ESCHERICHIA COLI (O-TYPES 111, 55 AND 26) AND THEIR ASSOCIATION WITH INFANTILE DIARRHOEA. A FIVE-YEAR STUDY

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Taylor, Powell & Wright (1949) reported a clinical and bacterological investigation of cases of infantile diarrhoea and vomiting, with particular reference to the association of *Bacterium coli* D433 (*Escherichia coli* O.111) with sick babies and its absence in control groups. They concluded that the aetiological significance in diarrhoea and vomiting of this serological type of *Bact. coli* was undecided, but suggested lines for further research. Among these was the investigation of the correlation between the clinical findings and the presence of the specific serological type of organism.

At that time the Public Health Laboratory in Southampton was receiving rectal swabs or faeces from sick infants of 12 months or under from four of the five hospitals in the town, and from residential nurseries and clinics under control of the Local Authority. The fifth hospital had no special infant wards, but from time to time specimens were received from this institution and in addition material from infants attended by General Practitioners was referred to the laboratory. Since the majority of the faecal specimens from cases of infantile diarrhoea occurring in the town were examined in this laboratory it seemed that the collection of the clinical, bacteriological and epidemiological records obtained during this survey might provide information of interest. This communication presents the main results in tabular form, together with some detail of the work undertaken.

Plan of survey

When the survey commenced in the autumn of 1949 there were only two commonly recognized serological types of *Esch. coli* associated with infantile gastro-enteritis—O.55 and O.111. Later, in May 1953, a third type, O.26, was added. Since then other sero-types have been recognized, but this survey is concerned with these three named types and mainly with the first two.

As far as possible the investigation covered all cases of gastro-enteritis in the district whether institutional or otherwise, but special facilities existed at the Children's Hospital where there was a gastro-enteritis unit of eight beds and rectal swabs from all infants to be admitted were taken in the Out-patients Department before the patient was sent to the ward. After admission specimens were taken twice weekly as a routine until the patient was discharged. Whenever a specific type of *Esch. coli* was isolated detailed inquiries were made to assess the laboratory findings and to try to determine the source of infection. Many of the infants were found to have had association with other hospitals, residential nurseries or 'Communal Houses' where specific infections had occurred, and soon after the

beginning of the investigation interest became equally centred in the pattern of spread of infection throughout the district and the correlation of the clinical and laboratory findings. In the records the term 'excreter' covers all individuals excreting specific organisms; 'symptomless excreter' indicates that, as far as could be ascertained, the individual presented no clinical evidence of disease.

Laboratory methods

As a general rule moist rectal swabs or emulsified specimens of faeces were plated without delay on to the surface of horse-blood agar and MacConkey bile-salt agar. After overnight incubation suspicious colonies were picked off and examined by slide agglutination with the specific O-sera of the *Esch. coli* types available. The reports to the clinicians were based on the results of the slide-agglutination tests, but all presumably positive cultures of recognized enteritis types of *Esch. coli* were transferred to slopes of Dorset egg-medium and subsequently submitted to full biochemical and serological tests. Wright & Villanueva (1953), investigating a limited series of cultures of *Esch. coli* O.55, found that their biochemical reactions varied in accordance with the particular H-antigen carried. These observations suggested a simple method of identifying the H-antigen of cultures and the method has been used in these studies as a provisional means of identifying the H-antigens of *Esch. coli* O.55, but all the results were subsequently checked by conventional serological methods.

The H-antigens of *Esch. coli* O.111 were not identified by the author, but were examined on a limited scale in the Pasteur Institute, Paris (see below).

RESULTS

General picture of the outbreaks

The general pattern of *Esch. coli* enteritis as seen in infants in the Southampton area during the years of this study is indicated in Table 1, which sets out the monthly isolations of *Esch. coli* O.55 and O.111 from the beginning of the survey (O. 26 added in May 1953). It shows that until the early part of 1952 these organisms were infrequently encountered and only in sporadic cases. During the period October 1949 to March 1952 faecal specimens from 270 infants, under the age of 12 months and suffering from enteritis, were examined bacteriologically and *Esch. coli* O.55 was isolated from four (1·5%) and *Esch. coli* O.111 from seven (2·6%). During a similar period—February 1950 to February 1952—faecal specimens from 175 infants of the same age group, but suffering from various conditions other than gastro-enteritis, were similarly examined and *Esch. coli* O.55 was isolated from one (0·4%) and *Esch. coli* O.111 from two (0·7%). Although all the infants examined were patients in hospital, there were no examples of cross-infection and it would appear that, irrespective of the presence or absence of diarrhoea, these two sero-types did not, at that time, establish themselves as epidemic strains. The position with regard to *Esch. coli* O.111 remained unchanged for another year, but the picture was entirely different with regard to *Esch. coli* O.55. In March 1952, following the admission of a case of infantile enteritis excreting the latter organism,

there was a rapid spread of the infection in the ward of that hospital and within a short space of time the infection appeared in the infant patients in the other three hospitals and also in a Communal House and a number of private homes in the area, where careful inquiry failed to disclose any direct connexion with the hospital cases. Indeed a child taken ill within a few hours of arrival in the district from a town twenty miles distant was found to be excreting *Esch. coli* O.55.

This outbreak, which was widespread in the spring of 1952, died down in the latter half of the year but flared up in the early part of 1953 as a serious infection and persisted right into the next year. As the outbreak of *Esch. coli* O.55 was waning in November 1952 *Esch. coli* O.111 began to appear and this organism was responsible for much of the gastro-enteritis in the early part of 1953. But, whereas the O.55 infections persisted throughout the year until the following spring, the O.111 infections gradually fell off and, apart from a few scattered isolations, there were no further outbreaks due to this type over the period of these studies.

Experience with *Esch. coli* O.26 was limited to a relatively short period as compared with the other types, but during that time it did not establish itself as an epidemic type, or give any indication that it was likely to do so, in the way that *Esch. coli* O.55 and O.111 had done.

H-antigens of the strains of Escherichia coli *O.55 and O.111 isolated*

The determination of the H-antigens carried by these coli types provided valuable epidemiological information, especially with regard to *Esch. coli* O.55, for which typing sera were available. During the outbreak in the spring of 1952 of *Esch. coli* O.55 enteritis the H-antigens of all the 54 strains isolated were determined; 51 carried the H.2 antigen and 3 the H.7 antigen. In this group was a child admitted to hospital with an O.55 H.7 infection; the other nine occupants of the ward were suffering from O.55 H.2 infections. The infant recovered and had five completely negative stools before discharge from hospital. Eight days later the child was re-admitted with diarrhoea and her stools yielded pure cultures of O.55 H.7. Two days after her first discharge from hospital another patient was admitted. He was not suffering from diarrhoea and his stools were negative for the specific coli, but he acquired the infection subsequently. Now, although there were nine children in the ward excreting O.55 H.2 this patient developed an O.55 H.7 enteritis. Whether these two O.55 H.7 infections were related to an undiscovered carrier or to a long-term contaminated environment could not be determined, but the examples are of considerable interest for without the H-antigen determination all the infections would have been classified under a common source.

It was not then feasible to undertake the serological identification of the H-antigens of *Esch. coli* 111 by the above means, but Dr Nicolle of the Pasteur Institute, Paris, very kindly arranged for the examination of a number of strains of O.111 by his phage-typing technique by which means the phage types appear to be associated with particular H-antigens. Dr Nicolle's reports indicated that the widespread outbreak in 1953 was partly due to *Esch. coli* O.111 H.2 and partly to O.111 H.12, whereas practically all the strains isolated in the 1954 outbreak belonged to type O.111 H.12; the O.111 H.2 type was not encountered.

Table 1. *Monthly isolations of* Escherichia coli *O.55, O.111 and O.26*

		All age groups			Less than 12 months		
Year	Month	Cases	Symptom-less excreters	Deaths	Cases	Symptom-less excreters	Deaths
			O.55				
1950	July	1	—	—	1	—	—
	Aug.	—	1	—	—	—	—
	Nov.	—	—	—	—	—	—
1951	Feb.	—	—	—	—	—	—
	Mar.	1	—	—	1	—	—
	Apr.	—	—	—	—	—	—
	Oct.	1	—	—	1	—	—
	Nov.	1	—	—	1	—	—
1952	Jan.	—	1	—	—	1	—
	Mar.	10	—	—	10	—	—
	Apr.	13	6	2	11	1	2
	May	20	1	1	19	1	1
	June	4	—	—	4	—	—
	July	—	—	—	—	—	—
	Aug.	1	—	—	1	—	—
	Nov.	4	7	—	3	1	—
	Dec.	—	—	—	—	—	—
1953	Jan.	—	—	—	—	—	—
	Feb.	—	—	—	—	—	—
	Mar.	11	5	3	9	5	3
	Apr.	4	5	—	3	1	—
	May	13	10	1	10	8	1
	June	3	6	2	3	5	2
	July	13	14	—	12	2	—
	Aug.	3	3	—	3	3	—
	Sept.	4	—	—	4	—	—
	Oct.	2	—	1	2	—	1
	Nov.	12	4	—	11	1	
	Dec.	5	6	1	4	3	1
1954	Jan.	2	—	—	1	—	—
	Feb.	9	—	—	9	—	—
	Mar.	1	1	—	1	1	—
	Apr.	1	—	—	1	—	—
	May	1	—	—	1	—	—
	June	1	—	—	—	—	—
	July	—	—	—	—	—	—
	Aug.	—	—	—	—	—	—
	Sept.	—	—	—	—	—	—
		141	70	11	126	33	11
			O.111				
1950	July	—	—	—	—	—	—
	Aug.	2	—	—	2	—	—
	Nov.	1	—	—	1	—	—
1951	Feb.	1	—	—	1	—	—
	Mar.	—	—	—	—	—	—
	Apr.	2	1	—	2	1	—
	Oct.	—	—	—	—	—	—
	Nov.	1	—	—	—	—	—

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Table 1 (*cont.*)

		All age groups			Less than 12 months		
Year	Month	Cases	Symptom-less excreters	Deaths	Cases	Symptom-less excreters	Deaths
1952	Jan.	1	1	—	1	1	—
	Mar.	—	—	—	—	—	—
	Apr.	—	—	—	—	—	—
	May	—	—	—	—	—	—
	June	—	—	—	—	—	—
	July	—	1	—	—	—	—
	Aug.	—	—	—	—	—	—
	Nov.	1	—	—	—	—	—
	Dec.	2	—	—	2	—	
1953	Jan.	6	1	—	4	—	—
	Feb.	5	1	—	4	1	—
	Mar.	11	1	1	10	1	1
	Apr.	16	4	—	12	1	—
	May	5	—	—	5	—	—
	June	2	—	—	2	—	—
	July	1	8	—	1	3	—
	Aug.	2	—	—	2	—	—
	Sept.	—	—	—	—	—	—
	Oct.	—	—	—	—	—	—
	Nov.	1	1	—	1	—	—
	Dec.	1	—	—	—	—	—
1954	Jan.	—	—	—	—	—	—
	Feb.	4	7	—	4	2	—
	Mar.	—	—	—	—	—	—
	Apr.	—	—	—	—	—	—
	May	—	—	—	—	—	—
	June	—	—	—	—	—	—
	July	2	—	—	2	—	—
	Aug.	—	—	—	—	—	—
	Sept.	—	—	—	—	—	—
		67	26	1	56	10	1
				O.26			
1953	May	1	1	—	1	—	—
	June	4	1	—	4	1	—
	July	1	—	1	1	—	1
	Aug.	2	—	—	2	—	—
	Sept.	3	—	—	2	—	—
	Oct.	—	—	—	—	—	—
	Nov.	—	—	—	—	—	—
		—	—	—	—	—	—
1954	Jan.	—	—	—	—	—	—
	Feb.	—	—	—	—	—	—
	Mar.	—	—	—	—	—	—
	Apr.	—	—	—	—	—	—
	May	—	—	—	—	—	—
	June	1	1	—	—	1	—
	July	3	—	—	2	—	—
	Aug.	1	—	—	—	—	—
	Sept.	1	—	—	—	—	—
		17	3	1	12	2	1

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Clinical picture

There was no essential difference in the clinical picture of infections due to any of the three bacterial types of infection. There was every degree of severity from the very grave case of acute gastro-enteritis, with dehydration passing on to a fatal issue, to the simple excretor without clinical evidence of disease. On the whole, cases due to infection with *Esch. coli* O.55 tended to be more severe, but this organism was encountered more frequently and the epidemiological pattern suggested that once this type became established in the area it became widespread and developed into an epidemic strain. Although there were eleven deaths following infections with this type it must be pointed out that there were serious contributory factors in eight of these cases—congenital heart disease, prematurity and malnutrition.

Table 2. *Incidence rate and ages*

	Esch. coli O.55			*Esch. coli* O.111			*Esch. coli* O.26			Total percentage of symptomless excreters
Age groups	Cases	Symptomless excreters	Deaths	Cases	Symptomless excreters	Deaths	Cases	Symptomless excreters	Deaths	
Less than 4 weeks	34	5	4	3	9	0	0	0	0	12·0
4 weeks to 3 months	24	5	1	9	2	0	2	0	0	16·6
3 months to 6 months	35	7	4	14	3	1	3	1	0	17·4
6 months to 12 months	33	16	2	30	5	0	7	1	1	24·0
Over 12 months	15	37	0	11	16	0	5	1	0	63·5

Overall death rate = 5·8 %.

It was a characteristic of these studies that a significant proportion of the infants excreting the specific organisms presented no clinical evidence of disease (Table 2). This was mainly in the children over the age of 12 months, but there were examples in very young infants, even in those as young as 2 weeks. This is difficult to explain, but the host-response to infection in comparable age groups among the very young was extremely variable. In one set of twins in which there was a small weight difference at birth the slightly heavier infant was excreting *Esch. coli* O.55 without evidence of disease, while the other was gravely ill with acute gastro-enteritis and dehydration.

There were several examples of infants excreting a specific bacterial type for several days (even a week or longer) before developing signs of enteritis. There were others in which the enteritis appeared as a secondary infection and the clinical progress of the primary disease determined the pattern of the coli infection. An infant of 5 weeks of age was in hospital with broncho-pneumonia and found to be excreting *Esch. coli* O.55. The chest conditions improved and by the time she

was well enough to be sent home she was no longer excreting the coli type. One month later she was re-admitted with pneumonia and within a day or two she was again excreting the coli type. From then on for the next 3 months, when the infant died from the broncho-pneumonia, the results of the bacteriological examination of the stools varied almost from day to day, so intermittent was the excretion of the specific coliform organism.

The symptomless excreter

Attention has already been drawn to the proportion of young children who excreted the specific sero-types of *Esch. coli* without presenting clinical signs of disease.

In certain instances it was difficult to decide about the classification of individuals as cases of infantile gastro-enteritis or as symptomless excreters, because a number of infants excreting the specific organism showed no other abnormality than perhaps an unformed stool on a single occasion. There may have been other instances of this extremely mild and transient diarrhoea that were overlooked, but the observations were carefully controlled and the few cases where there was any real doubt were not included in these records.

Table 3. *Isolation of* Escherichia coli *O.55 (irrespective of the presence or absence of diarrhoea)*

(Infants less than 12 months)

Time periods	Epidemic or not	Total no. of infants examined	No. positive O.55	Percentage positive O.55
Oct. 1949–8. iii. 52	Not epidemic	546	5	0·9
9. iii. –24. vi. 52	Epidemic	104	46	44·2
25. vi.–10. xi. 52	Not epidemic	51	1	2·0
11. xi.–25. xi. 52	Epidemic	11	4	36·4
26. xi. 52–4. iii. 53	Not epidemic	82	0	—
5. iii.–25. ix. 53	Epidemic	174	68	39·1
26. ix.–1. xi. 53	Not epidemic	21	2	9·5
2. xi.–23. xii. 53	Epidemic	75	19	25·5
24. xii. 53–7. ii. 54	Not epidemic	44	1	2·3
8. ii.–26. ii. 54	Epidemic	26	9	34·6
27. ii.–30. ix. 54	Not epidemic	100	4	4·0
		1234	159	12·9

Epidemic periods: average percentage of excreters, 37·2. Non-epidemic periods: average percentage of excreters, 1·2.

Tables 3–5 show that at epidemic periods the proportion of symptomless excreters to cases in all age groups is much higher than at non-epidemic periods. This may be merely a reflexion of the wider contamination of the general environment and an increase in the number at risk; during epidemic periods greater numbers of examinations were carried out and there were more positive isolations.

Although symptomless excreters may be seen in the very early age groups—even in those under 4 weeks old—the proportion is much higher in children above 1 year,

but adults, or even adolescents, are not commonly found to be excreting these organisms either in quiescent or epidemic periods. During the 1952 outbreak of gastro-enteritis due to *Esch. coli* O.55, the stools of 123 adult contacts were examined bacteriologically and only one excreter was found. This was a nurse of 23 years of age working in an out-patients department where the contact was by no means close. From this and similar evidence it would appear that the adult excreter is not a significant factor in the spread of infection in virtue of this character. Nurse attendants, irrespective of whether or not they are excreting the infecting organism may, however, play some part in the hospital spread of the disease. This is considered in another section.

Table 4. *Isolation of* Escherichia coli *O.*111 (*irrespective of presence or absence of diarrhoea*)

(Infants less than 12 months)

Time period	Epidemic or not	Total no. of infants examined	No. positive O.111	Percentage positive O.111
Oct. 49–1. i. 53	Not epidemic	734	11	1·5
2. i.–16. vi. 53	Epidemic	158	41	25·9
17. vi.–2. vii. 53	Not epidemic	12	0	—
3. vii.–4. viii. 53	Epidemic	23	5	21·7
5. viii. 53–7. ii. 54	Not epidemic	181	2	1·1
8. ii.–15. ii. 54	Epidemic	12	6	50·0
16. ii.–30. ix. 54	Not epidemic	114	2	1·8
		1234	67	5·4

Epidemic periods: average percentage of excreters, 26·9. Non-epidemic periods: average percentage of excreters, 1·4.

The frank case of acute gastro-enteritis is passing frequent and loose motions containing almost pure cultures of the specific organism and the environment rapidly becomes contaminated (Rogers, 1951). The symptomless excreter, on the other hand, passes infrequent and formed stools; the specific organism is present in varying proportions, but often only very small numbers can be found. Contamination of the general environment by the symptomless excreter is thus less favourably weighted.

There were one or two examples of infants discharged from hospital apparently free from infection yet being able, in the close contacts of home life, to pass on the infection to another member of the household. These were confirmed by follow-up examinations and full serological examination of the strains isolated.

The symptomless excreter may be responsible for keeping alive in a community a particular sero-type, but there is insufficient evidence to determine its influence in initiating an outbreak. Certainly hospital cross-infection and general spread of infection can be more closely related to the acute case. Moreover, it was a common finding that outbreaks in one institution were accompanied by outbreaks in homes and other institutions in the area, pointing to a very wide dispersal of the infecting organism (Table 6).

Table 5. *Proportion of cases to symptomless excreters at different age groups during epidemic and non-epidemic periods*

	Epidemic periods					Non-epidemic periods				
Age groups ...	Less than 3 months	Over 3 months to 6 months	Over 6 months to 12 months	Over 12 months to 2 years	Over 2 years to 10 years	Less than 3 months	Over 3 months to 6 months	Over 6 months to 12 months	Over 12 months to 2 years	Over 2 years to 10 years
Cases O.55	53	30	32	7	6	5	4	2	2	0
Symptomless excreters O.55	8	7	16	15	20	2	0	0	1	0
Cases O.111	10	11	22	6	2	2	4	7	2	1
Symptomless excreters O.111	2	2	4	4	9	0	1	1	0	2
Total cases	63	41	54	13	8	7	8	9	4	1
Total symptomless excreters	10	9	20	19	29	2	1	1	1	2
Proportion of cases to symptomless excreters	1:0·2	1:0·2	1:0·2	1:1·5	1:3·6	1:0·3	1:0·1	1:0·1	1:0·3	1:2
Total cases—all age groups			179					29		
Total symptomless excreters—all age groups			87					7		
Proportion of symptomless excreters to cases—all age groups			1:2					1:4		

Table 6. *Places of origin of excreters during outbreaks*

Year	Month	*Esch. coli* O.55	*Esch. coli* O.111	*Esch. coli* O.26
1952	Mar.–June 1952	1. Hospital B, Hospital A, Hospital C, Hospital D, Communal house F, Private house (1), Private house (2) — All connected 2. Private house. Town S 3. Private house. Town S 4. Private house (hut encampment B outside town S) 5. Private house. Town P entering town S	—	Organism not examined for
1953	Jan.	—	1. Hospital A (2 wards) probably connected 2. Private house. Town T	Organism not examined for
	Feb.	—	1. Hospital D 2. Hospital A (1 ward)	Organism not examined for
	Mar.	1. Gypsy camp B 2. Hospital A (2 wards) 3. Hospital B	1. Hospital D 2. Hospital A (2 wards) 3. Private house. Village T outside town S 4. Private house. Town S 5. Private house. Town S	Organism not examined for
	April	1. Hospital A, Hospital B connected 2. Hospital D 3. Private house. Town S	1. Hospital D 2. Communal house G. Town S 3. Residential nursery E. Town S 4. Hospital A (1 ward) 5. Private house. Town S 6. Ship from Far East docking at town S	Organism not examined for
	May	1. Hospital D 2. Hospital A (3 wards). Hospital B 3. Private house. Town S 4. Private house. Hut encampment A outside town S 5. Private house. Town S 6. Communal house G. Town S	1. Hospital A (1 ward) 2. Private house. Town S 3. Private house. Town S 4. Hospital D	1. Hospital A
	June	1. Hospital A 2. Hospital B 3. Hospital D 4. Private house. Town S	1. Hospital B 2. Hospital A (3 wards) 3. Hut encampment A (outside town S)	1. Private house. Town S 2. Hospital D 3. Private house. Village T outside town S 4. Hospital. Town W 5. Private house. Village W
	July	1. Hospital B 2. Hospital A (2 wards) 3. Hospital D 4. Private house. Town S	—	1. Private House. Town S

Table 6 (*cont.*)

Year	Month	*Esch. coli* O.55	*Esch. coli* O.111	*Esch. coli* O.26
1953	Aug.	1. Hospital C 2. Hospital A	—	1. Private house. Town S. 2. Private house. Town R
	Sept.	1. Communal house F 2. Hospital C 3. Private house. Town T	—	1. Private house (1) Private house (2) connected (town E) 2. Private house. Town S
	Nov.	1. Hospital D 2. Hospital A (3 wards) } connected Private house. Town S } 3. Hospital B 4. Hospital C 5. Private house outside town S 6. Private house. Town S 7. Residential nursery E. Town S	—	—
1954	Feb.	1. Hospital D 2. Hospital A (2 wards) 3. Hospital B 4. Private house. Town S	—	—
	June	—	—	1. Residential nursery E. Town S
	July	—	—	1. Residential nursery E. Town S 2. Private house. Village B 3. Private house. Town S
	Aug.	—	—	1. Private house. Town S
	Sept.	—	—	1. Hospital B

Possible factors concerned in spread of infection

Ward environment contamination

Rogers (1951) found that, within a few hours of admission into a clean hospital cubical a child suffering from acute enteritis due to *Esch. coli* O.55, the organism could be cultured from the walls, floor, bedding, clothes, hospital furniture and ward-dust. In the present study, during the height of an outbreak of *Esch. coli* O.55 enteritis, the infecting organism was isolated from swabs of dust, cupboards, lockers and from the outside balcony of infected wards at two of the hospitals in the area. On a later occasion *Esch. coli* O.26 was cultivated from the dust of a small ward containing only two children, one of whom was a symptomless excreter of this organism. The other child subsequently developed an acute gastro-enteritis due to this type.

Ward dust and respiratory infection

The presence of the epidemic strain in dust and the subsequent infection of the other infant suggested that it might be carried to the infant on the nurse's hands

or directly in the dust in the air. Laurell (1952) reported that both *Esch. coli* O.55 and O.111 were commonly found in the respiratory tract and that aerial infection from infected dust suspended in the air was considered to be a likely method of spread of disease.

In order to obtain further information on this point some 4000 nose and throat swabs from infants under 1 year in the gastro-enteritis unit of one of the hospitals in the district were examined for specific types of coli. Seven nasal and two throat swabs were positive (seven patients), but as the seven infants had been vomiting the significance of these findings is very doubtful. It would appear, therefore, that inhalation of infected dust is not a major factor in the spread of infection in the present investigations. On the other hand, infected dust and generally infected environment, so commonly found in children's wards, could readily contaminate a nurse's fingers, even with frequent hand washing, and the infection transferred to the infant's mouth during the process of feeding.

Viability of organisms in ward dust

The importance of infected dust as a factor in spreading the disease would largely depend on the survival time of the organism in this medium. Ward dust, naturally contaminated with *Esch. coli* O.127, an organism belonging to the same epidemiological group as those under study, was exposed to ordinary room conditions, but sheltered from direct sunlight. Small portions—approximately 0·5 g.—were cultured daily and positive isolations were obtained up to 12 days. During this time the relative humidity ranged from 44 to 84·8 % and the temperature of the room from 67·5 to 79° F. Other specimens gave positive cultures after storage for 9, 8, 7 and 5 days respectively. Divided specimens (one half exposed to direct sunlight when available, and the other half maintained in the shade) showed that the survival time in the former group was 5 days and in the latter 7 days.

Numbers of pieces of lint were each contaminated with a measured dose of *Esch. coli* O.55 (approximately 9×10^6 organisms as a broth culture). One series was exposed to direct sunlight and the other to shaded daylight. The sun temperatures ranged from 63 to 95° F. and the relative humidity from 35·5 to 95 %. In the lint exposed to direct sunlight the organisms survived for 30 hr., but in the lint kept in the shade the organisms were alive after 15 days.

Dissemination of organisms during bed making

Culture plates were exposed in an enteritis ward during the processes of floor sweeping and bed making. The plates were on the bed-side locker of an infant (he was passing loose stools but there was no acute diarrhoea). Plates were also exposed on a table separated from the bed by a screen 8 ft high. The specific organism was cultured from the plates exposed on both the locker and the table.

Although the above-described experiments demonstrate the long survival time, under certain conditions, of this group of organisms in hospital ward dust and the ease of dissemination of this infective material there is insufficient evidence to show that hospital cross-infection actually occurs through this means. Anderson,

Crockatt and Ross (1954), in a study of gastro-enteritis in three hospital wards with differing standards of nursing technique, found that each showed a very similar cross-infection rate. This observation could be explained by the heavy contamination of the ward environment with highly infectious material to which a very susceptible population is exposed. Jameson, Mann & Rothfield (1954), in an epidemiological survey of infantile diarrhoea and vomiting in children's wards, found that 'closure of the ward, partial emptying and fumigation was not effective in stopping an outbreak and that only complete closure and emptying and formalin spraying was successful'. This is a further example of the importance of the contaminated environment.

Meterological factors and spread of infection

It has been shown in the experiments described above that certain types of *Esch. coli* can remain viable in floor dust for as long as 2 weeks, but that survival under shaded conditions is longer than in direct sunlight. If, therefore, a specific type of this organism were introduced into a hospital ward of susceptible infants at a time of plentiful sunshine and the ward itself received a maximum amount of sunlight it might be expected that conditions would not favour long survival of the infecting organism. In order to ascertain if meteorological conditions had any significant influence on the spread of infection, local readings were obtained relating to average temperatures and relative humidities and total sun-hours for the day of isolation of the particular organism and the two following days. This information would reflect the condition of the environment to which the organism was exposed at the time of its isolation. These observations are recorded in Table 7, and they indicate that external relative humidity, temperature and sun-hours do not have any significant effect in determining whether or not an outbreak follows the introduction into a ward of an enteritis-producing coliform bacillus. Further investigations are needed to determine factors that influence the survival of infective organisms and the spread of infection.

Table 7. *Meteorological factors and outbreaks of infection*

Date of isolation of specific organisms		Outbreak or not	Average relativity humidity % for 3 days	Average ° F. temperature for 3 days	Total sun-hours for 3 days
1. x. 50	O.111	No outbreak	89·2	46·8	2·0
6. ii. 51	O.111	No outbreak	86·3	42·3	12·5
14. iii. 51	O.55	No outbreak	86·2	45·7	13·5
15. x. 51	O.55	No outbreak	91·2	54·2	16·7
8. i. 52	O.55	No outbreak	86·0	45·2	5·7
22. iii. 52	O.55	Outbreak	87·5	49·0	5·7
11. xi. 52	O.55	Outbreak	76·8	40·5	15·7
28. ii. 53	O.111	Outbreak	82·8	43·7	18·3
20. x. 53	O. 55	Outbreak	94·8	54·7	3·3
8. ii. 54	O.55	Outbreak	91·8	35·5	4·8
No outbreak (average readings)			87·8	46·8	10·1
Outbreak (average readings)			86·7	44·7	9·6

During the present study it was observed that an outbreak in any one institution was frequently accompanied by similar outbreaks in other institutions in the district. Jameson *et al.* (1954), reporting similar observations, consider these to be examples of transference of infection from one community to another. This is obviously a very important method of spread, but in many instances in the present study it was not possible, in spite of detailed inquiries, to establish inter-institution or home connexion between the cases.

Age group of population at risk

The introduction into a community of one of the recognized infantile enteritis-types of *Esch. coli* was not always followed by an outbreak of diarrhoea among the children so exposed. In attempting to find a reason for this the age composition of the children at risk, when the first isolations of the infecting organisms were made, were accordingly investigated. Wards were chosen from which specimens from all contacts were examined after the first isolation of the sero-type concerned. Two of the wards were subdivided into three or four smaller wards opening from a central corridor, but there was a free passage for nursing staff between them, with a thoroughfare for patients from one to the other so that in effect the occupants formed a single community. Any positive excreter found during the 7 days following the first isolation was presumed to be an integral part of the outbreak. For the purpose of analysis the wards were divided into those containing children of any age up to 10 years, and those containing infants of mainly 12 months or less. The results, displayed in Tables 8 and 9, suggest that outbreaks of infection are favoured by a community in which there is a high proportion of children under the age of 1 year. There is no doubt, however, that there are other factors that play their part.

Virulence of organism

Thomson (1955), in discussing the ebb and flow of infection, draws attention to 'the great cyclical variations in virulence which have occurred through all the centuries' and postulates the mutation of the infecting agent as the cause of such variation. The epidemiological aspects of the present studies suggest that even in this short space of time such changes may well have occurred. The infrequent occurrence of these sero-types before 1952, the sudden sharp outbreak in that year with its local spread, the heavy prolonged and widespread outbreak in 1953, and the sudden cessation with virtual disappearance of the infecting organisms—especially *Esch. coli* O.55—in 1954, would support this hypothesis.

While there is a good deal of evidence to show as a general rule that the very young infants are more susceptible to infection with these types of *Esch. coli*, there is always a significant proportion of infants who excrete the specific organism without showing clinical signs. This failure to develop symptoms may be due to a true natural resistance in some infants, but not all, for instances were noted of 'so-called symptomless excreters' later developing the disease, much in the same way that in outbreaks of paratyphoid B fever adults will excrete the infecting organism without symptoms for some days before developing the typical clinical manifestations of the disease.

Table 8. *Age of population at risk following isolation of specific types of coliform bacillus*

(Infant wards—mainly less than 12 months)

Date	Organism	No. of children at risk			Average age		Nos. of excreters less than 12 months		No. of excreters over 12 months		Percentage of infants less than 12 months in the population at risk
		Less than 12 months	Over 12 months	Total	Less than 12 months (months)	Over 12 months (years)	Cases	Carriers	Cases	Carriers	
Isolation followed by outbreak											
7. iii. 52	O.55	5	1	6	2·2	1·3	3	0	0	0	—
11. xi. 52	O.55	3	1	4	5·2	1·2	3	0	0	1	—
28. v. 53	O.55	3	0	3	5·8	—	3	0	0	0	—
Total		11	2	13	4·0	1·3	9	0	0	1	84·6
Isolation not followed by outbreak											
1. xi. 50	O.111	5	0	5	3	—	1	0	0	0	—
14. iii. 51	O.55	5	0	5	3·8	—	1	0	0	0	—
15. x. 51	O.55	6	0	6	8·0	—	1	0	0	0	—
Total		16	—	16	5·1	—	3	—	—	—	100

'Carrier' = symptomless excreter.

Table 9. *Age of population at risk following isolation of specific types of coliform bacillus in ward*

(Mixed wards: ages up to 10 years)

Date	Organism	No. of children at risk			Average age		Nos. of excreters less than 12 months		Nos. of excreters over 12 months		Percentage of children less than 12 months in the population at risk
		Less than 12 months	Over 12 months	Total	Less than 12 months (months)	Over 12 months (years)	Cases	Carriers	Cases	Carriers	
Isolation followed by an outbreak											
1. iv. 52	O.55	6	15	21	2·5	6·5	5	0	0	4	—
10. iv. 52	O.111	10	17	27	5·4	3·0	7	1	0	1	—
17. iii. 53	O.55	7	16	23	7·5	4·4	5	0	0	1	—
19. iii. 53	O.55	2	5	7	3·0	3·0	1	0	2	0	—
6. vii. 53	O.55	2	5	7	5·0	3·7	2	0	0	2	—
22. vii. 53	O.55	5	16	21	7·5	4·6	2	1	1	2	—
8. ii. 54	O.111	12	13	25	3·6	4·6	3	2	1	4	—
Total		44	87	131	5·0	4·4	25	4	4	14	33·6
Isolation not followed by an outbreak											
9. i. 52	O.111	4	11	15	4·1	5·3	1	0	0	0	—
21. xi. 52	O.55	1	5	6	12·0	2·9	0	0	1	2	—
24. xi. 53	O.55	3	13	16	10·3	5·2	1	0	0	0	—
19. xi. 53	O.55	3	15	18	4·0	6·5	1	0	0	0	—
2. i. 54	O.55	1	4	5	8·0	2·5	0	0	1	0	—
Total		12	48	60	6·6	5·2	3	0	2	2	20

'Carrier' = symptomless excreter.

SUMMARY

The relationship of *Esch. coli* O.26, O.55 and O.111 to the incidence and spread of infantile gastro-enteritis in a defined area has been studied over a period of 5 years in the Public Health Laboratory, Southampton.

In the main, the study was concerned with infants up to 1 year of age suffering from gastro-enteritis, and from this age group faecal specimens from 1234 individuals were examined for three sero-types of *Esch. coli* (O.55 and O.111 from the autumn of 1949 until September 1954 and O.26 from May 1953 until September 1954). *Esch. coli* O.111 was isolated from 66 infants of whom 56 had enteritis, type O.55 from 159 infants of whom 126 had acute symptoms, and type O.26 from 14 infants all but two of whom had enteritis.

During widespread outbreaks there were sometimes multiple foci of infection. The determination of the H-antigen carried by the O sero-types showed, for instance, that the O.55 outbreak in 1952 was almost entirely due to subtype O.55 H.2, but that a second subtype O.55 H.7 was also incriminated. Similarly, an O.111 outbreak in 1953 was due to a mixture of two subtypes (O.111 H.2 and O.111 H.12), but in 1954 the former subtype was not seen and only O.111 H.12 was identified.

During epidemic times *Esch. coli* O.55 was isolated from 37·2% of the infants examined, whereas in non-epidemic periods the figure was only 1·2%. In the case of type O.111 the figures were 26·9 and 1·4% respectively.

Symptomless excreters were found throughout the period of the study and at all ages, but the proportion as compared with cases was significantly higher in children over 1 year of age. Nevertheless, there were several symptomless excreters less than 4 weeks old. While there was some evidence to suggest that the young child who was a symptomless excreter might be responsible for maintaining a low-grade infection in a community, there was no indication that the rare adult-carrier played any significant part in this.

The specific types of these coliform organisms can survive for long periods outside the body. Naturally infected dust contained viable organisms 12 days after it was first found to be so contaminated; the dust was maintained in a cool shady room.

There is great variety in the clinical severity of the disease as seen in comparable groups of infants, from a very grave illness to the very mildest of diarrhoeas. The very young and those with some other complicating illness are always at a greater risk.

The pattern of the outbreaks as seen in this study suggests a gradual enhancement of virulence of the two main types of *Esch. coli* with local spread at first and then wide dispersal throughout the district followed by a reversion to the poorly invasive type.

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