exert no influence upon the behavior of uranium as activator toward sodium fluoride.

Summary.—A photoluminescence method was described for the detection of uranium by fusing uraniferous materials with potassium fluoride and subjecting the resulting mass to excitation of near ultra-violet light.

It was observed that when columbium, in the form of columbic acid, is fused with sodium fluoride and subjected to the excitation of near ultra-violet light, luminescence is produced.

A method was described for the detection of traces of uranium by fusing uraniferous materials with sodium fluoride and exciting with light from an iron spark.

¹ Nichols and Slattery, *J. Opt. Soc. of America*, **12**, 449 (1925).

² An arc lamp manufactured by C. Reichert of Vienna and intended for use in connection with a fluorescence microscope was employed in this work. Current was supplied from a 110-volt line.

³ Made by Corning Glass Works, Corning, New York.

⁴ The Andrews Ultra-violet Light Generator, manufactured by the General Electric Company, was employed.

CANCER STUDIES IN MASSACHUSETTS. 1. THE RELATIONSHIP BETWEEN CANCER AND DENSITY OF POPULATION IN MASSACHUSETTS

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In the Special Report of the Departments of Public Health and Public Welfare (House Document 1200),¹ a correlation was shown to exist between the density of population and the adjusted cancer death rate in Massachusetts. It was found that the logarithm of the adjusted cancer death rate increased with the logarithm of the density of the population up to densities of about 4000 persons per square mile and from there on remained practically constant. These rates were computed for the town of usual residence of the cancer cases and not for that of the place of death. As the age distribution of the population for 1915 was the latest available for the towns of Massachusetts, adjustments were made for each locality for a four and one-half year period centering on 1915. Towns were grouped according to their density and the average death rate from cancer was obtained for each group. No attempt was made to explain the relationship between the cancer death rate and the density of population. The present study attempts to determine the reasons for this relationship.

1. *Method of Calculation.*—The towns and cities of the state were

grouped into six ranges of density; under 50, 50-150, 150-500, 500-1500, 1500-3000, and over 3000 persons per square mile. Each range of density was considered as a unit. The rates for each density were computed from the total deaths and the total population of the communities falling within that unit, rather than as the average of individual town rates which was reported in House Document 1200.

The rates were computed separately for each of the years, 1921, 1922, 1923, 1924 and 1925 and an average of these figures was obtained. Adjustments were made by sex and age using five-year groupings from 35 to 79, with one group under 35 and one 80 and over. Adjustments were based on a standard population which was that of Massachusetts for 1920.

There are no age distributions of the population in the six density groups available since the State census of 1915, since these figures were not given in the census of 1925. It was necessary to rely upon population estimates for 1925 and then upon the interpolated estimates for the years 1921-1924, inclusive. The following method was finally adopted after other trials.

The tables available in the 1905 and 1915 censuses comprised the age distribution in five-year intervals for the density groups. A theoretical population for any one age group in any one density group could be computed by multiplying the percentage of the total population in that age group for the State as a whole by the population of the given density. Then, by dividing the actual population of the age group in the density group by the theoretical population of the same age group a ratio could be obtained for 1905 and 1915 for each age group. It could then be assumed: (1) that the ratios for each group had a uniform trend and the ratios for 1925 could be found by extrapolation from those of 1905 and 1915, or (2) that the ratios in 1905, 1915 and 1925 were essentially constant, the variations for each group being in the nature of statistical fluctuations and the values for 1925 could be taken as the means of the values for 1905 and 1915. The second alternative gave the more reasonable results, judged by the Federal Census of 1920, and was, therefore, adopted. Having now the 1925 ratios and the theoretical populations of each group for 1925, the estimated actual populations were then computed. By interpolation, the table for 1920 was computed, the resulting totals of which were checked with available comparable data of the census of 1920 and were found to agree very well. The whole work was done for each sex separately.

To express the above method algebraically let:

- f = actual population in any age group in a density group (1905 or 1915)
- D = actual population of all ages in a density group (1905, 1915 or 1925)
- A = actual population in any age group in the State (1905, 1915 or 1925)
- P = actual population of all ages in the State (1905, 1915, or 1925)

DA/P = theoretical population in any age group in a density group (1905,

1915 or 1925). Then $R = \text{ratio} = fP/DA$ (1905 or 1915) is taken to be constant and except for statistical fluctuations the average values of R for 1905 and 1915 are taken to be the best available estimates of R of 1925.

Using populations estimated by the above method and the cancer deaths by usual residence rather than by place of death, the adjusted rates for each year were computed and the average of these showed conclusively that cancer increases with the density of population.

TABLE 1
AVERAGE ADJUSTED CANCER DEATH RATE BY DENSITY GROUPS,
MASSACHUSETTS, 1921-1925

DENSITY	UNDER 50	50-150	150-500	500-1500	1500-3000	OVER 3000
Male	64.9	61.3	73.1	85.1	93.9	113.9
Female	106.9	114.1	116.6	136.0	127.7	148.4
Both sexes	86.3	88.3	95.3	111.0	111.1	131.4

2. *Effect of Nativity.*—In the years 1920-1923 Massachusetts had the highest death rate from cancer of any state in the Union, when adjustments had been made for age and sex distributions. During this same period New York had the second highest rate, Rhode Island the third, and Connecticut the fourth, while many of the southern states had very low rates. The states with the high rates have a high concentration of urban population and many foreign born. Individuals born in foreign countries taken collectively have a high death rate from cancer and their children likewise. From these observations it seems reasonable to assume that a part, at least, of the apparent relationship between cancer and density might be due to differences in the proportions of the populations native or foreign in the different density groups.

Rates were computed for: (1) native born of native parents, (2) native born of foreign parents, (3) native born of mixed parents, and (4) foreign born. These will be called nativity groups, reserving the word nationality for use where the foreign born or their children are classified by country of extraction.² All rates were adjusted for age and sex to the standard population of Massachusetts for 1920. The adjustments have been made by five-year age groups between 35 and 79, those under 35 in one group, and those 80 and over in another. The cancer deaths for five years, 1921-1925, centering on 1923, have been used with the populations of 1920 to obtain the adjusted rates.³

TABLE 2
CRUDE AND ADJUSTED CANCER RATE BY NATIVITY GROUPS

	CRUDE RATE	ADJUSTED RATE
Native born of native parents	107.6	85.1
Native born of foreign parents	69.3	160.0
Native born of mixed parents	50.8	141.1
Foreign born	200.0	136.8
Total population	116.5	116.5

The foreign born and the children of foreign-born and mixed parents comprise about two-thirds of the population of Massachusetts but only a small fraction of the population in many of the southern states. Hereafter these three groups, when discussed collectively, will be called the "foreign-extraction group." Individuals of foreign extraction have a large concentration in the cities. The percentage of these by density in Massachusetts was as follows in 1915:

TABLE 3
PERCENTAGE OF THE POPULATION OF FOREIGN EXTRACTION BY DENSITY GROUPS,
MASSACHUSETTS, 1915

DENSITY	UNDER 50	50-150	150-500	500-1500	1500-3000	OVER 3000
Per cent of						
foreign extraction	37.1	49.2	60.2	63.7	67.5	72.7

There is no way to obtain data by nativity, age and sex for the six density groups. Data is available for cities of certain sizes for 1920 by broad age groups for the foreign born as a whole. There is no way to obtain adjusted rates for the foreign born of individual countries since the age distributions are not available. The crude rates of the nationalities show that there is considerable variation among them and varying percentages of these nationalities would, therefore, appreciably change the rates of the foreign-born group. The crude rates for the larger nationalities groups in Massachusetts are as follows:

TABLE 4
CRUDE CANCER DEATH RATE BY NATIONALITY,
MASSACHUSETTS, 1921-1925

United States (native parents)	108
Ireland	323
Italy	84
England, Scotland, Wales	267
Canada	248
Russia-Poland	104
All others	143

3. *Adjusted Rates by Nativity.*—The State has been divided into three groups of communities, those with a population over 100,000, those with a population between 25,000 and 100,000 and those under 25,000. The first group comprises 68 per cent of the sixth density; the second group 28.3 per cent of the sixth density, 62.2 per cent of the fifth, and 24.2 per cent of the fourth; and the remaining group the rest. This division gives a fair though imperfect picture of density. The adjustments are made on the following age distributions: under 35, 35-44, 45-64, 65 and over. In the case of cities over 100,000 it was possible to make a five-year age distribution as well. The comparative figures are shown in the following table:

TABLE 5
ADJUSTED CANCER DEATH RATE BY NATIVITY GROUPINGS FOR COMMUNITIES OF
VARYING SIZES, MASSACHUSETTS, 1921-1925

	COMMUNITIES OVER 100,000	COMMUNITIES BETWEEN 25,000-100,000	COMMUNITIES UNDER 25,000
	5-YEAR AGE ADJUSTMENTS	BROAD AGE ADJUSTMENTS	BROAD AGE ADJUSTMENTS
Native Born of Native Parents			
Male	65.1	65.6	61.4
Female	104.7	106.3	114.9
Both sexes	85.2	86.4	88.5
Foreign Born			
Male	132.4	129.1	103.2
Female	155.2	152.6	145.7
Both sexes	143.9	141.0	124.8
Native Born of Mixed Parents			
Male	101.6	93.8	88.0
Female	183.4	173.0	160.0
Both sexes	143.2	134.1	124.8
Native Born of Foreign Parents			
Male	136.6	126.6	113.0
Female	175.4	172.8	187.9
Both sexes	156.4	150.1	148.6
Total Population			
Male	109.7	107.7	80.9
Female	140.9	139.1	132.8
Both sexes	125.5	123.7	107.4

The difference between adjusted rates and crude rates classified by nativity in the three groups in which the State has been divided is shown in the following table:

TABLE 6
ADJUSTED AND CRUDE RATES BY NATIVITY IN COMMUNITIES OF VARIOUS SIZES,
MASSACHUSETTS, 1921-1925

	COMMUNITIES OVER 100,000		COMMUNITIES BETWEEN 25,000 and 100,000		COMMUNITIES UNDER 25,000	
	CRUDE	ADJUSTED	CRUDE	ADJUSTED	CRUDE	ADJUSTED
Native born of native parents	88.9	86.4	103.5	88.8	123.6	88.5
Foreign born	201.5	141.0	194.0	139.6	202.5	124.8
Native born of mixed parents	46.1	134.1	54.5	149.1	51.6	124.8
Native born of foreign parents	63.4	150.1	66.7	163.3	177.8	148.6
Total population	113.0	123.7	108.7	124.6	122.8	107.4

It is apparent that adjustment is very important in dealing with these broad classifications. The rural sections have older populations than the urban sections. The foreign born is an older group than any of the others. The children of the foreign born and mixed parents comprise a young group. The comparison in table 5 between these groups adjusted on a five-year basis and on the broader age groups shows that the rate for

the native born becomes higher with the broader adjustment, and all the foreign extraction groups become lower. As the five-year adjustment is better than the broader one, it is evident that when we are dealing with the broader adjustment in the comparison of our three divisions of the population, we are minimizing the differences between native-born and the foreign groups, and any conclusions reached by a study of these broad adjustments should be so interpreted.

From these figures it appears that the apparent increase of cancer with density is completely removed among native born of native parents. We have calculated the probable errors of sampling for the figures and even after making all reasonable allowances for them the density phenomenon for the native born of native parents would be greatly lowered. Among the foreign groups it may be either removed, lessened, or increased, depending on how chance fluctuation and changes due to incomplete analysis have affected the figures.⁴

4. *Effect of Diagnostic Inequalities.*—The facilities in the cities for diagnosis are better than in the rural districts, but, on the other hand, easy transportation permits rural inhabitants to receive the advantages of the city. The question arises as to what is the difference in diagnosis between these two groups. It is very difficult to obtain an accurate estimate of the relative accuracy of diagnosis, but an attempt has been made to do so by approaching the problem in a variety of ways.

From the death records of cancer patients the methods of diagnosis are classified as either "Clinical," "Pathological," "X-Ray," "Surgical" or "Autopsy." All unstated methods are considered to be "Clinical." It seems fair to assume that in communities where the diagnosis is "Clinical" the general diagnosis is not so good as in those communities where additional methods are used.⁵

TABLE 7

PER CENT OF CLINICAL DIAGNOSIS IN CANCER DEATHS, MASSACHUSETTS, 1921-1925						
DENSITY	UNDER 50	50-150	150-500	500-1500	1500-3000	OVER 3000
1921	63.5	67.6	60.0	61.7	54.0	61.0
1922	73.1	67.8	65.5	62.2	58.0	63.1
1923	72.8	66.1	68.4	62.4	58.3	61.8
1924	62.9	60.2	59.5	59.6	51.2	55.5
1925	67.8	72.8	70.3	66.6	63.5	76.5
Average	68.0	66.9	64.7	62.5	56.5	63.6

The per cent of cancer deaths of unoperated cases is another method of checking diagnosis. Communities with a larger per cent of operated cases probably diagnose better than those with smaller percentages. In the six densities the per cent of unoperated cancer deaths is shown with a result similar to that of clinical diagnosis.⁶

The deaths which are certified under number 164 and 205 in the Manual of the International List of Causes of Death as "Senility," and "Cause of

TABLE 8

PER CENT OF UNOPERATED CANCER DEATHS BY DENSITY, MASSACHUSETTS, 1921-1925

DENSITY	UNDER 50	50-150	150-500	500-1500	1500-3000	OVER 3000
1921	70.2	75.1	67.2	68.2	62.2	66.5
1922	75.9	70.3	70.7	68.7	66.9	68.7
1923	70.9	69.1	75.9	67.7	64.4	67.7
1924	70.1	63.8	66.2	67.0	61.0	64.3
1925	68.5	72.4	69.8	66.0	64.9	66.1
Average	71.1	70.1	70.0	67.5	63.9	66.7

death not specified or ill-defined," give some index of diagnosis and certification. The combined rates for these two causes of death are shown by density in the following table:

TABLE 9

DEATH RATE BY DENSITY FOR SENILITY AND ILL-DEFINED DISEASES
MASSACHUSETTS, 1921-1925

DENSITY	UNDER 50	50-150	150-500	500-1500	1500-3000	OVER 3000
1921	17.9	16.2	11.3	9.0	7.1	6.8
1922	19.2	16.4	13.7	8.8	9.2	5.9
1923	21.9	15.9	11.1	10.7	7.2	6.0
1924	12.9	16.1	9.8	7.0	6.5	4.1
1925	10.4	11.0	9.1	6.3	6.2	4.7
Average	16.5	15.1	11.1	8.4	7.2	5.5

These three checks on diagnosis all point to better diagnosis in the larger densities and show that as the cancer death rate increases with density unskilled diagnosis decreases.⁷ It is impossible to estimate quantitatively the effect of varying diagnostic accuracy upon the cancer death rates but it is probably a factor in the density phenomenon.⁸

5. *Some Correlations by States.*—In order to see how the variables of nationality, density and diagnosis affect cancer throughout the United States correlations have been made using figures from the thirty-four registration states. The adjusted cancer death rate is used, adjustment being made on the Standard Million of England and Wales of 1901. The per cent of rural population is used to measure density.⁹ Diagnosis is measured by the combined death rate for senility and ill-defined diseases. Nativity is measured by the per cent of native born of native parents. The above death rates were an average of 1920-1923 and the population figures were from the 1920 census. The correlations are as follows:

TABLE 10

CORRELATION COEFFICIENTS

Adjusted cancer death rate and per cent rural population.....	-0.82
Adjusted cancer death rate and per cent native born of native parents.....	-0.87
Adjusted cancer death rate and diagnosis (rate for old age and ill-defined diseases).....	-0.79
Per cent rural and per cent native born.....	+0.72
Per cent rural and diagnosis.....	+0.68
Per cent native born and diagnosis.....	+0.71

The partial correlations between cancer and the per cent rural population

with the per cent of native born of native parents and the ill-defined and unknown diseases and senility rates held constant, give the correlation of -0.50 ± 0.17 . This shows that there is a correlation between cancer and the per cent of rural population for the thirty-four registration states. It does not agree with the Massachusetts findings which were done by the method of actual sub-division in contradistinction to that of partial correlation, and the difference might be wholly the result of the difference in these two methods or to the difference between the problem in Massachusetts and in the country as a whole.

Summary.—The phenomenon of increase of cancer death rate with density of population in Massachusetts is largely if not completely eliminated among the native born of native parents when proper adjustments for age and sex distribution have been made. With our limited figures it is impossible to state whether or not this occurs for the foreign extraction group. A small part of the density phenomenon may be attributed to diagnosis. The adjusted rates for foreign born as a whole and the children of foreign born are much higher than those of native born of native parents although there is apparently a difference between different nationalities of the foreign born.

¹ Special Report of the Departments of Public Health and Public Welfare Relative to the Prevalence of the Disease of Cancer throughout the Commonwealth, and Particularly of the Disease in Its Inoperable Stage or Form.

² The Chinese and Indians have been omitted as they constitute a very small part of the population and it was impossible to classify them as to native or foreign birth. All negroes have been classified as native born, though in a few cases this is erroneous.

³ While the difference between the population year and the center year of the cancer deaths makes a slight error, it is felt that for such comparisons as are made in this study the error will not be significant.

⁴ It should be noted that all groups of foreign extraction are based upon smaller numbers than the native born and the fluctuations are, therefore, larger. There may be fluctuations other than those due to chance; reference to table 4 indicates such great differences by nationality that there are probably considerable differences by nationality in the adjusted rates and hence a different distribution by nationality in the three different groups of communities might make differences larger than the chance fluctuations.

⁵ It appears from the table that the group 1500–3000 is lowest in each year, and that 1924 is the lowest year in each group. One can imagine that there should be an optimum density neither largest nor too small, but why should the percentage of clinical diagnosis be 6 to 10 higher in 1923 and 5 to 12 higher in 1925 than in 1924? Chance fluctuations will not account for the variation.

⁶ Observe that again the best results are in the 1500–3000 density, and that 1924 again tends, though not uniformly nor so strikingly, to be the best year.

⁷ Tables 7, 8 and 9 were analyzed according to R. A. Fisher's method of analyzing variance and the differences between the densities were found to be significant in tables 8 and 9, but not significant in table 7. Table 7, however, is consistent with the results of the other two and is, therefore, included.

⁸ It might be a decidedly different factor in the different nativity groups and among different nationalities.

⁹ This is admitted to be a poor figure, but in dealing with large groups like states it is probably as good as any density figure.