi murium	228	310	249	206
Enteritidis type	73	39	77	52
S. paratyphosum B	0	0	0	0
Other types	93	26	60	95
	394	375	386	353

that they are definitely less common proportionately than in enteric fever, which I should anticipate viewing the paratyphoid bacillus as a *Salmonella*.

The possible, but certainly very rare, presence of true *Bact. paratyphosum* B in animals other than man is understandable on the basis of an organism which as yet has not obtained a complete and established differentiation as an obligate human parasite. While any explanation on the basis of bacterial evolution must be in part conjectural, I do suggest that to attempt it clarifies the data and helps to explain those differences between paratyphoid fever and enteric fever which are so usually ignored.

SUMMARY AND DISCUSSION

The present review furnishes evidence that paratyphoid fever exhibits a good many differences from enteric fever in its epidemiological features.

The incubation period is decidedly variable and, in general, shorter than it is in enteric fever. Not only is the disease usually milder, but the case mortality figure in the present series is particularly low and one more comparable to the case mortality in *Salmonella* food poisoning than that of enteric fever.

It has to be recognized that acute gastro-intestinal symptoms may be present, very rarely indeed associated with all the cases but more often affecting a proportion of them, which so closely simulate acute food poisoning that that condition may be diagnosed. Usually, however, the same patients later exhibit the normal enteric picture.

The seasonal prevalence, at least as regards the onset of multiple outbreaks as distinct from isolated cases, shows a definite summer prevalence more comparable to the distribution of *Salmonella* food poisoning than to that of enteric fever.

The vehicles of infection are markedly different and, apart from outbreaks spread by case-to-case infection as in some institution outbreaks, almost invariably the vehicle is some form of food. Whereas milk and ice cream are common agencies in spreading both diseases water and shellfish are absent, or very rare, as vehicles in paratyphoid fever. For this disease cream takes pride of place.

I suggest that these conspicuous differences of vehicle are not associated so much with lack of opportunity to infect as with the need for a vehicle in which multiplication of the paratyphoid bacillus can occur previous to ingestion. These differences of vehicle are explainable on the assumption that the paratyphoid bacillus is less efficient at invading the human body than the typhoid bacillus, and therefore only vehicles which ensure its ingestion in considerable numbers are effective. The few water infections cited in the report bear out this contention, for in all of them water was only effective when massively infected and repeatedly consumed. This explanation is, of course, only a hypothesis, and it may be that other factors, such as preformed toxin, are also required for successful invasion.

The special implication of cream, it may be advanced, is partly due to this factor, and also that this vehicle is one which affords special opportunities for specific infection from an infective food handler.

The vehicle infectivity rate is definitely low, and in many outbreaks a surprisingly small proportion of persons at risk are attacked. The comparative infrequence of definite explosive outbreaks, even with a vehicle from which we should anticipate an outbreak to be explosive in character, is noticeable. Both these facts add support to the view that the paratyphoid bacillus does not readily infect man.

As regards the sources of infection of the vehicle I suggest that the importance of the chronic carrier has been overstressed, and that such carriers are less important in paratyphoid fever than in enteric fever. Our information is still inadequate, but the facts incline one to believe that the true chronic carrier is proportionately rarer than in enteric fever but is likely to be more associated as a causal agent with individual infections where there are opportunities for repeated infections.

On the other hand, my series of outbreaks emphasizes the fundamental importance of the transitory carrier who may be either a mild unrecognized case or a symptomless bacterially infected person. It is evident that in most outbreaks there is in addition to the recognized and so notified cases a reservoir of infected persons in one or both of these groups. Unrecognized by themselves and unknown to the Health Authority they constitute a pool of potential infection, the effectiveness of infection only limited by opportunity, and, to a minor extent, by the difficulty of the paratyphoid bacillus to establish itself as a cause of disease in the human body. No system of control can afford to neglect the potential menace of these two groups of persons.

Much more attention might profitably be given to a detailed study of the extent to which bacillary infection occurs without recognized symptoms and the extent to which these cases clear up within a reasonable period. A comprehensive investigation of isolated single cases of paratyphoid fever would, I am sure, yield valuable epidemiological results.

Influenced no doubt by the prevailing emphasis on the chronic carrier as the commonest source of infection my series shows a tendency to label any person who handled the infected vehicle and whose stools contain the paratyphoid bacillus as the source of infection of that vehicle without steps being taken to prove the contention. So frequently can the presence of the specific bacillus be equally well accounted for on the assumption that the person is a victim of infection in the actual outbreak that some attempt at proof is essential. Modern bacteriological methods are in a position to throw considerable light on the distinction between a potential cause of the outbreak and a victim of that outbreak and ought invariably to be employed.

I am impressed with the extent to which the undoubted fact that *Bact. paratyphosum* B is a true *Salmonella* influences the epidemiological picture, and I have suggested that a study of it from this angle furnishes us with a rational explanation of the main differences between its epidemiological behaviour compared with that of the typhoid bacillus.

REFERENCES

Anderson, T. (1940). *Lancet*, **2**, 189.

Begbie, R. S. & Gibson, H. J. (1930). *Brit. Med. J.* **2**, 55.

Bloch, E. & Peters, R. J. (1940). *Lancet*, **2**, 429.

Bowie, F. J. T., Kinloch, J. P. & Smith, J. (1926). *J. Hyg., Camb.*, **25**, 444.

Brincker, J. A. H. (1928). *Report No.* 2643 to London County Council.

Brown, G. A., Gray, J. S. M. & Adam, T. (1937). *Med. Offr*, 28 Aug. p. 89.

Browning, C. H., Coulthard, H. L., Cruikshank, R., Guthrie, K. J. & Smith, R. P. (1933). Chronic Enteric Carriers and their Treatment. *Rep. Med. Res. Coun., Lond.*, no. 179, H.M.S.O.

Bullough, W. A. (1931). *Ann. Rep. C.M.O.H. Essex* for 1931.

Bumke, E. (1925–6). *Z. Hyg. InfektKr.* **105**, 342.

Carpenter, H. (1931). *Spec. Rep. M.O.H. Ventnor U.D.C.*

Caspersen, J. (1937). *Norsk. Mag. Laegevidenskapen*, **98**, 138.

CHALMETON, P. (1938). *Rev. Hyg. Police sanit.* **60**, 543.
CHARLES, J. A. & PORTEUS, E. (1930). *Newcastle Med. J.* **11**, 10.
CHRISTENSEN, A. (1937). *Z. Hyg. InfektKr.* **120**, 123.
DAVIES, L. M. (1927). *Spec. Rep. C.M.O.H. Northants.*
DAVIES, I. G., COOPER, K. E. & FLEMING, D. S. (1942). *Lancet*, **1**, 129.
DAVIES, I. G., COOPER, K. E., WISEMAN, J. & DAVIES, J. M. (1940). *Lancet*, **2**, 778.
DUDLEY, S. F. (1935). *Proc. Roy. Soc. Med.* (Epidem. Section), **29**, 1.
ELIOT, C. & CAMERON, W. R. (1941). *Amer. J. Publ. Hlth*, **31**, 599.
FAXÉN, N. (1938). *Nord. Med. Tid.* **16**, 1092.
FEEMSTER, R. F. & ANDERSON, G. W. (1937). *Amer. J. Publ. Hlth*, **29**, 881.
FLEMING, G. W. T. H. (1933). *Brit. Med. J.* **1**, 412.
FRANKLIN, J. P. & HALLIDAY, C. H. (1937). *Can. Publ. Hlth J.* **28**, 82.
FRAZER, A. M. (1924). *Ann. Rep. M.O.H. Portsmouth* for 1924, p. 32.
FRAZER, W. M. & GLOVER, B. T. J. (1937). *Brit. Med. J.* **2**, 369.
GARD, S. (1938). *Z. Hyg. InfektKr.* **121**, 139.
GILL, D. G. (1927). *J. Amer. Med. Ass.* **89**, 1198.
GLASS, V. & WRIGHT, H. D. (1937). *J. Path. Bact.* **45**, 431.
GOLDIE, W. L. & WARD, H. G. (1924). *Med. Offr*, 5 Jan. p. 5.
GRAHAM-STEWART, A., MANSON-BAHR, P. & GODDARD, T. R. (1928). *Brit. Med. J.* **1**, 934.
GRAY, J. D. A. (1929). *Brit. Med. J.* **1**, 112.
HAMBURGER, R. & ROSENTHAL, F. (1918). *Dtsch. Arch. Klin. Med.* **125**, 415.
HAROLD, C. H. H. (1935). *30th Ann. Rep. Metrop. Water Board.*
HAROLD, C. H. H. (1936). *31st Ann. Rep. Metrop. Water Board.*
HAROLD, C. H. H. (1937). *32nd Ann. Rep. Metrop. Water Board.*
HENNEBERG, G. (1938). *Arch. Hyg. Bakt.* **119**, 257.
HIPPE, L. (1938). *Arch. Hyg. Bakt.* **121**, 56.
HOGG, C. B. (1936). *Spec. Rep. M.O.H. Kettering.*
HOGG, C. B. & KNOX, R. (1942). *J. Hyg., Camb.*, **41**, 553.
HOHN, J. & HERRMANN, W. (1940). *Z. Bakt.* **145**, 209.
HOLT, H. D., VAUGHAN, A. C. T. & WRIGHT, H. D. (1942), *Lancet*, **1**, 133.
HOUSTON, A. (1932). *27th Ann. Rep. Metrop. Water Board*, and subsequent reports.
HUGHES, T. L. & HARWOOD, H. F. (1940). *Lancet*, **2**, 601.
HUNTER, J. H. (1941). *Spec. Rep. M.O.H. Ipswich.*
KAUFFMANN, F. (1941). *Die Bakteriologie der Salmonella Gruppe.* Copenhagen.
KAUFFMANN, F. & HENNINGSEN, E. J. (1939). *Acta path. microbiol. Scand.*
KRISTENSEN, M. & KAUFFMANN, F. (1937). *Z. Hyg. InfektKr.* **120**, 149.
LAIDLAW, S. (1938). *Lancet*, **2**, 855.
LEDINGHAM, J. C. G. & ARKWRIGHT, J. A. (1912). *The Carrier Problem in Infectious Diseases.* London.
LEISHMAN, W. B. (1923). *Official History of the Great War.* Medical Series: Pathology. Section: 'The Enteric Fevers.'
MAGNUSSON, K. E. (1938). *Z. Hyg. InfektKr.* **121**, 136.
MCKAY, A. L. (1932). *Can. Publ. Hlth J.* **23**, 303.
MCMASTER, A. B. (1926). *Publ. Hlth*, **39**, 177.
Monthly Bull. of Emergency Publ. Health Lab. Service (1942), Feb.
PAGE, G. B. (1940). *Ann. Rep. M.O.H. Exeter*, p. 21.
PEIRCE, E. R. (1938). *Brit. Med. J.* **1**, 217.
POOLE, J. (1942). M.O.H. Rhayader. Personal communication.
PRINGLE, A. M. N. (1935). *Med. Offr*, 5 Oct. p. 141.
SAVAGE, W. G. (1932). *J. Prevent. Med.* **6**, 425.
SAVAGE, W. G. & WHITE, P. B. (1925). *J. Hyg., Camb.*, **24**, 37.
SHAW, W. V. (1925). *Ministry of Health Spec. Rep.* no. 30.
SHAW, W. V. (1928). *Ministry of Health Spec. Rep.* no. 53.
SIMPSON, J. V. A. (1939). *Lancet*, **2**, 1235.
SOOTHILL, V. F. & LEGGAT, G. L. (1927). *Lancet*, **1**, 1233.

TEILE, F. H. (1934). *J. Path. Bact.* **39**, 391.
TESTAL, M. (1937). *Z. Hyg. InfektKr.* **119**, 28.
WALKER, J. G. (1932). *Ann. Rep. M.O.H. Consett.*
WARD, I. V. I. (1928). *Lancet*, **1**, 389.
WARIN, J. F. (1942). *Med. Offr*, 17 Jan. p. 21.
WARREN, S. H. (1941). *Publ. Hlth*, **54**, 139.
WEAR, A. H. (1932). *Ann. Rep. M.O.H. Blackwell* and personal communication.
WELCH, S. W., DEHLER, S. A. & HAVERS, L. C. C. (1925). *J. Amer. Med. Ass.* **85**, 1036.
WILKINSON, A. G. (1942). Personal communication, M.O.H. Egham.
WILLIAMS, H. (1925). *J. Amer. Med. Ass.* **84**, 251.
WILSON, J. G. (1942). Personal communication, M.O.H. Cardiff.
WILSON, W. J. & BLAIR, E. M. M. (1931). *J. Hyg., Camb.*, **31**, 138.

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