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Salmonellae in cattle and their feedingstuffs, and the relation to human infection

*A Report of the Joint Working Party of the Veterinary Laboratory Services of the Ministry of Agriculture, Fisheries and Food, and the Public Health Laboratory Service**

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INTRODUCTION

The majority of food poisoning outbreaks in man that are due to the salmonella group of organisms follow the consumption of food directly or indirectly associated with infection of some animal. The chief animal reservoirs of *Salmonella* are fowls, pigs and cattle. Fowls and pigs have been regarded as forming a more important source of human infection than cattle (Wilson & Miles, 1955). The number of different serotypes that have been isolated from cattle is less than the number isolated from fowls and pigs. There has, therefore, been a tendency to minimize the part played by cattle in the spread of salmonella infection to man.

Abattoir surveys in Yorkshire and South Wales (McDonagh & Smith, 1958; Harvey & Phillips, 1961) have shown a relatively close relationship between *S. typhi-murium* infection in animals and man over corresponding time periods; approximately 77 % of the typable strains isolated from human infections in South Wales belonged to phage-types found in the abattoir environment or in local farm animals. It would, therefore, be reasonable to assume that many salmonella incidents in man are caused by the consumption of meat or meat products derived from native animals.

As will be shown later, *S. typhi-murium* is the second most common type isolated from cattle, and it is also the major cause of human infections. The development of

* The Working Party included the following members of the Veterinary Laboratory Services of the Ministry of Agriculture, Fisheries and Food:

Mr D. W. Menzies, Weybridge (*Chairman*)
Mr D. R. Allen, Cardiff
Mr N. H. Brooksbank, Liverpool
Mr I. H. Fincham, Starcross
Mr H. I. Field, Weybridge
Dr E. A. Gibson, Norwich
Mr G. B. S. Heath, Penrith
Mr R. M. Loosmore, Reading
Mr W. B. V. Sinclair, Leeds
Mr W. J. Sojka, Weybridge
Mr J. A. J. Venn, Langford, Bristol

and the following members of the Public Health Laboratory Service:

Dr R. W. S. Harvey, Cardiff (*Secretary*)
Dr E. S. Anderson, Colindale
Dr J. A. Boycott, Taunton
Dr W. Chas. Cockburn, Colindale
Dr D. G. Davies, Carlisle
Dr L. M. Dowsett, Norwich
Dr N. S. Galbraith, Colindale
Dr B. C. Hobbs, Colindale
Dr G. B. Ludlam, Leeds
Dr J. McCoy, Hull
Dr B. Moore, Exeter
Dr P. M. Poole, Chester
Dr P. J. Wormald, Salisbury
Dr Joan Taylor, Colindale

Requests for reprints should be addressed to Dr R. W. S. Harvey, Public Health Laboratory, Institute of Preventive Medicine, The Parade, Cardiff.

a scheme for phage-typing of strains of *S. typhi-murium* (Felix & Callow, 1943; Callow, 1959), has allowed accurate comparisons to be made between human and animal infection. It was observed by Anderson (1960), that 97 % of animal strains of *S. typhi-murium* submitted for typing during a particular period of 1958, came from chickens and calves. The phage-type distribution in fowls was quite different from that in cattle, but when the groups were combined the distribution of common types had general similarities to that in human beings. This suggested that fowls and calves, or their products, might be the source of most human infections with *S. typhi-murium* in England and Wales. Other salmonellae also might originate from this source.

Table 1. *Areas served by veterinary investigation laboratories on the working party*

Veterinary investigation centre	Areas served	Veterinary investigation centre	Areas served
Bristol	Dorset Gloucestershire Somerset Wiltshire	Liverpool	Cheshire Lancashire
Cardiff	Carmarthenshire Glamorgan Monmouthshire Pembrokeshire	Norwich	Norfolk East Suffolk
Exeter (Starcross)	Cornwall Devon	Penrith	Cumberland Westmorland
Leeds	East Riding Yorkshire West Riding Yorkshire	Reading	Berkshire Buckinghamshire Oxfordshire Northamptonshire

In 1959, a joint working party of the Public Health Laboratory Service and the Veterinary Laboratory Services was set up to study salmonella infection in cattle and calves and in their feedingstuffs. The problem of the spread of salmonella infection from cattle to man was also investigated when opportunity offered. The areas served by the Veterinary Investigation Laboratories on the working party are shown in Table 1.

The husbandry and movement of cattle has a direct effect on the epidemiology of cattle salmonellosis, and a review of the situation is therefore given.

THE CATTLE POPULATION OF ENGLAND AND WALES

The total number of calves and cattle in England and Wales is approximately 8,800,000 (Agricultural Statistics, 1962).

A clear-cut division into beef and dairy cattle is impossible because many herds serve a dual purpose. Thus about three-quarters of home produced beef originates from dairy herds and consists either of 'cow beef' or, of greater importance, of beef produced from the bull calves and surplus heifer calves from dairy herds.

In March 1961 (Agricultural Statistics, 1962), there were about 3,850,000 cows and heifers in milk or in calf, of which 84 % formed part of the national dairy herd and 16 % formed part of the national beef herd. A preponderance of dairy cows is found, with few exceptions, in most areas of England and Wales.

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The cattle population includes some 2,200,000 bull calves and steers being reared for beef, and about 2,700,000 young females. The latter include both beef animals and dairy replacements.

The annual calf crop amounts to about 3,500,000 calves of which 500,000 form replacements for the national dairy herd, about 2,000,000 are reared for beef production and 1,000,000 are slaughtered as calves. The number of calves born monthly is roughly 300,000 but there is some seasonal variation.

The distribution and movement of dairy cattle

The counties with the largest number of dairy cows are, in order, Somerset, Devon, Cheshire, Lancashire, the West Riding of Yorkshire, Shropshire and Staffordshire, all of which have more than 100,000 head. In Wales the chief dairying counties are Carmarthenshire and Pembrokeshire with approximately 80,000 and 51,000 respectively.

In the past there has been much short-term movement of adult dairy cows as herd replacements, but movement of this kind has now decreased.

The distribution and movement of beef cattle

The distribution of *adult* beef cattle shows some overlapping with that of the national dairy herd, the counties with the highest populations being Northumberland, Devon, the Lindsey division of Lincolnshire, Herefordshire, Cornwall and Shropshire. All these counties have more than 20,000 beef cows. In Wales, Montgomery, Radnor and Brecon each have 15,000 to 16,000 head.

Concentrations of *young* cattle being reared and fattened for beef are found in the Midlands, Yorkshire and East Anglia.

In contrast to the limited degree of movement shown by dairy cattle, the movement of calves and store cattle is an outstanding feature of the beef industry. Until recently store cattle commonly changed hands several times before slaughter, but the present trend is to reduce the number of changes to one or two. The main streams of movement are as follows.

Calves and store cattle

Large numbers of surplus calves from the dairy herds move from the west and south-west into East Anglia, the East Midlands and some other eastern counties for rearing and feeding for beef.

Considerable numbers of calves are retained in the south-west and west for fattening in the valleys of Devon, Somerset and Cornwall. Calves that are bought privately, or by the better class of calf-dealer, may be taken direct to their new premises without passing through a market. Others are exposed for sale in one or more markets—each occasion providing opportunities for cross-infection, chilling and dietary abuse. Because of these risks direct sales between calf breeders and calf rearers are becoming more common.

Considerable numbers of weaned calves move each autumn from the uplands of southern Scotland and northern England, from Wales and from south-west England to the arable areas of the Midlands and East Anglia where they are fattened in yards to light weight beef over winter or finished on grass the following summer. Each spring, yearlings and older cattle are sent to the Midlands and Southern grazing areas, although the high price of these older stores is now tending to restrict this trade.

Imported fat and store cattle

In the decade 1951–60, live cattle imported into Great Britain averaged 604,000 annually, all from Northern Ireland and Eire except for about 0·1% from the Channel Islands and the Isle of Man. During this period the average number of live cattle imported annually from Northern Ireland was approximately 267,000 (fat cattle 177,000; store cattle 90,000) and from Eire approximately 336,000 (fat cattle 86,000; store cattle 250,000).

Whatever their origin, fat cattle move again when they are sold for beef. This generally involves exposure in a market followed by a journey—often of considerable length—to the slaughter point. These movements provide opportunities for cross-infection.

THE MEAT TRADE

Home killed meat

About 3,300,000 cattle and 1,000,000 calves are slaughtered annually in the United Kingdom. Of the cattle slaughtered, approximately 2,500,000 are beef or

Table 2. *Estimated beef and veal supplies in the United Kingdom* 1960

(Thousand tons)

Home produced or imported	Country	Beef fresh and salted	Chilled beef	Frozen beef quarters, sides, carcasses, and bones	Veal	Total supplies
Home produced	United Kingdom	800·6	—	—	19·3	819·9
Imports	Irish Republic	13·8	0·1	1·0	—	14·9
	Australia	—	1·7	61·8	1·1	64·6
	Bechuanaland	—	—	6·2	—	6·2
	New Zealand	—	1·5	17·3	1·8	20·6
	Rhodesia and Nyasaland	—	1·3	3·7	—	5·0
	Other Commonwealth countries	—	—	0·1	—	0·1
	Argentina	—	181·8	22·2	—	204·0
	Brazil	—	0·2	—	—	0·2
	Netherlands	—	—	—	2·6	2·6
	Uruguay	—	20·6	12·0	—	32·6
	United States	—	—	0·3	—	0·3
	Other foreign countries	—	1·1	1·9	—	3·0
Total		13·8	208·3	126·5	5·5	354·1

Total home produced	819·9 (70)
Total imports	354·1 (30)
Total supplies	1174·0 (on the bone 1125) (boneless 49)

Figures in parentheses are percentages as integers.

* Modified from Tables 25 and 26, *Meat* (1962). Commonwealth Economic Committee. London: H.M.S.O.

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dual purpose cattle or the progeny of dairy cows reared for beef, 500,000 are discarded dairy cows and rather more than 250,000 are imported as fat cattle ready for slaughter.

The calves slaughtered are almost entirely from dairy or dual purpose herds. The majority are killed within a few days after birth as 'bobby' calves; the remainder are slaughtered at about 3 months of age as veal.

Imported meat

Table 2 shows the countries of origin of our imports of beef and veal and compares these imports with our home-produced supplies.

Table 3. *Salmonella serotypes identified from bovine sources in the United Kingdom* 1956–61

Serotype	No. of cultures identified	Serotype	No. of cultures identified
S. abaetetuba	1	*S. llandoff*	1
S. agama	27	*S. london*	1
S. anatum	5	*S. manhattan*	3
S. bareilly	1	*S. menston*	3
S. binza	1	*S. newport*	2
S. bovis morbificans	2	*S. niloese*	2
S. braenderup	2	*S. oranienburg*	3
S. brancaster	4	*S. poona*	1
S. bredeney	4	*S. pullorum*	6
S. bury	1	*S. reading*	6
S. california	1	*S. richmond*	1
S. cholerae-suis	2	*S. ruiru*	1
S. cubana	1	*S. saint-paul*	7
S. derby	1	*S. senftenberg*	2
S. dublin	1375	*S. simsbury*	1
S. emek	7	*S. stanley*	1
S. enteritidis	21	*S. stanleyville*	1
S. gallinarum	2	*S. tennessee*	6
S. give	4	*S. thompson*	9
S. heidelberg	29	*S. typhi-murium*	560
S. kinshasa	1	*S. vejle*	5
S. liverpool	2		

Of the 2116 cultures listed above, 276 were derived from the Salmonella Reference Laboratory, Colindale, and 1840 were derived from the Weybridge Laboratory, having been isolated either there, or at Veterinary Investigation Centres. Of these 1840 cultures, 1147 (62 %) originated from calves and 693 (38 %) from older cattle.

Salmonella serotypes isolated from bovine sources

This information was derived from the records of the Central Veterinary Laboratory, Weybridge, and the Salmonella Reference Laboratory of the Public Health Laboratory Service, Colindale. The period covered is 1956–61. The results are given in Table 3.

Certain serotypes are relatively host specific; *S. cholerae-suis*, which is common in pigs, was isolated only twice from bovine sources, and *S. gallinarum* and *S.*

pullorum, common in fowls, only eight times. The specificity of *S. dublin* for bovine animals is shown by the great number of isolations compared with other serotypes. *S. typhi-murium* is not host-specific, but was the second most common serotype, 560 having been isolated in a total of 2116. Because of the lack of host-specificity of *S. typhi-murium*, a wide search may be necessary for the source of infection. The presence of certain other serotypes (Walker, 1957; Report, 1959*a*; Report 1961; Harvey & Price, 1962), suggests that animal feedingstuffs may be implicated.

The dominance of *S. dublin* and *S. typhi-murium* in Table 3 is noteworthy. *S. dublin*, although the commonest cause of salmonellosis in cattle in England and Wales, plays little part in human infection. *S. typhi-murium*, in contrast, causes by far the greatest number of infections in man. It was, for example, responsible for 73% of the incidents of salmonella infection in man in the period 1954–59 (Report, 1960).

Table 4. *Seasonal incidence of salmonella infection in calves and older cattle*

	Calves				Older cattle			
Month	*S. dublin*	*S. typhi-murium*	Other sero-types	Total	*S. dublin*	*S. typhi-murium*	Other sero-types	Total
Jan.	43 (6)	31 (9)	4 (11)	78 (7)	18 (3)	22 (15)	1 (5)	41 (6)
Feb.	55 (7)	21 (6)	0	76 (7)	11 (2)	8 (6)	0	19 (3)
Mar.	52 (7)	24 (7)	5 (14)	81 (7)	31 (6)	14 (10)	1 (5)	46 (7)
Apr.	41 (6)	11 (3)	2 (5)	54 (5)	25 (5)	1 (1)	2 (9)	28 (4)
May	40 (5)	9 (2)	2 (5)	51 (4)	38 (7)	5 (3)	4 (18)	47 (7)
June	36 (5)	12 (3)	1 (3)	49 (4)	47 (9)	2 (1)	1 (5)	50 (7)
July	37 (5)	18 (5)	0	55 (5)	56 (11)	11 (8)	1 (5)	68 (10)
Aug.	42 (6)	18 (5)	3 (8)	63 (6)	54 (10)	9 (6)	0	63 (9)
Sept.	65 (9)	43 (12)	7 (19)	115 (10)	62 (12)	13 (9)	2 (9)	77 (11)
Oct.	113 (15)	60 (17)	4 (11)	177 (15)	59 (11)	27 (19)	3 (14)	89 (13)
Nov.	119 (16)	62 (17)	4 (11)	185 (16)	67 (13)	12 (8)	4 (18)	83 (12)
Dec.	103 (14)	52 (14)	5 (14)	160 (14)	52 (10)	20 (14)	3 (14)	75 (11)
Total	746	361	37	1144	520	144	22	686

Figures in parentheses are percentages as integers.

In calves the incidence of both *S. dublin* and *S. typhi-murium* infection is highest in the autumn and winter. In older cattle, *S. dublin* infection shows a similar seasonal incidence, but the pattern of *S. typhi-murium* infection is not quite so clear cut. Rearrangement of the incidence on a quarterly basis, however, does show a more definite seasonal variation (see Table 5).

SEASONAL INCIDENCE OF SALMONELLA INFECTION IN CATTLE AND CALVES

The seasonal incidence derived from the records of the Central Veterinary Laboratory, Weybridge, is given in Table 4. The figures were collected over the period 1958–61, and refer mainly to incidents. An incident comprises either a sporadic case, or a group of epidemiologically related cases.

The pattern of incidence in Table 4 is a general one for England and Wales as a whole and may obscure local variations.

Table 5 relates the incidence of calvings to the incidence of salmonella infection in calves and cattle. In this table the average number of calves born during the period 1958–61 in different quarters of the agricultural year is shown. It has not been possible to obtain figures for each separate month, or to arrange the data in terms of a calendar year. The seasonal incidence of infection in Table 4 has, therefore, been re-arranged in terms of the quarters of the agricultural year.

In cattle and in calves, the peak period of infection is September–November for *S. dublin* and *S. typhi-murium*. In cattle *S. dublin* is low in December–February, but *S. typhi-murium* infection is high in the same period. A similar raised incidence in December–February is seen in *S. typhi-murium* calf infections. The September–November quarter is that during which the maximum number of calvings takes place. It is probable that a high incidence of calvings in certain quarters is related to an increased spread of salmonella infection.

Table 5. *Relation of incidence of calvings to incidence of bovine salmonella infection*

Agricultural year quarter	Average no. of calvings 1958–61	Incidents *S. dublin*		Incidents *S. typhi-murium*		Incidents All serotypes	
		Calves	Older cattle	Calves	Older cattle	Calves	Older cattle
Dec.–Feb.	823,000 (26)	201 (27)	81 (16)	104 (29)	50 (35)	314 (27)	135 (20)
Mar.–May	795,000 (25)	133 (18)	94 (18)	44 (12)	20 (14)	186 (16)	121 (18)
June–Aug.	580,000 (18)	115 (15)	157 (30)	48 (13)	22 (15)	167 (14)	181 (26)
Sept.–Nov.	976,000 (31)	297 (40)	188 (36)	165 (46)	52 (36)	477 (42)	249 (36)

Figures in parentheses are percentages as integers.

MATERIALS AND METHODS

Materials examined

(*a*) Faeces from cattle, calves and other animals.
(*b*) Faecal pats from grassland on infected farms.
(*c*) Swabs from walls of loose-boxes on infected farms.
(*d*) Necropsy specimens from cattle, calves and other animals.
(*e*) Milk.
(*e*) Animal feedingstuffs.
(*g*) Moore's swabs (Moore, 1948) from drains of farms, abattoirs and retail shops.
(*h*) Faeces from human beings.

Bacteriological methods

Little alteration was made in the technique normally used by both services for salmonella isolation. In general, selenite F broth or tetrathionate broth was used as enrichment medium. Deoxycholate–citrate agar was employed as the main plating medium. Some laboratories also used Wilson and Blair's medium and brilliant green neutral red taurocholate lactose agar. Enrichment media were incubated at 37° C. and were subcultured at 24 hr. Plating media were incubated at 37° C. and were examined after 24–48 hr. incubation.

There were modifications of this general routine depending on personal preference.

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RESULTS

The results of the investigations of the laboratories constituting the working party are given in a general fashion in Tables 6–8.

Table 6 shows the three main classes of serotype isolated from bovine salmonella incidents. The total cattle population in each area is included in this table and the percentage of cattle under one year old. *S. dublin* was isolated from 68 % of the incidents, *S. typhi-murium* from 27 % and other serotypes from 6 %.

Table 6. *Bovine salmonella incidents at veterinary investigation centres* 1959–61

Veterinary investigation centre	Total cattle in area served	Percentage of total cattle under 1 year	Incidents			
			S. dublin	*S. typhi-murium*	Other serotypes	Total
Bristol	1,008,771	19	56 (59)	34 (36)	5 (5)	95
Cardiff	478,583	22	178 (89)	13 (7)	9 (5)	200
Exeter*	804,401	23	30 (68)	11 (25)	3 (7)	44
Leeds	525,220	26	73 (72)	23 (23)	5 (5)	101
Liverpool	579,659	18	37 (73)	7 (14)	7 (14)	51
Norwich	274,258	30	125 (57)	82 (38)	11 (5)	218
Penrith	427,940	25	3 (33)	6 (67)	0	9
Reading	473,069	23	78 (55)	55 (39)	8 (6)	141
Total			580 (68)	231 (27)	48 (6)	859

Figures in parentheses are percentages as integers.
* Starcross.

Table 7 gives the distribution of phage-types of *S. typhi-murium* isolated from 155 of the 231 incidents recorded in Table 6. Untypable strains have been excluded. The total number of phage-types isolated was 28. The types most frequently encountered were 1 var. 5 (U 9) and 1a (2) which together represent 42 % of the isolations in the period studied. Isolations of *S. typhi-murium* from animal feeding-stuffs are shown and the commonest phage-types found in man are marked with an asterisk. The isolations from feedingstuffs were made from material distributed during 1959–61, although a few of the actual isolations were made in 1962.

Ten incidents of bovine infection were studied in detail by members of the working party in order to determine if spread had occurred. Table 8 shows the local and general distribution of infection in these incidents.

Salmonella infection and calf movements

Calf infection on a dealer's premises

Calves entering a dealer's premises in Norfolk were surveyed by the Norwich Veterinary Investigation Centre. The calves were purchased in the West Country. Most were bought at markets, but some were collected direct from their home

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farms. They were brought to Norfolk in the dealer's own lorries, and rectal swabs were taken from them within an hour or so of their arrival at his premises.

By the end of December 1961, eighty-three batches of calves comprising 4258 animals had been examined. Salmonellae were isolated from twenty (0·5 %) of the calves. Of the eighty-three batches, eleven (13 %) were infected. Five sero-types were found. The results are given in Table 9.

Table 7. *Bovine* Salmonella typhi-murium *incidents at veterinary investigation centres* 1959–61, *untypable strains excluded*

Phage-type	A	B	C	D	E	F	G	H	Total	Animal feeding stuff isolations 1959–61
1 (1)*	—	1	1	—	—	8	—	1	11 (7·1)	—
1 var. 2 (U 41)	—	—	—	—	—	3	—	1	4 (2·6)	—
1 var. 5 (U 9)*	7	1	—	1	—	22	1	7	39 (25·2)	—
1a (2)*	8	—	—	1	—	12	—	5	26 (16·8)	5
1a (U 57)*	—	1	1	1	5	2	2	—	12 (7·7)	2
1a var. 1 (3an)*	—	—	—	—	—	6	—	3	9 (5·8)	—
1a var. 2 (3aer)	—	1	2	—	—	—	—	1	4 (2·6)	—
1b (4)	—	—	—	—	—	—	—	—	—	1
1b (4a)	—	—	—	—	—	—	—	—	—	1
2 (9)	—	—	1	—	—	—	—	—	1 (0·6)	—
2 (10)	—	—	—	—	—	—	—	1	1 (0·6)	1
2 (12)*	2	2	—	—	—	10	—	1	15 (9·7)	2
2 (12a)*	—	—	—	—	—	—	—	—	—	1
2a (13)	—	—	1	—	—	—	—	—	1 (0·6)	—
2b (17)	—	—	—	1	—	—	—	—	1 (0·6	—
2b (18)	1	—	—	—	—	—	—	—	1 (0·6)	—
2b (29)	—	—	—	1	1	—	—	—	2 (1·3)	—
2c (14)*	—	—	—	—	—	3	—	5	8 (5·2)	—
2c (15a)	—	—	—	—	—	1	—	—	1 (0·6)	—
2d (20a)	—	1	—	—	—	2	—	1	4 (2·6)	—
4 (8)*	—	—	—	—	—	2	—	—	2 (1·3)	—
22	—	—	—	—	—	—	—	—	—	1
28	1	—	—	—	—	—	—	—	1 (0·6)	—
32	—	—	1	1	—	—	—	—	2 (1·3)	1
U 15	—	—	—	—	—	1	—	—	1 (0·6)	—
U 20	—	—	—	—	—	—	—	—	—	1
U 29	—	—	—	—	—	1	—	—	1 (0·6)	—
U 38	—	1	—	—	—	—	—	—	1 (0·6)	—
U 39	1	—	—	—	—	—	—	—	1 (0·6)	—
U 59	—	—	—	—	—	2	—	—	2 (1·3)	—
U 72	1	—	—	—	—	—	—	—	1 (0·6)	—
U 107	2	—	—	—	—	—	—	—	2 (1·3)	—
U 117	1	—	—	—	—	—	—	—	1 (0·6)	—

A = Bristol E = Liverpool
B = Cardiff F = Norwich
C = Exeter (Starcross) G = Penrith
D = Leeds H = Reading

Phage-typing column. Figures in parentheses refer to the new typing scheme (Callow, 1959). All type designations preceded by letter U are provisional.

Total column. Figures in parentheses are percentages.

* Common phage-types in man. Phage-type 2c (14) usually associated with fowls. Phage-type 4 (8) frequently associated with ducks.

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Most owners treated the infected calves when told the result of the examination. It was noted that at this stage none of the calves showed signs of clinical salmonellosis.

This survey confirmed beyond doubt that dealers' calves were introducing a

Table 8. *Distribution of salmonella infection in ten incidents*

Incident and description	Infection in man	Infection of other animals and animal feedingstuffs, etc.
1. *S. typhi-murium* 1a (2). Calf infection	2 infections in children	Infection in contact calves and older store cattle
2. *S. typhi-murium* 1a (2). and *S. dublin*. Calf infection	1 infection in child	*S. dublin* infection of dog
3. *S. typhi-murium* 1a (U 57). Calf infection	2 infections on farm; 6 infections in village receiving milk from farm	
4. *S. dublin*. Calf infection		*S. dublin* infection of dog
5. *S. typhi-murium* 1 (1). Bovine infection	1 infection of milk handler on farm	
*6. *S. typhi-murium* 2 (12). Bovine infection	122 infections in county	*S. typhi-murium* 2 (12) isolated by Moore's swabs from 2 abattoirs. 1 pig and 1 rat at abattoir infected. Origin of pig traced to local farm. Same phage-type isolated from 13 butchers' shops by drain swabs
7. *S. typhi-murium* 1 var. 5 (U 9). Calf infection	3/8 infections on farm 1 infection from direct contact with calves	
8. *S. typhi-murium* 1a var. 2 (3aer). Calf infection	Infection of farm workers or their families	Symptomless infection of chickens
*9. *S. heidelberg*. Udder of cow and milk infected	3/3 symptomless infections of farm workers. 74 infections in community from milk	*S. heidelberg* isolated from rectal swab of calf fed on milk from herd. *S. heidelberg* was also isolated from English meat and bone meal samples at factory supplying cattle cake to farm. *S. heidelberg* was *not* isolated from the cattle cake
10. *S. typhi-murium* 2 (12). Bovine infection	1 infection on farm	Geese and ducks on farm infected. Other farms receiving turkey poults from original farm experienced outbreaks due to *S. typhi-murium* 2 (12). Same type was isolated from 2/2 opened bags of poultry food fed to affected poults on original farm

* For full description of these incidents see (incident 6) Harvey, Price, Bate & Allen (1963); (incident 9) Knox *et al.* (1963), Davies & Venn (1962).

variety of salmonella serotypes into East Anglia. As far as could be ascertained, each infected calf came from a different farm.

Investigations were made by the Bristol Veterinary Investigation Centre on the home farms of three of the calves, with negative results.

Table 9. *Serotypes isolated in a survey of a dealer's calves*

Serotype	No. of strains isolated
S. agama	8
S. cubana	1
S. dublin	4
S. saint-paul	1
S. typhi-murium, 1 var. 2 (U 41)	3
S. typhi-murium, 1a (2)	1
S. typhi-murium, U 29	1
S. typhi-murium, untypable	1

Table 10. *Farm outbreaks caused by* S. typhi-murium *in East Anglia*

Outbreak no.	Phage-type
1	1a (2)
2	1a (2)
3	1a (2)
4	1a (2)
5	1a (2)
	1 var. 5 (U 9)
6	1 (1)
7	4 (8)

Farm outbreaks, East Anglia

A series of outbreaks in calves was also studied by the Norwich Veterinary Investigation Centre. In this investigation the starting point was the occurrence of an outbreak on a farm. Seven outbreaks were investigated. The infecting serotype was *S. typhi-murium*. The phage-types isolated are given in Table 10.

In outbreaks 1–5, the clinically affected batches of calves had all been purchased from a dealer near Wrexham, Denbighshire. Their common origin, the common phage-types of the strains, and the fact that some of the affected batches had been delivered direct to the purchasers, without passing through local markets, showed convincingly that the infection had been brought into East Anglia with the calves. It seems probable that cross-infection occurred either at the dealer's premises or during transit.

Farm outbreaks, East Yorkshire

Similar observations in the East Yorkshire area (Leeds Veterinary Investigation Centre; Hull Public Health Laboratory) were made during 1959 and 1960. Here it was found that 18/19 incidents of salmonella infection in calves followed within 2 weeks of the arrival of calves on the farms. These calves were purchased locally and from Lancashire, Hertfordshire, Cheshire and South Wales. It is of interest

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that the calves responsible for two incidents due to *S. typhi-murium* 1a (U57) came from South Wales. This phage-type was responsible for some bovine infection in Glamorgan in 1958.

Contact with other animals in transit

Contact with other farm animals in the course of calf movement may be responsible for some infection. An outbreak caused by *S. heidelberg* occurred on a farm receiving calves from the Chichester area. These calves arrived at irregular intervals over a period of 3 months from one dealer. During investigation of the source of the outbreak, *S. heidelberg* was isolated from pig faeces collected at the market through which these calves passed. Pigs were taken to the market in lorries. Calves were taken from the market in the same lorries and cross infection may have taken place in these vehicles.

Persistence of infection on farm premises

The Norwich Veterinary Investigation Centre demonstrated the survival of *S. dublin* for up to 36 weeks in pats of infected faeces on rough grassland, and for at least 11 months on the walls of a loose-box soiled by a carrier cow. A group of young calves housed in the loose-box at the end of this period developed infection with *S. dublin* within 2–4 days.

It is known that salmonellae can exist a very long time in faeces and on pasture. For instance, Henning (1939) showed *S. dublin* to survive for at least 1069 days in artificially dried bovine faeces. Josland (1951) in Australia demonstrated that *S. typhi-murium* could be recovered from shaded pastures over periods ranging from 14 to 22 weeks. Watts & Wall (1952), using earth contaminated with infected sheep faeces, found that samples were still positive for *S. typhi-murium* after 200 days. Mair & Ross (1960), showed the survival of *S. typhi-murium* in garden soil in this country for at least 251 days.

Table 11. *Salmonellae in animal feedingstuffs in relation to bovine salmonellosis*

	Raw materials	Protein conc. meals	Meals/ mashes	Pelleted foods	Bovine sources
Total samples	2801	893	1955	1459	—
Samples positive	587	94	64	8	2116
S. dublin	2 (0·3)	0	0	0	1375 (64·9)
S. typhi-murium	37 (6·3)	5 (5·3)	0	1 (12·5)	560 (26·5)
Other serotypes	548 (93·4)	89 (94·7)	64 (100)	7 (87·5)	181 (8·6)

Figures in parentheses are percentages of number of positive samples.

Persistence of infection in a locality

The development of phage-typing of *S. typhi-murium* has enabled this to be observed more effectively than hitherto.

In Monmouthshire, incidents occurred due to *S. typhi-murium*, phage-type

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2 (12), on farms in the same area in 1960 and 1961. Pigs were involved in the first incident and a heifer and poultry in the second. Persistence of infection in a locality has also been recorded by Anderson, Galbraith & Taylor (1961). The infections observed were caused by *S. typhi-murium*, phage-type 20a.

DISCUSSION

Table 11 presents the relationship between salmonellae isolated from animal feedingstuffs and salmonellae isolated from bovine sources. Both home produced and imported animal feedingstuffs are included. This table is derived from data in Table 3 and from sources already published (Walker, 1957; Report, 1959*a*; Report, 1961; Harvey & Price, 1962). The data as presented in Table 11 are not in the form in which they were originally published.

The contrast between serotypes commonly found in feedingstuffs and those found in bovine infections is marked. The most important types found in bovine salmonellosis are *S. dublin* and *S. typhi-murium*. These two serotypes are rarely isolated from animal feedingstuffs. Dutch and American workers have made somewhat similar observations in their own countries (van der Schaaf, van Zijl & Haagens, 1962; Edwards, 1962). This evidence does not suggest that animal feedingstuffs are an important cause of bovine infection due to *S. dublin* and *S. typhi-murium*.

When, however, the phage-types of *S. typhi-murium* found in animal feedingstuffs and in bovines are compared, some similarity of type emerges. This may be *fortuitous and may indicate that materials derived from native animals have been* used for the manufacture of the meat and bone meal present in these feedingstuffs. Seven out of the ten phage-types listed in the last column of Table 7 have been found in bovine infection in the United Kingdom (Anderson, E. S., Personal Communication). These phage-types are 1a (2); 1a (U57); 2 (10); 2 (12); 2 (12a); 22; and 32, although types 2 (12a) and 22 were not encountered in cattle during the present survey period, 1959–61.

In Table 7, nine phage-types are marked with an asterisk as being frequent causes of human disease (Anderson, E. S., Personal Communication). In 1961, these types were together responsible for 70% of human infection with *S. typhi-murium* in England and Wales. Their order of frequency in that year was as follows:

2c (14) 1a (2) 1 var. 5 (U9) 1a var. 1 (3an) 2 (12a)
1 (1) 4 (8) 1a (U57) 2 (12)

It is pointed out in a footnote to Table 7 that types 2c (14) and 4 (8) are commonly associated with fowls and ducks respectively, and these avian sources are probably responsible for a considerable proportion of infections caused by these two types. In 1961, types 2c (14) and 4 (8) caused jointly some 23% of human infections.

During 1959–61, the majority of animal strains of type 2 (12a) were isolated from pigs, although more recent work has shown it to be commonest in bovines. The remaining six phage-types, 1a (2), 1 var. 5 (U9), 1a var. 1 (3an), 1 (1), 1a (U57) and 2 (12), are primarily of bovine origin. These types were responsible, in 1961, for 41% of human infections, a high figure for a single animal source. This is all the more striking when it is pointed out that the total number of phage-types of *S. typhi-murium* isolated in 1961 was about 80. All the above information is derived from Anderson (in the press).

Finally, when animal feedingstuff isolations of *S. typhi-murium* are compared simultaneously with bovine and human isolations in Table 7, it is noted that phage-types 1a (2), 1a (U57) and 2 (12) are commonly found both in cattle and in man.

Two local comparisons of cattle and human strains of *S. typhi-murium* were also made. In Yorkshire, before 1959, phage-type 1 var. 5 (U9) had not been isolated. In 1959, however, this type was found both in cattle and in man and since then has become the dominant type in human infections. In South Wales, comparison of the phage-types of *S. typhi-murium* isolated from local animals and from local infections in man has been routine practice since 1958 (Harvey & Phillips, 1961; Harvey *et al.* 1963). From 1958 to 1961, phage-types 1a var. 1 (3an), 1a (U57), 1 (1) and 2 (12) have been isolated from local cattle in this sequence. The same phage-types have been isolated over the same period and *in the same sequence* from human infections in Glamorgan. The human infections invariably occurred within a few weeks of the bovine isolations. The association is naturally emphasized by the coincidence in location and timing.

Further work is clearly required into the epidemiological significance of animal feeds as a source of salmonellosis. Although, as yet, there is little evidence to incriminate them as a major cause of bovine salmonellosis, their importance should not be entirely disregarded as a potential starting point of a chain of infection with man as the ultimate host (Report, 1961; Niven, 1962).

The spread of bovine salmonellosis, particularly infections caused by *S. dublin* and *S. typhi-murium*, may be attributed largely to the movement of cattle and calves. The movement of calves is probably the most important factor.

The seasonal incidence of infection is shown in Tables 4 and 5. It is evident that with both *S. dublin* and *S. typhi-murium* the peak incidence occurs in the last quarter of the year. It is suggested that the concentration of calf infections in this quarter is connected with the sale and movement of calves through markets and dealers' premises to calf rearing areas and abattoirs and with overcrowding of a susceptible population.

The conditions under which calves travel encourage the spread of disease, as animals are herded together in temporary accommodation and lorries on their way to their ultimate destination. Stress factors such as travel weariness, dietary changes and chilling on the journey are also thought to increase susceptibility to infection.

The seasonal incidence of *S. typhi-murium* infection in bovines is different from that in man, as warm atmospheric temperatures leading to bacterial multiplication in food is a major factor in determining the human peak incidence in the third quarter of the year. This factor is of little importance in bovine infection.

In Table 6 the frequency of infection due to *S. dublin* and *S. typhi-murium* is apparent, as is the high relative incidence of *S. dublin* infection in South Wales. This is in keeping with previous surveys (Field, 1948, 1949*a*, *b*). Gibson (1961), commented on the fact that *S. dublin* is endemic in adult and yearling cattle in

South Wales whereas it is rarely found in adult cattle in East Anglia. There is a marked contrast between these two regions, because South Wales is a breeding area in which the effect of calf movement is little felt, and East Anglia is a rearing area where the movement of calves is probably of major importance. The distinction between breeding and rearing areas is not quite so clear cut in the other regions.

Table 8, which gives details of the spread of salmonella infection to different animal species in ten of the incidents studied by members of the Working Party, places the limited problem of bovine salmonellosis in a wider context. The discovery, in two of the episodes in Table 8, that poultry were infected is in keeping with the observations of previous authors (Stenert, 1938; Sellers & Sinclair, 1953), who found poultry infections in mixed farms where cattle salmonellosis was discovered. This finding is possibly of importance. Müller (1957) stated that in Denmark *S. typhi-murium* infection of calves is often traced to poultry. It is possible that some bovine salmonellosis in this country may originate from the same source.

The farm dogs from which salmonellae were isolated in Incidents 2 and 4 (Table 8), were probably examples of secondary infection. Dogs may play some part in the persistence of infection on a farm or in the transfer of salmonellae to young children in close contact with them.

Cross-infection of calves during transport has been discussed. The observations on the effect of moving young animals from breeding to rearing areas also suggest strongly that infection is conveyed to the rearing areas by this means. Gibson (1961) considered that *S. dublin* was introduced into East Anglia by calves bought from areas such as those in South Wales (Field, 1948, 1949*a*, *b*), where the serotype causes endemic infection in cattle. It would appear that the transfer of calves from Wales has introduced particular phage-types of *S. typhi-murium* into Yorkshire and East Anglia.

The length of time during which infection persists in a herd after termination of an outbreak of clinical disease depends on a number of factors including the following:

(*a*) The duration of the active carrier state in recovered clinical cases and in symptomless excreters.

(*b*) The establishment of infection in other animals in contact with the infected cattle.

(*c*) The survival of organisms shed by infected animals.

Adult and yearling cattle recovering from clinical salmonellosis due to *S. dublin* usually excrete the organisms constantly in the faeces for years, possibly for life. Subclinical infection can also result in an active carrier state of similar duration. The term 'active carrier' denotes an apparently healthy animal which excretes salmonellae in its faeces; a 'latent carrier' is an animal from whose organs salmonellae can be isolated although they are not found in the faeces during a limited number of examinations. It is thought that various stress factors, such as intercurrent disease, can cause latent carriers to become active carriers, or to develop clinical signs of salmonellosis. The carrier state that occurs in adult cattle

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after infection with *S. typhi-murium* probably does not last as long as that induced by *S. dublin* (Report, 1959*b*).

In contrast to what occurs in adult cattle, calves that recover clinically from either *S. dublin* or *S. typhi-murium* infection almost invariably cease to excrete the organism, although it is possible that latent carriage may persist in some of these animals (Gibson, 1958). Exceptionally, active carriage may continue (Field, 1948).

As adult cattle may be active carriers of *S. dublin* for long periods and may give rise to gross contamination of pastures and buildings, the question of the disease establishing itself in other domestic or wild animals would seem to be of secondary importance in maintaining infection. Infection of farm rats (Field, 1948; Gibson, 1958, 1961) and sheep (Shearer, 1957; Watson, 1960), may be considered as possible causes of prolonging *S. dublin* incidents on a farm, but observations on farm rats in contact with infected livestock do not suggest that rodents form permanent reservoirs of *S. dublin*. Cross-infection of other animal species seems to be more important with *S. typhi-murium* because of the wide host range of this serotype compared with *S. dublin*.

Table 12. *Holding time in abattoir lairages in England and Wales*

Maximum holding time (days)	Calves	Older Cattle
1	117	106
2	10	47
3	2	31
4	4	24
5	0	8
6	0	6
7	0	15
Over 7	0	4

McDonagh & Smith (1958) produced evidence to show that the shortening of the holding time in Bradford abattoir controlled cross-infection in animals and was followed by a reduction in human salmonellosis in the area. The importance of cross-infection in lairages has also been demonstrated by Galton, Smith, McElrath & Hardy (1954) and Anderson, Galbraith & Taylor (1961).

Information on the range of holding times in a series of abattoirs was collected by members of the Working Party. This information is given in Table 12. It is obvious that the range is wide and that holding times could profitably be shortened by extension of legislation.

On farms, cross-infection can be reduced by preventing indiscriminate intermingling of cattle and other animals (Dolman, 1957).

Conclusions

When we consider the control of salmonellosis, many difficulties are encountered. Several lines of attack on the problem do exist, that on the animal-to-animal cycle probably being the most important (Dolman, 1957; Newell, 1959). Methods of practical control of infection can be classified under three main headings:

(1) *Prevention of infection of cattle on farms*

(*a*) The freeing of animal feedingstuffs from salmonellae.

Although such materials are apparently unimportant in causing *S. dublin* infection, they carry other salmonella serotypes which may be responsible through cattle for human disease. Since Report (1961) appeared the contamination of animal feedingstuffs with salmonellae has been greatly reduced by selection of raw materials. Bone meal is not used by compounders as a source of minerals in animal foods on account of the risk of its containing anthrax spores, and steamed bone flour has been, to a great extent, replaced by purely inorganic phosphates, which are free from micro-organisms (McCoy, J., Personal Communication). The identification of Angola sun-dried fish meal as the most heavily contaminated raw material of animal foods led to its disappearance. The introduction of new and improved processing plants for the production of meat meal and meat and bone meal from native animal wastes has reduced the salmonella content of materials to probably the irreducible minimum. In addition to the reduction in contamination of raw materials, the process of pelleting is known to diminish 10-fold the salmonella content of meals and mashes produced from contaminated raw materials. It must be appreciated that even the sterilization of all animal foods used in the United Kingdom could not prevent infection of man from the serotypes of salmonellae established in native flocks and herds. These are responsible for the majority of human infections.

(*b*) The maintenance of a high standard of cleanliness in farm buildings.

(*c*) It has been shown that the purchase of infected calves from other farms and markets is important in the introduction of salmonellosis into clean herds. It is difficult to see how this source can be controlled.

(2) *Prevention of spread of infection from animal to animal in transit*

(*a*) Implementation of the recently introduced Statutory Instrument (S.I. 1963) requiring improved conditions of transport for young calves.

(*b*) Control of housing of animals during transport. Special attention should be paid to calf housing with the object of reducing stress factors.

(*c*) Encouragement of direct sales to eliminate intermediate housing.

(3) *Prevention of spread from animals to man*

(*a*) Reduction of holding time for live animals en route for the abattoir.

(*b*) Improvement of abattoir hygiene in order to avoid contamination of flesh by infected material such as faeces.

(*c*) Improved hygiene during transport of carcasses from abattoirs.

(*d*) Improvement of hygiene in butchers' shops in order to minimize cross-contamination of meat.

(*e*) Increased use of refrigeration in shops and houses in order to prevent multiplication of salmonellae in the final products.

SUMMARY

1. The incidence of salmonellosis in cattle in England and Wales has been investigated.

2. *S. dublin* and *S. typhi-murium* were much the commonest serotypes encountered.

3. The frequency of both serotypes was highest in the last quarter of the year, which is the period of maximum calvings. The high incidence of calf infection in this quarter is probably related to calf sales and movement.

4. In the previous investigations (Reports, 1959*a*, 1961), these serotypes were isolated only infrequently from the raw materials of animal feedingstuffs and from complete animal foods.

5. The distribution of phage-types of *S. typhi-murium* in cattle was compared with that in man and in animal feedingstuffs. Six phage-types were common both in cattle and in man. These types were: 1a (2), 1 var. 5 (U9), 1a var. 1 (3an), 1 (1), 1a (U57) and 2 (12). Three of the types found in feedingstuffs were common in both human and bovine infections. These types were: 1a (2), 1a (U57) and 2 (12).

6. In a study of ten incidents of salmonellosis in cattle, it was shown that the same phage-type or serotype was commonly found in man in other farm animals and occasionally in feedingstuffs.

7. It is clear that salmonellosis is spread into different regions of the country by calf movement.

8. The importance is endorsed of conditions of travel and lairage, and of the holding time at abattoirs, in the promotion of cross-infection with salmonellae.

9. Measures are outlined for the reduction of salmonellosis in cattle and of its transfer to man.

REFERENCES

Agricultural Statistics (1962). *Agricultural Statistics* 1960/1961 *England and Wales.* Min. of Agric. Fish and Food. London: H.M. Stat. Off.

Anderson, E. S. (1960). Special methods used in the laboratory for the investigation of outbreaks of salmonella food poisoning. *Roy. Soc. Hlth J.* **80**, 260.

Anderson, E. S., Galbraith, N. S. & Taylor, C. E. D. (1961). An outbreak of human infection due to *Salmonella typhi-murium*, phage-type 20a, associated with infection in calves. *Lancet*, i, 854.

Callow, B. R. (1959). A new phage-typing scheme for *Salmonella typhi-murium*. *J. Hyg., Camb.*, **57**, 346.

Commonwealth Economic Committee (1962). *Meat.* London: H.M. Stat. Off.

Davies, E. T. & Venn, J. A. J. (1962). The detection of a bovine carrier of *Salmonella heidelberg*. *J. Hyg., Camb.*, **60**, 495.

Dolman, C. E. (1957). The epidemiology of meat-borne diseases. In 'Meat Hygiene'. *World Hlth Org. Monogr. Ser.* no. 33.

Edwards, P. R. (1962). Summary—salmonella symposium. *Proc. U.S. live Stk sanit. Ass.* **65**, 475.

Felix, A. & Callow, B. R. (1943). Typing of paratyphoid B bacilli by means of Vi bacteriophage. *Brit med. J.* ii, 127.

Field, H. I. (1948). A survey of bovine salmonellosis in Mid and West Wales. *Vet. J.* **104,** 251, 294, 323.

Field, H. I. (1949*a*). Salmonella infection in cattle. *Vet. Rec.* **61,** 109.

Field, H. I. (1949*b*). The examination of bile samples as a means of assessing the incidence of salmonella infection in cattle. *Vet. Rec.* **61,** 275.

GALTON, M. M., SMITH, W. V., MCELRATH, H. B. & HARDY, A. V. (1954). Salmonella in swine, cattle and the environment of abattoirs. *J. infect. Dis.* **95**, 236.

GIBSON, E. A. (1958). Ph.D. Thesis, London.

GIBSON, E. A. (1961). Salmonellosis in calves. *Vet. Rec.* **73**, 1, 284.

HARVEY, R. W. S. & PHILLIPS, W. P. (1961). An environmental survey of bakehouses and abattoirs, for salmonellae. *J. Hyg., Camb.*, **59**, 93.

HARVEY, R. W. S. & PRICE, T. H. (1962). Salmonella serotypes and Arizona paracolons isolated from Indian crushed bone. *Mon. Bull. Minist. Hlth Lab. Serv.* **21**, 54.

HARVEY, R. W. S., PRICE, T. H., BATE, W. & ALLEN, D. R. (1963). An outbreak of food poisoning caused by *Salmonella typhi-murium*, phage-type 12, probably spread by infected meat. *J. Hyg., Camb.*, **61**, 419.

HENNING, M. W. (1939). The antigenic structure of salmonellas obtained from domestic animals and birds in South Africa. *Onderstepoort, J. vet. Sci.* **13**, 79.

JOSLAND, S. W. (1951). Survival of *Salmonella typhi-murium* on various substances under natural conditions. *Aust. vet. J.* **27**, 264.

KNOX, W. A., GALBRAITH, N. S., LEWIS, M. J., HICKIE, G. C. & JOHNSTON, H. H. (1963). A milk-borne outbreak of food poisoning due to *Salmonella heidelberg*. *J. Hyg., Camb.*, **61**, 175.

MAIR, N. S. & ROSS, A. I. (1960). Survival of *Salmonella typhi-murium* in the soil. *Mon. Bull. Minist. Hlth Lab. Serv.* **19**, 39.

MCDONAGH, V. P. & SMITH, H. G. (1958). The significance of the abattoir in salmonella infection in Bradford. *J. Hyg., Camb.*, **56**, 271.

MOORE, B. (1948). The detection of paratyphoid carriers in towns by means of sewage examination. *Mon. Bull. Minist. Hlth Lab. Serv.* **7**, 241.

MÜLLER, J. (1957). Le problème des salmonelloses au Danemark. *Bull. Off. int. Epiz.* **48**, 323.

NEWELL, K. W. (1959). The investigation and control of salmonellosis. *Bull. World Hlth Org.* **21**, 279.

NIVEN, C. F. (1962). Industry's role in reducing the incidence of salmonella in animal feeds *Proc. U.S. live Stk sanit. Ass.* **65**, 453.

REPORT (1959*a*). Salmonella organisms in animal feeding stuffs and fertilizers. *Mon. Bull. Minist. Hlth Lab. Serv.* **18**, 26.

REPORT (1959*b*). Joint WHO/FAO expert committee on zoonoses. Second report. *World Hlth Org. techn. Rep. Ser.* 169.

REPORT, (1960). Food poisoning in England and Wales, 1959. *Mon. Bull. Minist. Hlth Lab. Serv.* **19**, 224.

REPORT (1961). Salmonella organisms in animal feeding stuffs. *Mon. Bull. Minist. Hlth Lab. Serv.* **20**, 73.

SELLERS, K. C. & SINCLAIR, W. B. V. (1953). A case of *Salmonella typhi-murium* infection in cattle and its isolation from other sources. *Vet. Rec.* **65**, 233.

SHEARER, G. C. (1957). An outbreak of abortion in ewes due to *Salmonella dublin*. *Vet. Rec.* **69**, 693.

STATUTORY INSTRUMENT (1963). No. 1,228. *The Transit of Calves Order* 1963. London: H.M. Stat. Off.

STENERT, H. (1938). Ein beitrag zur epidemiologie des Bact. ent Breslau. *Tierärztl. Rdsch.* **44**, 656.

VAN DER SCHAAF, A., VAN ZIJL, H. J. M. & HAGENS, F. M. (1962). Diermeel en salmonellosis. *Tijdschr. Diergeneesk.* **87**, 211.

WALKER, J. H. C. (1957). Organic fertilizers as a source of salmonella infection. *Lancet*, ii, 283.

WATSON, W. A. (1960). *Salmonella dublin* infection in a lambing flock. *Vet. Rec.* **72**, 62.

WATTS, P. S. & WALL, M. (1952). The 1951 *Salmonella typhi-murium* epidemic in sheep in South Australia. *Aust. vet. J.* **28**, 165.

WILSON, G. S. & MILES, A. E. (1955). *Topley and Wilson's Principles of Bacteriology and Immunity*, 4th ed. London: Arnold.