TUBERCULOSIS MORTALITY IN RELATION TO ALTITUDE, HUMIDITY AND POPULATION DENSITY.

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The relation between climate and tuberculosis is a question which has intrigued physicians since Hippocrates, and no doubt savages and their medicine men have puzzled over it since the dawn of thought, or since man's first encounter with the disease. Nevertheless it still remains in the foggy regions of speculation and prejudice. The available data are so inadequate and present such complex difficulties of interpretation that it has been the natural thing to ignore them and to form opinions untrammelled by any attempt to learn the facts.

Ichok, in a recent study[1], has tried, with full recognition of the perplexities involved, to put the problem on a rational basis. He divides France into seven climatic regions which are described with references to temperature, humidity, rainfall, altitude, and wind, and compares their tuberculosis mortality, general, urban (towns of more than 5000 inhabitants), and rural. Allowing for possible sources of fallacy, he concludes that climatic factors have an influence on tuberculosis motality, though this influence is only relative, not absolute; that "the climate of Auvergne takes first place (with the lowest mortality) which is to be attributed to the altitude of the region"; that "the bad effects correlated with humidity and frequent rains are apparent in the climatic regions of Brittany and Paris" (rural as well as urban).

We have undertaken to make a similar study for the United States, making use of the data provided by the United States Census Bureau, Weather Bureau, and Geographic Survey. We tabulate these data by states for which mortality figures are available, showing the approximate mean altitude, humidity (when available), density of poulation, and death rates from tuberculosis (Table 1). The figures on humidity are approximate averages taken from several

stations over a period of years, and usually based on observations made at 8 A. M. and 8 P. M. The word approximate should be stressed, for the data provided by the Weather Bureau on this important point have not been adequate in the past; at present they are being rapidly and greatly improved. Future reports will cover drying and cooling rates, which are the resultant of relative humidity and air movement, and have been shown by Leonard Hill to bear an important relation to metabolism. The figures on population density are from the 1920 census and those on death rates from the 1920 mortality statistics. It did not seem possible to take averages over longer periods, as a number of states have only recently entered the registration area; and while death rates fluctuate, the relation of state to state in this respect remains fairly constant.

Before attempting to correlate, even in the roughest way, the tuberculosis death rates with any of the factors considered, it is necessary to analyze this table and make some exclusions from it. As regards states with a very large negro population, the Report of the Census Bureau calls attention to the very much higher mortality from tuberculosis in this race than among whites, and cautions against making regional comparisons without allowing for this; we therefore exclude the Southern states. The same report says, "There are many localities to which persons afflicted with this disease (tuberculosis) are attracted because of climatic conditions favorable to the treatment of this disease. States and cities which annually show high death rates from tuberculosis (all forms) are not always those which have conditions tending to the development of tuberculous disease, but often are health resorts." On the strength of this obvious fact we have excluded Colorado and California, the registration states having the largest number of imported tuberculous invalids.

It will be noted that the death rate from tuberculosis (all forms) in Colorado in 1920 was 225.4. A recent study by Sewall[2] indicates that less than 17% of these deaths are among native Coloradoans. The rate for Denver in 1920 was 318.1 per 100,000 but the deaths from tuberculosis "contracted in Colorado", as determined by the Denver Department of Health, were less than 16% of the total. In 1905 one of the present writers (C. F. G.), who had been studying

the matter closely since 1889, wrote, "At Colorado Springs, with a population of from 15,000 to 30,000, there has been but one (fatal) case each year originationg among the native population..... I have no record of other forms than pulmonary, but meningeal, glandular, or bone tuberculosis is not more frequent than in other places, although a large proportion of our children have a tubercular parentage"[3]. During the past 11 years the deaths from non-imported pulmonary tuberculosis have averaged 2.1 per year in a population of about 30,000, possibly half of which is made up of health seekers and their families. Even if we assume that only 10,000 are natives and therefore candidates for tuberculosis "contracted in Colorado" this still gives a rate of only about 20 per 100,000, or about 1/7 of the rate for the country at large during the same period. Such data however are open to more criticism than the rest of the material with which we are dealing, and we have no similar reports from California, so we have thought best to omit these two resort states from the graphic correlations.

For the remaining group of 22 states*, we have prepared diagrams showing the death rates per 100,000 from tuberculosis (all forms) in relation to altitude, humidity, and density of population (figures 1, 2, 3). It is clear that many possible sources of misinterpretation still remain A state with a very small population per square mile may have a large percentage of that population crowded into one or two cities. A state with a high mean altitude may have most of its population living along the coast practically at sea level. A dry state may report a rather high relative humidity because the stations are located in the more humid sections, or vice versa. We do not mean to draw any dogmatic conclusions from material presented, but merely to offer it, following Ichok's good example, as a contribution to the study of climate in its relation to disease.

With this insistent disclaimer of any conclusive certainty, we may note some inferences suggested by the curves. In general, the states showing high mortality are those which combine low altitude, high humidity, and marked density of population,—the industrial

*Twenty-one states in the case of humidity. No figures for New Hampshire.

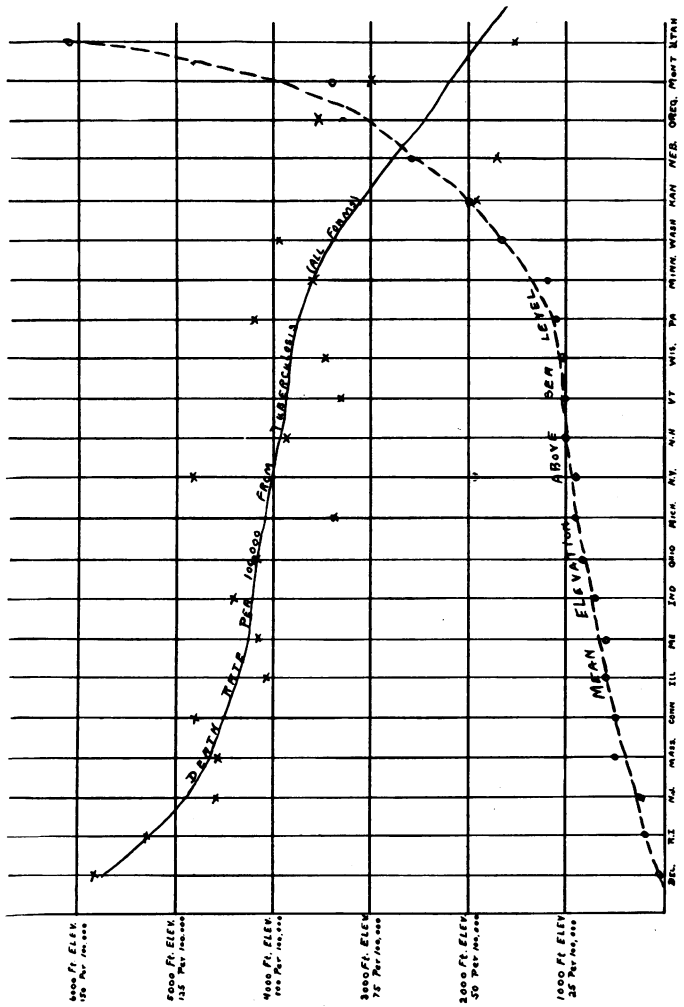

Fig 1.

Curves of Altitude and Tuberculosis Mortality Plotted Together

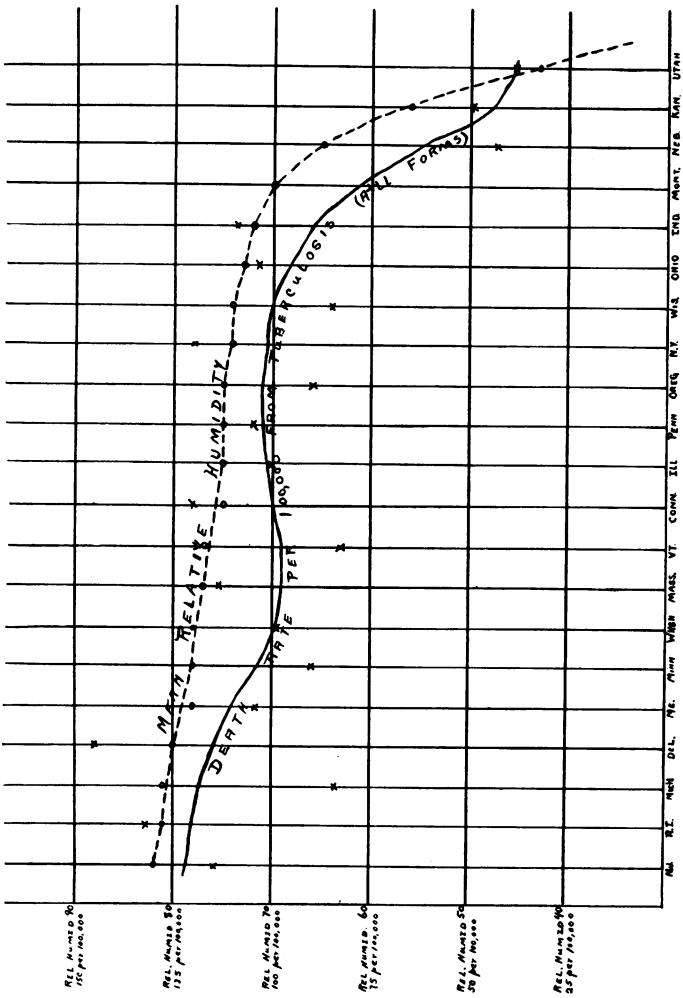

FIG 2

Curves of Relative Humidity and Tuberculosis Mortality Plotted Together.

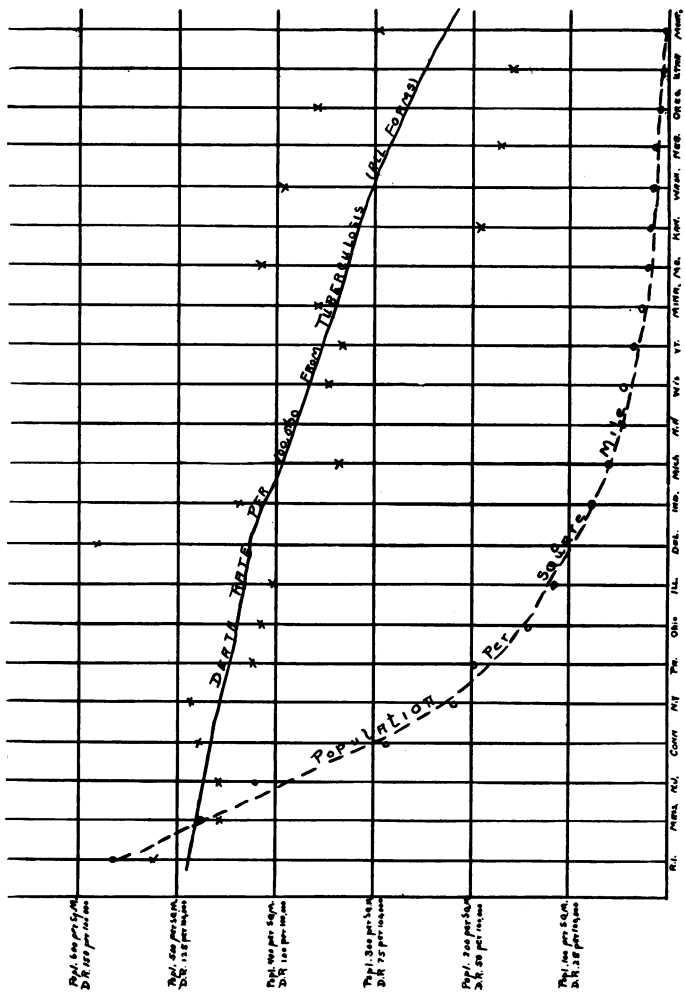

Fig. 3
Curves of Population Density and Tuberculosis Mortality Plotted Together

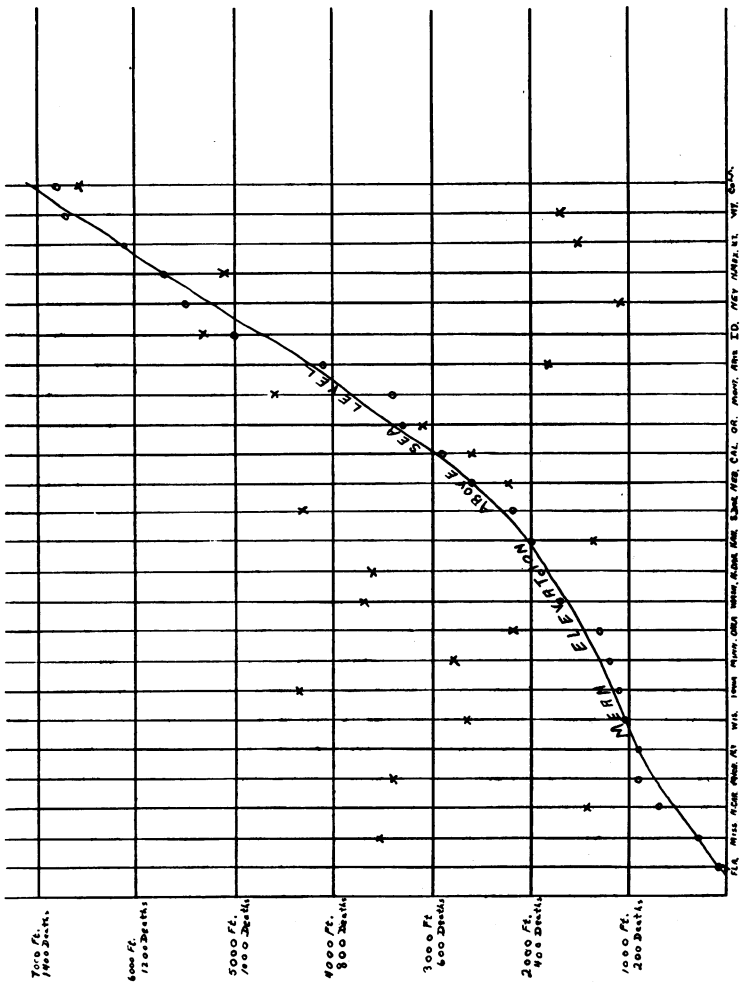

Fig. 4. Altitude and Indian Tuberculosis Mortality Plotted Together

coast states; while the states showing decidedly low death rates are high, dry, and sparsely populated—the inland plateau states. The average rates for the latter region are half or less than half those of the former. Whether we arrange the states in order of ascending altitude, decreasing humidity, or decreasing population density, the same group of states occupies the first division, and the same group the last division; and the curve of mortality drawn in relation to each of these other curves as a basis falls in a more or less similar way on each chart. However they are not exactly the same, and inspection, verified by a rough mathematical analysis, shows that the correlation between death rates and climatic factors is somewhat closer than that between death rates and population densities. Moreover the low death rates of the favored states (about 40 per 100,000) are not only much lower than the general rate for the registration states as a whole (113.2 per 100,000), but much lower than the rural rate for that area (108.1 per 100,000).

From these facts we think it fair to infer that while scarcity of population, character of population and industries, relative absence of poverty, and so forth, are of great importance, there are in addition climatic factors, notably altitude and dryness, which are largely accountable for the extraordinarily low tuberculosis death rates prevailing in the inland plateau region of the United States.

In addition to the general tuberculosis death rates, we have for our own satisfaction plotted the curves of mortality from pulmonary and non-pulmonary tuberculosis in relation to the same factors. In general the three mortality curves ran closely parallel, and it does not seem desirable to multiply or complicate diagrams in order to show them. The relation between descending mortality from pulmonary tuberculosis and ascending altitude was somewhat closer than in the case of non-pulmonary tuberculosis.

A recent report by a Committee of the National Tuberculosis Association appointed to collaborate with the Senate Committee on Indian Affairs[4] provides data which enable us to make some crude comparisons between the regional tuberculosis death rates in this race and in the population at large. Feeling that this might add something to the valuable studies of Bushnell[5], Cummins[6], Deycke and Much[7], and others, on the differences between tuberculosis in

races which have long been accustomed to it and races to whom the disease is new, we analyzed these data in the same way. (Table 2). Relative density of Indian population could not be determined. As regards altitude and dryness, the correlation with tuberculosis death rates which appeared to exist in the case of the comparatively immune general population is entirely wanting in the case of the susceptible savage. It was impossible to draw a resultant curve of mortality rates, which were scattered helter-skelter all over the chart (Figure 4). There seemed to be greater susceptibility in those Indians living in the newest parts of the country and hence having the shortest racial history of exposure, but this was not constant enough to be stated as a fact.

It is of course true in general that the more immunity exists already, the more it can be exalted by favorable conditions to which an organism of low resistance will not respond. This general statement probably applies in the case of the Indians. However it has been reported that in South America, the Indians of the high Andes show much lower tuberculosis death rates than those of the plains[8]. As regards another class of highly susceptible material, namely experimental animals, we noted some years ago[9] that rabbits inoculated with bovine tubercle bacilli seemed to live longer at Colorado Springs (6,000 ft.) than at sea level, and we have recently observed the same thing in the case of guinea pigs inoculated with human tubercle bacilli, though the differences are neither great nor constant. The number of lymphocytes[10] and mononuclear leucocytes in the blood is as shown first by Webb and Williams, increased in these animals, as in man, at high altitudes, and we believe this fact to have a bearing—much discussed but not yet explained—on resistance to tuberculosis.

CONCLUSION.

The high inland plateau region of the United States has a remarkably low death rate from tuberculosis, both pulmonary and non-pulmonary, as compared with lower and damper regions, and this appears to be due not only to favorable hygenic, economic, and social conditions, but also in considerable part to climatic factors, notably altitude and dryness.

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State	Approx. Mean Elevation In feet	Approx. Mean Relative Humidity	Population per Square Mile	Death Rates per 100,000 Inhab. All Forms TB.	Pulmonary TB.	Non-Pulmonary TB.
Delaware	60	80	113.5	146.0	131.7	14.3
Florida	100	80	17.7	104.1	95.1	9.0
white				67.1	59.7	7.4
colored				176.8	164.4	12.4
Louisiana	100	76	39.6	141.2	132.7	8.5
white				80.9	74.4	6.5
colored				236.2	224.5	11.7
Rhode Island	200	81	566.4	131.3	110.6	20.7
New Jersey	250	82	420.0	114.0	102.0	12.0
Mississippi	300	78	38.6	127.8	121.2	6.6
white				47.8	44.7	3.1
colored				201.2	191.5	9.7
South Carolina	350		55.2	120.0	111.9	8.1
white				65.5	58.9	6.6
colored				172.0	162.5	9.5
Maryland	350	74	145.8	146.8	132.1	14.7
white				110.4	99.7	10.7
colored				326.6	292.0	34.6
Massachusetts	500	77	479.2	113.8	96.9	16.9
Connecticut	500	75	286.4	119.4	103.8	15.6
Illinois	600	75	115.7	100.6	89.1	11.5
Maine	600	78	25.7	103.8	85.1	18.7
Indiana	700	72	81.3	108.8	92.9	15.9
North Carolina	700	84	52.5	116.5	106.4	10.1
white				82.8	75.3	7.5
colored				194.2	178.2	16.0

State	Approx. Mean Elevation In feet	Approx. Mean Relative Humidity	Population per Square Mile	Death Rates per 100,00 Inhab. All Forms TB.	Pulmonary TB.	Non-Pulmonary TB.
Kentucky	750	76	60.1	152.9	133.9	19.0
Missouri	800	71	49.5	106.9	97.9	9.0
Ohio	850	73	141.4	102.8	88.3	14.5
Michigan	900	81	63.8	83.6	72.0	11.6
New York	900	74	217.9	120.9	106.1	14.8
Tennessee	900	76	56.1	164.6	145.2	19.4
white				129.3	112.8	16.5
colored				312.6	281.1	31.5
Virginia	950	79	57.4	142.9	128.9	14.0
white				94.8	84.1	10.7
colored				256.2	234.6	21.6
New Hampshire	1000		49.1	97.0	81.4	15.6
Vermont	1000	77	38.6	81.8	67.0	14.8
Wisconsin	1050	74	47.6	85.6	75.0	11.6
Pennsylvania	1100	75	194.5	105.0	91.5	13.5
Minnesota	1200	78	29.5	89.6	77.1	12.5
Washington	1700	78	20.3	98.4	81.5	16.9
Kansas	2000	56	21.6	48.2	41.2	7.0
U. S. A. (1)	2500		35.5	113.2	99.8	13.4
Nebraska	2600	65	16.9	43.0	35.4	7.6
California (2)	2900	77	22.0	159.6	141.8	17.8
Oregon	3300	75	8.2	89.1	73.2	15.9
Montana	3400	70	3.8	75.1	65.6	9.5
Utah	6100	43	5.5	39.1	32.0	7.1
Colorado (2)	6800	45	9.1	225.4	212.5	12.9

(1) Registration States.

(2) Includes great numbers of imported cases: see text.

State	Approx. Mean Elevation In Feet	Approx. Mean Relative Humidity	Indian Population	Indian Deaths From Tuberculosis	Indian TB. Mortality per 100,00
Florida	100	80	454	0	0
Mississippi	300	78	1400	10	714
North Carolina	700	84	2432	6	248
Michigan	900	81	1093	7	640
New York	900	74	6072		
Wisconsin	1050	74	9713	52	535
Iowa	1100	70	345	3	870
Minnesota	1200	78	12378	69	558
Oklahoma	1300	70	15028	66	439
Washington	1700	78	9639	71	736
North Dakota	1900	71	9018	65	721
Kansas	2000	56	1466	4	272
South Dakota	2200	70	22649	197	870
U. S. A.			336337		446
Nebraska	2600	65	2461	11	447
California	2900	77	13241	69	521
Oregon	3300	75	4042	25	618
Montana	3400	70	12374	114	921
Arizona	4100	38	42400	153	361
Idaho	5000	63	4048	43	1062
Nevada	5500	50	10900	23	211
New Mexico	5700	45	21530	220	1022
Utah	6100	43	1641	5	305
Wyoming	6700	57	1748	6	343
Colorado	6800	45	796	11	1382

DISCUSSION.

DR. J. M. MILLER: To draw any conclusions from statistics, it would seem that there are other factors that were more important. There are certainly a great many factors that are more important in the incidence of tuberculosis than are these factors of environment.

DR. WEBB: I do not lay great stress on this paper, but just presented it as a short contribution.