The Relation of Solar Radiation to Cancer Mortality in North America*

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Several observers (3, 6, 11) have noted that the organ incidence of cancer among peoples of European origin varies considerably with geographic location, although the total cancer death rate shows comparatively minor variations, from about 70 to 150 per 100,000 population. We find, for example, that in England stomach cancer accounts for only 22 per cent of all cancers in men, but that this rises to 42 per cent in the United States and Australia, 55 per cent in Holland and Bavaria, and 66 per cent in Czechoslovakia. Conversely the relative incidence of certain other forms of cancer decreases in the reverse order (6). One explanation of this would be that the appearance of cancer in one site confers some immunity to cancers in other sites. This conclusion, in general, is apparently supported by certain animal experiments (3, 4).

In further support of this contention some authors refer to an inverse relationship between skin cancer and the total cancer rates. Peller (11), for instance, has produced evidence that in those environments and occupations in which skin cancer is increased, other cancers are diminished; *e.g.*, in the United States Navy the skin cancer rate is 8 times that found among men of the same age range in the general population, but the total death rate from cancer of other organs is only two-fifths of the expected rate (12). Peller, therefore, suggests that we should deliberately induce cancer of the skin, which grows slowly and is easily treated, by applying light rays of suitable intensity to suitable surfaces, in order to reduce the numbers of less accessible and more malignant cancers. The total number of cases in the Navy however would seem to be too small to warrant such conclusions, and indeed more recent studies throw considerable doubt on Peller's conclusions. For instance, Conrad and Hill (2) have shown that in England and Wales, skin and total cancer mortality rates vary in the same direction. Warren and Gates (14) have also found that in a "population with cutaneous cancer there is definitely more cancer of organs exclusive of the skin than would be encountered in a similar population . . . . at large. Cancer of the skin does not protect against development of cancer elsewhere."

It is our purpose to re-examine the relationship between skin cancer and other cancers and to present evidence that the actual production of a skin cancer is not only unnecessary, but that the presence of skin cancer is really only an occasional accompaniment of a general *relative cancer immunity* in some way related to exposure to solar radiation.

Our data are derived from two sources, statistical and experimental. The latter, derived from observations extending over more than 2 years, will be published later. The former have been taken from the official figures of the United States and Canada, for the purpose of comparing the cancer and other figures from the various states and provinces. Such a comparison however involves certain difficulties.

Statistics.—Statistical accuracy is at present impossible. Although figures for all cancer cases, cured and uncured, are being collected in certain localities, we have to rely on those for fatal cases only for making comparisons between all North American states. It is probable that in some of the more scattered populations and poorer states the diagnostic facilities and the education of the people with regard to the necessity for early treatment may lag behind those of other states, thus tending to unduly high cancer death rates. In addition, a larger proportion of cancer deaths may be recorded as deaths from senility. Although these possibilities are difficult to refute, they can hardly account for the unexpectedly straight line relationships, the high coefficients of correlation and the wide range of the various graphs shown. In some graphs the figures used are the averages of the 5 years 1934-38, inclusive, kindly supplied by the Public Health authorities of the various American states and Canadian provinces. In others, the figures have been adjusted for differences of age distribution, calculated from data obtained from the United States Census figures, 1930. In most of the graphs however the gross figures have been preferred to the adjusted figures since the latter were not available for the Canadian provinces, and we wished to include the Canadian figures in order to survey as wide

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a geographical area as possible with the maximum differences in climatic conditions.

Racial differences.—Since the skin cancer rate in negroes is only about 1/7 that of white persons, it follows that a large negro population in a state must unduly lower the figures for that state. Therefore all states with a negro population of 5 per cent or more have been excluded from consideration in certain of the graphs shown. Owing to lack of information we are unable to deal with possible variations in cancer incidence due to the uneven distribution over the continent of other racial stocks.

Occupation.—Since one of the important matters in this study is the relation of skin and other cancers to solar radiation it at first seemed that we should investigate the relation of cancers to the total annual radiation in each state. Further consideration however seemed to indicate the actual number of people exposed to sunlight as a much more significant factor than the annual available radiation. A group of office clerks could not be expected to have as much skin cancer as a group of farmers, irrespective of the total solar radiation. It was not possible to obtain the proportion of each state population engaged in occupations most exposed to sunlight. Broders (1), however, has shown that the farming class provides 54 per cent of skin cancers in his experience, and farmers form by far the largest class so exposed. It was therefore decided to investigate the relation of skin and total cancer death rates in each state to the proportion of the population engaged in agriculture. The latter figures (1933) were obtained from the *National Encyclopedia,* for the United States, and from the Dominion Bureau of Statistics at Ottawa, for the Canadian provinces.

Climate, latitude, and temperature.—Any attempt to estimate the effects of these factors is unsatisfactory. We shall however in some cases refer to the mean annual temperatures of the various states as a factor in skin cancer, using figures obtained from the *National Encyclopedia* and the *Meteorological Tables* of the Canadian Department of Marine. In other cases we have employed the Solar Radiation Index calculated for each state by James Smith (13). Reference should be made to Smith's paper for the method of calculation. Consideration of the degree of exposure to wind, dusts, and other surface irritants which might act in conjunction with solar radiation has been omitted for lack of sufficient information.

It will be obvious that a correlation between cancer rates and the number of people exposed to sunlight would indicate some direct effect of the latter on cancer incidence. On the other hand a correlation between cancer and the amount of solar radiation alone would suggest rather that the effect of sunlight on cancer might be an indirect one.

The Relation of Skin Cancer Mortality to Solar Radiation

In Fig. 1 the skin cancer deaths per 100,000 population for each state in the United States and Canada are plotted against the per cent of the populations engaged in farming (farmers and farm laborers). It is at once clear that, (a) with the exception of what we shall designate the "cold state group" (the Dakotas, Minnesota, Wyoming, Alberta, Saskatchewan, Manitoba, and Quebec, all with a mean annual temperature

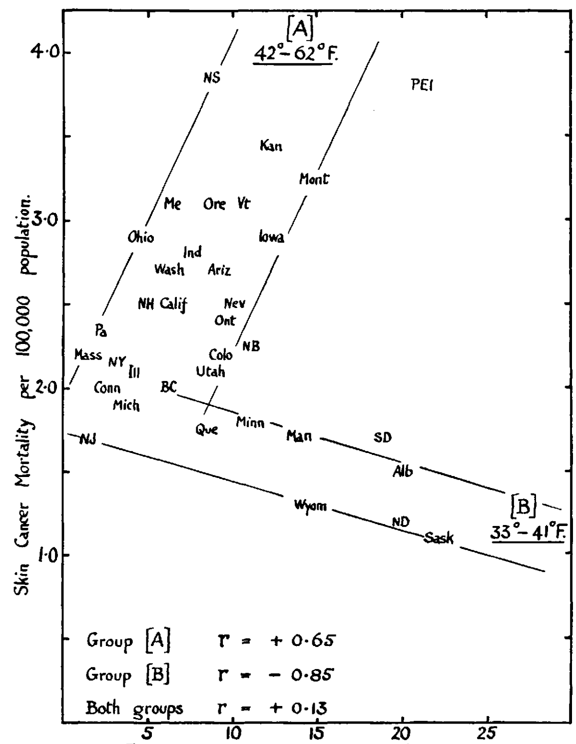

Fig. 1.—Showing the relation of skin cancer mortality rate to the proportion of farmers and farm workers in the populations of the American and Canadian states. (For calculating the values of *r*, certain states have been included in both groups; *viz.*, Mass., N. Y., Ill., Conn., Mich., N. J., B. C., and Que.)

of less than 42°F.), skin cancer deaths vary, in general, with the agricultural population. The lines of regression of these groups cut the ordinate at about 2; *i.e.,* there still remains a skin cancer rate independent of the hazards of farming and presumably due to other causes. (Vermont and Prince Edward Island also have mean annual temperatures less than 42°F., but fall in with the majority group). (b) When, however, the mean annual temperature falls to less than 42°F. (the "cold state group") we find a peculiar phenomenon; *viz.,* not only does an increase of the farming population have no effect in raising skin cancer mortality, but it actually does the reverse and skin cancer mortality falls.

Figure 2 shows the relationship between Smith's Solar Radiation Index and skin cancer mortality rate for white populations adjusted for age. In the case of 6 states (Arizona, California, Colorado, Kansas, Nebraska, and Utah) the calculated index figures were stated by Smith to be excessive. These states are therefore omitted. Since the Canadian figures were unavailable, the general position of the "cold state group" cannot be ascertained.

tion. Fig. 4 shows the same relationship for cancers per 100,000 people over the age of 45. Fig. 5 shows the relation of total cancer (white population) to the Solar Radiation Index of Smith (13). These results have been evaluated statistically and the coefficients of correlation (r) recorded on each graph. According to Snedecor's *Statistical Methods* (1937) these coefficients are highly significant. It is therefore evident from these graphs that the general cancer rate declines with increasing solar radiation and with increasing numbers of people exposed thereto.

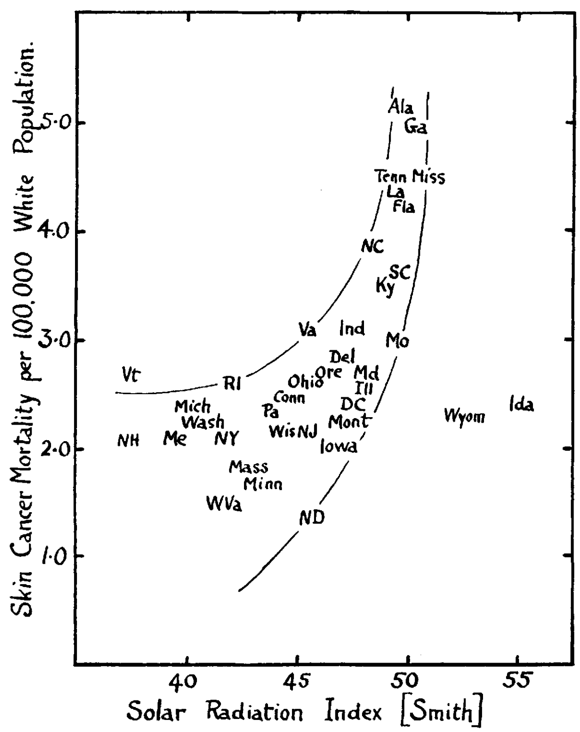

FIG. 2.—Showing the relation of skin cancer mortality rate (white population, adjusted for age) to Smith's Solar Radiation Index in the American states.

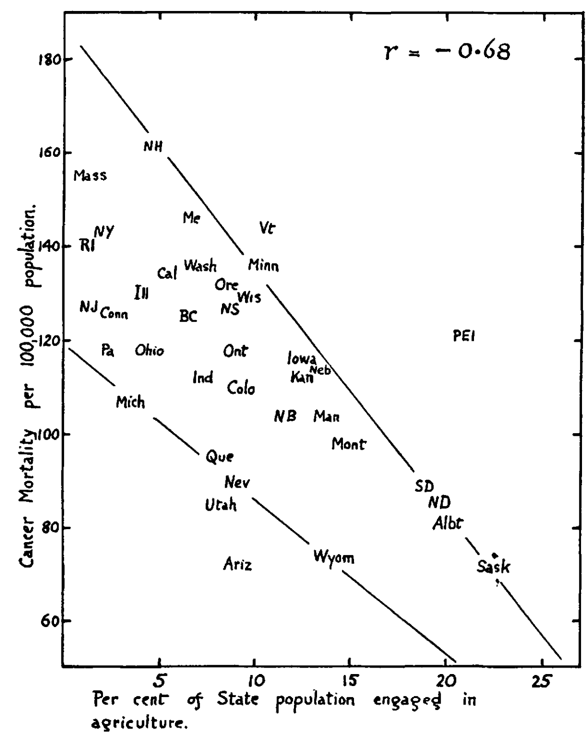

FIG. 3.—Showing the relation of total cancer mortality rate to the proportion of farmers and farm workers in the populations of the American and Canadian states.

The decline of skin cancer in the colder states might be brought about by one or both of two factors: (a) an increasing agricultural population means a diminution of the numbers engaged in those occupations which are responsible for other forms of occupational cancer, thus leading to a decrease in total skin cancers. Since we have no data on these occupations in the various states, this factor is difficult to evaluate. (b) Sunlight, of insufficient intensity to cause cancer of exposed skin, may in some other way produce a relative immunity to cancer in general, including skin cancer. This was next investigated.

The Relation of the Total Cancer Mortality to Solar Radiation

Figure 3 shows the relation of the total cancer mortality per 100,000 population to the farming population.

It now seems clear that we are dealing with the operation of two mutually opposing forces; *i.e.,* that solar radiation or something closely associated therewith, has two separate effects, (a) it produces some sort of relative immunity to cancer in general and, in those localities where the mean temperature is less than about 42°F., even to skin cancer, but, (b) at mean temperatures above 42°F., solar radiation produces more cancer on those parts of the skin exposed thereto, in spite of a generally raised immunity.

These generalizations help us to understand why different observers have failed to show any consistent correlation between skin cancer and total cancer; *e.g.,* Peller's population, living in warmer climates, shows an inverse relationship, whereas the relationship is a direct one in the colder and less sunny climates of England and Wales (2).

Data From Other Countries

For comparison with the North American figures it is of interest to cite those from various other coun-

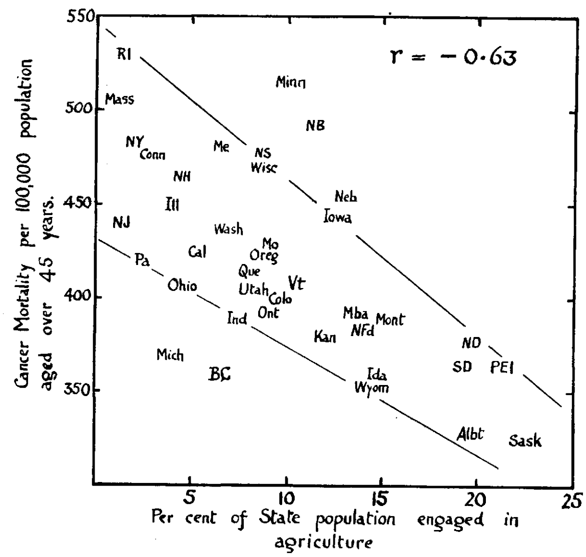

FIG. 4.—Showing the relation of total cancer mortality in that part of the population aged 45 years or more, to the proportion of farm workers in American and Canadian states.

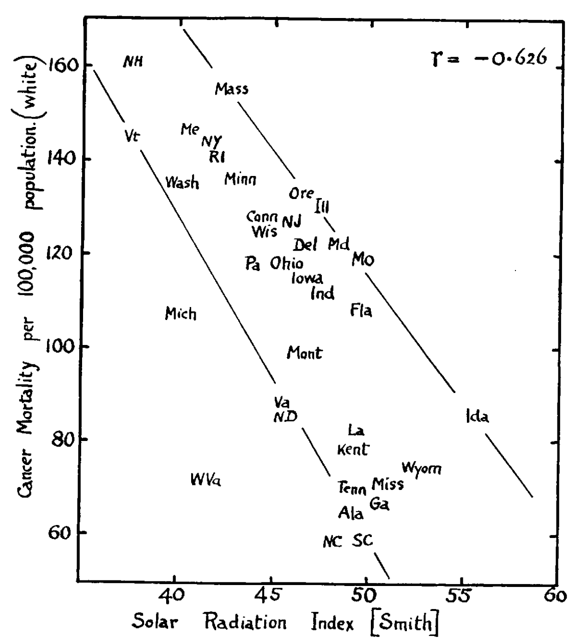

FIG. 5.—Showing the relation of total cancer mortality rates to Smith's Solar Radiation Index in the American states, (white population only).

tries at different latitudes. However, many difficulties of interpretation and other indeterminate factors arise. Thus it is probable that the facilities for the diagnosis of cancer are not as adequate in many of the tropical countries as in those of more temperate climates, and therefore their statistics are less reliable. On the other hand in cities diagnosis is likely to be more accurate. It is therefore more significant to compare figures for cities arranged in groups according to latitude. Table I, from Hoffman (5), shows the progressive decline in total cancer mortality with approach to the equator. Also, the total cancer rates in southern Europe (Italy, Spain, Portugal, and southern France) are much lower than those in northern Europe, even when corrections are made for differences of population ages (5, 7).

TABLE I: MORTALITY FROM CANCER IN CITIES ACCORDING TO LATITUDE, 1908-12 *

Number of cities	Degrees of latitude	Deaths from cancer	Rate per 100,000 population
35	60 N—50 N	119,374	105.7
48	50 N—40 N	121,216	92.4
24	40 N—30 N	37,451	78.1
7	30 N—10 N	5,696	42.3
4	10 N—10 S	1,056	40.9
7	10 S—30 S	3,040	37.7
5	30 S—40 S	11,048	89.8

* Modified from Hoffman (5).

The Nature of the Relation of Solar Radiation to Cancer Mortality

Assuming the truth of our thesis concerning an inverse relationship between total cancer and exposure to solar radiation, we must next consider the nature of that relationship. There are two possibilities:

(a) That the relative immunity from cancer in farming states is an indirect effect, possibly brought about by some beneficent effect of solar radiation on the larger amounts of foodstuffs produced in these states. Although with modern transport these foodstuffs are probably fairly evenly distributed and consumed over the continent, it is also probable that the more expensive green vegetables and raw foods would be less available to the low wage masses in the manufacturing states and cities than to those in the farming states which produced the food. In that case, all cities, irrespective of latitude, would have nearly equally high cancer rates. As Table I shows, however, cancer in cities also falls with approach to the equator and increasing solar exposure.

(b) That relative immunity to cancer is a direct effect of sunlight. The only direct evidence of which we are aware that bears on this question is certain experimental work on animals which, however, as always, must be applied with caution and reserve to human problems. Pierce, Van Allen, and Brown (9, 10) have found in a series of experiments extending over 4 years, that constant light (Mazda and mercury arc lamps) lowers the malignancy (*i.e.,* incidence, mortality, and number of metastases) of transplanted cancers in rabbits. More recently Morton *et al.* (8) found that, of 2 groups of mice painted with benzpyrene for 17 weeks, the group exposed to artificial daylight for 12 hours daily had fewer tumors (papillomas and skin cancers) than had the group kept in darkness. The appearance of the tumors was also delayed. Our own incomplete experiments with cancer-strain mice over a period of more than 2 years seem to point to a similar conclusion.

Conclusions

1. The apparent discrepancy between the views of those who claim that skin cancer and the general cancer rates vary inversely when different localities are compared, and of those who claim a direct relationship between these two groups of cancer, is shown to be a matter of climate. In hot climates the relation is an inverse one, in cold climates a direct one.

2. The total cancer mortalities of the various American states and Canadian provinces are shown to fall with increasing solar radiation and with the number of people exposed thereto, and are independent of the production of skin cancer. The fall of skin cancer with increased exposure in cool climates is merely one example of this general rule. In warmer climates, however, skin cancer may indeed rise in spite of the relatively increased general immunity. In other words the production of skin cancer is not necessary for the appearance of general cancer immunity, as claimed by some observers, but is merely an occasional accompaniment.

3. It is suggested that we may be able to reduce our cancer deaths by inducing a partial or complete immunity by exposure of suitable skin areas to sunlight or the proper artificial light rays of intensity and duration insufficient to produce an actual skin cancer. A closer study of the action of solar radiation on the body might well reveal the nature of cancer immunity.

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