Reprinted from AMERICAN JOURNAL OF TROPICAL MEDICINE AND HYGIENE
Vol. 12, No. 4, pp. 567-579 July, 1963
Copyright © 1963 by The Williams & Wilkins Co.
Printed in U.S.A.

STUDIES OF DIARRHEAL DISEASE IN CENTRAL AMERICA*

V. ENVIRONMENTAL FACTORS IN THE ORIGIN AND TRANSMISSION OF ACUTE DIARRHEAL DISEASE IN FOUR GUATEMALAN VILLAGES†

HANS A. BRUCH,‡ WERNER ASCOLI,§ NEVIN S. SCRIMSHAW,‖ AND JOHN E. GORDON¶

Institute of Nutrition of Central American and Panama (INCAP), Guatemala, Central America

In Guatemala the diarrheas and the dysenteries occur so frequently among children in the first few years of life that they are the leading cause of death for the population as a whole.[1] The main difficulty is at the time of weaning[2] when the child is 6 to 18 months old. The synergistic interaction of intestinal infection and malnutrition,[3] so commonly manifested clinically as kwashiorkor,[4, 5] has been shown to be an important cause of death, and of equal significance in restricting the growth and development of the children who survive.[2] The impact is far reaching, because as in most preindustrial areas, the young child population is large in relation to total numbers.

In highland Guatemala the seasonal migration of the village people incident to labor demands of the coastal plantations, and the periodic visits to urban market centers provide fresh reservoirs of infection that result in a high endemic prevalence of acute diarrheal disease with frequently interposed epidemics. The infectious and nutritional agents have been discussed[6–8] and host factors considered.[9] The present investigation centers on the environment, here considered broadly as having three primary components the physical, the biological and the social.[10]

* This work was supported by the Pan American Health Organization, the World Health Organization, and Grant AM-4827 from the National Institutes of Health (U. S.).

† Many members of the professional and technical staff of INCAP participated in the general field studies of which this investigation was a part. Special acknowledgment is made to Romeo de León, Miguel A. Guzmán, Virginia Pierce and Marta de León.

‡ Division of Statistics, INCAP.
§ Epidemiology Service, INCAP.
‖ Department of Nutrition, Food Science and Technology, Massachusetts Institute of Technology, Cambridge, Massachusetts and Consultant Director to INCAP.
¶ Department of Epidemiology, Emeritus, Harvard University and Consultant in Epidemiology to INCAP.

INCAP Publication I-250.

FIELD METHODS AND MATERIALS

The present observations are from successive studies of acute diarrheal disease[9] in two rural populations of the central Guatemalan highlands over periods of 12 and 16 months within the years 1956 to 1959. The first population of 1164 people, included within the adjacent villages of Santo Tomás Milpas Altas and Santa Lucía Milpas Altas, was in the early phase of what turned out to be a protracted epidemic of diarrheal disease. The annual attack rate during the study period was 135.4 cases per 100 preschool children aged 0 to 5 years. The year ended with a rate of 182.3. As shown in Figure 1, the outbreak continued to build up and did not end until 22 months later.

The other population of 3147, constituting the contiguous villages of San Antonio Aguas Calientes and Santa Catarina Barahona, was in the final stages of a similar outbreak which extended in all over a period of 36 months. When observations ended, the situation was essentially endemic. The annual attack rate during the study was 40.7 per 100 children and the year ended with a rate of 17.3.

The two populations were enumerated by census at the start of the study, and maps were made locating households and other environmental features pertinent to the spread and behavior of the disease. An organized survey of the various social, biological and cultural characteristics of the two communities was made by a physician, a sanitary engineer and a social worker. The occurrence of acute diarrheal disease during the year was determined through home visits by local field workers to all households every 2 weeks. Changing environmental conditions and items not included in the original survey also were investigated. A physician supervised the program. In some few instances, environmental factors not represented in these observations have been supplied from general experience of the past 7 years.

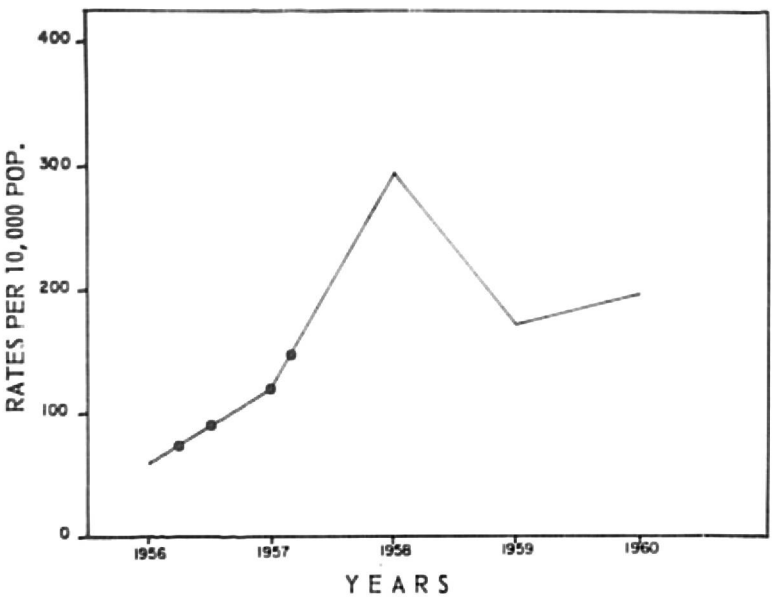

FIGURE 1. Deaths per 100,000 population per year, 1956–1960. The dots on the curve correspond to dates on the maps (Fig. 6).

Because of tradition and terrain, residents of the region live in villages usually of about 1000 persons. From the village the people go out to work the land of nearby valley, plateau and mountain side. Few reside on individual farms, although the economy is almost wholly agricultural. The inhabitants are predominantly Indian or "Ladinos" of mixed blood, resident there for hundreds of years and having their origin in the Mayans.[11]

The average daily income of a family is about 60 cents (U. S.), including earnings from seasonal labor during January to March on the large plantations. The climate is mildly temperate, within an annual range of 11°C to 25°C, being favorably influenced by an altitude of about 5000 feet. Life in the villages is simple and to a large extent self-contained. Much of the farm produce is sold in nearby market towns to obtain the necessities not within the range of village production. Included in the foods sold are most of those of animal origin and the bulk of fruits and vegetables. The village diet is mainly corn, beans and coffee. Nutritional difficulties rank high among village health problems.

The streets of a village are winding dirt lanes bordered by continuous adobe walls or high cornstalk fences which completely conceal the compounds that lie behind, each housing an expanded family group of as many as 25 persons. Although the way is often devious, the streets eventually converge on a central plaza having either a fountain or a well as a central water source; sometimes there is a surrounding park but more commonly the plaza is a treeless plain.

FIGURE 2. Public water faucet and communal laundry facilities of a Guatemala highland village.

The church stands at the head of the square, and the village elementary school and government offices occupy adjacent sides. Somewhere in the plaza is a center with stone slabs and a water supply where women come together to wash clothes. Throughout the day, and often with their babies strapped to their backs, they are busy with the accumulated laundry of the village. This facility is a main social center of the community (Fig. 2).

Environmental sanitation is as casual as the layout of the village. Few communities have a local health service. Local medical care is provided by practitioners of the traditional folk medicine and by shopkeepers who stock a variety of remedies, including penicillin. Obstetrical service is by midwives, most of them untrained and illiterate.

SOURCES OF INFECTION

Few cases of human intestinal infection arose from animal reservoirs; man was almost the sole reservoir and also the principal source of infection because direct contact was the outstanding mode of transmission. Secondary sources of infection and indirect transmission of infectious agents through food, water and flies had a recognized place in the genesis of epidemics, and they made a significant contribution to endemic cases.

Feces disposal. Village practices in the disposal of human wastes ranged from casual deposit wherever chance or necessity dictated, to provision of simple outdoor privies. No indoor sanitary facility of any kind existed in the villages studied. In one of the four villages, 40% of the households had no formal provision for

TABLE 1

Families with privies of all types, by size of family in four villages of rural Guatemala, 1956 to 1959

Family size	No. families	Families with privies	
		No.	%
1–3 persons	162	105	64.8
4–6 persons	371	277	74.7
7–9 persons	191	141	73.8
10 and more	50	48	96.0
Total	774	571	73.8

sanitary disposal of human wastes, and in the most favored village, 15% were without such accomodations. In such circumstances, the common use was of the surrounding fields, of the village streets, and perhaps most often a corner of the household compound, a practice which marks progress in that feces are deposited in a single place.

Large families more frequently had privies than small families, with a fairly regular progression from households of 1 to 3 persons to those of 10 or more, as shown in Table 1. These findings are not representative of usual village conditions. The national health service started a program of health education several years ago and currently local authorities of the four study villages provide directions and materials for construction of sanitary privies. In other villages in the region as many as 85 to 95% of households were without privies.

The sanitary type of privy is brick-lined, has a cement cover and an adequate adobe or cornstalk housing although such improved installations sometimes were seen with no housing at all. Only 21% of the privies of the study villages were of this improved construction (Fig. 3). The unimproved or ordinary privy varied greatly. Its vault was regularly unlined; some had a seat and cover of wood, others of wood and adobe. An enclosure was usual, commonly of cornstalks but sometimes adobe. Occasionally the provision was no more than a simple latrine, a shallow hole in the ground with or without a cover.

The practical consideration was how regularly privies were used and the sanitary state in which they were maintained. Direct inquiry of owners gave the usual result; less than 2% admitted failure to use existing facilities. Inspection of the premises always gave some evidence of use but just about as frequently feces could be identified in the neighborhood of the privy as well as in it. Children particularly appeared to have acquired the idea of what a privy was for, yet failed to make proper use of it. The distance of privies from the house also interfered with their use in rainy weather and at night.

Using a scoring system designed to appraise sanitary adequacy a sample of 195 privies showed 48% to be in a satisfactory state of cleanliness and order. Improved privies were better kept than unimproved by 2-fold, but many of each were in such disorder that outdoors was clearly to be preferred. Use evidently was much less consistent than reported.

The best test of the influence of privies on the frequency of acute diarrheal disease, under the conditions they were used, is through comparison of rates in families with and without those facilities. Average annual attack rates per 100 persons of all ages, as shown in Table 2, were 16.8 for members of families having privies and 22.4 for those without, a difference significant at a 1% level of probability. The spread between rates was greatest for families of 7 to 9 members; for families of 1 to 3 persons, privies had no significant effect on the frequency of diarrheal disease. For families of 10 or more persons, too few were without a privy to make a valid comparison.

For children under 1 year of age the presence of a privy in the household was associated with numerically more diarrheas than in households without that facility, as shown in Table 3, al-

FIGURE 3. Improved privy and a better class house in a Guatemala highland village.

TABLE 2

Case rates of acute diarrheal disease per 100 persons per year by size of family, with and without privies, in four villages of rural Guatemala, 1956–1959

Family size	With privy			Without privy		
	Persons at risk	Cases of diarrhea	Rate per 100 persons/year	Persons at risk	Cases of diarrhea	Rate per 100 persons/year
1–3 persons	277	53	16.6	95	18	15.0
4–6 persons	1500	292	16.9	361	86	21.6
7–9 persons	1177	193	14.3	281	81	26.0
10 or more	610	144	21.1	10	2	20.0
Total	3564	682	16.8	747	187	22.4

TABLE 3

Annual case rates of acute diarrheal disease per 100 persons at risk by age in households with and without privies in four villages of rural Guatemala, 1956–1959

Age	With privies			Without privies		
	Persons at risk	No. cases	Rate per 100 persons	Persons at risk	No. cases	Rate per 100 persons
Under 1 year	136	123	80.7	35	21	52.8
1–5 years	524	365	60.3	122	107	80.3
6–14 years	795	81	9.3	180	24	11.7
15 and over	2109	113	4.6	410	35	7.3
Total	3564	682	16.8	747	187	22.4

though the difference was not statistically significant. Because of the custom of carrying the young child on the mother's back, even as she goes about her daily tasks, children less than 18 months old are less in contact with the dirt of the family compound than the immediately older children. Children 1 to 5 years old had more diarrhea when they lived in a home without a privy but only at a 5% level of significance. For families with privies, diarrheal disease decreased progressively with age. For those without privies the sample of children under 1 year was small; otherwise, the frequency by age was of the same pattern.

In theory, variations in the severity and duration of disease are possibly because of differences in dosage and in the nature of the infectious agent, according to access to privies. In fact, the relative frequencies of mild, moderate and severe infections were almost identical in the families with and without privies. The data thus give no indication that privies, as they were used in the villages, contributed anything to the control of diarrheal disease in children under 1 year of age, but for children of 1 to 5 years and older persons they were of value.

Water supply. Water has such a well-defined influence on the frequency of diarrheal disease through its potential content of intestinal pathogens, that a second consideration, the amounts available for hygienic purposes,[12] does not always receive due attention.

Of the two populations, that with the lower annual rate for diarrheal disease had an abundant water supply derived from a mountain spring about 1 km away. The water was caught in a concrete collecting tank and piped into the village by gravity. Even in the dry season, water was never scarce. About 90% of the 580 families obtained water from public faucets at 16 water points throughout the area; the remaining 10% had private faucets within the compound where they lived. No need existed for private wells, and there were none.

Since water from community faucets must be transported in earthenware jars carried on the head, usually by women and children, the amounts used by the family were less than for households with a private faucet; it was still at the relatively high level of 3 to 4 gallons per person per day. Deficiencies in the distal half of the pipe line to the village, and frequent breaks, gave opportunity for contamination. Bacteriological examination of water at the public faucets on several occasions showed a high degree of pollution as judged by the presumptive *Escherichia coli* test.

The frequency of diarrhea was slightly less among children of 0 to 5 years when water was from private faucets than from public, 32.4 per 100 children per year as compared with 38.9. Potential differences in amount of water and in opportunities for contamination thus were not reflected in statistically different rates for diarrheal disease.

The other population of the study shared with the neighboring village of Magdalena Milpas Altas a water supply drawn from a spring, but that village owned the rights to the water and controlled the amount allotted to the study area. The quantity usually was limited; sometimes several days passed without water. In such circumstances the women walked to a river about 2 km distant to wash clothes and bring back drinking water. During the rainy season an auxiliary supply was collected from roofs into metal drums. Almost a fourth of the families, 48 of 194, had water delivered within the compound from their own faucet. This increased the quantity of water available, providing the central source was functioning, but did not eliminate the necessity from time to time to depend on emergency supplies of river water or collected rain water with their doubtful quality. As a consequence rates for diarrheal disease among pre-school children were 128.6 for those with private water faucets and 134.8 when the family used public faucets.

The frequency of diarrhea in the population with a limited and presumably poorer quality of water, was more than three times that of the population with an abundant supply. Differences in water supply were an attractive explanation. It will be recalled however, that the high rates were in a population with a rising epidemic and the low rates in the one at the end of an epidemic, presumably with most of the susceptibles exhausted. The important consideration is that neither epidemic ran a course characteristic of water-borne intestinal infection. The evolution was slow and in both instances the duration of the outbreak exceeded 32 months. The recent epidemic in San Pedro Sula, Honduras, is a good illustration of diarrheal disease spread by water.[13]

The city has a population of about 61,000. On May 30, 1962, 42 persons became ill with acute diarrheal disease in a restricted section of the city having a population of about 18,000. The next day the number of patients doubled and the epidemic peaked on the fifth day. In all there were some 3034 cases, more than two-thirds of them in the local area first affected. The epidemic subsided as rapidly as it rose. After an interval marked by infrequent secondary cases, conditions were normal by the 32nd day. Deaths were relatively few. The water was heavily polluted with the ordinary fecal bacteria and cases studied showed a variety of infectious agents including enteropathogenic *E. coli*, *Shigella*, and *Salmonella*, and many with no demonstrable agent. The difficulty was traced to a defective water main supplying that part of the community.

Waste disposal. The main health consideration in disposal of garbage and similar wastes is in relation to fly breeding. Garbage in the form of waste food is close to non-existent in these village communities, as in most tropical regions with a hard-pressed economy. Food is altogether too precious to waste, a circumstance perhaps best illustrated by the usual absence of trichinosis because no raw garbage is left for the pigs. The occasional left-over tortillas fed to pigs or dogs are inconsequential. Trimmings from vegetables taken to market are fed to chickens and pigs.

About a third of village families keep pigs and nearly every home has dogs and chickens. Horses are rare. In Santo Tomás a third of families owned cows but in the other villages there were few and sometimes none.

Trash in the form of corn husks, dried leaves from cornstalks and similar material is either buried in the compound to serve as fertilizer, or periodically deposited in the fields for the same purpose. Animal feces are the main available fertilizer for field crops. Composting of feces is uncommon but collections are made and periodically distributed on the land.

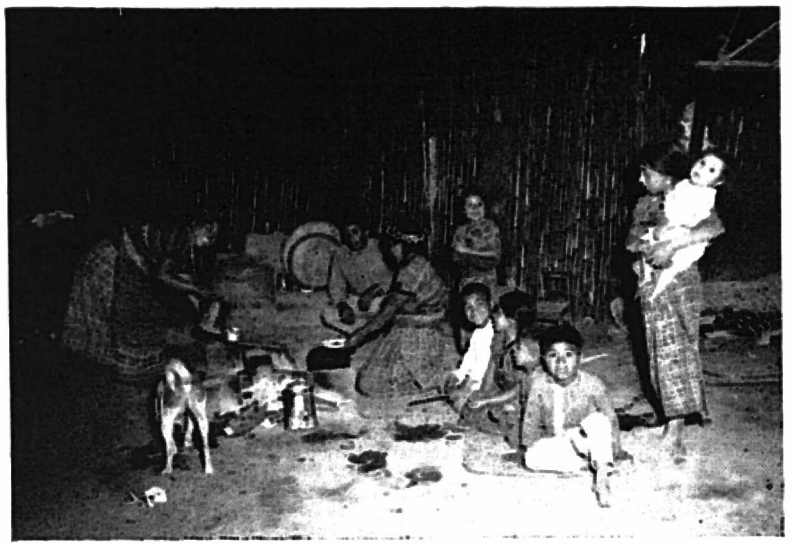

FIGURE 4. Preparation of the noon meal; an Indian family of a Guatemala highland village.

In general, the compounds bordering a village street are remarkably neat and orderly, the paths between houses swept, and plots for growing vegetables well kept to make use of all available land. The indiscriminate scattering of human feces appears incongruous in such a setting.

Preparation, preservation and storage of food. The simplicity of the diet and the restricted amounts of food modify the risks ordinarily anticipated in preparation and preservation of food under conditions such as those of highland Guatemalan communities (Fig. 4). No village home of the area had a refrigerator, and whole villages often were without that accommodation. An occasional store had a refrigerator, but it was used for soft drinks and beer rather than perishable foods.

Corn and beans were the staple diet. Corn is eaten mainly in the form of tortillas, thin flat cakes of the general appearance of a pancake. The necessary amount of corn for use the next day is boiled with lime the night before and tortillas are made the following morning, ready to serve at the noon meal. They are warmed over for the evening meal and for breakfast the next morning. A 24-hour supply of boiled black beans is usually prepared during the morning and reheated for later meals. Boiled beans spoil after 24 hours, unless reheated each day or first ground and fried; the high cost of fats precludes the latter practice except by a few families. During planting and harvesting both foods are sometimes prepared in amounts to last 2 or even 3 days.

The average consumption of meat, chiefly beef and pork, was about one pound per family twice weekly; ordinarily the meat is cooked and eaten the day it is purchased. Animals were slaughtered locally; butcher shops were without refrigeration and meats were hung in the open with little or no protection from contamination by handling or by flies. The elapsed time between butchering and sale was usually not more than a day. Eggs were mainly marketed; few were eaten other than by children and that was uncommon. A family chicken was an occasional addition to the diet.

The use and availability of dairy products varied little from one village to another. When cattle were kept, the usual practice was to sell the milk in the neighboring town. Milk was rarely drunk by adults and little was provided for the children. An intensive dietary survey of 30 families in one of the villages showed that only the children of one family had milk to drink.

Some families prepared a soft cheese from whole milk once a week for home consumption, a supply that usually lasted for 2 or 3 days. Where milk was not available locally, a truck visited the village weekly bringing cheese for sale. Most people bought a 2 or 3 day supply; stores purchased sufficient for their needs during the coming week. All was maintained without refrigeration. Extensive outbreaks of food poisoning have been traced to this source.

Vegetables and fruits were raised in abundance. Since they are the principal cash crops, little entered into the ordinary family diet. Every compound had large garden plots; the fields were devoted to corn, beans and potatoes. Some of the ordinary vegetables such as carrots, beets, and squash, as well as others peculiar to the country, were consumed almost daily being prepared and eaten the same day. The intake did not exceed 10% of the total diet. Fruits were eaten even less and mainly by children.

Storage of staple foods was a minor consideration. They consisted mainly of corn and beans. In the study villages production of both was small due to the limited land area, and supplies necessarily were supplemented by purchase from other parts of the country where production was greater. Little difficulty was experienced with corn, but beans were invaded with ease by weevils and other insects.

Housing. The dwellings of people are a useful index of social and economic influences on frequency of diarrheal disease. Types of construction and the degree of crowding together of dwellings

FIGURE 5. Typical class C house and expanded family compound in a highland village of Guatemala.

are also factors in transmission. The superior type A class of house had a roof of tile or tin, walls of cement or adobe and a floor of cement or brick. Exceptionally, walls were brick. Type B houses were those with the same tile or tin roof, but with walls made of cornstalks plastered with mud. Floors were of dirt. Type C houses had a thatched roof, the walls were of cornstalks lashed together, and the floor again was of dirt (Fig. 5).

The lowest class of housing predominated to the extent of 80%. Ladino villages had more type A houses than did Indian communities, 16% compared with 8%. The provision of privies was in good agreement with quality of housing; the better class houses had more privies. Density of population within a compound (Table 2) was a more important determinant of diarrheal disease than type of housing.

Since acute diarrheal disease occurred mainly among young children, the rates might have been anticipated as greater when floors were of dirt, types B and C. That was true of the intermediate class B houses, to a significant degree, but diarrheal disease was no more frequent among residents of the poorer type C houses than with the best type of housing. Differences in clinical severity according to housing were not apparent. The social environment appeared to exert its greatest effect through the habits of the people and the food they ate rather than the houses they lived in.

Rats and mice. The rat population varied materially from one village to another, as estimated from evidence of rat runs and rat droppings. Where little corn was stored, as in Santo Tomás, rats were few; they were more plentiful in San Antonio. Nevertheless, rats and mice were only a minor health hazard; *Salmonella* infections were few in all of the villages and no more frequent in those with more rats.

Flies. The prevalence of animals incident to an agricultural economy, the concentration of people in villages, the climate, and the poor environmental sanitation, all led to a frequency of flies beyond ordinary numbers. Flies were most numerous during the rainy season from May to October, with the greatest numbers in the month of September. This did not parallel the occurrence of diarrhea, which was at its height toward the end of the dry season and less frequent in the rainy months. A small secondary peak in September and October might have been associated with fly prevalence.

MODES OF TRANSMISSION

Environmental conditions clearly are responsible for many secondary sources of infection and for indirect transmission by vehicles and vectors. Pollution of water by human wastes occurs regularly and readily. Food is susceptible to contamination in its preparation and preservation. Flies are a hazard. On the other hand, living conditions are such as to favor direct contact spread. The problem is to relate these various modes of spread to the observed epidemiologic pattern of diarrheal disease in the villages. The time-place-person relationships are examined to advantage.

Distribution of diarrheal disease by place. The two populations in the study differed epidemiologically. In the villages at the end of an epidemic, the distribution of cases by place of occurrence coincided with that expected of hyperendemicity; numbers were small, the distribution was random and it was compatible with transmission by direct contact.

The population at the beginning of an outbreak is the more informative. The data on origin and spread are limited to cases among children less than 6 years old; they include the first year of the outbreak. The start was abrupt with cases reaching an annual incidence of 187.3 per 100 children during the first month; the decline that followed was just as sharp. The behavior (Fig. 6-A) was compatible with water-borne spread after low grade contamination. Cases were numerous,

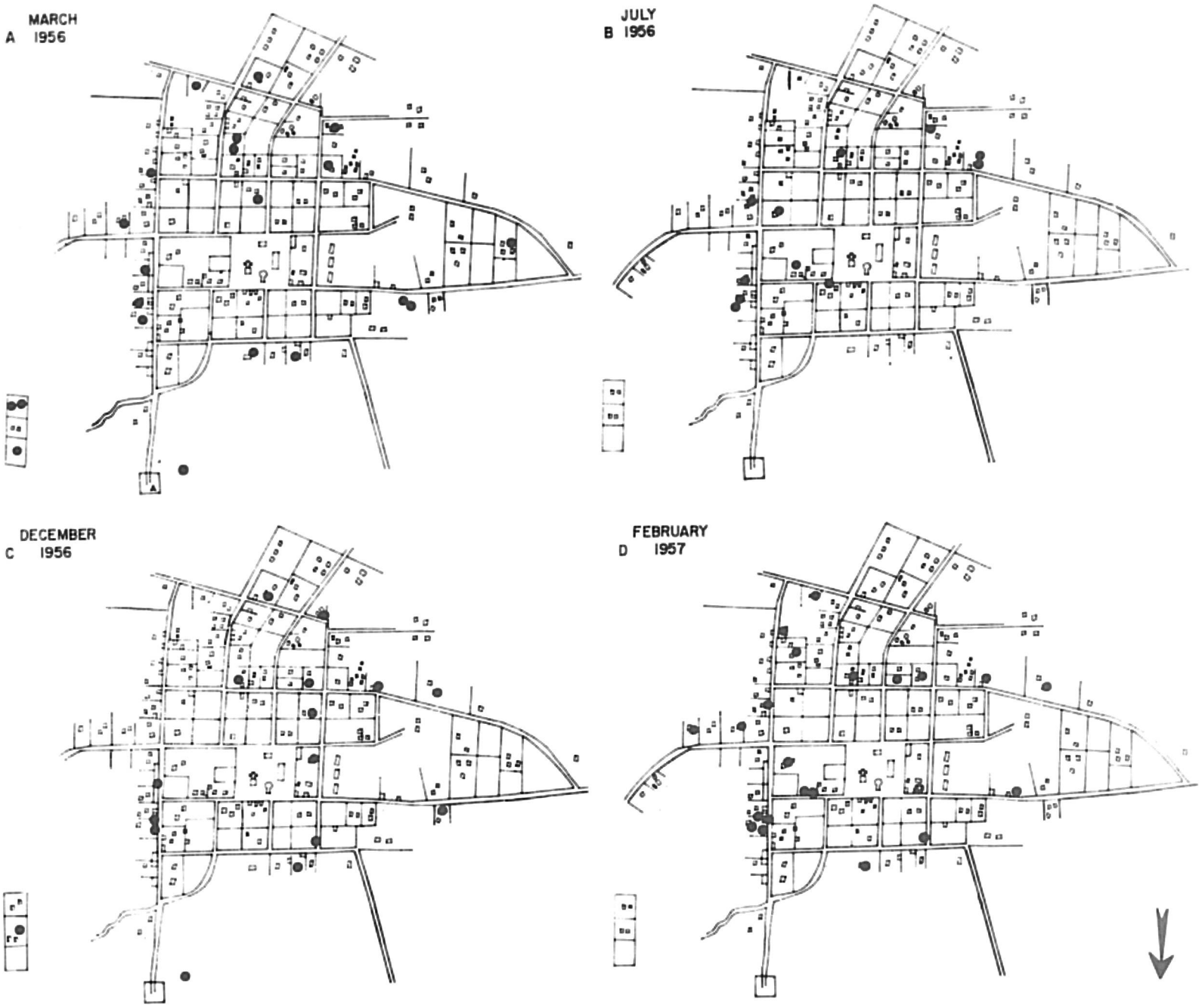

FIGURE 6. Village of Santo Tomás, distribution of cases of acute diarrheal diseases, all ages, by selected months. The dots represent cases of diarrheal disease.

they occurred throughout the village, the rise and fall were of equal duration, the village had a common water supply, and the time was the dry season with water in limited quantity and of questionable quality. During subsequent weeks, the incidence remained low, with local grouping of cases in particular parts of the village as in Figure 6-B, a situation suggestive of contact spread.

The epidemic built up slowly during the rainy season which began in May to show a small secondary peak in October. Thereafter the distribution of cases continued village wide and at random with a tendency toward excess numbers on the outlying fringes of the village (Fig. 6-C) to give an annual incidence of 182.3 as observations ended in February (Fig. 6-D). The subsequent course of this epidemic, as determined by officially reported deaths is shown in Figure 1. The times to which the maps apply are indicated by dots on the curve.

The village was divided into 21 sectors, each with about 6 families, primarily for the practical conduct of field studies. Annual rates of diarrheal disease among children were calculated for individual sectors and differences determined by standard deviation from the average for the village. The map of Sto. Tomás, presented in Figure 7 shows that the different sectors varied materially in annual frequency of diarrheal disease. Sector J had an annual rate that exceeded the average for the village at a probability of 1%. Adjoining sectors at the opposite east side of the village varied among themselves to an equal extent; two sectors had an average rate, two were below the average and one above. Without exception, the other 3 villages in the study showed similar differences in frequency, irrespective of

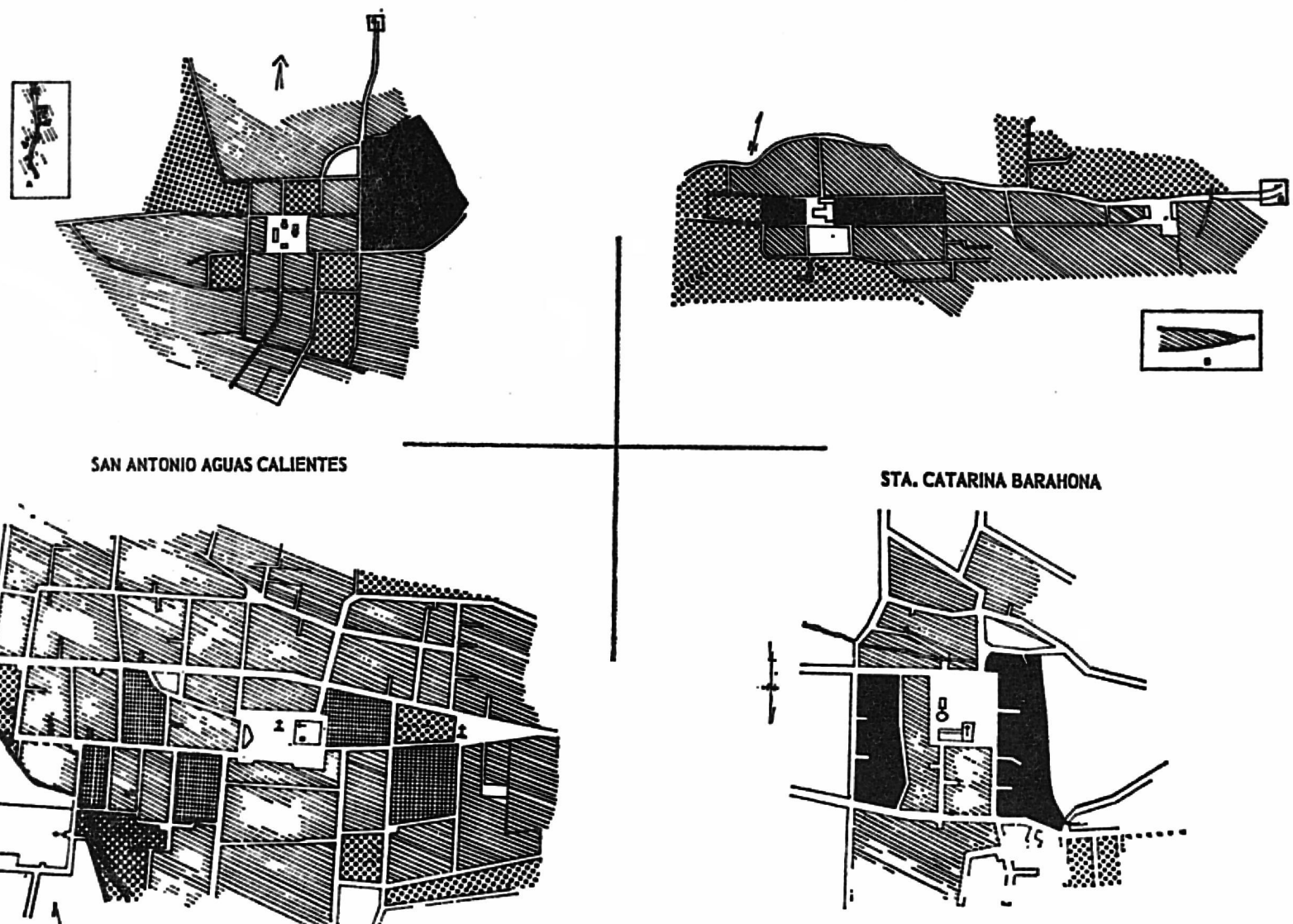

FIGURE 7. Annual attack rates, cases per 100 persons aged 0–5 years, in four villages by sectors: ■ more than 2 standard deviations above the average for the village; ▩ more than 1 standard deviation above; ▨ within 1 standard deviation above or below; ⊡ more than 1 standard deviation below; □ no children in the sector.

whether gross incidence was high or low, or the epidemiologic situation that of epidemic or endemic occurrence. The suggestion is that different environmental factors were active in the several sectors in what was predominantly contact spread.

Distribution by person. The data of Table 4 show a preponderance of diarrheal disease among children 0–5 years of age, the rate being 66.3 per 100 per year. The frequency among school children was much less, 9.7, and relatively few cases occurred among adults. The family now is taken as the epidemiological unit in an effort to learn more of mode of spread.

TABLE 4

Cases of acute diarrheal disease per 100 persons at risk per year by age in four villages of rural Guatemala, 1956–1959

Ages	No. cases	Rate per 100
−1 year	144	75.0
1–5 years	472	64.1
6–14 years	105	9.7
15 and over	148	5.1
Total	869	17.7

In the epidemic villages (Table 5) almost precisely two thirds of the families were invaded by diarrheal disease one or more times during the year. The number of invasions and the number of cases that followed naturally depended on family size; the likelihood of repeated attacks during a year was also greater the larger the family. One-fourth of small families of one to three persons had diarrheal disease during the year. When the family had 4 to 6 members, 71% had diarrhea, and 88% were affected when parents and children together exceeded 7 persons. As many as 14

TABLE 5

Family outbreaks of acute diarrheal disease in four villages of rural Guatemala, 1956–1959

Family size	No. families in the population	No. families with one or more episodes of diarrhea		No. outbreaks per family/year											No. cases
		No.	Rate	0	1	2	3	4	5	6	7	8	9	14	
1–3	38	9	23.7	29	7	1	1								12
4–6	84	60	71.4	24	22	11	5	7	8	2	2	2	1		205
7–9	52	46	88.5	6	13	7	10	7	1	4	4	4			159
10 and over	20	15	75.0	5	6	1		3	1	2	1			1	74
Total	194	130	67.0	64	48	20	16	17	8	7	2	1	1	1	450

separate epidemics occurred during the year in one family of 19 persons. The two villages in an endemic situation followed the same progression, although the number of families attacked was less, fewer persons were involved, and repeated invasions were far less frequent.

Family index cases. The usual sequence of events in family outbreaks of infectious disease is an initial contraction of the illness by a school child, less commonly by an adult, and then secondary cases, frequently among preschool children and proportionately among older members of the family according to immunity status. The present data show a striking departure from this behavior.

The usual index or primary case was not an older child or adult. In 71% of 390 family outbreaks, the disease first appeared in a preschool child, aged 0 to 5 years. School children introduced it into the family less frequently than did adults, but the differences were inconsequential—12% for school children and 17% for adults. These frequencies were out of all proportion to numbers within a family. Adults and school children together made up 80% of members of households; they provided the index case in only 29% of family outbreaks.

In no less than a third of the total index cases were infants less than 1 year old. More than half were children in the first 3 years of life. Because of the system of expanded families, where several closely related units are represented within one household, there were few families with only preschool children. Of 27 such families there were 22 family epidemics of diarrheal disease and a preschool child was the index case in 19 of them. Diarrhea appeared 12 times in the 28 families with only adult members.

Multiple index cases, the appearance of the disease in more than one member of a family within a period of 24 hours, occurred in only 5 of the 390 family outbreaks. They are characteristic of common source infections as from milk or water. The infrequency in this experience strengthens the conclusion that contact spread was the major means of transmission.

Secondary attack rates. Secondary cases are those occurring in susceptible members of a family within an accepted incubation period following a primary or index case. Secondary attack rates for diarrheal disease are necessarily computed from total family members excluding the index case, because of inability to identify susceptibles. The incubation period was taken as 1 to 7 days. On this basis, the over-all secondary attack rate was only 1.4%, indicating that most of the family members were immune. A more reliable datum is based on children of preschool age who may be judged as more regularly susceptible. The secondary attack rate for that age group was 4.1 percent. Similar age specific secondary attack rates were 1.3% for school children and 0.3% for adults 15 years or older. Of a total of 450 cases in families of the population experiencing an epidemic, 86.7% were primary cases, only 7.5% were secondary infections and 5.8% were tertiary of subsequent cases.

The spread of infection within the family was no greater when preschool children were the index case than when an older person introduced the disease. The secondary attack rate where the primary case was a child under 6 years, was 1.2%, a school child 1.6%, and in those following an adult index case 1.8 percent. This is further confirmation that most older family members were

immune to the prevailing agents of diarrheal disease and that diarrheal disease in these communities does not usually spread to adults regardless of the age of the index case.

Secondary cases in families of the populations experiencing endemic diarrhea were less frequent than in the epidemic situation just presented. The same preponderance of index cases among persons in early childhood held for all four villages.

Distribution in time. Deaths from diarrheal disease as recorded in local registers of the four villages and in some 13 others similarly examined showed a continued presence of the disease. The usual course in the 10-year period investigated was a succession of epidemics of long duration, often 2 years or more, rather promptly following each other after an interval of no more than one or two years.

The seasonal distribution of cases and of deaths reached its height in the dry period of the year, commonly in March or April. The increase sometimes began as early as October or November, but more frequently a month or two later. This behavior of fewer cases in the rainy season of May to September is duplicated in other tropical areas with a similar climate, notably the monsoon region of India.[14] Epidemic as well as endemic years show the same seasonal variation.

DISCUSSION

At least two factors contribute to the seasonal rise in diarrheal disease in the Guatemalan highlands midway in the dry season. In many of the villages, migration is heavy with residents returning from several months work on plantations of the coastal regions where diarrheal disease has been demonstrated as measurably more frequent.[7] This provides fresh sources of infection. Water also is commonly at a premium at that time of the year; supplies are more susceptible to pollution and emergency sources, as from rivers, often come into use.

The sharp rise and equally prompt decline in numbers of cases which initiated the outbreak in Sto. Tomás strongly suggest a water-borne origin with the pollution of minor degree. Cases were distributed at random throughout the village. The peak was not great and the outbreak subsided promptly. Some other factor was involved in the subsequent slow build-up to the major peak of the epidemic 14 months later, and its protracted course over a period of 32 months. The particular pattern of behavior has been duplicated innumerable times in highland villages, as judged by deaths derived from municipal registries and by field observation. It was the characteristic course of events in all four villages presently studied. Contact spread is believed to be the main mechanism although other modes of transmission contribute.

If water were the dominant factor in the highland diarrheas, its effect should be evidenced by occasional explosive epidemics involving large numbers of people and lasting no more than 2 or 3 weeks because most villages have a common water supply. In a field experience of 7 years and more than 17 villages no such explosive outbreak has been encountered. Epidemics were plentiful, but of the nature described and illustrated. Water is not thereby eliminated as a source of infection. Low grade, intermittent or accidental contamination could contribute to the general incidence.

Numerous opportunities exist for pollution other than at the original source of supply. Peripheral water points often have cement collecting tanks supplied by a faucet. The jars of the individual householder are dipped into the tank, rinsed, and filled indiscriminately. The jars themselves may contaminate a clean supply. Multiple chances for pollution occur during the storage in the home. The smaller jars with water from the source are emptied into a large earthenware vessel of about 70 liters, the contents of which are rarely exhausted and the vessel almost never cleaned. By direct observation, it is known to collect a variety of contaminants. During water shortages, families differ in the sources they seek as an emergency supply. All do not get the same water. Infections under such circumstances could present a pattern simulating contact spread rather than water-borne because contamination of water in the home would be variable and individual. The contribution to total cases conceivably is appreciable.

Food as a vehicle of transmission occupies much the same position as water. The villages have no central or common eating establishments. Therefore, typical food-borne outbreaks of intestinal infection involving a large part of the community are not to be expected nor do they occur with any frequency. The lack of refrigeration and the almost regular use of warmed-up

left-overs, however, is conducive to family outbreaks. The observed infrequency of multiple index cases is evidence that this does not happen often. Nevertheless, the extreme frequency of diarrhael disease during the time that infants are being weaned suggests that food has an important part in introducing infectious agents.

Milk is an inconsequential factor. Some villages have a few cows; most have none. Where cows are kept, there is little sale within the villages. Such transmission as may occur would be in family outbreaks, and again the few multiple index cases are against that. Flies exist in great numbers during the rainy season. The incidence of diarrhea at that time is at its lowest point. Flies are especially frequent in September just as the rains end. The rather common increase in diarrhea in that month or in October may well be associated with flies. The problem is being evaluated by trapping counts and bacteriological studies. Air-borne spread by droplet nuclei or dust is a minor consideration with intestinal infections; it would appear particularly unimportant under the conditions of village life. In summary, the principal features in transmission, much favored by the habits and the customs of the people, seemingly reside in food as a vehicle and in direct contact spread with other environmental sources of infectious agents a lesser consideration.

The behavior of acute diarrheal disease in families has several unusual characteristics. In this instance, 71% of index cases were among preschool children, while with most communicable diseases school children or adults introduce the disease into the home. The low secondary attack rate, especially among older children and adults, was another feature. The recurring epidemics in the general population at 2 to 3 year intervals match the behavior of measles in a continuously infected population where epidemics promptly follow accumulation of a new crop of susceptibles. The age distribution of acute diarrheal disease is that of poliomyelitis as it occurs in these same areas. In both diseases, communities are so well seeded that infection is more or less usual in early life; inmunity follows, with the result that infections occur among susceptible children, and older children and adults remain unaffected. Not only does clinical diarrhea center in the younger age groups, but also as in poliomyelitis it differs from the diarrheas manifest in older persons of the area or the characteristic disease of other regions where nutrition and environmental sanitation are good. The constitutional reaction tends to be less, the duration longer and relapse is a common feature. How much is due to a particular kind of infectious agent and how much to host factors remain to be differentiated. Malnutrition is an important consideration, increasingly supported by an imposing amount of evidence.

The failure to demonstrate the usual bacterial and protozoal agents of dysentery under village conditions is not altogether surprising. The majority of patients were infants and toddlers. Until weaned at a relatively late age, often 2 and sometimes 3 years, the child leads a rather protected existence, strapped to his mother's back, with less than usual exposure to the external environment. The diet is largely breast milk. And yet this is the period when diarrheal disease is most prevalent. If these diarrheas are of infectious origin, and if in the majority of cases the usual agents are not isolated, a large proportion must be of a different nature than those of later life.

A possibility, seriously to be considered, is that the initial experience of badly nourished children with infectious agents of ordinarily low pathogenicity, such as enteric bacteria of the colon or other groups, or viruses of the general class of echo, adenovirus, Coxsackie or others results in diarrhea which would not appear under more favorable conditions. In many aspects, the weanling diarrhea of technically underdeveloped countries is as distinct epidemiologically from the diarrheas and the dysenteries of later life as epidemic diarrhea of the newborn has long been recognized to be.

SUMMARY

The acute diarrheas and dysenteries of infancy and early childhood predominate among intestinal disorders of Guatemalan highland villages. The correlation with weaning practices and the attendant malnutrition is sufficient to characterize weanling diarrhea as an epidemiologic entity, as distinct among the diarrheas and the dysenteries as epidemic diarrhea of the newborn.

Transmission is primarily by direct contact, highly favored by the habits and customs of the people, and also indirectly by food contaminated by the environment or through the agency of

other family members. The index case in family outbreaks is predominantly the infant or young child, and yet with strong indication that this does not mark the original introduction of infection into the family. Conceivably, manifest disease depends upon two factors. First, an immunity having its origin in a more or less universal disease occurring at an early age protects older children and adults. Secondly, the prevailing malnutrition conditions the immature host to invasion by infectious agents ordinarily of low pathogenicity and perhaps not numbered among the normal adult intestinal flora, as well as to infection by recognized enteropathogens.

REFERENCES

1. Pan American Sanitary Bureau, Regional Office of the World Health Organization, 1958. Summary of four-year reports on health conditions in the Americas. Washington. Scientific Publication No. 40.
2. Scrimshaw, N. S., Béhar, M., Pérez, C., and Viteri, F., 1955. Nutritional problems of children in Central America and Panama. *Pediatrics*, **16:** 378–397.
3. Scrimshaw, N. S., Taylor, C. E., and Gordon, J. E., 1959. Interactions of nutrition and infection. *Am. J. M. Sc.*, **237:** 367–403.
4. Autret, M. and Béhar, M., 1954. Síndrome pluricarencial infantil (Kwashiorkor) and its prevention in Central America. Food and Agriculture Organization of the United Nations, Rome, Italy. FAO Nutritional Studies No. 13.
5. Scrimshaw, N. S., Wilson, D., and Bressani, R., 1960. Infection and kwashiorkor. *J. Trop. Pediat.*, **6:** 37–43.
6. Beck, M. D., Muñoz, J. A., and Scrimshaw, N. S., 1957. Studies on diarrheal diseases in Central America. I. Preliminary findings on cultural surveys of normal population groups in Guatemala. *Am. J. Trop. Med. & Hyg.*, **6:** 62–71.
7. Gordon, J. E., Pierce, V., Ascoli, W., and Scrimshaw, N. S., 1962. Studies of diarrheal disease in Central America. II. Community prevalence of *Shigella* and *Salmonella* infection in childhood. *Am. J. Trop. Med. & Hyg.*, **11:** 389–394.
8. Pierce, V., Ascoli, W., León, R. de, and Gordon, J. E., 1962. Studies of diarrheal disease in Central America. III. Specific etiology of endemic diarrhea and dysentery in Guatemalan children. *Am. J. Trop. Med. & Hyg.*, **11:** 395–400.
9. Scrimshaw, N. S., Bruch, H., Ascoli, W., and Gordon, J. E., 1962. Studies of diarrheal disease in Central America. IV. Demographic distributions of acute diarrheal disease in two rural populations of Guatemalan highlands. *Am. J. Trop. Med. & Hyg.*, **11:** 401–409.
10. Gordon, J. E., and Augustine, D. L., 1958. Tropical environment and communicable disease. *Am. J. M. Sc.*, **216:** 343–357.
11. Direccion General de Estadística, 1960. Sexto censo general de población. Guatemala.
12. Hollister, A. C., Jr., Beck, M. D., Gittelsohn, A. M., and Hemphill, E. C., 1955. Influence of water availability on *Shigella* prevalence in children of farm labor families. *Am. J. Pub. Health*, **45:** 354–362.
13. Galdos Larrú, M., (Epidemiologist) Pan American Health Organization / World Health Organization. Personal communication. 1962.
14. Gordon, J. E., Singh, S., and Wyon, J. B., 1962. Demographic characteristics of deaths in eleven Punjab villages. *Ind. J. M. Res.* In press.