WORLD LEPROSY IN RELATION TO CLIMATIC STIMULATION AND BODILY VIGOR.[1]

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In this article is set forth evidence tending to indicate that leprosy, in its geographic distribution over the world and its time fluctuations in certain regions, is basically determined by climate—by the degree of bodily vigor engendered in population masses by the climatic stimulation of their habitat. Masses of carefully collected statistics now leave little doubt that human energy and vigor are largely controlled by climate. Cool, changeable weather leads to high energy levels and an active life, while prolonged moist heat results in a more sluggish metabolism, a low energy level of existence, with a care-free and complacent attitude toward life. Animal studies and human statistics also indicate that resistance to infection varies directly with the general level of energy and bodily vigor. An inquiry whether leprosy would show climatic relationships, to a degree that would warrant considering it climatically controlled, is therefore believed to be of special interest.

It is well first to describe briefly the response to artificial climates exhibited by laboratory animals under controlled conditions (17, 18, 24). At 60-65°F. growth is most rapid and maturity reached earliest, the young are lusty and vigorous, and the adults highly fertile. At 88-92°F. and 60-70 per cent relative humidity, body metabolism is more sluggish, and fertility and resistance to infection low; the young grow more slowly and develop into lean types that mature late. In the cooler atmosphere practically all matings result in litters of lusty young; in the heat the animals mate freely, but conceptions are more rare and result in small liters of low viability. In the matter of heat production, also, marked adaptation takes place. In the moist heat oxygen consumption is depressed and animals largely lose their ability to produce heat quickly when chilled. Those adapted to the cold have a high heat production and meet chilling well. These basic changes in energy level and vital functions occur under different climatic conditions when all other factors of life (diet, light, ventilation, etc.)

[1] The author is indebted to the Leonard Wood Memorial for an opportunity to study leprosy and climate in the Philippine Islands during the spring of 1935.

are held constant. They therefore truly represent body response to climatic stimulation.

Man exhibits similar responses to his climatic environment. In moist heat his oxygen consumption and heat output fall, and he withstands chilling poorly. The temperature comfort zone for tropical people stands almost 10°F. higher than for people of the northern United States. Blood pressure also falls in the heat, and the reserve capacity to meet sudden energy needs is more limited. Body development and sexual maturity of people are delayed by tropical heat, and fertility falls as mean temperatures rise above 70°F. (13, 14). This is contrary to the general belief, held by the medical profession and laity alike, that maturity is accelerated in tropical heat, a belief, moreover, that is contradicted by carefully collected statistics, as shown in Table 1. Nowhere else on earth

TABLE 1.—*Mean age at menarche, and index of climatic drive, in various regions of the earth.*

City	Subjects	Year	Mean age at menarche, years	Index of climatic stimulation
Minneapolis	College girls, White.	1934	12.8	18.5
Cincinnati	College girls, White.	1930	13.4	19.4
New York	Jewish orphans.	1934	13.5	15.6
Montreal	Obstetrical cases, White.	1934	13.5	14.6
Baltimore	Obstetrical cases, White.	1935	14.1	17.4
Richmond	Obstetrical cases, White.	1930-4	14.0	20.8
St. Johns, N. B.	Obstetrical cases, White.	1934	14.1	18.3
Panama	Obstetrical cases, Negro.	1934	14.1	3.0±
Manila	Obstetrical cases, Filipino.	1930-5	14.7	2.2
Tokyo	College girls, Japanese.		14.8	12.0
Cebu, P. I.	Clinical cases, Filipino.	1935	15.2	1.6
Hong Kong	Obstetrical cases, Chinese.	1930-5	15.3	2.5±

does puberty seem to come so early as in the stormy area lying to the west of the Great Lakes. The mean age of 12.8 years for the menarche at Minneapolis is more than two years earlier than that in tropical and Oriental countries where moist heat dominates existence. In all immigrant stock that settled in our north central states there has been a steady progress of the menarche toward earlier ages. In this region domestic animals also thrive best, verifying in their

growth and development our findings on experimental animals in the laboratory.

Children in their growth and body development further demonstrate the dominance of climatic stimulation. In the tropical heat, where the menses come late, child growth shows a progressive lag behind that of more stimulating climates. By the age of puberty this lag is between two and three years, so that a Filipino or Chinese child of 15 years has much the appearance of an American child of 12. The fact that such growth lag can be produced in healthy animals on fully adequate diet by subjecting them to moist heat, renders it likely that such delayed development in the tropics is not due to faulty diet, as has repeatedly been claimed. This question is a fundamental one applying to man's welfare in the tropics, and deserves careful investigation.

Accompanying these climatic effects on body growth and development go differences in resistance to infection. In both man and animals it has been shown that ability to fight infection declines as environmental temperatures rise (13, 25). Southerners, both white and colored, who migrate to our northern states show a distinctly lower resistance to tuberculosis than do native northerners (22). Similar observations have been made by Swiss physicians in regard to Europeans from the Mediterranean countries as contrasted to those from north of the Alps (27). In all countries the acute nephritis death rate is negatively correlated with climatic stimulation, being several times higher in regions of moist heat than in cooler, more stormy areas (5, 16). With acute appendicitis the findings are most striking, for although such attacks occur most frequently where storm changes are most severe, the fatality rate shows a steady rise as one goes from cooler regions toward tropical moist heat; in the southern United States the rate at Atlanta is 13.5 deaths per 100 cases as contrasted to 5.3 deaths in the northern states (19).

It seems clear, then, that the level of climatic stimulation over the world is a factor of major importance in determining such basic human factors as growth rate and body development, energy level of existence, and finally, of most importance for our present purposes, tissue resistance to infection (20).

Leprosy is now in the main a tropical disease, being unable to maintain itself in the more stimulating regions of the earth. In the cooler portions of the temperate zones it tends to become quiescent,

noncontagious, and of little moment. This has held true in North China, West Central Europe, and in North America to the north of the Gulf states. Particularly impressive was the failure of the disease to gain a foothold in and around Minnesota after many scores of cases had been imported there from Scandinavia. Only in the tropics and subtropics does it go on from decade to decade, with little apparent regard for man's efforts at its eradication. Even in the tropics it becomes distinctly more mild and less prevalent at higher altitudes where the climate is more invigorating, tending to go over to the more chronic, neural, anesthetic type, and to be less contagious.

Statistics on the prevalence of leprosy in any country can have only a relative value, serving to indicate comparative differences in different regions or population masses. Nowhere is the actual number of infected cases known with accuracy, because of the long latent period and the difficulty of early diagnosis. However, available statistics can be used to indicate roughly the regional differences in the prevalence and severity of the disease, and its relation to climatic stimulation.

In Table 2 are shown some of the 1911 census estimates of leprosy in India per 100,000 population. The highest rates are seen around the Bay of Bengal, particularly in its upper portion, with a marked lessening in the incidence toward the northwest frontier. Afghanistan is said to have very little leprosy. Comparing these data with Text-fig. 1, which depicts the intensity of climatic stimulation at various points over the world, one readily sees that the most heavily infested leprosy areas in India are those with very low levels of climatic stimulation. The number of lepers declines as climatic stimulation rises; furthermore, the character of the disease also changes. From the more contagious, more progressive cutaneous type seen around the Bay of Bengal it passes over into a more sluggish disease, mainly of the neural anesthetic type, in northwest India. The people of India, in their body build and vigor, also show this difference in climatic drive, for from the northwest come the tall, stalwart men of martial spirit, and it is there that the British have encountered greatest difficulty in times of uprisings.

Rogers (26) believes the high leprosy rates of the humid heat areas in India to be due to the softening effect of perspiration on the skin itself, making dermal penetration easier for the leprosy or-

TABLE 2.—*Climatic stimulation and leprosy over the world.*

Station	Latitude	Altitude (feet)	Year	Index of climatic stimulation	Lepers per 100,000 population
Mexico					
Saltillo, Coahuila .	25°30′N		1899	12.37	23
Colombres	26°N		1911	11.35	14
Leon, Guanajuinto .	21°7′N	5,970	1901	10.34	16
Morelia, Michoacan	19°40′N		1909	8.55	30
Guadalajara, Jalisco	20°50′N		1911	6.49	46
Oaxaca, Oaxaca ..	17°4′N	5,160	1897-9	6.56	6
Culiacan, Sinalao .	24°55′N		1909	6.24	73
Tuxtla, Chiapas ..	20°58′N		1900	5.00	14
Merida, Yucatan .	21°N	70	1913	3.36	41
Valledolid	20°20′N	70	1913	3.63	120
Europe					
Greenwich, Eng. ..	51°28′N	160	1923-9	18.60	
DeBilt, Neth.	52°6′N	10	1923-6	17.77	
Coimbra, Spain ...	40°20′N		1923-6	16.83	
Paris, France	48°20′N	160	1923-8	16.63	
Armagh, N. Ireland	54°40′N		1884-93	16.49	
Munich, Germany .	47°50′N		1923-8	16.16	
Zurich, Switzerland	47°23′N	1,630	1923-8	15.95	Practically none
Sofia, Bulgaria ...	42°35′N		1923-8	15.54	
Budapest, Hungary	47°30′N		1923-7	15.25	
Lemberg, Poland .	49°35′N		1923-7	14.99	
Hamburg, Germany	53°30′N		1923-8	14.54	
Vienna, Austria ..	48°15′N	660	1923-7	14.00	
Aberdeen, Scotland	57°10′N	90	1920-5	13.46	
Odessa, U. S. S. R.	46°30′N		1925	12.38	
Oslo, Norway	59°55′N	80	1925	12.26	
Naples, Italy	41°N		1923-7	14.49	
Stockholm, Sweden	59°30′N		1923-7	11.27	Mild and infrequent
Milan, Italy	45°28′N	490	1923-8	11.05	
Tortosa, Spain ...	41°N		1923-8	10.92	
Haparanda, Sweden	65°50′N	30	1925	10.84	
Africa					
Cairo, Egypt	30°N		1925	8.88	
Khartoum, Sudan .	15°37′N	1,290	1925	7.13	Relatively mild
Entebbe, Uganda .	0°5′N	2,842	1916	1.28	Very bad (800)
Kimberley, S. Africa	29°20′N		1894-7	17.51	20
Turkey					
Angora	40°N		1926	14.03	
Siberia					
Krasnoiarsk	40°0′N	70	1911	20.24	
Irkoutsk	52°16′N	1,540	1911	15.82	Very little
Omsk	55°1′N	290	1911	14.61	
China					
Mukden	41°N		1925	12.09	Very little
Shanghai	31°11′N	20	1924	7.75	
Hankow	30°35′N	120	1925	9.00	Moderate

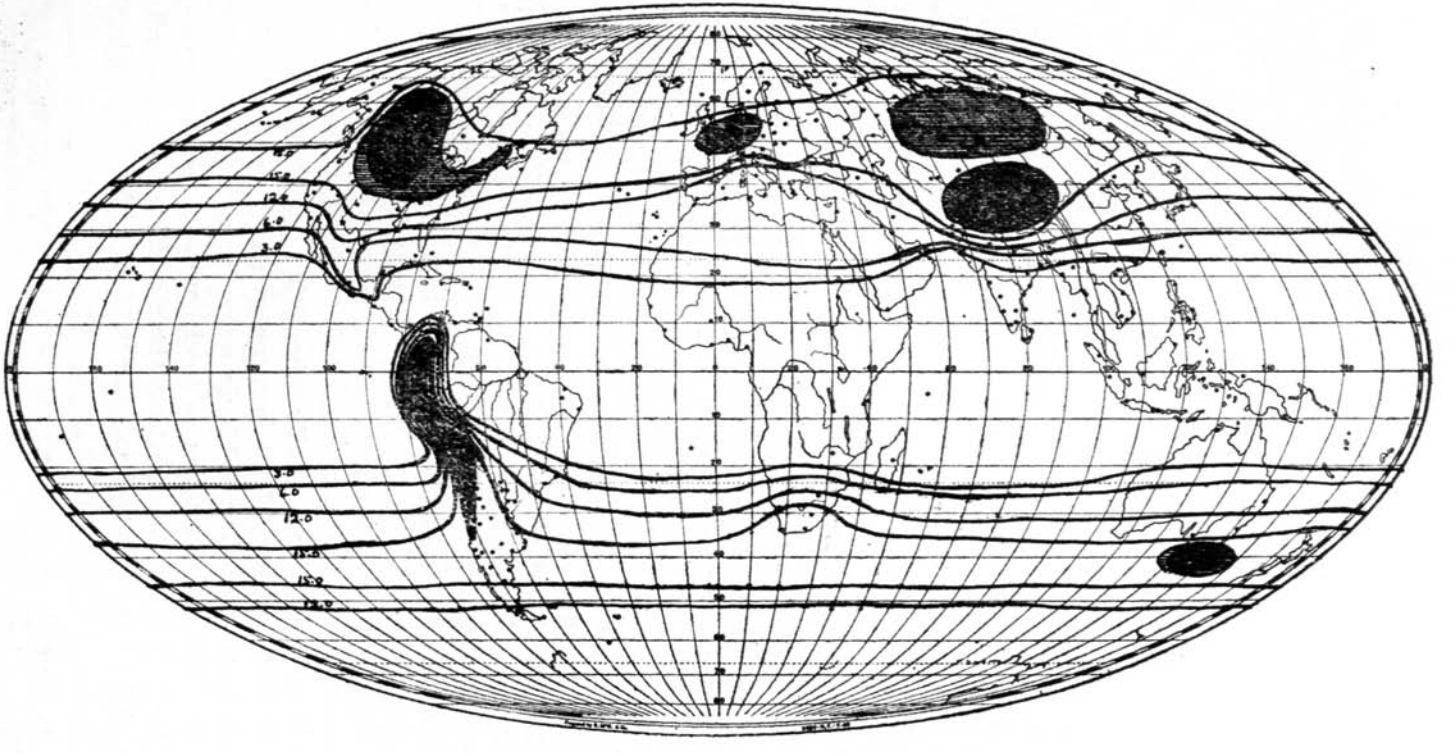
TABLE 2.—*Climatic stimulation and leprosy over the world*—(Continued).

Station	Latitude	Altitude (feet)	Year	Index of climatic stimulation	Lepers per 100,000 population
Japan					
Tokyo	35°41′N	70	1925	12.05	
Nagasaki	32°44′N	440	1925	10.05	
India					
Kalat, Baluchistan	28°58′N	6,620	1928	21.82	19
Srinagar, Kashmir	34°N		1928	12.12	85
Peshawar, N.W.P.	34°2′N	1,160	1928	10.45	0
Lahore, Punjab	31°34′N	700	1891	10.33	25
Jaipur, Rajputana	26°55′N	1,430	1928	7.82	12
Allahabad, U.P.	25°28′N	310	1891	6.91	59
Nagpur, C.P.	21°9′N	1,020	1891	4.44	91
Karachi, Bombay	24°51′N	10	1928	3.80	75
Calcutta, Bengal	22°32′N	20	1928	3.78	116
Mandalay, Burma	21°49′N	250	1865-75	3.33	75
Mysore, Mysore	12°35′N		1902-3	3.26	26
Rangoon, Burma	16°47′N	20	1928	2.72	116
Bombay, Bombay	18°55′N	40	1891	2.31	75
South America					
Quito, Ecuador	0°5′S		1930	22.94	20
Sucre, Bolivia	19°S		1923	21.08	Very little
Buenos Aires, Arg.	34°36′S	80	1919	17.91	Very little
Valparaiso, Chile	33°27′S	1,720	1915	14.80	Very little
Tucuman, Arg.	26°50′S	1,480	1919	12.60	Slightly more
Bogota, Colombia	4°40′N		1928	11.97	80 (Colombia)
Manaos	3°S		1916	2.85	720 (Province)
Quixeramobim	5°16′S	650	1910	2.38	80 (Province)
Georgetown B.G.	6°50′N		1923	1.24	230 (Province)
Australia, etc.					
Melbourne	38°S		1902-7	21.85	Present only in northern tropical areas
Sidney	33°52′S	140	1899-1902	9.58	
Perth	32°S		1910-12	14.45	
Brisbane	27°78′S	135	1910-12	7.09	
Wellington, N. Z.	41°16′S	10	1923-8	16.37	None
Netherlands India					
Batavia	6°11′S	30	1925	2.17	
Philippine Islands					
Atok, Mt. Prov.		5,200	1929	5.74	
Bontoc, Mt. Prov.	17°10′N	3,300	1929	4.35	
Bayombong, N.V.	16°45′N	1,100	1929	3.28	
Aparri, Cagayan	18°22′N	20	1928	2.74	Mild in mountain regions, severe in low lowlands
Manila	14°35′N	50	1927-9	2.24	
Zamboanga	6°55′N	30	1928	1.98	
Albay, Albay		30	1928	1.98	
Tacloban, Leyte	11°15′N	10	1929	1.87	
Iloilo, Iloilo	10°42′N	20	1929	1.77	
Cebu, Cebu	10°25′N	30	1929	1.55	
Hawaiian Islands					
Honolulu	21°19′N	40	1925	2.09	100

ganism. I would agree with him as to moist heat being the effective agent, but would differ as to the manner of its action; I believe it is the general depression of body metabolism and vitality by the heat that renders the people more susceptible to the infection. Manalang (10) has also suggested that the local skin condition favors infection in tropical warmth, and also that, because of the scanty clothing worn, actual skin-to-skin contact between children and parents is frequent and prolonged. He accounts in this way for the frequency with which leprous lesions appear on the cheeks (from nursing at the leprous mother's breast) and around the waist and on the buttocks. In cooler climates, as with the Scandinavian lepers in the Minnesota area, the body is more nearly covered with clothing, and close skin-to-skin contact less frequent. More facts are necessary before we can say with certainty whether such differences in ease of transmission are due to local skin differences or to more basic metabolic factors.

In China leprosy data have hardly reached the level of statistics, but a rough idea has been gained of the disease prevalence in different regions (11). The southern provinces of Yunnan, Kwangtung, Kweichou and Kwangsi are most heavily infested. In Fukien leprosy is very common, but farther north, in Chekiang, Kiangsi, and Hunan it is less prevalent. In Kiangsu, Shantung, Hupeh and Kansu, lepers are quite commonly seen in medical practice, but the disease is by no means as severe as in the southern provinces. In North China, in Anhwei, Honan, and Shensi, little is known of its prevalence so it is probably of little moment, and it is practically absent from Hopei and Shansi, while in provinces beyond the great wall it exists almost entirely as a disease imported by immigrants from the south. In these northern areas it becomes a slowly progressive disease, mostly of the neural anesthetic type. Nowhere on the plains of China is the climate really stimulating, mainly because of the depressing moist heat of the monsoon summer season. Back in the elevated interior regions real invigoration is provided by the altitude, but we have no information as to the prevalence of leprosy there. In North China, where the total climatic drive is much similar to that of the United States bordering the Gulf of Mexico on the north, the disease is of very minor importance.

In Korea it is said that "a line can be drawn across the country dividing a leprosy-free north from a heavily infested south" (11).



TEXT-FIG. 1. World chart showing zones of climatic stimulation.

Likewise in Australia it is only in the northern tropical areas that the disease prevails. South America, in its southern end that lies in the path of the south temperate zone storms and in the countries of the Andes highlands, is relatively free of leprosy. In the northern provinces of Argentina, however, it begins to be prevalent (6), and it becomes an increasingly serious problem as one goes northward in Brazil (6). In the upper reaches of the Amazon jungles, where the rainfall is heavy and the humid heat exceedingly depressive, leprosy becomes a real scourge, comparable in its severity to that of central African countries. In the northern arid portions of Africa, where the heat becomes less oppressive, leprosy is less severe (2).

In the Philippine Islands the disease is worst at Cebu, where climatic stimulation falls to a very low level. Those parts of the Islands that consist of low-lying plains, with their year-round blanket of depressing moist heat, are most heavily infested. In the upland regions the disease is less prevalent, and in the mountainous parts of northern Luzon it is relatively infrequent. At 7,000 to 9,000 feet elevation the tropical climate is replaced by one of mild but delightful stimulation. The lowlands of Luzon are given a partial respite from heat during January and February, but at Cebu and Iloilo the depressive effects continue the year round. Tuberculosis in the Philippines is also worst in those same general regions where leprosy is most prevalent, but patients sent to the mountain regions of northern Luzon do well. Recovery usually gives way to relapse, however, when such patients return to the lowland heat. The comparative infrequency of leprosy at the higher elevations, and the beneficial effects that these regions exert on tuberculosis, suggest the probable wisdom of segregating leprosy cases at stations in the mountains rather than near sea level where the heat is most depressing to body metabolism.

Leprosy also shows definite regional differences in Mexico (28).[2] It is worst on the Yucatan Peninsula, and next highest in the western coastal states, while throughout the plateau regions and eastern states bordering the Gulf of Mexico its prevalence is low. Table 3 depicts this prevalence by states and also roughly indicates the comparative climatic stimulation of different zones. Here, as

[2] It must be pointed out that Urueña, in his figure showing leprosy distribution over Mexico, used data from the wrong column of his table. His graph indicates the total estimated number of cases and not the number per 100,000 population.

in India and other countries, leprosy is reduced to relatively insignificant proportions as the index of climatic stimulation rises to about 10.0 or above, but becomes more severe in regions with a low index. Northeastern Mexico benefits somewhat from the storm stimulation of the polar waves that sweep down the western plains, but the remainder of Mexico's climate is ruled by tropical stagnation. Only

TABLE 3.—*Leprosy and climatic stimulation in Mexico.*

State	Estimated leprosy incidence [a]	Climatic stimulation	
		Station	Index
Tlaxcala	0		
Tabasco	2		
Hidalgo	2		
Mexico	3		
Puebla	5		
San Luis Potosi	6		
Oaxaca	6	Oaxaca	6.6
Chihuahua	7		
Morelos	8		
Vera Cruz	8		
Durango	9		
Aquascalienta	12		
Zacatecas	13		
Nuevo Leon	14	Colombres	11.4
Chiapas	14		
Tamaulipas	16		
Guanajuanto	16	Leon	10.3
Campeche	17		
Sonora	19		
Nayarit	19		
Coahuila	23	Saltillo	12.4
Colima	29		
Guerrero	30		
Michoacan	30	Morelia	8.6
Queretero	31		
Federal District	34		
Yucatan	41	Merida	3.4
Baja California	42		
Jalisco	46	Guadalajara	6.5
Sinalao	73	Culiacan	6.2
Quintana Roo	120	Valladolid	3.6

[a] Number of cases per 100,000 population.

over the Yucatan peninsular and western coast states is this stagnation broken during the typhoon season by repeated low-pressure storms. These storms are not stimulating, but instead may exert a potent influence in predisposing population masses to infection.

All the Mexican states with a leprosy rate above 16 per 100,000 population, with the exception of Coahuila, Queretara, and the Federal District, lie either on the Yucatan Peninsula or along the western coast that is lashed by typhoons. The remainder of the states with rates below 17 lie in the plateau regions or near the Isthmus of Tenuantepec, and in both cases receive a noticeable benefit from the occasional polar cold waves that sweep down the western plains of the continent. The Isthmus of Tenuantepec particularly has its tropical heat relieved at frequent intervals by the strong northern winds that play such havoc with shipping as a high pressure area in the Gulf of Mexico overflows into the Gulf of Tenuantepec.

One might be led to conclude, from the distribution of leprosy in Mexico, that importation of cases plays a dominant role, since the disease is worst in the states nearest the West Indies and next worst around the low-lying ports on the west coast where there is most frequent contact with oriental commerce and migration. Something more than mere foreign contact seems necessary, however, to raise a real leprosy problem, else more temperate-zone cities engaged in world commerce would have become involved. The two factors of contact with the disease and a low level of bodily vigor and resistance seem more to determine leprosy prevalence and severity in any region.

The possible rôle of typhoons, with their sudden lowering of barometric pressure and disturbance of the water balance in the body, needs careful investigation. There are indications that sudden lowering of tissue resistance to bacterial invasion may accompany the drops in pressure and may be responsible especially for many of the respiratory infections where such pressure changes are severe and frequent. Those tropical countries lying in the typhoon areas are not only heavily infested with leprosy, but also with tuberculosis, which runs a rapid course. The West Indies and the Yucatan Peninsula, the western coast of Mexico, the lowlands of India particularly around the upper end of the Bay of Bengal, the East Indies, the Philippines, the South China coast, Formosa and Japan—all these regions, heavily infested with leprosy, are cursed with

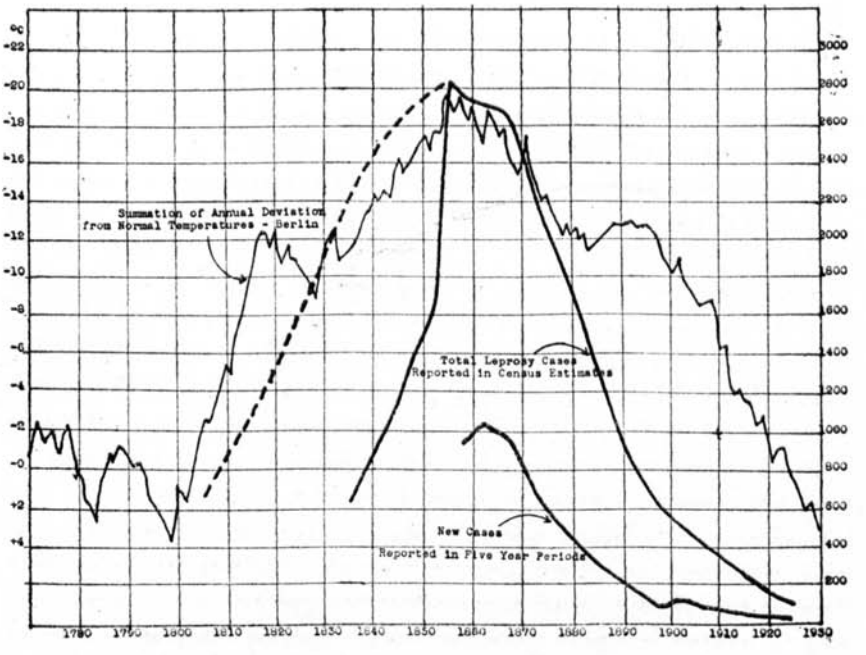
tropical typhoons for a considerable part of each year. Only by careful laboratory study under controlled conditions can we come to an understanding of how pressure changes affect tissue resistance to infection. This question has never been attacked, but its relationship to leprosy and respiratory infections warrants intensive investigation.

The beneficial effects of altitude were carefully studied in Puerto Rico by de Borao (3), who found very few cases of leprosy in the upland portions of the island except along heavily traveled routes. Conclusions as to altitude effect cannot safely be drawn from his study, however, because the people of the low coastal regions are mainly colored, while in the upland regions whites are more numerous.

Europe has always provided the real enigma in leprosy, for it has never been satisfactorily explained how an otherwise tropical disease was able to spread through the temperate zone as it did in the Middle Ages and then continue for many centuries to maintain itself in Scandinavia and Iceland. This one instance of severe leprosy in a cold climate was most confusing to scientific attempts at working out its epidemiology. The puzzle would now seem to be solved by viewing climatic stimulation as the basic factor determining the maintenance and spread of the disease. The steady benumbing cold of most of Scandinavia for the greater part of each year, together with its low degree of variability in diurnal and storm temperature swings, causes its effect on human energy to drop to about the same level as that of such Mediterranean countries as Italy or Spain. Only from the Alps northward to the Baltic inlet, and westward to include the British Isles, does the climatic drive on man rise to real energizing levels. Data in Table 2 set forth these regional differences in Europe, and, I believe, explain the similarity of leprosy prevalence in southern and in far northern portions of the continent.

This conception of benumbing cold lowering the energy level of people somewhat as heat does is new and may be doubted by many, but it nevertheless seems to be a fact. Experimental animals very definitely show the stunting effects of an environment that taxes their heat-adaptive mechanism on either the low or high temperature side. Of still greater interest in relation to Scandinavian leprosy is the additional fact that the last great wave of the disease,

which reached its peak in the middle of the 19th century, coincided to a remarkable degree with a prolonged wave of low temperatures over Europe. No temperature records for Scandinavia go back so far, but at Berlin the records date back to 1778. In Text-fig. 2 is shown the accumulated excess (or deficiency) of temperature in



TEXT-FIG. 2. Correlation of the last wave of leprosy in Norway with the temperature variations of Northern Europe (Berlin data).

degrees centigrade from 1781 to 1930, together with the numbers of lepers in Norway (9). As the accumulated temperature deficiency grew toward its peak in the cold decades of the century, lepers appeared in increasing numbers, but with the turn to temperatures above normal, about 1865, there likewise occurred the beginning of a wane in the disease. Since 1890, with the irregularly rising temperatures of the world, leprosy in Scandinavia and Iceland has gradually declined almost to the vanishing point.

In the United States and Canada this same effect of climate is in evidence. Only in the Gulf region where body stimulation is least, does the disease succeed in maintaining a foothold similar to that in the northern Mexican states. In the stormy, stimulating, north central states it seems unable to propagate itself; but farther

northeast in the maritime provinces of Canada we again see somewhat the same phenomenon as in Scandinavia. The index of climatic drive for Cape Race, Newfoundland, is about the same level as that of Mobile or Houston, due to the long steady cold of winter with its benumbing effects. And here again leprosy existed during the cold decades of the past century, but has practically disappeared with the rising temperatures of the past seventy years.

There is much inferential evidence that during the Middle Ages in Europe, when humanity settled back into a dark abyss and leprosy flared forth, there was present a long period of high temperatures and reduced storminess. Huntington (8) believes that around 600 to 1000 A.D. the principal storm pathway over Europe shifted from its old position across the Mediterranean countries northward to its present route across central Europe and the Baltic inlet. During these centuries the people of Scandinavia, perhaps relieved of their benumbing cold, fared forth over the earth with an irrepressible energy of conquest. That they successfully navigated the North Atlantic Ocean in their small craft, not once but with commercial regularity, and maintained a thriving colony in Greenland for probably two centuries, must mean that the northern climate was less cold and stormy then than in the 19th century. With the excessively high temperatures of the past five years, however, we must have reached almost the temperature level attained in Viking times, for Viking warrior remains have recently been excavated in Greenland after having been in solidly frozen earth for probably nine centuries. Skeletal studies on the buried remains of the languishing Greenland colony indicate that in the last century of its existence there was an increasing skeletal deficiency, most likely due to a growing environmental handicap—lack of sunlight, or improper diet, or both (12).

It is at least a remarkable coincidence that, within the period covered by accurate temperature records, leprosy should have been prevalent in far northern countries during prolonged periods of low temperature when the benumbing cold became more severe, and that the disease should apparently have spread up over Europe so heavily during the Middle Ages, when high temperatures and lack of storms had lowered the vigor and vitality of population masses in central and southern European countries. Link these facts with what we know of the disease at present—its quiescent, noncontagious character in the more invigorating regions of the earth, and the dis-

couraging problem it presents in tropical regions of moist heat—and we have an insight into the biologic background that seems to determine leprosy prevalence and severity.

The stormy, stimulating climates of the "roaring forties," both north and south, are in the main leprosy-free. On the world map of climatic drive (Text-fig. 1) the belts of greatest stimulation lie around the earth in these latitudes, except for certain divergences produced by mountain ranges or continental topography. The significant point for special emphasis in this paper is that, as the climatic drive lessens (Table 2 and Text-fig. 1), all indices of human vigor and vitality decline and leprosy increases in frequency. Only in regions with a climatic stimulation index of less than about 6 does the disease become severe, while in regions with an index of less than 3 it constitutes a real menace to man. With an index above 12 there need be little fear of it, and particularly so among people adapted to the drive represented by an index of 20 or over. The way the disease conforms to this pattern the world over, by continents and within individual countries, should give food for thought to students and workers in the leprosy field. If climate dominates the disease in this fashion, much use can be made of this circumstance in the fight against it.

It is not inconceivable that leprosy should again invade the temperate zones. Earth temperatures have been rising for eighty years, and at a rapid rate during the last fifteen years or so. Blood pressure and oxygen consumption in Americans of the Middle West dropped almost to the tropical level with the heat of the 1934 summer ([23]). Tropical diseases, such as malaria, sleeping sickness and dysentery, also made their appearance in a degree unusual for temperate regions. Figures obtained in Cincinnati also indicate that the long trend toward earlier menarche may have been stopped by the high temperatures, for most recent figures in young age groups show a slightly later age for onset of the menses. Population masses over the earth do respond to climatic changes in these basic ways, and it is not a far cry to the possibility of leprosy invading the temperate regions again, if present upward temperature trends continue.

Of greatest importance, however, is the significance that the data and views here presented have in regard to the handling of leprosy patients. In the past, leprosaria have usually been located in regions where the disease is worst and patients most numerous. The more logical course would now seem to be to segregate them at tropical

elevations of 7,000 to 10,000 feet, or transport them to more temperate climates, or else apply the proper degree of stimulation to them in their home climate by modern air-conditioning methods.

Leprosy would seem to be distinctly more easily transmissible during the early years of life, as is true with so many other infectious diseases. Therefore, with its long latent period its control seems of necessity a family problem. All children of leprous parentage must be considered as potential leper material. Would it not seem logical to apply prophylactic stimulation to their body metabolism so as to raise them to a less susceptible level? In other words, whole families, where a parent is leprous, should be removed to the most stimulating region available if there is to be any expectation of stamping out the disease.

In the Philippines this would mean colonizing such families in the upland regions at or above 5,000 feet, instead of segregating the patients in lowland leprosaria and permitting the potentially infected families to continue in the depressing heat. In India such stimulation is available in the northern and northwestern portions of the country. In China and Japan mountain elevations are also readily available. For Africa and Brazil the problem is more difficult, especially in view of the low economic level of existence and the large number of cases of leprosy. The problem in Mexico is rendered easy of solution by the wealth of stimulating highlands from Mexico City northward. In the United States logic would seem to dictate segregation of lepers in North Dakota rather than in Louisiana, while in Europe, Switzerland might well welcome lepers to her invigorating climate with much the same benefit that she offers to tuberculosis patients.

There are many ways in which leprosy is similar to tuberculosis, epidemiologically as well as pathologically. Both seem to be strongly influenced by general bodily vitality and nutrition, and for both diseases, as I have shown, climatic stimulation is an important element. The wave of leprosy that afflicted so large a proportion of the population on the island of Nauru (4, 7) following an epidemic of influenza is similar to the increase in tuberculosis that follows such epidemics of influenza. It would be of great interest to have data on the incidence of tuberculosis in the Nauru population before and after the influenza, to see if it showed any such increase as leprosy did. More detailed study and collection of statistics are needed to

make more certain of the extent to which climate determines leprosy as a human disease. The implications of such results in the handling of the disease make it very important that such studies be made. Further studies on rat leprosy under artificial climatic conditions might well show it to be influenced by depressive heat in the same way as the human disease seems to be.

The leprosy problem by its very immensity seems rather hopeless, but proper knowledge of the biologic background of the disease may tend to reduce the hopelessness of the picture. Air conditioning for protection from the effects of tropical heat now offers a possible means of raising the metabolic level of the people, and of securing better bodily growth and development and a greater degree of resistance to such diseases as tuberculosis and leprosy. This means not so much cooling by mechanical means as by proper use of insulating materials for protection against the sun's heat. The time may come when man will be brought to a more uniform energy level over the earth by such environmental control (18). Sample groups of industrial workers in the tropics have been cooled and their efficiency and productiveness increased 25 to 30 per cent, so it is only a question of time before such artificial stimulation will become more widespread. When it does come, the disease picture and body development are bound to change, with tropical man achieving more nearly the vigor and robust build of temperate-zone residents.

SUMMARY AND CONCLUSIONS

As with other infectious diseases over the world, leprosy tends to be more severe and rapidly progressive in the regions of lesser climatic stimulation.

It is almost universally true that those areas of the earth with a stimulation index of less than 3.0 are cursed with leprosy as a major public health problem. With an index above 6.0 the disease becomes distinctly more mild and less prevalent, while above 12.0 it continues to exist only by importation of cases. Where the stimulation rises to 18.0 or above, there seems to occur a spontaneous cessation of the disease as a public health problem.

Leprosy, imported from the tropics into cooler portions of the earth, persists only in those regions of benumbing cold where the real index of climatic stimulation falls to subtropical levels. Scandinavia and the maritime provinces of Canada, with their long cold

winters, exemplify this depressing effect of prolonged cold on body vitality.

The last wave of leprosy in Norway coincided to a remarkable degree with a world-wide period of subnormal temperatures and increased storminess. On the other hand there is considerable evidence that, when the disease spread with such virulence over Europe in the Middle Ages, the earth was under the influence of a major heat wave that sapped the vigor and vitality of population masses in temperate zones.

These facts seem to have definite implications concerning the handling of the leprosy problem. As with tuberculosis, leprosy patients should be segregated, not where the disease is worst, but in the most stimulating regions available. Potential leper material, such as the children of leprous parents, should also be transferred to invigorating climates if we would make progress in eradicating the disease.

The use of artificial climatic stimulation by indoor air-conditioning methods needs careful consideration and trial by those attempting to bring the disease under control.

One cannot stress too strongly the close relationship between resistance to infection and the level of general body vitality. Since the climatic environment so largely determines bodily vigor and vitality, it must be considered of fundamental importance in studying the biology of disease.

[NOTE.—The author will be glad to send reprints of his articles on climatic and weather effects to those specially interested in the subject.]

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