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Social and Demographic Aspects of a Leprosy Epidemic on a Polynesian Atoll: Implications of Pattern[1]

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The authors, an anthropologist and a linguist respectively, agreed to help document an epidemic of Hansen's disease on Ponape and Kapingamarangi Atoll in Micronesia while conducting anthropological research there in 1982. Dr. Robert Worth informed us of the epidemic in the Kapingamarangi (hereafter Kapinga) population, and asked us to help document the probable paths of infection. We have had long experience in the community, and speak the language with reasonable fluency. After a brief but intensive orientation to the more salient features of Hansen's disease and its treatment, Dr. Worth advised us to design our own methods of data collection based on our knowledge of the community.

As our research proceeded, we were struck by how highly patterned the spread of this disease was in this community. It quickly became clear that who could have infected whom was dependent on well known rules of who can and cannot interact with whom and on the timing of interactions. Not only does the spread of Hansen's disease in this community replicate patterns of personal mobility, which vary by gender and age categories, but variations in demographic patterns between the two Kapinga communities are reflected in variations in their patterns of infection, as we shall demonstrate.

The paths of infection are demonstrably non-random—it is not the case that every lepromatous person has an equal probability of infecting every potential victim. Given several possible means by which the disease might be transmitted from one person to another, demographic patterning should render some means more probable and others less probable. We follow this logic to offer the hypothesis that the most likely avenue of infection in this population is a skin-to-skin transmission and that the ubiquitous pandanus leaf mat is the most likely transmission agent of the disease. We then take advantage of the correlation of infection with demographic patterning to show how genetic inheritance of resistance to the disease can be disentangled from the specifics of demographic patterns of the population.

The community. Kapingamarangi is a tiny atoll located 65 miles north of the equator and 485 miles south and west of Ponape, a high island that is the headquarters for both Ponape state and the Federated States of Micronesia, of which Kapingamarangi is part (Fig. 1). The atoll's 0.42 square miles of land area supports a population of about 450 persons, who make their living by tending groves of coconut, breadfruit, and pandanus trees and growing taro. The bulk of the protein in their diet is from fishing. Although rice and tinned fish and meat are common on the atoll at present, traditional subsistence activities still provide much of their diet.

Effective colonial control of the atoll was established in 1914 by the Japanese colonial administration. Kapingamarangi was part of the Ponape administrative district whose headquarters continue to be in Kolonia Town on Ponape. Contact with Kapingamarangi was maintained through regular visits of a field trip ship, which linked the Kapinga with Nukuoro, Ngatik, Pingelap, Mokil, and Kusaie (now Kosrae, a separate state of the Federated States of Micronesia, hereafter FSM) as well as with Ponape. In 1919, the Japanese administration gave the

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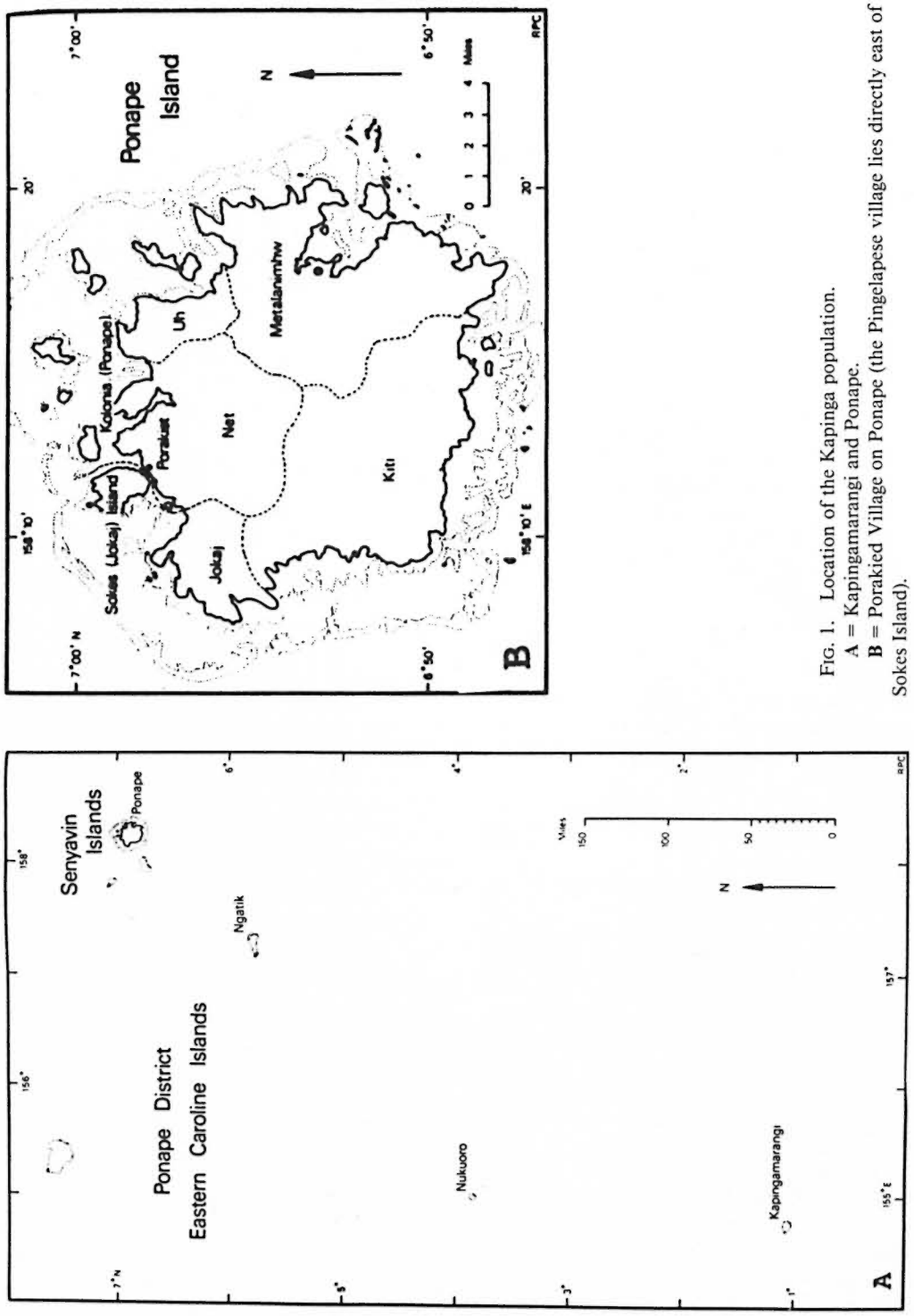

FIG. 1. Location of the Kapinga population.
A = Kapingamarangi and Ponape.
B = Porakied Village on Ponape (the Pingelapese village lies directly east of Sokes Island).

Kapinga people a lease to a 21-acre site in Kolonia Town which eventually became Porakied Village, a permanent Kapinga settlement with a population of approximately 600 persons today. Beginning as a Kapinga colony of Kapingamarangi Atoll, Porakied had become an autonomous political entity by the early 1960s. Contact between the atoll and Porakied has been by ship, with a continual stream of people moving both ways since 1918 ([4]).

Kapinga people are Polynesian in language, physical type, and culture, and are quite distinctive in the Micronesian social environment on Ponape. Their early adaptation to Ponape owes to the fact that they were (until after World War II) practically the only deep-sea fishermen on Ponape. Thus, they were the major suppliers of deep-sea fish, particularly of yellow fin tuna, for both the Japanese and the Micronesians. They were very desirable exchange partners for that reason, and Kapinga men and women formed numerous "friendships" with Micronesian landowners, exchanging fish for vegetable foods. Among these many friendships, which connected the Kapinga village with Micronesians throughout Ponape Island, were several Pingelapese landowners living on Sokes Island directly across the small inlet from Porakied Village. It was through such friendships, both between adults and between school children, that leprosy was first introduced to the Kapinga population.

Pingelapese people have experienced repeated epidemic episodes of Hansen's disease since 1918, when it was first introduced from Nauru ([6]). It was through visits by Kapinga people to Sokes Island that two lepromatous cases were infected by Pingelapese in 1962 and 1965. Two brothers were also infected in 1963 and in 1967 with tuberculoid leprosy contracted through friends at school. As far as could be determined through our research, all subsequent cases are ultimately traceable to one of the two initial lepromatous cases—a girl aged 8 years at first infection, her symptoms appearing in 1964, and a man about 47 years of age at first appearance of symptoms in 1967.

The girl was the younger of two children who had been adopted by a maternal aunt after the girls' mother's death. She lived with her adopters on Ponape throughout most of her childhood. Her adoptive father, a skilled fisherman, spent a good deal of time with Micronesian friends outside of Porakied Village, often taking his wife and adoptive daughter along for extended stays. He was particularly close with two Pingelapese families on Sokes Island, where he and his family often visited them. Given the high incidence of Hansen's disease in the Pingelapese population and the large proportion of lepromatous cases among those infected, it is not surprising that sustained contact should have resulted in infection. Although this girl first noticed symptoms in 1964 and was repeatedly examined by both Micronesian and American physicians over an 11-year period, her symptoms were not diagnosed until 1975.

The second case is similar in pattern to the first. A man in his forties was on Ponape being treated as an outpatient for tuberculosis. He had Micronesian, especially Pingelapese friends, throughout Ponape. He spent a good deal of time on Sokes Island with a Pingelapese family, who had one child who was an active, untreated lepromatous case in 1964 and 1965. The man noticed symptoms in 1967, was diagnosed as having lepromatous leprosy, and was isolated for about 5 months at the Ponape hospital, returning to the atoll thereafter. Although he was repeatedly brought back to Ponape by public health officials to check on his tuberculosis, he was never subsequently treated for Hansen's disease for over a decade.

MATERIALS AND METHODS

We first compiled a list of identified and/or suspected cases, using records from the public health department of the Ponape state hospital. These records had recently been updated and organized under the direction of Dr. Worth, who organized surveys of the Kapinga population in 1980, 1981, and 1982. The records supplied 130 cases, and these were supplemented by five more cases, discovered during June, July, and August of 1982 by Ms Jeanne Windsor, by health aides on Kapingamarangi and Ponape, and by the authors. A sixth case, that of a deceased man, was known to us previously. Our total number of cases was 136 as of 17 September 1982.

For each patient, we recorded name; date of birth; parents' and/or guardian's names; specific diagnosis [indeterminate (I), tuberculoid (T), borderline tuberculoid (BT), lepromatous (L), etc.]; site of first lesions (when that information was available); and date of diagnosis. Our research was designed to collect the following categories of information: a) date of first notice of symptoms and who noticed them, b) probable donor and the place(s) where infectious contact occurred, c) relationship between probable donor(s) and the victim that would explain the type and regularity of contact, and d) the specific settings of infectious contact between (probable) donor and victim.

Given the starting assumptions, it seemed to us that the most productive research strategy would be to concentrate our data collecting on identified patients and the nature of their contacts with people known to be lepromatous and infectious in the years prior to the patients' first notice of symptoms. We used two research strategies: interviews with patients and their families and observations of various sorts of physical contact between persons of various age and sex categories.

We interviewed all 136 identified patients and/or their families. For each patient, we identified the date of first notice of symptoms (month and year) and who noticed them. Next, we elicited a biographical account of all contacts with persons known to have lepromatous leprosy over the previous 5 years. We were careful in these biographical accounts to ascertain the kind of relationship between donor and victim (kinsman, friend, etc.) and the specific places (household, work place, the specific house, which island, etc.) in which the relationship was enacted. What made this strategy feasible was that there were so few lepromatous cases to deal with. By September 1982, there were only 17 people identified as being lepromatous; 8 of these had exhibited symptoms before 1980, but only 4 of these before 1978. The possibilities for infectious contact, therefore, were quite limited. Because a clear trend among the cases of a 2–3-year incubation period emerged, we limited our biographical questioning to 3 years. We cross-checked these data with ship passenger lists from 1977 onward, allowing us to pinpoint at least which island people were on during any given month of a given year.

We also conducted a series of observations of people of various age and sex categories in natural social interactions. We noted patterns of physical contact and the specific physical settings in which the interactions took place. These included children's play groups, women's and men's work groups, meetings, conversations, church services, drinking bouts, and the like.

Our demographic data were collected as follows. We conducted household censuses, two each at 6-month intervals, in the Ponape and atoll communities, in 1978 and 1979 and one each in 1980 and 1982. We compared these to two censuses (two per community at 5-month intervals) conducted in 1965 and 1966 to ascertain any shifts in pattern of residence over that 17-year period. We cross-checked our census material with household censuses done in both communities by the Protestant church (for food assessments) and by the Kapingamarangi municipal council for 1978, 1979, and 1982. These cross-checks were further refined by reference to ship passenger lists between 1979 and 1982. We also sampled men's and women's work groups over periods of 4–5 hours, noting comings and goings (and places of origin and destination) over the periods of observation. We sampled adults' and children's "play" groups, e.g., card-playing groups, peer groups, bingo houses, and the like, noting place, personnel, and changes in personnel over periods of 1–3 hours. It is from these detailed observations that we were able to construct a profile of mobility patterns for people of various age and sex categories.

RESULTS

Of 136 people documented through intensive questioning, all are seen to have had some contact and most seem to have been in regular contact with at least one lepromatous person. There are 25 people (19% of the total) in regular contact with more than one lepromatous patient. Given the information on first notice of symptoms in combination with contact histories, the incubation period appears to vary between 2 and 3 years, infants' incubation time being less than 2 years. Figure 2 shows the cu-

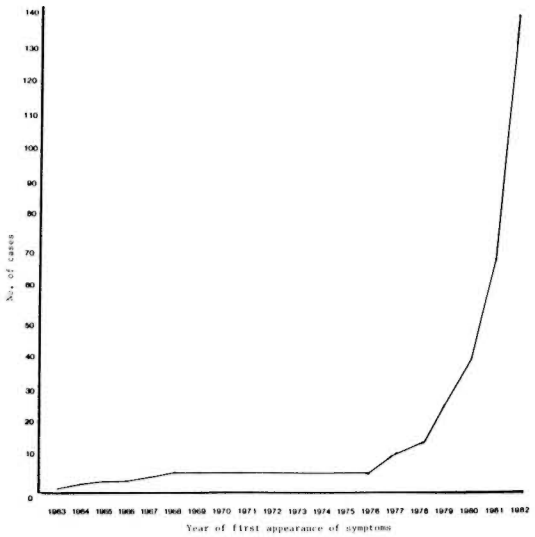

FIG. 2. Cumulative curve of new cases by year of first appearance of symptoms.

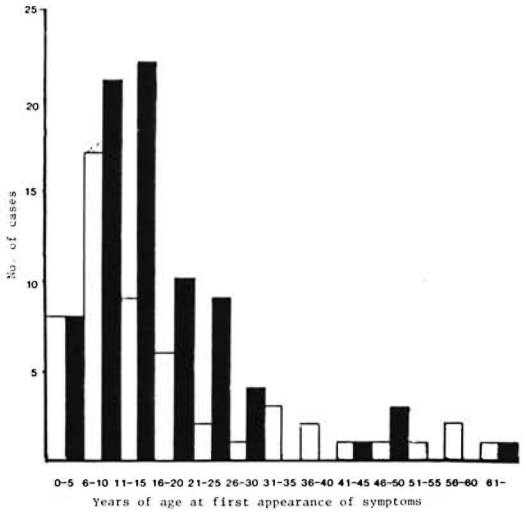

FIG. 3. Distribution of all leprosy cases by age and gender (□) = female; (■) = male.

mulative onset of new cases, accelerating rapidly after 1976.

Of the 136 cases, 76% are 20 years of age or less (the youngest being 14 months). Figure 3 shows the distribution of cases by age and sex through the combined atoll and Porakied populations. The ratio of male to female patients is 3:2. This distribution, while certainly not uncommon in small Pacific populations, appears to us to be significant in that it is so highly patterned.

This pattern of disease faithfully replicates the patterns of personal mobility characteristic of this community: a) After the age of 4 years, males and females work and play in geographically separate places, and males are always more mobile than females. b) Females are most mobile up to puberty, after which they become decreasingly mobile (moving mainly between kin-related households) as their labor and sexuality come under increasing parental control. c) Males are most mobile during their late teens and early twenties, after which they become decreasingly mobile as they acquire skills needed by their elders. d) Both sexes become least mobile after marriage when movement is restricted by the economic responsibilities of household maintenance. e) Females of different age categories are in regular contact and communication with one another through household work and conversation. f) Males of different age categories (e.g., boys, young men, married men, older men) are socially segregated, and do not maintain much contact with one another. Given our initial assumptions and what we know about community demography, this distribution of cases might well be expected. The bulk of the cases occur among that segment of the population that has the most personal mobility with a corresponding decrease in frequency of infection in less-mobile categories of persons.

Figures 4 and 5 contain the same data as those in Figure 3, but the cases are divided by island where infection most probably occurred. Note that patterns of infection among people 20 years of age and younger are almost identical in the two communities. But there is a striking difference between the Kapingamarangi and Ponape populations as regards infection among older men. While not one man over 30 years of age is infected on the atoll, six men between the ages of 45 and 61 are infected on Porakied. One could contend that the cases are too few in number to be significant, and this might be the case. But there is a remarkable correlation between the incidence of infection in this age and sex category and an important, nontrivial demographic and social difference between males in these two communities.

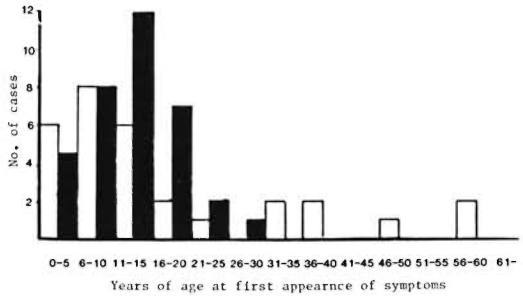

FIG. 4. Distribution of leprosy cases originating on Kapingamarangi by age and gender (□) = female; (■) = male.

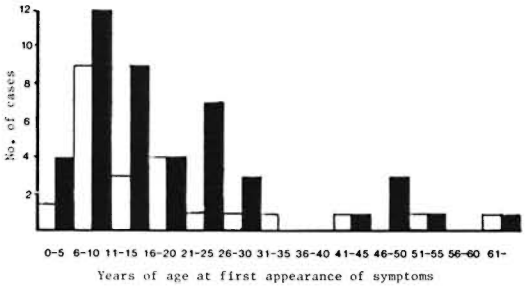

FIG. 5. Distribution of leprosy cases originating on Ponape by age and gender (□) = female; (■) = male.

On Kapingamarangi, adult males rarely come into regular social contact with boys and young men other than their own children. There is a tradition of separation of adult males from younger males that is codified in terms of "respect" that amounts to avoidance of elders by their juniors. Boys tend to avoid contact with their elders whenever possible. What contact there is occurs at feasts and major work projects in which the participation of both is required. In Porakied Village on Ponape, this respect relationship has been rapidly disappearing as the village has shifted to a cash economy. The economic mainstay of the village has been handicraft production since the early 1970s. Men specialize in wood carving, a skill that, unlike the traditional specialty of fishing, can be learned quickly with far fewer and much-less-expensive tools. Boys of 13 years of age are making full-time livings producing and marketing their carvings. Carving is done almost entirely in groups at four or five "craft houses," the modern equivalent of the "men's house." The age range of a typical craft house encompasses males from 13 years to 60 or more. All of the males in a craft house do much the same work, cooperating in procuring wood, sharing tools, and in helping in production when one of the group has a deadline to meet. Members of a craft house group also eat and socialize together. Seven men, ranging in age from 18 to 59 years, appear to have been infected in this context. By way of contrast, one group of full-time fishermen have maintained the age separation. They spend most of their time at the lagoon shore, where their canoe houses are located. These men also make handicrafts at their canoe houses. Younger males are not specifically excluded from this group, but only a few younger men occasionally frequent the canoe houses. Only one man from this group has been infected (by a younger man who visits him regularly).

These data show a correlation between patterns of infection and patterns of mobility by age and gender category, but they tell us little about who might have infected whom and by what means. The latter questions demand finer discriminations of patterns of regular contact between specified categories of persons. It should be hardly surprising that patterns of regular contact are governed by well-known rules of kinship, friendship, and associations around common interests (such as work groups, church groups, peer groups, and card-playing groups). The contexts and settings in which these kinds of relationships are enacted can be divided into domestic and nondomestic contexts.

The domestic setting is the compound, a plot of land that contains from 1–5 households, a central house for cooking, and other outbuildings. Residents of a compound are those with ownership rights inherited through descent from a former owner and in-married spouses. Household membership is fluid, since people have rights in as many compounds as they have recognized ancestors. Adoption, which is very common ([5]), illness of a relative in another compound, quarrels within the compound, temporary needs of kin for one's labor, or leaving the island, all operate to cause periodic shifts of residence by individuals or whole families. The frequency of these shifts indicates a regular circulation of persons between compounds. Not all members of a

compound actually sleep there. Adolescent males move to a men's house or other quarters to sleep until marriage, eating and occasionally working at their natal compounds. Not all persons with rights to compounds actually associate with their relatives there. People tend to associate with either their father's or mother's kin depending on which compound they resided in as children. They remain at a respectful distance from kin on the distaff side. In-laws, even those residing in the same compound, avoid contact with one another.

A compound by day is inhabited by a core of related women and their young children. Men and boys are there in the early morning and the early evening to eat and, for men, to occasionally entertain friends or visiting relatives. Women's female kin visit throughout the day for various purposes. A compound may also be a work place for women's craft groups, for a canoe-making group, or for a women's card-playing group.

Domestic contexts can be viewed, then, as a set of specific locales—compounds—whose activities are organized by principles of kinship and friendship and presuppose a continual, regulated flow of persons between compounds.

Nondomestic contexts are also specific locales, including canoe houses, men's houses, craft houses (on Ponape), bingo parlors and pool halls (on Ponape), and church buildings where people meet to work, transact business, and socialize. Bingo parlors and church facilities involve both sexes, while the other locales are frequented by males. Principles of friendship and common interest regulate the circulation of people through these settings.

Table 1 summarizes the data on the probable avenues of infection of people in each context, specifying the relationship between probable donor and victim. Note that about 70% of infections appear to have occurred in domestic contexts.

For all its apparent neatness as a summary, the results in Table 1 are ambiguous. Twenty-five cases involve more than one lepromatous contact in various contexts. More serious is the fact that in 19 cases (14% of the total) no regular contact with a lepromatous donor could be established. In at least 10 of these cases, no personal contact whatever with any lepromatous person was reported, although all 10 reported regular contact with known tuberculoid cases.

These anomalous cases suggest two possible explanations. Either tuberculoid cases may show wide fluctuations in the number of bacteria that are present over time or there is some medium or media in the environment that is extremely efficient in transmitting the bacteria in the absence of regular lepromatous contact. The second possibility, an effective medium of transfer, is realized in two possible ways. One is the possible spread of bacteria through coughing and sneezing. Micronesian populations are well known for their low resistance to respiratory and bronchial infections, and the Kapinga population is no exception. Common colds, asthma, and tuberculosis have a long history in this population. While adults are careful about covering their faces when coughing or sneezing, very young children are not nearly so scrupulous.

Another, probably more effective, medium of transfer are the floor and sleeping mats universally used by Kapinga in their sleeping houses, cook houses and, in some cases, in work houses. Their mats are made of dried strips of plaited pandanus leaf in two widths ([1]). The sleeping mat has a leaf width of about ½″ and the floor mat ¾″. With usage over time, the leaf fibers begin to fray, producing a surface that consits of thousands of tiny needles. The frayed surface causes tiny skin punctures whenever bare or thinly covered skin comes in contact with the mat. For example, frayed fibers are perfectly capable of puncturing skin covered with the sarongs that Kapinga usually wear. Conceivably, the mat fibers puncturing the skin can release bacteria underneath the skin and hold them, inserting them into another person who later sits or lies on the infected fibers. Mats are periodically but irregularly aired in the sun.

Sleeping mats are made in various dimensions, depending on the size of the person, and are kept rolled up during the day and spread out in sleeping spaces at night. Each person has his or her own mat, but small children sleep with their mothers (or with a woman who plays that role). Friends of the same sex sometimes share sleeping mat space. However, siblings of the oppo-

site sex (which includes cousins in this culture) are forbidden from contact with one another's sleeping mats (as well as clothing). Siblings of the same sex may share sleeping mat space, but they rarely do this after the age of 8 years or so. Males particularly are less likely to share sleeping mats with their brothers, especially if there is a large age gap between them. When boys reach puberty, they remove their sleeping mats from their natal houses and sleep in the men's communal house, in canoe houses, or in friends' houses (not being used by adults). Males do continue to eat and work at their natal households. Thus, considering infection through sleeping mats, young men are more likely to be infected by their friends than by their brothers, unless they spend a lot of time in and around their households.

Floor mats are found in sleeping houses and in work houses on the atoll, where they cover a floor of coral pebbles. In Ponape Village, where houses are built on stilts or are (increasingly) made of cement block, floor mats are used in sleeping houses and cook houses. Cook houses in Ponape Village are constructed much like sleeping houses but are smaller, the thatch roof covering both floor space and fire pit areas. The cook houses are used mostly by women for work space and, when necessary, for sleeping space. While women use cook houses, men and boys frequent them for various purposes. Children come there for meals. When a family eats together (usually in the evening), it is often in the cook house or on a floor mat spread outside the cook house. Cook houses are a very likely common point of infection for adult women and for children and teenagers of both sexes. They are also used for women's card-playing groups, which meet once a week to play for up to 12 hours.

Sleeping houses are used in both communities almost exclusively for sleeping and for storing valuables, clothing, utensils, and the like. Kapinga spend most of their waking hours out of doors or in work houses, men's houses, canoe houses, or cook houses. Access to sleeping houses is restricted to members of the household and to close relatives, usually those in the same compound. Men's houses are much less used today than in past times, and they have no floor mats. Men who work in them (mainly on the atoll) bring their own small mats to sit on. Small floor mats (usually scraps of discarded house mats) are used in some craft houses (on Ponape), canoe houses, and work houses in both communities.

If we are to assign probabilities to sneezing/coughing and mats as the more likely medium of transport of *Mycobacterium leprae,* that of mats seems higher. Spread of bacteria through sneezing and coughing can occur only: a) if the lepromatous person has a cold; b) if the bacteria are not impeded in their path, e.g., the person does not obstruct sputum through holding a hand up in front of his/her face and does not turn away from others during the sneeze or cough; and c) if the person to be infected is in close enough proximity to the one sneezing or coughing. Reliance on this medium of transport as an explanation encounters several difficulties. One must first assume that infectious contact is dependent on colds or other bronchial infections that involve coughing and sneezing. One must also hypothesize that those incidents in which people do not cover their faces and/or turn away from others are responsible for infection. The difficulty with this second assumption is that one must assume infection to be the result of a rare occurrence over the population or assume that it is young children, who do not cover their faces or turn away, who are responsible. The first assumption presupposes a whole series of coincidences—random occurrences—as sufficient to explain a pattern of infection. The second alternative, that young children are responsible for spreading the infection, simply flies in the face of the facts. Even a combination of both explanations still does not yield a high probability of occurrence.

We do not encounter the same problem of assuming rare, random events to explain patterned consequences in the case of mats. They are used and stored in dark, moist places that favor the retention of live bacteria for several days. Their patterns of use, moreover, replicate the patterns of infectious contact delineated in Table 1. Who can lie on or sit on a particular sleeping or floor mat depends on the nature of the social relationships between those who share (or cannot share) its use. Moreover, the use and

TABLE 1. *Contexts of infectious contact.*

	KAP[a]		PON[b]		Total	%
	M	F	M	F		
Domestic						
Lepromatous person infects:						
Members of same household (eat, work, sleep)	7	13	6	9	35	25.9
Person eating and working regularly at household	1	1	4	4	10	7.4
Regular visitor to household (eats, works)	6	0	1	3	10	7.4
Regular visitor to household (eats, converses)	8	5	5	12	30	22.2
Occasional visitor to household (babysitter, kin)	3	2	2	2	9	6.7
Total	25	21	18	30	94	69.6
Nondomestic						
Infected by a:						
Playmate (children under 12)	2	9	3	8	22	16.3
Friend	1	6	1	4	12	8.9
Co-worker	0	0	0	7	7	5.2
Total	3	15	4	19	41	30.4
Totals	28	36	22	49	135	100.0

[a] KAP = Kapingamarangi Atoll.
[b] PON = Ponape Island.

sharing of mats is ubiquitous in this population. Finally, direct contact between a lepromatous person and a victim is not necessary for the effective spread of the bacteria given this medium. A lepromatous person can sit or lie on a floor mat, leaving bacteria behind. Another person can sit or lie in the same place one or more days later and be inoculated by means of the mat fibers. With these considerations in mind, let us return to the 19 cases in which there is no regular contact between an identified victim and a lepromatous case.

In 1977, two new cases were discovered. One, a boy we shall call Pat, was diagnosed in 1977 as having tuberculoid leprosy. He was sent to Ponape for treatment, staying with his mother's brother, who was discovered to have lepromatous leprosy 2 years later. In 1980, four of Pat's playmates were found to have lesions which were diagnosed as tuberculoid leprosy. None of these five subsequent cases showed any history of regular or even occasional personal contact with a lepromatous case. Now, Pat's only contact with a lepromatous person was an indirect one. The older man, diagnosed as a lepromatous case in 1967, is said to have been engaged in a long-term sexual liaison with Pat's mother. This involved his visiting her either in her house or in the cook house adjoining it. These visits occurred late at night, and the liaison was consummated either on the floor mat or on the woman's sleeping mat (which Pat used on occasion). Pat and this man never had direct contact. Pat and several of his friends regularly visited the cook house to eat or play. When Pat's uncle accompanied him to the atoll in 1977, he stayed in his sister's house and ate at the cook house, providing ample opportunity for him to be infected through the floor mats of both the house and the cookhouse.

Five other cases, all women in their 40s, 50s, and 60s living on Ponape and having no personal contact with any lepromatous case, are similarly instructive. The one thing these women had in common was membership in a card-playing group that met in the same cook house every Sunday. From 1979 through 1982, this cook house was used as a work, study, eating, sleeping, and lounging place by three boys, all diagnosed as having lepromatous leprosy. We observed one of the boys at that house for a 1-hour period as he lounged, in a sarong and naked from the waist up, alternately sitting, lying on his back, lying on his side, and moving from side to side to scratch his back on the old and frayed floor mat. Card players similarly lounged on the same mat, sitting, lying on one side or on the stomach to play or to kibbitz. The likelihood of these

women, all of whose symptoms appeared in 1981, having contracted the disease in this context is much higher than having, say, been in the way of a person sneezing in church.

Adding to the likelihood of mats as the most probable means of transmitting the bacteria is the fact that the sites of first lesions, in those cases (93 cases or 68% of the total) where these data were available, include only those skin areas that are in regular contact with mats. The sites include arms, scapular area of the back, lower back, abdomen, thighs, shin, calf, buttocks, top of the foot, nares, and cheeks, as shown in detail in Table 2.

There is no case of lesions in the crotch, upper medial thigh, neck beneath the chin, top of the shoulder, inner arm pit, or any other site that never or rarely comes into contact with the mats. But if there were no relationship between site of infection and site of lesions, then we should expect by random chance at least a few lesions in areas such as the neck, crotch, or elsewhere not in contact with the mats.

Hypothesizing pandanus mats as a medium of transmission of *M. leprae* has the advantage of being consistent with the demographic facts of population mobility and infection patterns in this community. We claim no originality in presenting this hypothesis, since the possibility of mats as a means of spreading Hansen's disease was suggested to us by Michael Hamnett (University of Hawaii) in 1982 and by Carl Taylor in 1984. C. K. Job and his associates have found what is perhaps a similar pattern of infection and mobility among infected armadillos in southern Louisiana ([3]). The medium of infection in this case is hypothesized to be thorns in the animals' environment. Thorns have been found in the ears and noses of these animals and, in one case, there is no doubt that it is the thorn that transferred the infection.

This sort of hypothesis can be tested. One could inoculate the mat in the laboratory and develop techniques of recovery which would be effective to determine the presence of *M. leprae* and to distinguish it from other acid-fast bacteria that might also be present. This determined, it could then be replicated both in the laboratory with mats of known lepromatous patients and in the field. Our experiments with Kapinga mats should begin soon.

TABLE 2. *Site of first lesion(s).*[a]

Site	Male	Female
Face		
Cheek	1	
Nares	1	
Under lower lip		1
Thorax		
Upper chest	7	3
Lower chest	1	2
Abdomen	5	2
Pubis	1	
Back		
Scapular area	6	6
Mid-back	11	8
Lower back	5	1
Buttocks	4	3
Arms		
Upper arm lateral	5	8
Upper arm medial		1
Elbow	2	1
Forearm	4	1
Ventral wrist		1
Ventral hands	2	
Legs		
Thigh dorsal		1
Thigh ventral	4	2
Thigh, lower medial		1
Knee ventral	2	
Shin	1	4
Calf	1	2
Ankle distal	1	
Foot ventral	1	
Genitalia		
Penis ventral	1	

[a] There are 18 persons with multiple lesions that are distributed as follows: 12 = 2 lesions, 5 = 3 lesions, 1 = 5 lesions. Included in these 18 are 5 lepromatous cases; 3 with 2 lesions, and 2 with 3 lesions.

There is another implication of the correlation between the pattern of leprosy infection and the pattern of social mobility in the Kapinga population that is worth mentioning—an implication for the inheritance of susceptibility and resistance to the disease. We are fortunate in the Kapinga community to have accurate genealogical documents that reach back to about 1750 through the combined research of Dr. Kenneth Emory ([2]) and the authors. The data are adequate for testing genetic hypotheses to account for the distribution of infection (and of noninfection).

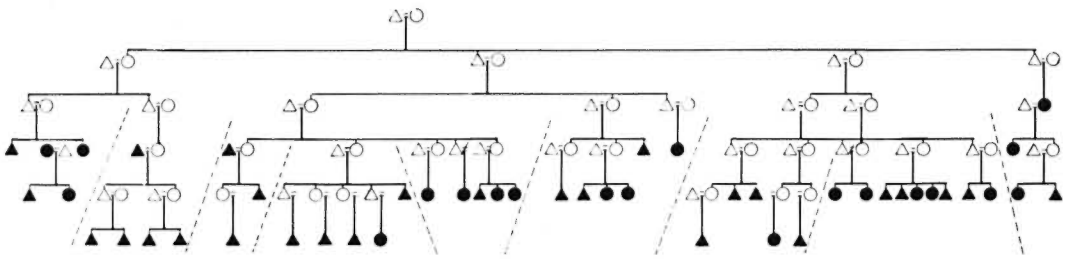

FIG. 6. Distribution of leprosy cases among descendants of an ancestral sibling set plotted against actual social contact between members of descendant sibling sets (△) = male; (▲) = infected male; (○) = female; (●) = infected female; (=) = married; (≠) = wedlock; (⊓) = children; (⋮) = boundary between noninteracting kin.

We have mapped the genealogical connections among the 136 victims by grouping sibling sets at each generation, treating them as units in the maps. Each map depicts an ancestral sibling set and its descendant sibling sets in lower generations, displaying the genealogical relationships between leprosy victims as parts of the larger set. Obviously, with each patient, the number of possible connections doubles as one proceeds to senior generations. Yet it is already clear that some sets of related people show large proportions of leprosy patients while other such genealogical groups show relatively few patients among its members, just as some compounds have several patients and others none. It is significant for purposes of genetic analysis that the groupings of relatives that appear on our genealogical maps form sets that are quite independent of the community's mobility and social interaction patterns. That is, people who are in fact genealogically related do not necessarily interact with one another on a regular basis, as already noted. Yet as a set of persons, they show much higher concentrations of leprosy patients than sets of relatives who do interact and are in regular contact with lepromatous persons. Figure 6 gives an example of this independence of genealogical connection and social interaction pattern. The dotted lines in the figure indicate that the group of persons set off do not regularly interact with the people on the other side of the line.

The relative independence of genealogical relationship and demographic-social relationship makes it likely that genealogical hypotheses accounting for susceptibility and/or resistance to leprosy can be applied to the Kapinga data for both explanatory and predictive purposes.

CONCLUSION

We have presented data on a leprosy epidemic in the Kapingamarangi populations of Kapingamarangi Atoll and Ponape Island in Micronesia. Our description has concentrated on the patterning of the spread of the disease and how the spreading of the infection faithfully replicates the mobility patterns of age, sex, and kinship and friendship relations in this community. The concentration on the correlation between pattern of infection and demographic patterns has at least two major implications. It suggests that as we search for the most likely modes of transmitting *M. leprae,* we must take into account not only what is a possible means of conveyance, but also that we be able to differentiate between what is a more-probable or a less-probable means. We do not deny that sneezing may be an effective means of transmitting the disease. But when this more random process of transmission is compared with that of sleeping and floor mats, the fit between the use of mats and the demographic facts, added to the fact that sneezing requires direct contact and mats do not, clearly points to mats as a more probable mode of transmission. The demographic facts make the mat hypothesis more probable. As an hypothesis, it is also much easier to test.

The second payoff of the correlation between infection and demographic patterns is its implications for approaching the problem of possible genetic inheritance of resistance to Hansen's disease. If the constraints that shape a genealogical grid were identical

to those which constrain daily association, it would be difficult to disentangle demographic from genealogical patterns. But this is not the case in this population. Rules of daily association in fact prohibit people in certain genealogical categories from associating with one another. Genealogical relationship and social intercourse are relatively independent of each other, although they do overlap where rules of association permit. The role of genealogical relationship in the transmission of resistance, thus, emerges relatively clearly on a genealogical grid such as that in Figure 6. The data presented here, of course, represent an incidence whose rate was still increasing at the time the authors left the field. This has its theoretical advantage, however, in that predictions of likely subsequent infections based on genealogical connection can be tested against the data on new cases after 17 September 1982.

SUMMARY

This study reports the results of field research on a leprosy epidemic among the Kapingamarangi people, Polynesians living in two communities on Ponape Island and Kapingamarangi Atoll in the Federated States of Micronesia. The patterns of infection in the two communities are seen to replicate in detail patterns of personal mobility by age and gender and patterns of kinship and friendship relations that order people's social interactions in the communities. These patterns of demographic and social relationship form the context of infectious contact, enabling us to differentiate between more- and less-probable means by which Hansen's disease is spread. We compare coughing and sneezing with inoculation through the frayed fibers of pandanus leaf floor mats and sleeping mats as alternative ways of spreading leprosy infection. We find that frayed mats, because they are ubiquitous in the contexts in which people interact, are more likely to spread infection than coughing and sneezing. Finally, we find that demographic patterns of the communities are not identical with genealogical relationships such that people with close genealogical relationships often do not interact on a regular basis. Thus, genealogical distance and social distance are independent of each other in this community. This makes genetic assessment of inheritance of resistance and susceptibility to *Mycobacterium leprae* an enterprise unencumbered by a necessarily linked demographic variable.

RESUMEN

En este trabajo se presentan los resultados de un estudio de campo sobre una epidemia de lepra entre la gente Kapingamarangi, polinesios que viven en dos comunidades situadas en la Isla Ponape y en la isla o atolón de Kapingamarangi, en los Estados Federados de Micronesia. Los patrones de infección en las 2 comunidades reflejan tanto el patrón de movilización personal según edad y raza, como el patrón de las relaciones familiares y amistosas que rígen las interacciones sociales en esas comunidades. Estos patrones demográficos y de relación social constituyen la base del contacto infeccioso y nos permiten diferenciar las formas más- y menos-probables de diseminación de la enfermedad de Hansen. Nosotros comparamos el estornudo y la tos, con la inoculación a través de las fibras desgastadas de las hojas de pándano que se usan para hacer tapetes de piso y tapetes de dormir como un medio alternativo de dispersión de la infección leprosa. Encontramos que los tapetes desgastados, dada su ubicuidad y participación en las interacciones sociales de la comunidad, son vehículos de dispersión de la infección quizá más importantes que la misma tos y el estornudo de los pacientes. Finalmente, encontramos que los patrones demográficos de las comunidades son independientes de las relaciones genealógicas ya que la gente con relación genealógica cercana raramente interacciona entre sí. El hecho de que las relaciones genealógicas y las relaciones sociales sean independientes en esta comunidad, permite que se pueda establecer la genética de la herencia de resistencia y/o susceptibilidad al *Mycobacterium leprae,* sin el obstáculo de varibale demográfica.

RÉSUMÉ

Cette étude relate les résultats d'une recherche menée sur le terrain, et porte sur une épidémie de lèpre parmi les populations Kapingamarangi, des Polynésiens qui vivent dans deux communautés sur l'île de Ponape et sur l'Atoll de Kapingamarangi, dans les Etats Fédérés de Micronésie. Les profils d'infection dans ces deux communautés reflètent étroitement la circulation des personnes, par âge et par sexe, et les relations familiales ou amicales qui y règlent les interactions sociales. Les profils démographiques et de relations sociales constituent le contexte du contact infectieux, ce qui permet de distinguer entre les moyens les plus probables et les moyens les moins probables par lesquels la maladie de Hansen est disséminée. On a comparé la toux et l'éternuement, avec l'inoculation par les fibres effilochées des nattes de feuilles de pandanus qui recouvrent le plancher et les matelas, comme facteurs de transmis-

sion de l'infection lépreuse. On a observé que les matelas effilochés, qui se retrouvent partout là où les gens se recontrent, sont plus susceptibles de disséminer l'infection que la toux ou l'éternuement. Enfin, on a constaté que les profils démographiques de ces deux communautés ne correspondaient pas parfaitement avec les relations généalogiques, car les individus ayant des relations familiales étroites souvent ne se rencontrent pas régulièrement. Dès lors, la distance généalogique et la distance sociale sont deux paramètres indépendants l'un de l'autre dans cette communauté. Il en résulte que l'évaluation des facteurs génétiques d'hérédité de la résistance ou de la susceptibilité à *Mycobacterium leprae* peut être menée sans tenir compte d'une variable démographique qui lui serait nécessairement liée.

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