An interesting finding was that gamma globulin prepared in January, 1952, from the pooled plasma of blood donors in the Edinburgh district had considerable power to protect mice against the virus. This activity was at least as great as the capacity of this sample to protect against measles, and thus there appears an indication that a considerable proportion of the adult population of Edinburgh had at some time been infected with the virus.

Unfortunately, no sample of gamma globulin taken before the epidemic was available for comparison. Before any epidemiological significance can be placed on this finding it will therefore be necessary to examine a further series of samples of gamma globulin obtained during non-epidemic times.

Discussion

Since neutralizing antibodies appeared in the serum, reached a titre of 1 in 125, and disappeared after eight months, it seems justifiable to conclude that both children were infected by the virus isolated.

The illnesses experienced by the two children were quite typical of Bornholm disease, being characterized by the sudden onset of severe intermittent pain in the upper abdomen, a short recrudescent course ending in complete recovery, and no evidence, radiological or otherwise, of an underlying pulmonary lesion. Occurring as they did during an epidemic, they fulfil all the criteria for the diagnosis of Bornholm disease (Scadding, 1951).

No sign of meningeal involvement was present either in the two children investigated or in the 16 other members of the group. In this there is a resemblance to the two cases described by Metcalfe Brown *et al.* (1952), but it is interesting to note that, in the epidemic which occurred at about the same time at Oxford, Davies and Warin (1951) reported a series of 79 cases, 4 of which had definite signs of meningitis. Bornholm disease may present a variable clinical picture with meningitic or myalgic symptoms predominating. It is possible that different strains of virus are associated with different clinical features, and that the Oxford epidemic was caused by a virus differing from that current in Manchester or Edinburgh at the time. On the other hand, it is well known that the same virus may cause both myalgic and meningitic illnesses.

The understanding of the epidemiology of Bornholm disease, of aseptic meningitis, and of non-paralytic poliomyelitis in this country may be expected to advance rapidly when more strains of the Coxsackie virus are isolated and their immunological characters are worked out.

Summary

In an outbreak of Bornholm disease a Coxsackie virus of Dalldorf's Group B was isolated from the faeces of two of the children affected. A rise and fall in the titre of antibodies in the patients' sera indicated that they had suffered a recent infection with this virus.

Our thanks are due to the physicians of the Royal Hospital for Sick Children in Edinburgh under whose care the children were; to Professor T. J. Mackie for help and advice; to Professor A. Murray Drennan for help with the histology; to Dr. R. A. Cumming for samples of gamma globulin; to Mr. J. Sutherland for technical help; and to Mr. J. Isaacson for the supply of suitable litters of mice.

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THE BACTERIAL CONTENT OF THE HEALTHY HUMAN SMALL INTESTINE

BY

JUDITH CREGAN, B.Sc.

AND

NANCY J. HAYWARD, M.Sc., Ph.D.

(From the School of Bacteriology, University of Melbourne)

This work was undertaken to determine the number and kind of bacteria that inhabit the healthy human small intestine. The results showed that their number is so small that they must be regarded as transient contaminants passing through with the ingesta rather than a resident flora colonizing the tract. They are chiefly those Gram-positive species that are usually found in the mouth and throat.

Experimental

Clinical

Patients undergoing gynaecological operations without any history of disease of the intestinal tract or of its associated organs were selected for the investigation. In every case no inflammatory process was proceeding in the abdomen; the general health of the patients was good, and they were fasting for six hours before the operation.

Collection of Specimens

In order that the sampling should be as precise as possible, intestinal contents were taken direct from the bowel with a syringe when the abdomen was open at operation. The syringe needle was inserted obliquely into the antimesenteric border of the small bowel.

Generally the bowel contained so little material that a sample of its contents could be obtained only as a washing. This was procured by injecting 2 ml. of sterile Ringer's solution (chosen because of its low toxicity for micro-organisms) into the lumen of the bowel while constricting the bowel with the fingers about 1 in. (2.5 cm.) above and below the site of injection; washing the bowel lumen with the fluid by sucking it back and forth with the syringe; and then removing the resultant diluted intestinal contents. Although these samples were diluted they were satisfactory because interest centred only on the relative numbers of organisms at various anatomical levels of the intestinal tract. It was necessary only that the technique should be uniform; therefore the same volume (2 ml.) of Ringer's solution was used for every washing, both for the small intestine and for the mouth and large intestine when they were sampled as controls.

This technique was first practised by our colleague Mr. E. E. Dunlop, honorary surgeon to the Royal Melbourne Hospital, who concluded that it was not prejudicial to the post-operative progress of the patient. This was confirmed by Professor Townsend in the present investigation; the post-operative course of the patients showed no evidence of leakage into the peritoneal cavity from the puncture of the bowel.

Bacteriological Examination of Specimens

The same technique was used for all specimens, and was designed to give both quantitative and qualitative information about the flora of the small intestine. Within a few

hours of taking the sample the following media were each inoculated with two drops (about 0.06 ml.) of the bowel washings:

Incubated at 37° C. in air	Sheep-blood agar Sheep-blood potato extract* agar MacConkey's agar Beer-wort agar
Incubated at 37° C. anaerobically with 5–10% carbon dioxide	Sheep-blood agar Sheep-blood potato extract* agar

The range of media inoculated and the methods of incubation were devised to provide the growth requirements of all species of bacteria likely to be found in the intestine, including non-sporing anaerobes which have been reported to be in large numbers in faeces (Sanborn, 1931; Torrey and Montu, 1931; Eggerth and Gagnon, 1933). Generally the use of specialized selective media and techniques to detect particular species present in only small numbers was purposely avoided because an overall picture of the flora was desired, most importance being attached to organisms present in largest numbers. However, MacConkey's agar and beer-wort agar were included to detect coliforms and yeasts respectively.

The method of inoculation was to spread the original two drops over an area at one side of the plate (A) and then to make three successive sets of four or five strokes at right angles (B, C, and D), thus covering the whole area of the plate. The media were examined at intervals up to at least four days, and the degree of growth was recorded as follows:

Growth in areas A, B, C, and D	+++
Growth in areas A, B, and C, not D	++
Growth in areas A and B, not C and D	+
Growth only in area A	±
No growth	−

All species isolated were identified as fully as possible. The systematic table recommended by Swift (1948) was used for streptococci. Three combinations of characters that did not fit any named species were encountered, and the strains with these characters were called varieties 2, 3, and 4 (Cregan, to be published). Staphylococci were named according to the classification of Shaw, Stitt, and Cowan (1951); and for *Candida* the classifications of Benham (1931) and Martin, Jones, Yao, and Lee (1937) were followed.

Direct smears of all specimens were made by allowing four or five drops to dry *in situ* on a microscope slide. They were stained by Gram's method, and the numbers and morphological types of organisms were recorded. These observations and the results of culture generally agreed. The results by direct smears were not included in the final assessment of the flora, but they provided a check on the adequacy of the media used for culture.

Results

In assessing the quantitative results it was of theoretical importance (see Discussion) to decide the maximum number of viable organisms that could be interpreted as transient contaminants unable to multiply in the environment of the part of the intestine sampled. For example, in view of the dilution in Ringer's solution during sampling, it was necessary to know whether as large an amount of growth as + indicated a transient flora or whether it must be taken to indicate a resident flora. To this end the contents of two parts of the alimentary tract known to harbour a resident flora—the mouth and the large intestine—were examined quantitatively. The large intestine was sampled in the same way as the small intestine, in two cases from the caecum and in one from the transverse colon; and the mouth was sampled in five cases by gentle rinsing with 2 ml. of Ringer's solution. All the samples were examined by the same technique as was used for the small-intestine specimens. It was found that the minimum degree of growth was ++. It was concluded, therefore, that + or ± growth could be interpreted as transient flora and ++ or +++ growth must be regarded as indicating a resident flora at the site sampled.

The decision that + and ± growth are not due to the effect of dilution during sampling has been strengthened by later experience in tests of samples from the small intestine in diseases of the digestive system (Cregan, Dunlop, Harrison and Hayward, to be published). In some diseases the small intestine yielded +++ growth, showing that the method of sampling does not over-dilute the intestinal contents when a flora is resident.

Fourteen cases were included in the present investigation, and the sites sampled were the upper jejunum, the mid-gut, and the lower ileum within 8 to 12 in. (20 to 30 cm.) of the ileo-caecal sphincter. The sites were determined by the anatomical appearance of the bowel and mesentery. The results are shown in the Table.

Flora of the Small Intestine

Site of Sampling	No. of Subjects	Quantitative Results			Qualitative Results	
		Sterile	Transient Flora	Resident Flora	Gram-positive Species	Gram-negative Species
Upper jejunum	14	12	2	0	*Lactobacillus sp.* (1) *Candida albicans* (1)	
Mid-gut (lower jejunum or upper ileum)	14	10	4	0	*Str. salivarius* (2) ,, *s.b.e.* (2) ,, *mitis* (2) ,, *acidominimus* (1) ,, *sp.* variety 2 (1) ,, ,, ,, 3 (1) ,, ,, ,, 4 (1) *Lactobacillus sp.* (1) *Candida albicans* (1)	*Bact. coli* Type 1 (1) *Veillonella gazogenes* (1)
Lower ileum	14	7	5	2	*Str. salivarius* (3) ,, *s.b.e.* (2) ,, *mitis* (2) ,, *sp.* variety 3 (1) ,, *faecalis* (1) *Cl. welchii* (1) *Lactobacillus sp.* (1) *Candida albicans* (1) *Staph. aureus* (1)	*Bact. coli* Type 1 (3) *Bact. aerogenes* Type 1 (1) *Veillonella gazogenes* (4) Anaerobic Gram-negative bacilli (1)

Sterile = no growth. Transient flora = ± or + growth. Resident flora = ++ or +++ growth. The figures in parentheses indicate the number of times each species was isolated.

The maximum growth in any of the samples from the upper jejunum and mid-gut was +. In 22 of the 28 samples no growth at all occurred. It can be confidently concluded, therefore, that these sites in the healthy individual are virtually sterile. Twelve of the 14 samples from the lower ileum yielded + or less growth, indicating that in most cases the normal lower ileum contains only transient organisms.

The qualitative results set out in the Table show that the few bacteria that contaminate the small intestine are predominantly Gram-positive species of the general type more commonly associated with the mouth than with the lower intestinal tract. However, in the two cases in which there was a resident flora in the lower ileum the organisms found there were of faecal type.

Discussion

The technique of sampling intestinal contents with a syringe at operation in order to determine the flora of the small intestine has four advantages: (1) samples are taken by a direct route, so that the risk of contamination is at a minimum; (2) the level of the intestine sampled can be anatomically defined by direct observation; (3) patients whose digestive tracts are completely normal can be included in the investigation; and (4) investigations can be made on the living subject.

There are numerous reports of investigations of the flora of the small intestine in health and disease using other techniques sharing some but not all of these advantages. For

*Slanetz and Rettger (1933).

the majority—for example, most of the 14 references in German published between 1912 and 1928 and quoted by Licht, 1929–30; Venables and Knott, 1924; Bogendörfer, 1924; Knott, 1927; Thomson, Einhorn, and Coleman, 1930; Kanzler, 1932; Nichols and Glenn, 1939; and Frazer, 1949—samples have been obtained indirectly with tubes of different kinds passed via the mouth. A disadvantage of this technique is that it is exceedingly difficult to ensure that a specimen from the depths of the intestine is not contaminated with organisms from a higher level. In addition, it is evident, from published reports of relative lengths of tubing and intestine, that the intestine creeps up on the rubber tubing, making it difficult to ascertain, even approximately, the anatomical level of the intestine sampled.

A number of investigations have been made of specimens taken direct from identified levels by swabbing the lumen of the small bowel when it has been exposed at or after operation for removal of a diseased adjoining part of the tract (Cushing and Livingood, 1900; Hewetson, 1904; Paulson, 1929; Barber and Franklin, 1946). Although this technique is inapplicable to normal bowel, for the types of bowel disease to which it is applicable the results are reliable and informative. Normal bowel has been examined by direct methods within twenty hours of death (Garrod, 1925; Blacklock, Guthrie, and Macpherson, 1937) but it appears (see below) that reliable information could be expected only within a few hours of death.

The techniques used in former investigations are all open to objections which are overcome by the technique used in the work reported here.

The quantitative results (see Table) showed that the normal small intestine is exceedingly sparsely populated or unpopulated along its whole length. This finding is at variance with the results of studies of normal subjects using intestinal tubes.

By intubation the duodenum was found to be often sterile or to contain very few micro-organisms (Venables and Knott, 1924; Knott, 1927; Licht, 1929–30; Kanzler, 1932), but at other levels of the small intestine organisms were found to be numerous, of the order of millions per millilitre of intestinal contents (Bogendörfer, 1924; Thomson and others, 1930; Nichols and Glenn, 1939). If one accepts the findings with the direct sampling technique reported here, the results of intubation studies for the lower small intestine must be judged to be erroneous. They have misled the teaching over the last 30 years, presenting a picture of the small intestine as an organ containing virtually no organisms at its upper end, but along its length progressively acquiring a flora, including coliforms, until at its lower end it is very heavily populated. Thus Stevenson (1950) was misled into suggesting that *Bact. coli* D433 (O 111) might be the normal inhabitants of the duodenum or jejunum, and Walther and Millwood (1951) carried out a serological investigation of strains of *Bact. coli* isolated from the duodeno-jejunal junction of 51 subjects after death when in fact no type of *Bact. coli* is an inhabitant of the upper or middle healthy living small intestine.

Our findings are confirmed, in part at least, by the results of other workers with samples removed direct from the bowel lumen at or after operations for intestinal disease. These consistently point to the conclusion that generally the small intestine is either sterile or contains very few organisms along its whole length. The most interesting of these studies were carried out 50 years ago by Cushing and Livingood (1900) in the United States and by Hewetson (1904) in Great Britain. On the basis of very careful bacteriology both investigations led to the conclusion that the upper and middle small intestines are generally sterile, Cushing and Livingood distinguishing between permanent and transient organisms. Hewetson recorded some cases in which the jejunum was sterile although the stomach was contaminated.

Later, by direct swabbing, the ileum in three cases of ileostomy was found by Paulson (1929) to contain only a few Gram-positive bacteria, and Barber and Franklin (1946) found that the duodenum was infected in only 7 of 50 cases of peptic ulcer or gastric carcinoma.

The upper jejunum and mid-gut were found to contain, if anything, organisms of oral type, predominantly streptococci not belonging to any of Lancefield's groups (see Table). In the lower ileum a similar population was found except in a minority of cases (2 out of 14) in which organisms of faecal type were present. This also is at variance with the findings of most intubation investigations, in which coliforms, although rare in the duodenum, were increasingly common at progressively lower levels of the small intestine.

The results of Blacklock and others (1937), who used the same sampling technique as ourselves, but who directed their attention almost solely to the detection of coliforms, are in agreement with our findings. They found that bacteria were scanty in the small bowel and failed to detect coliforms in all of nine specimens from the upper jejunum and in 12 of 18 specimens from the lower ileum. Samples taken within 12 hours of death contained coliform organisms in 11 of 36 duodenal specimens, showing that almost the entire length of the small intestine is invaded by organisms from the large intestine within a short time of death.

Since the small intestine is invaded so soon after death an antibacterial mechanism must operate in the living small intestine. The results of an investigation of the flora of the small intestine in cases of disease of the stomach (Cregan, Dunlop, and Hayward, to be published) show that the antibacterial mechanism of the small intestine is independent of the secretions of the stomach.

The nature of this antibacterial mechanism has not been investigated by us. Bogendörfer (1924) reported that there is a thermolabile antibacterial substance, of lipoidal nature and of molecular size similar to egg albumen, in the juice and mucous membrane of human small intestine. This has not been confirmed. Blacklock and others (1937) investigated the claim that bacteriophages were responsible, but their results were negative. Having discussed the literature they could draw no definite conclusion, and supposed that many factors combined to keep the small intestine fairly sterile.

Whatever the mechanism—chemical, mechanical, or cellular—it ceases to be effective in the region of the ileo-caecal sphincter. As in a minority of cases a profuse flora of faecal type was found in the lower ileum, it seems that the precise anatomical level at which the mechanism ceases to be effective varies from person to person and possibly also from time to time in the same person. It does not operate either in the environment of the large bowel or in the small bowel within a few hours of death.

Summary

The bacterial flora of the healthy small intestine has been investigated, using samples removed from the lumen of the bowel with a syringe at gynaecological operations.

The results have shown that the whole length of the small intestine contains only a transient flora, chiefly of Gram-positive species that are more commonly associated with the mouth than with the large intestine.

From the apparent inability of these organisms to become resident in the small intestine it is deduced that an antibacterial mechanism, distinct from the stomach mechanism, must be operating there.

Our thanks are due to Professor S. L. Townsend, professor of obstetrics and gynaecology, University of Melbourne, for taking the samples of intestinal contents for us. Without his willing co-operation this investigation would not have been possible. We also thank Professor S. D. Rubbo, professor of bacteriology, University of Melbourne, for his constant helpful advice, and the staff of the Women's Hospital, Melbourne, and Miss Marjorie Krohn for technical assistance. One of us (J. C.) was in receipt of a personal grant from the National Health and Medical Research Council.

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CHLORAMPHENICOL IN PROPHYLAXIS OF INFANTILE GASTRO-ENTERITIS

BY

R. McLAREN TODD, M.D., M.R.C.P., D.C.H.
Senior Lecturer in Child Health, University of Liverpool

AND

EDWARD G. HALL, M.B., B.Sc.
Pathologist, Alder Hey Children's Hospital, Liverpool

Infantile gastro-enteritis is a condition which usually affects infants under the age of 1 year. It is characterized by diarrhoea and vomiting, but other features such as anorexia and loss of weight may be present. In some cases diarrhoea may be the only symptom, in others toxaemia and dehydration may be marked, and in others diarrhoea and vomiting tend to recur. After reviewing the recorded outbreaks of neonatal gastro-enteritis, Kirby *et al.* (1950) concluded that the term "gastro-enteritis" had been applied to at least six different clinical syndromes.

In some patients with clinical gastro-enteritis, *Salmonella* or dysentery organisms may be the causative agents, but in others no specific organisms have been isolated. Since 1945 increasing attention has been paid to the occurrence of specific serological types of *Bacterium coli* in both sporadic and epidemic infantile diarrhoea and vomiting. In some outbreaks there has been a relatively high correlation between the incidence of the disease and the isolation of these specific types of *Bact. coli*. Kirby *et al.* studied an epidemic of neonatal gastro-enteritis associated with *Bact. coli* O 111 (D433) and showed that this organism might appear in the stools one to nine days before the onset of symptoms. Preliminary reports (Rogers *et al.*, 1949 ; Smellie, 1950) suggested that chloramphenicol was of value in the treatment of gastro-enteritis, and our own experience over the past two years has confirmed the value of the drug in established gastro-enteritis.

Present Investigation

This paper records our experiences with chloramphenicol as a prophylactic agent in infants from whom *Bact. coli* O 111 had been isolated, but in whom diarrhoea had not developed. The investigations were undertaken between November, 1950, and August, 1951, in two of the wards of the Liverpool University Department of Child Health, at Alder Hey Children's Hospital, Liverpool. These wards, each containing 14 single cubicles, are used primarily for the treatment of infants under the age of 1 year suffering from gastro-enteritis, but infants with other diseases such as respiratory-tract infections are also admitted when beds are available.

Rectal swabs taken from all infants on admission, and at intervals of not more than four days thereafter, were examined for *Bact. coli* O 111 according to the technique employed by Kirby *et al.* (1950). Patients becoming cross-infected with this organism but who had not developed diarrhoea were included in the investigation, and alternate patients ("trial" group) were given chloramphenicol in a dosage of 75 mg. per lb. (165 mg. per kg.) body weight per day, in divided doses three- or four-hourly, for a period of seven days. The remaining cases ("control" group) received no chloramphenicol. The day on which *Bact. coli* O 111 was first isolated is referred to as day 0.

Sixty patients were observed, 30 in each group, but four patients in the trial group were subsequently excluded because chloramphenicol was not given until more than three days after the rectal swab became positive for *Bact. coli* O 111.

The first dose of chloramphenicol was given on day 0 in one case, on day 1 in 15 cases, and on day 2 in 10 cases. In the one patient who received chloramphenicol on day 0 the drug was initially prescribed because of symptoms suggestive of whooping-cough. The details of age, diagnosis on admission, antibiotic therapy, etc., are recorded in Tables I and II.

TABLE I.—*Control Group*

Age	Diagnosis on Admission	Specific Therapy for Primary Illness	Days Between Admission and First Rectal Swab *Bact. coli* O 111	Days Between First Positive Swab and Onset of Gastro-enteritis	Gastro-enteritis
3 wks	Respiratory infection	Streptomycin; penicillin	4	6	Severe
5 ,,	U.R. tract infection	—	16	3	Mild
6 ,,	Acute otitis media	Penicillin	13	—	—
7 ,,	Bronchopneumonia	Sulphadimidine; streptomycin	4	7	Mild
7 ,,	Bronchitis	Penicillin	12	4	,,
8 ,,	Congenital pyloric stenosis	—	15	14	,,
8 ,,	Meningococcal meningitis	Sulphadiazine	8	5	,,
10 ,,	Diarrhoea and vomiting	Aureomycin	20	—	—
10 ,,	Vomiting, ? cause	—	8	3	Severe
10 ,,	Hypoplastic anaemia	—	32	8	Mild
10 ,,	Bronchitis	—	12	1	,,
10 ,,	Feeding disorder	—	23	2	Severe
3 mths	Diarrhoea and vomiting	—	9	2	Mild
3 ,,	Pylorospasm	—	12	2	,,
3 ,,	Oral thrush and conjunctivitis	Sulphadimidine	8	5	,,
3 ,,	Diarrhoea and vomiting	—	12	2	,,
4 ,,	,, ,,	—	12	—	—
4 ,,	Bronchopneumonia	Aureomycin	36	—	—
4 ,,	Pyelitis	Streptomycin	8	5	Mild
5 ,,	L.U.L. pneumonia	Streptomycin; penicillin	9	—	—
6 ,,	Acute bronchitis	Sulphadimidine	8	4	Mild
6 ,,	Hydrocephalus	—	30	—	—
6 ,,	Bronchopneumonia	Penicillin; streptomycin	8	1	Severe
6 ,,	Meningococcal meningitis	Sulphadiazine; penicillin	8	6	Mild
7 ,,	Acute bronchitis; acute otitis media	Sulphamerazine; penicillin	4	—	—
7 ,,	Intussusception	—	12	3	Mild
9 ,,	Tuberculous meningitis	Streptomycin	12	—	—
9 ,,	Primary tuberculosis	—	12	3	Severe
11 ,,	Hydrocephalus	—	12	1	Mild
12 ,,	Oesophageal chalasia	—	28	2	,,