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An Anthropological Method for Measuring Exposure to Leprosy in a Leprosy-endemic Population at Karimui, New Guinea *

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An epidemiologically useful method of calculating exposure to leprosy is described. The method is based on the application of anthropological principles, and was used successfully in the Karimui Leprosy Research Project in New Guinea. The method could also be adapted for use in other epidemiological studies.

The importance of patterned social relationships, and therefore contacts not only within but also outside the household of residence, is stressed. The patterned relationships are presented as a set of structural distance scales which allow a score to be awarded for contacts at various levels of intensity, taking into account age, sex, marital status, etc. An individual numbering system is used so that relationships can be coded for computer analysis. In view of the large number of comparisons to be made, in even small communities, the use of a computer is essential for the application of this method.

This paper presents a method developed to measure the exposure to leprosy of a population of people at Karimui, Territory of Papua and New Guinea. The method is based on the application of simple anthropological principles and was developed to provide an answer to a question posed by an epidemiologist.

The principles are as follows: first, that all people, everywhere, behave according to culturally determined patterns which are apparent from observation and enquiry; second, that in any society, the closeness or distance of social relationships, in general terms, will be determined by a set of stated or implicit rules which take into account such factors as age, sex, affinity and consanguinity, marital status, social status, work habits, religious practices and other customary behaviour.

The application of these principles, taken together, makes it possible to determine the major social contacts that an individual in any society will make, but the principles will not account for atypical, random or idiosyncratic behaviour. For this reason, a measure of contact derived in this way will represent a minimum and it is not claimed that all contacts that may have occurred in the study population are accounted for. It is claimed, however, that all the major patterned contacts are included.

Since, it is believed, close or repeated contacts between individuals are the most likely method of transmission of leprosy, measurements of such contacts seem particularly appropriate in an epidemiological study of this disease. The hypothesis on which the method is based is as follows: if leprosy is transmitted in a community by contact, the social structure of the community will reflect the transmission and distribution of the disease.

While time is a factor in all scores, the data have been coded as at one point in time (November 1966). A simple variation in the coding of data, and in the application of computer programmes, could allow for scoring at a number of appropriate points in time. A more refined coding method for familial relationships has been developed since the Karimui material was processed; this will be described later. Many other refinements are possible but are probably not important in an epidemiological study. The method is not an instrument of precise measurement and the numerical scores resulting from its use have no absolute value of their own but are comparable with each other.

* A summary version of this paper was read at the Ninth International Congress of Leprosy held in London in 1968.

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To make clear the particular application of the principles referred to, it is necessary to outline some of the important features involved in the method. Glasse (1962) made a brief study at Karimui and later Wagner (1967) made a much longer study of one linguistic group during the period 1963–65. The material presented here, however, is derived from the author's field work in 1966 and 1967.

The Karimui people live on a plateau to the north and west of Mount Karimui, which is situated in the bend of the Tua and Erave rivers in the extreme south of the Chimbu District of the Territories of Papua and New Guinea. Approximately 5000 people occupy the study area at any given time although about 6000 people were recorded during the period 1962–67; high birth- and death-rates and a very low rate of migration account for the difference. Population centres occur at elevations between 1000 and 1300 metres. The area is remote and even today is serviced entirely by air transport, the nearest road carrying traffic being 5 days' walk to the east of the Karimui Patrol Post (Fig. 1).

The first European contact with the Karimui people was not made until a patrol penetrated part of the area in 1939. Because of the intervention of the Second World War and the years of reconstruction, annual administrative patrols did not commence until 1956, while the Karimui Patrol Post was not established until 1961. The first census was conducted in 1962, and the Karimui Leprosy Research Project (Russell, Scott & Wigley, 1964; Scott, Wigley & Russell, 1966) commenced in the same year.

The Karimui Project started as a trial of BCG as a prophylactic against leprosy. The population was divided at random into 2 groups and the members of one group were given a BCG vaccination; the members of the other group were given a saline injection. Repeated visits were made to Karimui during the next 5 years to vaccinate new recruits (by birth or migration) and to examine the population for new cases of leprosy. Commencing in 1967, the Project moved into a treatment phase with the trial use of depot acedapsone for all cases of leprosy.

The initial stimulus for the development of the exposure method outlined in this paper was provided by the research team's wish to know whether the vaccinated and control groups were populations equally exposed to leprosy infection. Once the method had been developed, it was apparent that it was a useful epidemiological tool for the examination of leprosy transmission within the society.

The people of Karimui belong to two linguistic groups and are known as *Daribi* and *Tundauwhe*; the *Daribi* are located to the west and north of Mount Karimui and the *Tundauwhe* to the north-east; about 80% of the population belong to the *Daribi* group. The *Daribi* and *Tundauwhe* have no major differences in culture and commonly intermarry, but some minor variations may prove to be of anthropological interest.

The economics of the Karimui people are of a traditional Melanesian pattern and a slash-and-burn technique of gardening is used. There is considerable dependence on hunting and food gathering, and areas of rough bushland are reserved for, and abound in, game. Domestic pigs are important in exchanges and ritual but are not a regular source of meat. Wild and planted sago is available in some sections of the country; the staple crop, however, is sweet potato.

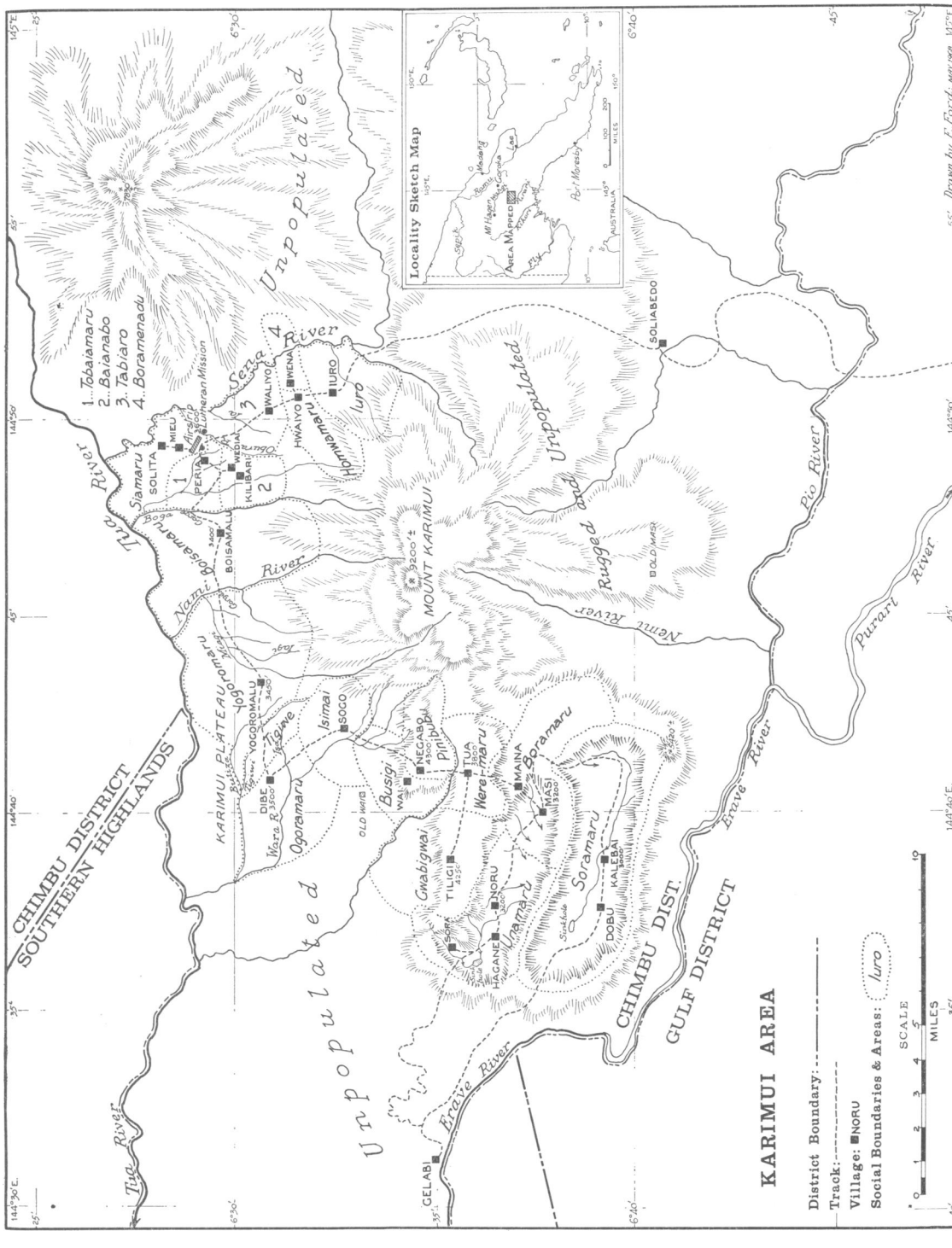
The over-all organizational pattern is patrilineal and patrilocal but there are numerous accepted variations. Although marriage is polygynous, only 25% of adult males have more than 1 wife. The age-group in which polygynous marriages are most numerous is 40–44 years; about 50% of men in this age-group have more than 1 wife. One man with 7 living wives in 1967 had the highest number recorded.

The normal Melanesian dichotomy of the roles in the community of the two sexes exists at Karimui. Males and females occupy separate ends of the typical house (*kerobei*) which has a door at either end, one for males and the other for females. An internal wall with only a small window at eye level divides the two sections of the house. Adult males never enter the female end of the house and adult females never enter the male end. Small children of both sexes live in the female end but move easily from one end to the other through the window. As children grow older the restrictions of their sexual roles are imposed gradually, and somewhat earlier on the females.

Girls are normally betrothed at a very early age and their marriage takes place at various ages between about 10 and 20 years. When a girl is married before she is considered to be sexually mature, she is given into the care of an older wife or a female relative of her husband until she matures sufficiently to become sexually available to her husband.

FIG. 1

KARIMUI STUDY AREA, NEW GUINEA



Sexual intercourse between husband and wife occurs in the bush or gardens. A wife is not sexually available to her husband during menstruation, pregnancy or the first year of lactation. The spacing of children in the families recorded suggests that these prohibitions are commonly accepted at Karimui. For example, if a baby dies at, or soon after, birth, the mother is likely to be pregnant again within a few months, whereas if the child survives, she is unlikely to produce another child for 2–3 years.

A wife returns to visit her father's village during times of sexual unavailability and these visits may be prolonged for several months. Visits at other times are shorter. Children establish a visiting pattern by accompanying their mothers on visits; the males continue this pattern throughout their lives if the males visited survive; the females modify their visiting once they are married.

Before European administration and control became effective, the area was strife-ridden and the people were involved in raid and counter-raid, and were continually on the alert for intruders into their territory. Even today, Karimui men do not travel far without some weapon, either axe or bow and arrows, or both. This internecine bitterness apparently led to the development of 2-storey long-houses (*siggybeis*) of a characteristic structure, with males living on the upper floor and females and children below. As many as 50 or 60 people are said to have lived in a single dwelling of this kind during times of crisis, each floor being provided with cubicles with a separate fireplace in each. A man and his older sons occupied the space above that occupied by his wives and their other children. These dwellings provided maximum security against surprise night attacks. Only two or three such houses are known to have been in use in 1967. During times of relative peace, *siggybei* families dispersed to live in bush- and garden-houses of much more modest proportions. Since 1961 some of the villages have constructed separate houses for unmarried adult males, but these *haus boi* were not an indigenous feature of Karimui culture. Where they have been built, there is usually, but not always, one *haus boi* for each clan.

The study population is organized into 48 clans and divided further into 105 subclans, which are the largest exogamous units in Karimui society. Some clans have no further subdivisions, while others have as many as 7 subclans. The clan groups roughly correspond to " villages " or " hamlets ". Clans are united to form 19 larger land-holding groups, 15 among the *Daribi* and 4 among the *Tundauwhe*.

Of 1646 married, widowed or divorced women living within the study area at any time during the period 1962–67, 294 (17.9%) were living in their clans of origin, 95 (5.8%) were from outside the study area, while 1257 (76.4%) were women of the study area resident in clans other than their clans of origin. From these counts it is clear that Karimui men obtain 94% of their wives from within the study population.

Apart from a hamlet of 18 leprosy-free people (1966 count) a full day's walk to the west, the Karimui have no neighbouring population centres closer than a 2 days' walk away. Traditional trade routes cross the area from the Chimbu country in the north to the Purari River and the coast of the Gulf of Papua in the south.

The Karimui population, then, is one in which only very recent contact with the outside world has occurred, and which is both geographically and socially isolated from its neighbours to a substantial degree. Within this population, both the broken nature of the country and fear of strangers have tended to restrict the movement of people still further.

PERSONAL IDENTIFICATION NUMBERS

In order to identify positively persons and their relationships, a numbering system was necessary. Each clan was given a number, each household within a clan was identified by a number, and each subclan was also numbered. A number such as 68.7.14 indicated house 14 of subclan 7 of clan 68.

Additionally, a number was needed to identify an individual within the household. The numbering system actually used in the Karimui study to identify individuals was devised by Dr G. C. Scott, long before the study had developed to the stage where it was decided to measure the exposure of the population to leprosy. It was simple, and satisfactory for the purpose for which it was designed and operated in the following way.

A village was allocated a block of adjacent numbers and each adult male was allocated one of these numbers with the affixed number .01 (say, 1281.01). The first wife of 1281.01 then became 1281.10 and her children were serially allocated the numbers 1281.11–1281.19; subsequent wives were allocated serially the number 1281.20 . . . 30 . . . 40, etc., to 1281.80. The children of subsequent

wives were identified in a similar way to the children of wife 1281.10. Adopted children were allocated numbers in the range 1281.91–1281.99, while attached adults such as the mother, sister, teenage brother of 1281.01, or an attached widow, were allocated numbers in the range 1281.02–1281.09. In this system, the number 0176.33 indicated the third child of the third wife of 0176.01, while the number 0176.03 would indicate an attached adult of 0176.01, and the number 0176.93 would indicate the third adopted child of 0176.01.

This numbering system was adequate for its purpose but proved less than perfect when used for the development of exposure scores as outlined in this paper. A number could not be used to identify clearly the relationships of attached adults, adopted children who were in the care of a particular wife, or of children of a wife by a former husband, remaining in their mother's care.

ALTERNATIVE NUMBERING SYSTEM

For future work the new numbering system shown in Fig. 2 covers all the potentialities of household membership found at Karimui (and probably elsewhere). If the identification numbers of the father and mother of a person are included with that person's data, a computer printout may be obtained of genealogies at any point in time for which data are available. The system does not identify twins or the sex of children, but in a computer programme, coded information on age and sex could cover these contingencies. When the number of persons in any category numbers more than that allowed for by the numbering system shown in Fig. 2 an additional column on the punched card would be required.

It can be seen that the individual numbers, in conjunction with a coding for clan, subclan and household, are sufficient to identify an individual precisely. For example, 68.05.12.3832 (clan, subclan, household, individual number) can be translated as follows: the second adopted child of the eighth wife of the man 3000, who is the second oldest resident brother of the household head of house 12 in subclan 5 of clan 68; the code number 14.10.03.1626 could be translated as: the sixth child, by a former husband, of the sixth wife of the man 1000, who is the household head of house 3, in subclan 10 of clan 14.

The use of such an identification system has the additional advantage that such numbers may be transferred, directly as coded information, on to punched cards. This numbering system shown in Fig. 2 was not used in the Karimui study but it is recommended that it should be adopted for further applications of the method for measuring exposure to leprosy described in this article.

FIG. 2

INDIVIDUAL NUMBERING SYSTEM DEVISED FOR USE WITH THE METHOD FOR MEASUREMENT OF EXPOSURE TO LEPROSY [a]

Male household head	1000			
Adult brothers of 1000	2000, 3000, 4000, 5000.			
Other household adult males	6000, 7000, 8000, 9000.			
Mother of man	1010, 2010 to 9010.			
Wives of man	1100 to 9100			
	↓ 1900		↓ 9900	
Adopted children of man (not in care of particular wife)	↓ 1091	to	↓ 9091	
	↓ 1099		↓ 9099	
Children of man and wife	1111 to 1911		9111 to 9911	
	↓ 1119 ↓ 1919		↓ 9119 ↓ 9919	
Children of wife and former husband	1121 to 1921		9121 to 9921	
	↓ 1129 ↓ 1929		↓ 9129 ↓ 9929	
Adopted children of man (in care of particular wife)	1131 to 1931		9131 to 9931	
	↓ 1139 ↓ 1939		↓ 9139 ↓ 9939	
Unmarried sister of man (in his care)	1021 to 9021			
	↓ 1029 ↓ 9029			
Married sister of man (in his care)	1030 to 9030			
	↓ 1050 ↓ 9050			
Children of married sisters	1031 to 1051		9031 to 9051	
	↓ 1039 ↓ 1059		↓ 9039 ↓ 9059	
Attached widows (in care of man)	1060 to 9060			
	↓ 1080 ↓ 9080			
Children of attached widows	1061 to 1081		9061 to 9081	
	↓ 1069 ↓ 1089		↓ 9069 ↓ 9089	

[a] The system would operate in the following way; the mother of man 1000 (the household head) would be 1010 and if man 1000 had resident brothers 2000 and 3000, their mother would be 1010 if, and only if, the three men had the same mother. However, if, as is possible in Karimui society, they shared only the same father (since Karimui males may be polygynists) then the following numbering could occur; 1000 (household head), 1010 (mother of 1000), 2000 (brother of 1000 in the male line), 2010 (mother of 2000 — not being the mother of 1000), 3000 (the brother of 1000 and 2000 in the male line), 3010 (the mother of 3000 — not being the mother of either 1000 or 2000). The men, 1000, 2000 and 3000 operate in Karimui as full brothers socially.

It is not considered necessary to code for brotherhood among attached household males 6000-9000 since brothers usually share a house unless they live alone. Attached males, other than the brothers of the household head, are thus normally male isolates without a brother. Common sense dictates that if two or more brothers in a household have the same mother and she is resident in the same household, she will be coded only once, e.g., if attached males 6000 and 7000 were brothers and their common mother was a household resident, her number would be 6010.

STRUCTURAL DISTANCE SCALES

In order to reflect the way of life at Karimui in an epidemiologically useful way, a set of structural distance scales was developed. Six scales (Fig. 3) allow for varying degrees of social distance which are evident, depending on whether the index case (a diagnosed case of leprosy for the base year) was

FIG. 3

STRUCTURAL DISTANCE SCALES GIVING SCORES FOR EXPOSURE TO LEPROSY BY DEGREE OF SOCIAL DISTANCE AT KARIMUI

Index Case by age-group, sex and marital status	Contacted Individual (relative to Index Case)									
	Level of Contact	Scores								
		8	7	6	5	4	3	2	1	0
SCALE 1 ADULT MARRIED MALE	Household		own daughters <10 and own sons	other household males	wives		other household females			
	Named sub-group (sub-clan)					other sub-clan males >10	other sub-clan males <10	other sub-clan females		
	Major named group (Village or clan)						other clan males >10	other clan males <10	other clan females	
	NIL									Other Persons

Index Case by age-group, sex and marital status	Contacted Individual (relative to Index Case)									
	Level of Contact	Scores								
		8	7	6	5	4	3	2	1	0
SCALE 2 ADULT MARRIED FEMALE	Household	own children <10	own daughter >10	other household females and all children<10	husband		other household males >10			
	Named sub-group (sub-clan)					other sub-clan females	other sub-clan males <10	other sub-clan males >10		
	Major named group (Village or clan)						other clan females	other clan males<10	other clan males >10	
	NIL									Other Persons

Index Case by age-group, sex and marital status	Contacted Individual (relative to Index Case)									
	Level of Contact	Scores								
		8	7	6	5		3	2	1	0
SCALE 3 ADULT SINGLE MALE	Household		father sisters <10 brothers	other household males			other household females			
	Named sub-group (sub-clan)				other sub-clan single males >10	other sub-clan males >10	other sub-clan males <10	other sub-clan females		
	Major named group (Village or clan)					other clan single males >10	other clan males >10	other clan males <10	other clan females	
	NIL									Other Persons

FIG. 3 (*continued*)

STRUCTURAL DISTANCE SCALES GIVING SCORES FOR EXPOSURE TO LEPROSY BY DEGREE OF SOCIAL DISTANCE AT KARIMUI

Index Case by age-group, sex and marital status	Contacted Individual (relative to index Case)								
	Level of Contact	Scores							
		8	7	6	5	4	3	2	1	0
SCALE 4 ADULT SINGLE FEMALE	Household	siblings <10	mother and female siblings >10	other household females and children <10			other household males			
	Named sub-group (sub-clan)				other sub-clan single females >10	other sub-clan females	other sub-clan males <10	other sub-clan males >10		
	Major named group (Village or clan)					other clan single females >10	other clan females	other clan males <10	other clan males >10	
	NIL									Other Persons

Index Case by age-group, sex and marital status	Contacted Individual (relative to Index Case)								
	Level of Contact	Scores							
		8	7	6	5	4	3	2	1	0
SCALE 5 CHILD <10 MALE	Household	mother siblings <10 sisters >10	father brothers >10 other household children <10	other household females and males						
	Named sub-group (sub-clan)				other sub-clan children <10		other sub-clan males and females >10			
	Major named group (Village or clan)					other clan children <10		other clan males and females >10		
	NIL									Other Persons

Index Case by age-group, sex and marital status	Contacted Individual (relative to Index Case)								
	Level of Contact	Scores							
		8	7	6	5	4	3	2	1	0
SCALE 6 CHILD <10 FEMALE	Household	mother siblings <10 sisters >10	father brothers >10 other household children	other household females			other household males			
					other sub-clan children <10	other sub-clan females >10		other sub-clan males >10		
						other clan children <10	other clan females >10		other clan males >10	
	NIL									Other Persons

male or female, child or adult, married or single. Each scale is a grid which allows for 4 possible levels of contact: household, subclan, clan or village, and non-village. At each level, the score achieved by a particular person depends upon the relative age, sex and familial relationship existing between the person being scored and the index case.

For example, in scale 2, in which the index case

is an adult married female, it can be seen that the highest score (8) is achieved at the household level by the index case's own children under 10 years of age, since these children have an intense mother–child relationship, sharing the same fireplace in the same end of the house and spending a considerable part of their out-of-house time with their mother. The index case's own daughters over 10 years of age achieve a score of 7, since the relationship remains intense but with modifications because of increasing age which lessens, to some extent, the interaction. Other household females, and all other household children under 10 years of age, achieve a score of 6 since they share the same end of the house but different fireplaces, and are members of the co-operating female work-group.

The husband of the index case achieves a score of 5 since, of the adult males, he interacts most intensely with his wife. His social distance is considered to be greater from his wife than that of female members of the household, since he lives in the opposite end of the house and his intense interactions with her outside the household are sporadic. Other household males, while members of the household unit, are nevertheless somewhat removed from the index case in terms of social distance and are accorded a score of 3.

At the subclan and village levels, the major considerations are those of age and sex, and scores between 4 and 1 have been assigned to reflect this.

Persons not in interaction at least at the clan or village level achieve a score of 0 in respect of the index case.

The five other scales reflect similar considerations and are organized in the same way. It is sufficient to say that the closer interaction between unmarried adult males, that between unmarried adult females, and that between children in play-groups has been allowed for in the appropriate scales. If other variables were significant (e.g., school- or occupation-group associations), they could be included on substituted in the structural distance scales.

INTERACTION

It should now be clear that at Karimui there are three significant situations in which contacts could occur: where a person lives, where he grew up, and where he visits. This being so, when a comparison is made between the data for an index case and those for any other person, there are 9 possibilities for interaction (Table 1). Of the 9 possibilities, it was decided to ignore the visiting–visiting comparison since, though it could be demonstrated that the person being scored and the index case both visited the same other house, it could not be established that they did so during the same periods and there was no certainty that they had contact. Thus, 8 possibilities of a score in any comparison of the data for any person with those for any index case were left.

TABLE 1
POSSIBILITIES FOR INTERACTION BETWEEN PERSONS[a]

Index case	Individual being scored		
	Residence	Origin	Visiting
Residence	1	4	7
Origin	3	6	8
Visiting	2	5	—

[a] The numbers indicate the order (or steps) in which comparisons were made.

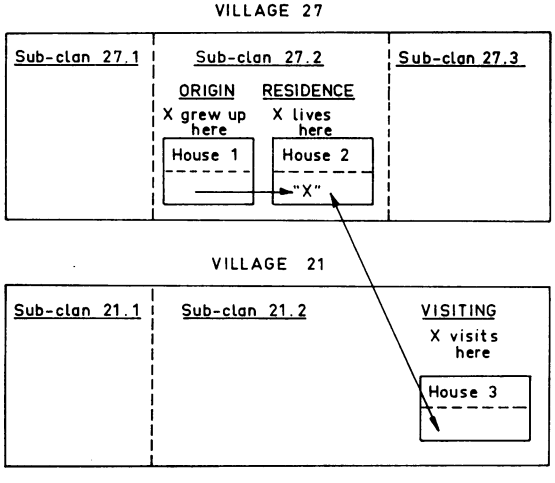
The aim of such comparisons was to produce scores of contact, using the structural distance scales, for each person in the population when the data for each individual were compared with the data for every diagnosed case of leprosy in the population in the base year (index cases). That is, each individual in the population was given the opportunity to achieve a contact score for residence, for origin and for visiting, in respect of every index case.

In order to simplify the procedure, and to ensure direct comparability of results achieved, the arbitrary decision was made to use the order of comparison given above because it placed primary emphasis on current residence, secondary emphasis on current visiting, and tertiary emphasis on past residence or origin. It was further decided to accept the first positive score achieved in this way under each heading and neither to add the scores nor to seek the highest score. Since every instance was to be treated in precisely the same way, the scores should be comparable but would not be the only possible scores that could be achieved. This method, when the data for any person had been compared with those for all index cases, produced three scores, one each for residence, origin and visiting, representing the total of all the scores obtained under each heading.

EXAMPLES

In Fig. 4 the example of the man "X" is represented. He grew up in house 1 and lives in house 2 in village 27; he visits house 3 in village 21. Every index case who lives in, visits, or came from either village will affect X's exposure score. X's origin score is determined by his associations with house 1, his residence score by his associations with house 2, and his visiting score by his associations with house 3. The actual numerical value given to X's score for a particular contact will be determined by whether the index case lives in the same house, the same subclan, or the same village, and it will also be influenced by consideration of the age, sex and familial relationship of X and the index case.

FIG. 4
EXAMPLE OF ASSOCIATIONS AND EXPOSURE TO LEPROSY OF MAN "X" AT KARIMUI



If we consider the examples given in Table 2, it can be seen in detail how the method is used. The necessary information is listed in the first column. The details concerning the index case are set out in column 2, and the details for two possible contacts are given in columns 3 and 4. To obtain a contact score for individual 1997.01 against the index case 1995.01, the method is as follows: by inspecting the age, sex and marital status information for index case 1995.01, it can be seen that he is a single, adult male. This indicates that scale 3 of the structural distance scales should be used. By inspecting the serial numbers of 1997.01 and 1995.01, it is found that the 4 initial digits are different and the two people are treated as not being familially related.

TABLE 2
EXAMPLE OF A COMPARISON BETWEEN AN INDEX CASE AND TWO POSSIBLE CONTACTS

		Index case	Possible contacts	
Serial no.		1995.01	1997.01	1982.20
Age		30	23	18
Sex		Male	Male	Female
Marital status		Single	Single	Married
Vaccination status		Saline	Saline	BCG
Type of leprosy		Lepromatous/ borderline [a]	Lepromatous/ borderline [a]	None
Year of onset		1962	1966	—
Residence	Clan	*Saia*	*Saia*	*Saia*
	Subclan	1	1	1
	Household	7	7	2
Visiting	Clan	*Sogo 2*	*Sogo 2*	*Anabai*
	Subclan	1	1	1
	Household	1	1	1
Origin	Clan	*Saia*	*Saia*	*Anabai*
	Subclan	1	1	1
	Household	12	12	1

[a] Sometimes referred to as "dimorphous".

We then compare (step 1) the clan of residence (*Saia*) for 1997.01 with the clan of residence (*Saia*) for the index case 1995.01 and it is found that they match. The house of residence of each is then compared and it is again found that they match; thus scale 3 is entered at the household level of contact. Since a familial relationship was not established between 1995.01 and 1997.01, 1997.01 is treated as an "other household male"; this relationship

achieves a score of 6. So for 1997.01's contact with the index case 1995.01 the residence score is 6 and steps 2 and 3 (as shown in Table 1) would not be taken. If, however, when the residence data for 1997.01 were compared with those for 1995.01, there was no match, step 2 would be taken. Step 2 involves the comparison of the residence data of 1997.01 with the visiting data for 1995.01. By the same procedure as outlined above, it can be seen that there would be no match since the residence for 1997.01 is *Saia* while the visiting for 1995.01 is *Sogo 2*. In this case, step 3 would be taken.

Step 3 involves the comparison of the residence data for 1997.01 with the origin data for 1995.01. In this case each would have the same clan (*Saia*) but when a match was attempted at the household level it would be found that the houses did not match; a comparison would then be made at the subclan level, where a match would be achieved (both being subclan 1). This would mean that scale 3 should be entered at the subclan level. At this level, 1997.01, with respect to 1995.01, would fall into the category " other subclan single males over 10 years of age ", and 1997.01's residence score would be 5.

To achieve an " origin " score for 1997.01 with respect to 1995.01, 1997.01's origin data (*Saia*, 1, 12) would be compared first with 1995.01's residence data (*Saia*, 1, 7); here it can be seen that there is a match at the clan and subclan levels but not at the household level. In this case, scale 3 would again be entered at the subclan level and again 1997.01 would achieve a score of 5 for contact with 1995.01.

If there was no match in this first comparison, the origin data for 1997.01 would next be compared with 1995.01's visiting data, and it can be seen from Table 2 that no match would be achieved. The next comparison would have been that between the origin data for 1997.01 and for 1995.01. Here, Table 2 shows a match at the household level, so that scale 3 would have been entered at that level and 1997.01 would be an " other household male " with respect to 1995.01 and thus achieve a score of 6.

To establish 1997.01's visiting score, the same procedure would be carried out by comparing his visiting data with 1995.01's residence data, and then with 1995.01's origin data if no match was achieved in the first instance. In this case, as was mentioned earlier, the visiting–visiting relationship was ignored in the comparisons. In this instance 1997.01's visiting score would be 0, as no match can be obtained in the two comparisons allowed.

For 1997.01, the exposure score would then be 6 for residence, 5 for origin and 0 for visiting, giving a total of 11 as his score for exposure to 1995.01.

The method was initially used in this way in the Karimui study, but other procedures could also be used. For example, all the possible scores could have been obtained for all 9 comparisons and then added to give a higher total score which would reflect all the patterned contact that had occurred. Alternatively, all 9 comparisons could have been made and the largest of these single scores selected and used alone as representing the closest known contact between 1997.01 and 1995.01. Such a score would place a greater emphasis on close contact.

Consideration was given to weighting the scores for residence, origin and visiting in various ways to reflect the duration of contact; however, it was decided that this would have begged the important question whether infection results from a single exposure, repeated exposures or exposure over a prolonged period. The weighting of scores in any way would have required a satisfactory answer to this question; it has not, in fact, been answered. In the further analysis of the Karimui data, all these procedures are being used since each involves a somewhat different emphasis, and comparisons of the different results may provide a further insight into the method of transmission of leprosy.

To achieve 1997.01's over-all exposure score, the kinds of comparison outlined above were made between his data and those for each of approximately 300 index cases taken one at a time; the summed totals were regarded as 1997.01's over-all exposure score within the Karimui population. In the same way, it could be established that 1982.20's exposure score in respect to 1995.01 is 2, her residence score being 2, and her score for origin and visiting being 0 in each case.

GENERAL DISCUSSION

In order to refine the scoring, and because it is known that different types of leprosy have different degrees of infectivity, the scores were tabulated as shown in Table 3, the scores achieved being divided according to the type of leprosy of the index cases. It can also be seen that provision was made for tabulating the number of each type of index case

TABLE 3

EXPOSURE SCORES BY TYPE OF INDEX CASE AND MEANS OF CONTACT; *SOGO 2*, KARIMUI

Serial No.	Sex	Age	Vaccination	Lepromatous contacts only					Tuberculoid contacts only					Burned-out tuberculoid contacts only					Total of all types of contact				
				Residence	Origin	Visiting	All means	Total contacts	Residence	Origin	Visiting	All means	Total contacts	Residence	Origin	Visiting	All means	Total contacts	Residence	Origin	Visiting	All means	Total contacts
17001	M	34		10	8	0	18	2	14	12	0	26	4	4	4	0	8	1	28	24	0	52	7
17010	F	28		5	9	2	16	6	13	38	25	76	21	2	5	8	15	5	20	52	35	107	32
17011	F	17		5	5	2	12	3	13	13	25	51	11	2	2	8	12	3	20	20	35	75	17
17012	F	6	BCG	5	5	2	12	3	13	13	25	51	11	2	2	8	12	3	20	20	35	75	17
17013	F	5		5	5	2	12	3	13	13	25	51	11	2	2	8	12	3	20	20	35	75	17
17014	M	2		9	9	3	21	3	15	15	23	53	11	3	3	9	15	3	27	27	35	89	17
17020	F	38	BCG	5	12	7	24	6	13	37	37	87	22	2	0	0	2	1	20	49	44	113	29
17021	M	14	BCG	10	9	6	25	5	14	12	47	73	20	4	4	0	8	1	28	25	53	106	26
17022	M	10		10	9	6	25	5	14	12	47	73	20	4	4	0	8	1	28	25	53	106	26
17023	F	7		5	4	7	16	5	13	12	37	62	20	2	2	0	4	1	20	18	44	82	26
17024	F	3	BCG	5	5	7	17	5	13	13	37	63	20	2	2	0	4	1	20	20	44	84	26
17101	M	23	BCG	10	8	0	18	2	14	12	0	26	4	4	4	0	8	1	28	24	0	52	7
17110	F	21		5	0	0	5	2	16	0	0	16	4	2	0	0	2	1	23	0	0	23	7
17111	M	1	BCG	9	9	0	18	2	18	18	0	36	4	3	3	0	6	1	30	30	0	60	7
17301	M	30		8	8	0	16	2	12	12	0	24	4	4	4	0	8	1	24	24	0	48	7
17310	F	29		4	0	0	4	2	12	0	0	12	4	2	0	0	2	1	18	0	0	18	7
17311	M	7	BCG	6	6	0	12	2	12	12	0	24	4	3	3	0	6	1	21	21	0	42	7
17312	M	3		6	6	0	12	2	12	12	0	24	4	3	3	0	6	1	21	21	0	42	7

TABLE 4

NUMBER OF PERSONS EXPOSED TO LEPROSY INFECTION BY LEVEL AND TYPE OF CLOSEST CONTACT AGAINST VACCINATION STATUS AND NEW CASES; *SOGO 2*, KARIMUI

Closest level of contact for residence, origin and visiting combined	Vaccination status	Number of persons in contact with cases of leprosy							
		Lepromatous cases		Tuberculoid cases		Burned-out tuberculoid cases		All types of case	
		All persons	New cases only	All persons	New cases only	All persons	New cases only	All persons	New cases only
No known contact at village, subclan or household level	BCG	0	0	0	0	0	0	0	0
	Saline	0	0	0	0	0	0	0	0
Closest known contact at village level only	BCG	0	0	0	0	0	0	0	0
	Saline	0	0	0	0	0	0	0	0
Closest known contact at subclan level	BCG	32	1	31	1	37	2	25	1
	Saline	38	0	37	0	44	0	34	0
Closest known contact at household level	BCG	13	1	14	1	8	0	20	1
	Saline	13	0	14	0	7	0	17	0
Total at any level of contact	BCG	45	2	45	2	45	2	45	2
	Saline	51	0	51	0	51	0	51	0

which contributed to the scores, and also many other relevant data.

It should be noted that the presence of a decimal point is assumed before the last 2 digits of each serial number in column 1 of both Table 3 and Table 5. The decimal point was deleted from the computer printouts as a matter of convenience.

Because it was possible that the total exposure of a person to index cases might not be as significant in the production of new cases as a single exposure of an intense kind, a further tabulation (Table 4) was developed and produced at the same time as that shown in Table 3. This tabulation shows the number of persons falling into a particular contact level when only a single, the closest known, contact is taken into account. In the adjacent column, the number of new cases which were diagnosed at each level is shown.

All individuals have been subdivided by the types of index case involved, and by their having received either BCG or saline inoculations in the BCG Trial. The 2 final columns in Table 4 show the same results when all index cases are considered in respect to each individual. The varying distribution of new cases according to the types of index case being tabulated should be the significant feature of this tabulation.

In order that a detailed analysis of the relationship of *any case* with any other case could be made, a further tabulation, giving in detail a computer printout of the exposure scores obtained for each person in contact with each index case, was produced (see Table 5).

It will be clear that the method outlined here can only be used if the computations and tabulations are made by means of a computer. The manifold comparisons involved in producing exposure scores for about 6000 persons with possible contacts with about 300 index cases involved tens of millions of comparisons. Once the method had been devised, appropriate computer programmes had to be developed and this work was done by Dr P. M. Moodie.[1] The programmes were tested and refined by comparing the tabulations with results obtained from a hypothetical set of data which was designed

[1] The programmes are available on request to Dr P. M. Moodie, School of Public Health and Tropical Medicine, University of Sydney, Sydney, Australia.

TABLE 5

DETAILED LIST OF LEPROSY CONTACTS OF A NEW CASE (No. 113) OF TUBERCULOID LEPROSY IN A MALE AGED 21 YEARS WHO HAD RECEIVED A SALINE INOCULATION; KARIMUI, 1967

Serial No.	Village of residence	Sex	Age	Level of contact with new case at:			Contact scores with new case at:			Total score
				Residence	Origin	Visiting	Residence	Origin	Visiting	
Lepromatous contacts										
630	1	F	21	Subclan	Subclan	None	2	2	0	4
1401	1	M	27	Subclan	Subclan	None	4	4	0	8
9220	3	F	21	Subclan	Subclan	None	2	2	0	4
Totals for all lepromatous contacts				Total contacts = 3			8	8	0	16
Tuberculoid contacts										
721	1	M	11	Subclan	Subclan	None	5	5	0	10
1110	1	F	29	Subclan	Subclan	Subclan	2	2	2	6
1111	1	M	16	Subclan	Subclan	None	5	5	0	10
1310	1	F	37	Subclan	Subclan	None	2	2	0	4
1392	1	M	16	Subclan	Subclan	None	5	5	0	10
1394	1	F	15	Subclan	Subclan	None	2	2	0	4
2130	1	F	23	Subclan	Subclan	None	2	2	0	4
3110	1	F	35	Subclan	Subclan	None	2	2	0	4
7120	3	F	30	Subclan	Subclan	None	2	2	0	4
7802	3	M	15	Subclan	Subclan	None	5	5	0	10
30013	9	M	19	Household	Household	None	6	6	0	12

to cover the possibilities of the method and scored by hand.

Second, it was necessary to record in the field the empirical data on residence, origin and visiting for every individual in the study population, and these data had to include information on household, subclan and clan membership. Other information was available in the study records.

When applied to the Karimui material, the method demonstrated that the random allocation for the leprosy study had been effective and that the groups inoculated with BCG and with saline were equally exposed populations. Further, as shown in Table 6, the results demonstrated that the incidence of new cases increases rapidly with the closeness of the known level of contact with a lepromatous case. Other hypotheses which are being tested include the following:

(1) That the number of infectious cases to which a person is exposed increases that person's chances of becoming infected.

(2) That all lepromatous cases become centres of distribution of infection, or that only some lepromatous cases become centres of infection.

(3) That it is more likely that an infectious case at Karimui will transmit the disease to contacts of the same sex than to contacts of the other sex.

TABLE 6

CRUDE, 5-YEAR LEPROSY ATTACK RATES BY LEVEL OF EXPOSURE TO LEPROMATOUS CASES FOR ALL PERSONS EVER RECORDED AT KARIMUI, 1962-67

Closest level of contact	Attack rate per 1000 persons		
	BCG vaccination	Saline inoculation	All persons
No known contact	3	6	5
Village or clan	8	16	12
Subclan	19	27	24
Household	46	63	55

(4) That the intensity of exposure influences the type of infection that develops.

It may be of interest that the total development of the method, the recording of data, the coding of the data for computer analysis and the production of the initial tabulations required for completion approximately 1 man-year's work. Only 12 weeks of field survey and recording by 1 man were involved, and less than 4 hours of computer time were needed to test the programmes and develop the initial tabulations.

CONCLUSIONS

The method, as used in the Karimui study, took into consideration only major factors; even at this comparatively simple level, however, it proved to have great value. The importance of looking beyond households into the pattern of social relationships in a society, when disease transmission is under investigation, is emphasized. When computer time is available, the number of variables that can be studied is limited only by common sense.

The exposure method described here could also be applied in any study in which a measurement of the extent of physical proximity (contact) between persons could lead to a better understanding of the epidemiology of a disease (G. C. Scott, unpublished data). The use of the method in such circumstances would require only that appropriate modifications should be made to fit method to the social structure and variables in the population being studied.

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RÉSUMÉ

MÉTHODE ANTHROPOLOGIQUE DESTINÉE À MESURER L'EXPOSITION À LA LÈPRE DANS UNE POPULATION OÙ CETTE MALADIE EST ENDÉMIQUE, À KARIMUI (NOUVELLE-GUINÉE)

L'auteur expose une méthode permettant de calculer le degré d'exposition à la lèpre d'une population. Elle est fondée sur l'application de deux principes d'anthropologie: le comportement des êtres humains est partout soumis à des influences d'ordre culturel et, dans toute collectivité, le caractère étroit ou lâche des rapports sociaux est déterminé par des règles, explicitement formulées ou non, qui tiennent compte de toute une série de facteurs vérifiables, comme l'âge, le sexe, le rang social, les coutumes religieuses, etc. Selon l'hypothèse de travail adoptée, si la lèpre se transmet par contact au sein d'une collectivité la structure sociale du groupe reflétera les modalités de la transmission et de la répartition de la maladie.

On a appliqué la méthode avec succès à l'étude de la population de Karimui, dans le Territoire de Papua et Nouvelle-Guinée où se déroule un projet de recherches sur la lèpre. D'abord axé, en 1962, sur la prophylaxie antilépreuse par le BCG, le projet s'est transformé en 1967 en un essai de traitement par l'acédapsone.

Les membres de la collectivité étudiée, au nombre de 5000 à 6000, mènent une existence quasi primitive et sont répartis en 44 communautés villageoises. La polygamie est autorisée, mais les hommes et les femmes séjournent dans des locaux séparés. Cette population est pratiquement isolée de ses voisines à la fois sur le plan social et sur le plan géographique et ce n'est que depuis peu d'années qu'elle est entrée en contact avec le monde extérieur.

On s'est servi d'un code numérique pour identifier chacun des habitants de Karimui. Après avoir décrit les avantages et les lacunes de ce procédé, l'auteur expose une méthode de remplacement — dont il préconise l'emploi lors des enquêtes ultérieures — qui permet de coder les relations sociales et facilite le traitement par ordinateur. On a d'autre part conçu six échelles graduées

permettant de donner une représentation chiffrée des niveaux de contact, importants du point de vue social, entre les sources d'infection connues et les autres éléments de la population. Ces échelles prennent en considération l'âge, le sexe, la situation matrimoniale, les liens de parenté et l'intensité des rapports sociaux.

La méthode permet de tenir compte des possibilités de contacts au lieu de résidence, au lieu d'origine et pendant les visites. Exemples à l'appui, on montre comment on parvient à chiffrer le degré d'exposition. On présente également des résultats qui illustrent le champ d'application de la méthode telle qu'elle a été mise à l'épreuve lors de l'étude de Karimui. On a constaté entre autres que les sujets vaccinés par le BCG et les sujets témoins sont exposés dans une égale mesure au risque d'infection et que l'incidence de la lèpre augmente rapidement en fonction de l'intensité des contacts avec un malade lépromateux.

La méthode, à la condition d'être adaptée dans chaque cas, pourrait se révéler utile pour l'étude épidémiologique des affections où l'on soupçonne l'intervention probable d'un facteur « contact ».

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