# THE EPIDEMIOLOGY OF LEPROSY 1

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## INTRODUCTION

The very close association of Hansen's bacillus with leprosy leaves no reasonable doubt regarding its causative role in that disease, but in the absence of scientific proof of the exact mode of infection the study of the epidemiology of leprosy is of practical importance in furnishing guidance in the difficult matter of prophylaxis against infection. In the earlier chapters of "Leprosy," by Rogers and Muir (47), the present writer dealt at length with the subject on the basis of a close study of the literature of the last half century or so, and he has since kept in contact with the subject by making abstracts of the current literature for the Tropical Diseases Bulletin. This review is written as one of the series that was planned when publication of THE INTERNATIONAL JOURNAL OF LEPROSY was begun, to summarize as briefly as possible our present knowledge of the matter.

### THE SPREAD AND INCIDENCE OF LEPROSY

History of the spread of leprosy.-The origin of leprosy is lost in the mists of antiquity, but it may not be without significance that the earliest account that is believed to refer to the disease, an Egyptian one of 1350 B. C., tells of its occurrence among Negro slaves from the Sudan; for at the present day tropical Africa shows the highest incidence in the world in proportion to the population. More reliable data are available regarding the introduction of leprosy into southeastern Europe at about 400 B. C. It was probably brought in by armies from Asia Minor and Egypt, and its first appearance in Italy has been attributed to the return of Pompey's soldiers from the East in 62 B.C., In the following few centuries it spread over Europe, apparently reaching its maximum during the crusades of the eleventh to the thirteenth centuries, and declining in western Europe from the middle of the fourteenth century. It is a disputed point how far this decrease was due to segregation of cases in leper houses (which was done after they had been deprived of all civil

<sup>1</sup> This article is one of the series of reviews by different writers, the plan for which was announced in the first issue of THE JOURNAL [1 (1933) 90].—EDITOR.

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rights and the males divorced from their wives), and how far to improved social conditions and diet, with the gradual introduction of fresh vegetables and meat in place of salted fish and meat. The destruction of about one-fourth of the population of Europe by the plague epidemic of 1349, known as the Black Death, may also have been a factor, for there is evidence of a decline of leprosy for at least a time following other epidemic diseases. An example of that has been seen in Iceland (47b).

All the evidence indicates that the Western Hemisphere was free from leprosy before its discovery by Europeans. Colombia was infected by Spaniards as early as 1543, and Brazil by the Portuguese. The African slave trade appears to have been responsible for the infection of the West Indies, Guiana and Mexico. During the eighteenth century French families became infected in the New Brunswick province of Canada, and in Louisiana in the United States. In the nineteenth century leprosy was carried, mainly by the Chinese, to Hawaii, New Caledonia, the Loyalty Islands, etc., where it caused serious epidemics. During the last two decades there has been an epidemic in the island of Nauru, in the Pacific.

The whole history of leprosy is thus one of the spread of a slowly communicable disease over the world through human intercourse.

The present incidence of leprosy.—The incidence of the disease in seventy countries is recorded in a table in the book of Rogers and Muir ( $^{47a}$ ), with brief notes on the information available at the time that book was written. The data doubtless only included advanced cases, for surveys in India of two and one-half million persons by Muir and his assistants ( $^{35}$ ) have revealed that, if early cases are included, the total number of lepers is at least four times as great as that of the advanced cases returned at the previous census. In a recent note Muir ( $^{33}$ ) has estimated the total number of lepers in the world at from two to four millions, distributed as shown in Table 1.

### FACTORS INFLUENCING THE INCIDENCE OF LEPROSY

*Climate.*—On preparing a map of the world showing the recorded leprosy rates, and comparing it with one of the rainfall, the writer found that all the rates of over 5 per mille, and a very large proportion of those between 1 and 5 per mille, occurred in countries in the tropical zone with annual rainfalls of over sixty inches, or between thirty and sixty inches. Moreover, the countries in the temperate zone with high leprosy incidence, such as Japan, Korea, Iceland, and

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Norway (before institution of the successful prophylactic measures of the latter half of last century), all have unusually heavy rainfalls for that zone. Equally striking is the practical absence of leprosy from those tropical areas with less than ten inches of rain annually, including the west coast of South America and the northerly tropical portion of what was German Southwest Africa. On preparing similar maps of India-the only large and densely populated country with very varying rainfall for which leprosy census figures are availablea most striking relationship between high rainfall and leprosy rates, and vice versa, was found in nearly all of the forty-three areas into which the country was divided. For details of this study the original paper should be consulted (42).

TABLE 1.—Estimated number of	lepers in	the world	(Muir).
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Country	Minimum	Maximum
China	1,000,000	1,500,000
India	500,000	1,000,000
Africa	500,000	1,000,000
Other British possessions	15,000	30,000
South America	100,000	150,000
Europe	6,000	10,000
Other countries	100,000	150,000
Total	2,221,000	3,840,000

Rainfall is, of course, only one factor. In the Philippine Islands, all of which have a high enough rainfall and temperature to favor leprosy, Rodriguez (39) found that the variations in the local incidence of leprosy do not correspond with the comparatively slight meteorological variations. A map prepared by Thornton (49) on the incidence of leprosy in different parts of the Union of South Africa does, however, show a close correspondence between the leprosy rates and rainfall, and Meyer in Nigeria (22) found the highest leprosy rates in the southern wet zone, and the lowest in the central, elevated, drier zone.

The writer (42) has suggested that the poorer inhabitants of hot humid climates, who wear scanty clothing, are greatly exposed to the bites of insects, which afford points of entry for leprosy bacilli in the case of those living in close association with infective lepers who discharge innumerable bacilli from the lesions of the nasal mucosa and skin. At about the same time Muir (47n) found that the first lesions in over one thousand early cases of leprosy were situated mainly on exposed parts of the face and extremities, parts that are

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most subject to insect bites and to excoriation of the skin. These observations may well have some bearing on the epidemiology of the disease.

Insects.-Many observers have demonstrated acid-fast bacilli in flies, ticks, lice, bugs, fleas and mosquitoes fed on leprous skin lesions and ulcers, but there appears to be no clear evidence that the infection is conveyed directly by the bites of insects. Insects may occasionally deposit leprosy bacilli on wounds or on mucous membranes, as at the orifice of the nose, but this does not appear to be a common mode of infection. Robineau (37) also considers that insects may play a mechanical role in transmission by producing a solution of continuity of the skin, thus admitting leprosy bacilli. Vedder (50) goes farther, for he found acid-fast bacilli by microscopical examination in 41 of 100 Aëdes aegypti immediately after feeding them on nodular leprous lesions, and thinks these mosquitoes may readily infect anyone bitten soon after such a feeding. Arazumi (1) suggests that cockroaches may infect food after being contaminated by contact with a leper, but there appears to be no reliable evidence of leprous infections through food.

Race.—The Indian Leprosy Commission Report of 1892 (11) recorded that no evidence was obtained of any special racial susceptibility to leprosy, and apart from the influence of social conditions there is very general agreement with this view. In Hawaii, Wayson and Rhea ( $^{52}$ ) found no definite racial peculiarity with regard to susceptibility. In 1929 Weidemann and Kaktin ( $^{53}$ ) examined the blood grouping of 106 lepers and 1,160 nonlepers and found no definite relationship between predisposition to the disease and the blood grouping of different races.

Sex.—There is also general agreement that, ordinarily, adult males suffer more from the disease than adult females, but that young children of both sexes are equally affected. The Indian census reports show a sex ratio of almost three males to one female, but concealment of female lepers under the purdah system, and earlier deaths of outcaste females, may partly account for this difference. Lowe  $(^{20})$  has recently worked out a curve showing a nearly equal incidence in the two sexes during the first fifteen years of life, a slightly higher female rate during the period of puberty, and the well-known preponderance of the disease in males of later life. This male preponderance is attributable to the greater exposure of males to infec-

tion, due to their more wandering habits and greater promiscuity. Among recent data are those of Wayson and Rhea ( $^{52}$ ) for Hawaii for 1890, which show 1.5 males to 1 female; of Kobayashi and Amagasaki ( $^{13}$ ) in Tokyo, with 3.4 times as many males as females among 6,693 cases; and of Hopkins and Denney ( $^{10}$ ) in the United States, with a 2.6:1 ratio among 700 Carville leprosarium cases. Klang and Wilson ( $^{12}$ ) recorded a ratio of 1.4:1 among 709 cases in Korea.

Special conditions may, however, reverse the proportions. In the province of Galicia, in Spain, there is a higher proportion of leprosy in females than in males, which has been attributed to the promiscuity of the former during long absences of their emigrant husbands ( $^{47c}$ ). Laquiéze ( $^{17}$ ) has recently reported that in two of the Loyalty Islands 73 percent of the cases were women, who were so promiscuous in their habits that they did not know who were the fathers of their children. In agreement with most writers, Lampe ( $^{14}$ ) found no decrease in the fertility of leper women as compared with the healthy.

Age.—By far the most important factor in relation to the prophylaxis of leprosy is the much greater liability of infection during the first two decades of life than later, and the comparative rarity of infection after the age of thirty; this is one of the numerous points of resemblance between leprosy and tuberculosis emphasized by the writer (<sup>44</sup>). Data regarding the age of over 4,000 patients at the time of infection are recorded by Rogers and Muir (<sup>47</sup>g), and in Table 2 of this paper, the first four lines of which are from the former publication, to which have been added more recent data from Korea and the Indian Deccan. An incubation period of three to five years was allowed for in the figures of the earlier table, in accordance with the data on that point recorded by the writer (<sup>43</sup>). In Table 2 the data are grouped in two ways; (a) by decades to thirty, all older cases being combined, and (b) in summation by five-year periods to thirty-five, older cases being separated.

The figures speak for themselves, for it is seen from the earlier data for South Russia, India and Hawaii that approximately 20 percent of the infections took place by the age of ten years, 50 percent by twenty years, 75 percent by thirty years and 80 percent by the age of thirty-five years. The rates for the earlier periods are still higher in the case of French West Africa, where there are exceptionally high leprosy rates among the population. It is noteworthy that

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the more recent data for Korea and India, which are doubtless more accurate than some of the older ones, reveal still higher early rates, with 90 percent infected by the age of thirty years.

Furthermore, Hopkins and Denney (10) reported that among 700 cases in the U. S. National leprosarium at Carville few occurred below the age of nine years, and a large proportion occurred between nine and thirty, with the maximum at the period of puberty. Weyson and Rhea (52) noted that in Hawaii children under fifteen are more frequently infected than older ones, especially in families with more than one case.

Age period	South Russia (Münch)	India (Commis- sion)	Hawaii (McCoy)	West Africa (Tonkin)	Korea (Klang & Wilson)	India, Deccan (Lowe)
By decades						
0-10	19.4	19.6	21.5	39.1	11.0	20.0
11_20	35.3	27.8	33.2	34.1	52.0	40.0
21-30	18.8	26.0	17.8	11.8	25.0	32.0
Over 30	26.5	26.6	27.5	15.0	12.0	8.0
Summation by five-year periods		. ***** ;				
0- 5	6.1	8.8	6.1	24.5		
0-10	19.4	19.6	21.5	39.1	11.0	20.0
0-15	37.2	82.7	40.7	59.1		40.0
0-20	54.7	47.4	54.7	78.2	63.0	60.0
0-25	65.5	63.1	65.0	80.9		80.0
0-30	73.5	73.4	72.5	85.0	88.0	92.0
0-35	80.0	83.5	80.9	89.4		
Over 35	20.0	16.5	19.1	10.6		

TABLE 2.- Age incidence of leprosy infections in different countries.

The special susceptibility of children.—That children are especially susceptible to leprosy was recognized long ago in Norway, in Iceland, and by Hillis in British Guiana  $(4^{7h})$ . In Iceland, Ehlers prohibited home segregation of lepers when any children resided in the house, with good results. In Norway, Sand and Lie recorded that among 2,010 children of 587 leprous couples, when the father alone suffered from the disease 7 percent of the children became infected, when the mother alone was leprous 14 percent became infected, but when both parents were affected 26 percent of the children contracted the disease. In Amboina, in Netherlands India, Lodder (18) found that only 3.2 percent of the children of leprous fathers contracted the disease, but that 7.6 percent contracted it when the mother was leprous. From Surinam, Lampe (16) reported that out of 60 children

of lepers who survived the first year of life 26 percent developed leprosy later; some of these he thinks were reinfected after leaving the asylum. He also mentions children born and infected in the asylum who lived in it for over eighty years, an expensive and now easily avoidable tragedy.

In the Philippines, Denney found 16 percent of infection among children of lepers from one to ten years of age, and no less than 44 percent of those who had lived with leper parents for seven to ten years. Later it was reported that among 308 children born in the Culion colony up to 1922, typical infections were met with in 14 percent and suspicious signs of early disease in another 19 percent, or a total of 33 percent. In a later report Rodriguez (38) dealt with 871 children born at Culion since 1906, of whom 398 had died and 75 had been taken charge of by relatives. Of the remaining 398 no less than 18 percent had definitely acquired leprosy, and another 24 percent showed suspicious symptoms of the disease, making a total of 42 percent; the remaining 58 percent were apparently healthy. Of the confirmed cases 50 percent became bacteriologically positive at from three to six years of age, the average age being five years and nine months. Still later the same observer (40) was able to report that, with improved conditions permitting earlier removal of the children from their infected parents, together with early and prolonged treatment of those who had become infected, the outlook for the children had so greatly improved that the yearly number of positive infections had been much reduced. During the period from 1922 to 1925 there was an average of 19 cases a year, while from 1926 to 1929 the average was only 2.25 per year.

Early age of childhood infections.—The urgent necessity of separating children from their leper parents at birth is illustrated by the statement of Hasselmann-Kahlert (9) that in 1928 at Manila 10 to 15 percent of the children of lepers had become infected through contact with their mothers before they were separated from them at the age of six months. Velasco (51) has pointed out that the earliest recognizable lesions in infants are most frequently observed on those areas of their skin that most frequently come in contact with that of their mothers, thus indicating direct infection.

*Heredity.*—In the prebacteriological days, when the great susceptibility of children was not recognized, the paralysing hereditary theory of the origin of leprosy was widely held. The Chinese have long believed that it is hereditary to the third generation, and also

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that it is transmissible by sexual intercourse. In Europe, Danielssen and Boeck, in their classical description of the disease (1848), supported the hereditary origin, but that was at a time when little was known of the laws of heredity. As late as 1865 a committee of the Royal College of Physicians of London reported in favor of the same view after a study of the replies to a questionnaire sent to British possessions, but Liveing, in his Gulstonian lectures before the College in 1873, held that the disease "was propagated by the imbibition of the excretions of those affected." With the discovery of the leprosy bacillus by Hansen, in 1871, the contagionist theory, which some of the more experienced of the earlier workers in leprosyinfected countries had never abandoned, steadily gain ground ( $4^{2f}$ ).

Separation of children from their parents.—The hereditary theory received its quietus through the proof that children separated at birth from their leprous parents remained free from the disease, and that in turn their children did not develop it. Thus, at the Tarn Taran settlement in the Punjab, India, Canon Guilford recorded that in the thirty years before the introduction of that measure:

"... of all those born there ... I know of only two men who have not become confirmed lepers, and even these, when I last saw them, began to show signs of the disease."

#### At a later date Jackson was able to report:

"On the other hand, for the same period of thirty years the children of leprous parents of the Almora Asylum (India) have been brought up in a home apart from their parents, with the result that only one of them has developed the disease. Several of these are now married, and have children, in whom the disease has not up to the present appeared. In not a few of these cases both parents were lepers."

He added that similar satisfactory results had been obtained in all the fourteen homes maintained by the Mission to Lepers since 1890, after which time all healthy children had been given up by their parents and brought up separately (47b).

A similar conclusion has been arrived at in the Philippines, for Rodriguez ( $^{38}$ ) reported that a detailed study of the abundant Culion material, with over 5,000 cases, had revealed no evidence of hereditary leprosy, and no conclusive evidence for or against hereditary predisposition. Simons ( $^{48}$ ), however, favors the idea of a hereditary predisposition.

Social conditions.—Overcrowding, usually due to poverty, is the most important social condition leading to increased numbers of infections. Thus, Hansen recorded that in poor leprous Norwegian

families it was customary for all the men to sleep under one coverlet and all the women similarly in another room, and visitors were considered to be "extremely rude to refuse to sleep in a bed with a person who is slightly leprous." Yet among one hundred sixty Scandinavian lepers who had migrated to the north central United States, he found that all but thirteen had died without giving rise to new infections, owing to their living in larger houses with separate bedrooms (47e). In Hawaii similar overcrowding has been reported. Lowe (19), in India, has noted that infection is favored by the joint family system, under which several married sons with their families all live together in their father's house. Among 400 cases of leprosy he found that 78 had contracted the disease from parents, 28 from brothers or sisters, and no less than 125 from other relatives living in the same house; this makes a total of 58 percent of the cases infected from relatives. Muir (30), in the course of leprosy surveys in India, noted that the disease is most prevalent among the poorer social classes and the castes with promiscuous social and sexual habits, and among the industrial laborers who live in overcrowded homes.

Occupation.—Occupation may also be a factor affecting the incidence of leprosy, for cases have been traced to infected household servants, to intimacy with leper prostitutes, and to leper washermen and -women, who may sneeze innumerable lepra bacilli over clothing worn next to the skin. Leprous wet nurses are the greatest possible danger to infants, and leprous food handlers are not without danger to others.

Diet.—Jonathan Hutchinson's theory that leprosy is directly due to eating rotten fish is not in accordance with our present knowledge, but it finds some basis as a predisposing cause in the observation of Muir (<sup>27</sup>) that both in the Arrakan Hills of Burma and among the aboriginal tribes of the Bankura district of Bihar the disease is especially rife in the low castes, who live largely on decomposed fish. Moreover, the very poor Bihar Bowri caste, who consume decomposing carcasses and stale rice, had two to five times as much leprosy as the neighboring different castes. Deficiency of milk and fresh vegetables has also been found a predisposing factor in Burma and in China. In the Anglo-Egyptian Sudan, Atkey (<sup>3</sup>) found that differences of climate and rainfall would not explain the incidence of leprosy, and he attributed the lower rates among Arabs as compared with Negroes to the fact that the former live largely on milk and animal food.

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Deficiency of vitamin B, especially  $B_2$ , led to the appearance of pellagra, which improved upon the administration of marmite, according to Basu (5).

Debilitating diseases.—It has been repeatedly pointed out by Muir  $(^{25})$  that the weakening effect of such complicating diseases as malaria, kala-azar, syphilis and hookworm infection predispose to the appearance of leprosy in those who have been exposed to infection, and also make treatment ineffective until the complication has been removed. He has also noted  $(^{28})$  that increased rapidity of the sedimentation of the red corpuscles of a patient is a sign of lowered resistance and unfavorable prognosis.

## CONDITIONS UNDER WHICH LEPROSY IS MOST FREQUENTLY CONTRACTED

An analysis of 700 cases of leprosy collected by the writer (47j) in which the probable source of infection was traced furnished the following data: Infections of one sex from the other through conjugal or cohabiting relationships in 18.3 percent. Other infections through living in the same house with a leper in 39.9 percent, including 9.1 percent sleeping in the same bed with a case (which made a total of 27.0 percent of bed infections). Attendance on lepers, usually while living in the same house, 19.9 percent. From a leper playmate or other close association, 19.4 percent. The remaining 2.5 percent included eight children infected by wet-nurses, three whose infection was attributed to wearing a leper's clothes, three who acquired the disease by arm-to-arm vaccination, and three infected by direct inoculation from a leper with a sharp instrument. In the cases of two surgeons so injured, the first leprous lesion developed in the wounded finger, and Marchoux (21) has recently added a similar case from Paris. These last instances are of great importance in proving that human leprosy, like the closely allied rat leprosy due to Stefansky's acid-fast bacillus, is an inoculable disease. The repeated failure of artificial attempts to produce human leprosy in this way is explainable by the fact that in almost all the recorded instances the inoculated persons were healthy, resistant adults, over the age of thirty (47k).

The above analysis shows that probably about 80 percent of infections are due to living in the same house with a leper, including about 25 percent who had slept in the same bed with one before contracting the diseases. However, the data under discussion (47i)

show that only from 3 to 6 percent of healthy persons who have been in contact with lepers contract the disease. The proportions of conjugal infections gave similar figures, owing to decreased susceptibility of adults.

Conjugal infections.—From recent data bearing on the question of conjugal infection the following may be mentioned. In Netherlands India, Lodder (18) met with only one such case among one hundred five married couples. Haddad (8), in the Belgian Congo, found 6 percent of conjugal infections among one hundred seven leprosy patients, and 42 percent due to close contact.

House and family infections.-All recent evidence confirms the frequency of family and house infections. Thus, in Fiji, Austin (4) reported that in spite of concealment for fear of compulsory isolation, 61 percent of 105 cases acknowledged having one or more leper relatives, varying in numbers from one to nineteen. He rightly adds: "It would be difficult to find a more cogent argument for the necessity of frequent and thorough examination of family contacts." In the United States, Hopkins and Denney (10) recorded 70 cases in thirteen families, usually with exposure for six to ten years or more before infection occurred. Neff and Snodgrass (36), in Fiji, met with a family of Indians in which, after a son had contracted the disease from a neighboring friend, both his parents and five of six brothers and sisters became infected; the only one who escaped had left the household. In Hawaii, Wayson and Rhea (52) reported 600 admissions, or 20 percent of the total numbers, from 420 families, and 43 percent of them had come from thirteen families, three or more cases occurring in 10 percent and two or more in 30 percent of the households. In South America, Arcos (2) found that in about 66 percent of 150 patients there were other cases in the family, but no conjugal cases had been met with. In an Indian village Muir (31) recently found that no less than thirteen out of seventeen persons in house contact with infectious cases of leprosy from birth up to the sixth year had contracted the disease, and ten of them had themselves become infectious; but of sixteen subjects first coming into contact with infectious cases between the ages of eleven and twenty-five years, nine had become infected and only one of them, a debilitated person, had reached an infective stage. This once more emphasizes the greater susceptibility of young children, and Muir agrees with the writer that leprosy would practically die out of any community within two generations if all children were protected from infection. Muir and Chatterji  $(^{34})$  report two Bengal family trees with 18 cases in one family, 15 of whom had apparently been infected by one person, and 5 in the other family.

In South Africa, Mitchell  $(^{23})$  reported that younger persons are most frequently infected by older ones, or by brothers or sisters, and that the great majority of infections take place during childhood or young adult life. He concluded:

"The lesson of all this is obvious. Until we can devise some system or method of securing *early discovery* and the early institution of precautions, we cannot hope effectively to limit its spread. I am satisfied we shall never accomplish this by methods of compulsion: we must secure the voluntary co-operation of the Native peoples."

Rodriguez and Plantilla  $(^{41})$  recorded that at the Cebu treatment center, in the Philippines, 80 percent of the bacteriologically positive cases had been in previous contact with a leper, and that 44 percent had lived in the same house with one; in bacteriologically negative cases the respective figures were 68 and 3 percent.

Type of case and infectiveness.—The very important point that nodular cases are highly infective, while purely neural cases are nearly always uninfective, is well illustrated by the data of 113 cases collected by the writer in which the type of the case causing the infection was recorded. No less than 107 of these infecting cases, or 94.7 percent, were nodular, and only the remaining 5.3 percent were neural cases, among whom there were possibly included some mixed ones. The reason why nodular cases are the more infective is obvious; they are nearly all discharging innumerable leprosy bacilli from their nasal secretions and cutaneous ulcers, whereas in pure neural cases the organisms cannot escape from the nerve trunks and are rarely discharged from the nose. Muir (29) has recently emphasized the high infectivity of advanced nodular cases because of their nasal discharges. He states that even nodular cases that do not discharge the bacilli from the nose are very slightly infective, and that in early neural cases the chances are not a billion to one that the bacilli will escape from the skin to cause infection, and that therefore the danger from them is absolutely negligible.

About a decade ago one-third of the lepers under compulsory segregation for life in South Africa were found to be negative bacteriologically and were released as harmless by Mitchell, who quoted the writer as an authority for so doing. It is also noteworthy that

the humane Norwegian policy, through which leprosy has been nearly stamped out during the last eighty years, laid particular stress on securing the hospitalization under good conditions of as many as possible of the highly infective nodular cases. The tendency of leprosy to self-healing, with gradual conversion of the milder cutaneous cases into the slightly infective neural form, is also well known, and has been emphasized by Muir ( $^{25}$ ). Lampe ( $^{15}$ ), among others, has also pointed out that many early cases of leprosy in children and young adults remain stationary or undergo spontaneous arrest. These facts simplify to some extent the control of the disease through prevention of contact of susceptible persons, especially children, with the more infective forms of leprosy.

## EPIDEMIOLOGY AND PROPHYLAXIS

In conclusion, it will be well to point out the bearing of the more important epidemiological facts above dealt with on the problem of reducing and eventually stamping out leprosy in any given area. Account is also to be taken of recent advances in treatment, by means of which it is now possible to prevent a large proportion of really early leprosy infections from going on to an infective stage. Another factor is the tendency of infective cases either to die or pass into a far less infective neural stage within about a decade. Only general principles can be laid down here, and that only briefly, for their application will vary widely in details with the conditions prevailing in different countries; furthermore, the subject of prophylaxis will be dealt with in a separate article of this series of reviews.

Up to about two decades ago little advance had been made in prophylactic measures since the Middle Ages. Compulsory isolation of all cases for life was the most generally advocated measure, though this was not the case everywhere; an important exception is to be noted in the case of the Philippines, where only bacteriologically positive cases have been segregated, and any that become negative are released. More logical than the usual practice was that of killing the lepers, which prevailed up to a few decades ago in the Indian Kattiwar States, Sumatra, Zululand, Pondoland, and Nyassaland ( $^{47d}$ ) and is said by Mayer ( $^{22}$ ) to account for the comparative rarity of the disease in the Yoruba area of Nigeria. This was a drastic measure, but scarcely more cruel than the eighty years imprisonment recorded by Lampe ( $^{14}$ ) in the case of some children

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born and infected in the Surinam leper asylum. It is now very generally admitted that the failure of rigid compulsory segregation, in the tropics at any rate, during the time when there was no effective treatment, was due to general hiding of the early cases, so that when they were discovered and isolated they had already suffered from the disease for several years, during which they had infected some of those in contact with them. The writer  $(^{45})$  has, therefore, repeatedly urged that rigid compulsory isolation of all cases, irrespective of the stage or degree of infectivity, may do more harm than good by causing the early cases to be hidden until they have passed the stage most amenable to modern treatment, and until they have infected members of their households or other contacts. Fortunately, increasing numbers of leprous persons are now coming forward voluntarily in order to have the benefit of the improved treatment.

For over a decade  $(4^{7m})$  the writer has advocated a plan for rapidly reducing leprosy by discovering and treating effectively a large majority of cases in the earliest stages. This plan was based on the facts: (a) that most infections (probably about 80 percent) are contracted by living in the same house with an infective leper; (b) that the earliest symptoms appear in most cases (probably some 80 percent), especially in the case of children, within five years of exposure to infection; and (c) that by prolonged modern treatment in the early stages the great majority can be prevented from going on to an infective stage. The proportion of cases that can be prevented from advancing is 90 percent according to Moiser (<sup>24</sup>), who also found examination of the households of all known lepers far more effective in discovering early cases than are surveys of the whole population, invaluable as the latter have proved in India (<sup>35</sup>) and the Sudan (<sup>46</sup>).

As the key to the problem is the early discovery and treatment of as many cases as possible, it is essential to examine from head to foot the household and other close contacts of every discovered case of leprosy every few months for at least five years, and if possible for ten years. If this can be done, and if the great majority of the discovered cases can be treated so as to prevent their going on to an infective stage, at the end of a decade most of the originally infective cases will have died off or passed into a less infective stage, and too few highly-infective cases will remain to maintain the disease to any serious extent.

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In addition, infective cutaneous-type patients should be persuaded to move to agricultural colonies and should be given good treatment; or they should be isolated in their own villages or homes. as was recently done in India by Muir (32). Preferably this should be done without compulsion, which, moreover, should never be employed in a form that will lead to extensive hiding of the early cases and so to the defeat of its own object. This plan was adopted on the writer's recommendation nearly a decade ago in the Pacific island of Nauru, with the very promising results already recorded by Bray (6) and by Grant (7), both of whom have informed the writer that few if any of over 300 early uninfective cases have gone on to an infective stage, and that two-thirds of over 300 infective cases have been cleared up within nine years. This has happened despite the fact that no less than 30 percent of the entire population were found to show signs of leprosy when they were first examined. Similar measures on a much larger scale are also proving effective in the Southern Sudan. The nearer it is possible to carry out such measures in any given area, the more rapidly is leprosy likely to be reduced to easily manageable proportions.

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