CHAPTER 22

Summarized Results of Chapters 6 - 21, and Discussion

• Part 1. Strong Support for Hypothesis-1 at Mid-Century

Chapters 6 through 21 have uncovered strong, positive dose-response relationships between PhysPop (medical radiation) and cancer MortRates --- with the exception of a single subset: Female Genital Cancers. The findings are summarized in Box 1.

The estimates of Fractional Causation in Box 1 certainly support the hypothesis that medical radiation was a highly important cause (probably the principal cause) of cancer-mortality in the USA in 1940. We discuss the period before 1940 later in this chapter (Part 5b). We consider the period after 1940 in Section Five of this book.

1a. Important Reminders about the Meaning of Fractional Causation

In Box 1, the G-Column presents the estimates of Fractional Causation by medical radiation of the corresponding 1940 National All-Cancer MortRate. Each estimate of Fractional Causation is an estimate of the percentage of cancer deaths which would NOT have occurred, if medical radiation had been absent.

It is worth repeating at the outset of this summary that a radiation-induced cancer MortRate does not mean that radiation is the ONLY agent contributing to such cases (Introduction, Part 5). It follows that, for cancer and other diseases having multiple causes, high Fractional Causation by medical radiation does not necessarily mean that other carcinogens have low Fractional Causations (Introduction, Part 5).

We emphasize also that, when an entry of ~ 100% occurs in Column G, such a finding is fully consistent with the fact that cancers of these organs occurred before introduction of radiation into medicine. Other causes of such cancers (including radiation exposure from nature itself) have been operative both before and after the introduction of medical radiation. A finding, of ~ 100% Fractional Causation by medical radiation in 1940, means that by 1940, a very low fraction of such deaths would have occurred without medical radiation as a co-actor.

1b. Estimates Supported by High R-Squared Values and Ratios

The strong, positive correlations in Chapters 6 through 21 indicate that the variation in accumulated radiation dose (PhysPop) is causing most of the the variation in the 1940 cancer MortRates among the Nine Census Divisions. But the purpose of this work is certainly not to re-invent the wheel.

No further evidence is needed to establish the fact that ionizing radiation is a cause of nearly all types of human cancer. That has been firmly established during several decades from other evidence (Chapter 2, Part 4).

The purpose of this work is to see if we have found objective databases from which it is possible to estimate HOW IMPORTANT medical radiation has been in causing the cancer mortality of the USA. And we submit that the high R-squared values (Box 1, Column E) and high X-Coef/SE ratios (Box 1, Column F) support considerable confidence that the resulting best-estimates of Fractional Causation in Box 1 are MEANINGFUL.

1c. Hypothesis-1: Independent of Cancer-Trends over Time

Hypothesis-1 proposes that "Medical radiation is a highly important cause (probably the principal cause) of cancer-mortality in the United States during the Twentieth Century."

It is important to recognize that Hypothesis-1 addresses the fraction of the cancer-deaths which DO occur, not whether the absolute number of cases (age-adjusted) per 100,000 is rising or falling between 1900 and 1999. Still, as we complete our analyses up to 1940, many readers will want to know that the available data (incomplete) on cancer MortRates before 1940 indicate that age-adjusted All-Cancer MortRates rose dramatically between 1900 and 1940 (details in Chapter 67).

The same incomplete data indicate that, between 1930 and 1940, MortRates for some cancers were falling --- especially cancers of the stomach, liver, and uterus (cervix+corpus) (ACS-CA 1992, pp.28-29). The big increase in the age-adjusted All-Cancer MortRate between 1900 and 1940 occurred DESPITE the net decrease for some specific cancers in pre-1940 MortRates.

The fact that age-adjusted MortRates simultaneously rise for some cancers, fall for others, and remain flat for others, is very strong evidence that causes OTHER than medical radiation contribute with medical radiation to produce a cancer's MortRate. We have emphasized earlier (Introduction, Part 5) that, for diseases which have multiple causes per case, the fraction of deaths due to ONE of the causes can be estimated by evaluating what the MortRate would be if that contributing cause were absent (e.g., if PhysPop = zero). And that is how we have estimated the Fractional Causation due to medical radiation in Chapters 6 through 21.

• Part 2. Biological Basis for the Steady Improvement in Correlations

Wilhelm Roentgen discovered xrays at the end of 1895, and the use of xrays in medicine was promptly initiated in a large way (Chapter 2, Part 2). Thus, in 1896, a new carcinogen (medical radiation) was introduced into the U.S. population --- a population which had a pre-existing cancer MortRate due to ancestral and direct exposures to natural background radiation, viruses, and carcinogenic chemicals (probably including some chemicals of viral, bacterial and fungal origin).

2a. The Mounting Response to Medical Radiation: Figure 5-A Revisited

During every year from 1896 onward, some fraction of the population received new exposures to medical radiation, and each annual set of exposures had its OWN trail of cancer consequences, spread over at least 40 years (Chapter 2, Part 8). Such trails are indicated by the horizontal rows in Figure 5-A of Chapter 5.

In Figure 5-A, the vertical columns tell their own story. For instance, the vertical stack of 20 "cancer boxes" for the year 1915 depicts why the rate of radiation-induced cancer in 1915 is influenced by ALL the doses of medical radiation delivered in 1896 through 1915: Each year of irradiation contributes a separate "cancer box" to the column which represents the rate of radiation-induced cancer delivered during 1915.

Worth attention, too, is Figure 5-A's column for 1935. By using any slip of paper as a measure, readers can confirm that there are many more "cancer boxes" (40 boxes) in the 1935 column than in the 1915 column (20 boxes) --- as a result of case-delivery during 1935 from an increasing number of irradiation-years. In other words, the annual rate of radiation-induced cancer is higher by

1935 than it was in 1915, even though the annual average radiation dose has been steady (in the model for Figure 5-A).

Some Distinctions between Figure 5-A and Our Real-World Studies

Of course, Figure 5-A is a simplified model which differs in many details from our real-world studies. For example:

(1) Figure 5-A approximates the consequences of introducing annual medical radiation into ONE population of mixed ages, whereas in our real-world dose-response studies, annual medical radiation has been introduced into NINE such populations, having nine DIFFERENT average dose-levels.

(2) Figure 5-A is for cancer incidence (including nonfatal cases), whereas our real-world data are for cancer MortRates.

(3) Figure 5-A has illustrative rates of radiation-induced cancer for every year, 1896-1991, whereas our real-world cancer MortRates are for 1940 only.

(4) Because of space-limits, Figure 5-A shows 1951 as the last year in which any medical irradiation occurred, whereas in reality, no cessation in use of medical radiation has ever occurred.

2b. Box 2: How Correlations Improve As the PhysPop Year Advances

Our studies reveal that the relationship, between PhysPop and 1940 cancer MortRates, tightens as PhysPop-years advance from 1921 toward 1940. To provide ourselves and readers with a convenient way to review this finding, Box 2 reproduces the summary of results from All-Cancers-Combined, and from Breast Cancer separately. The inclusion of Breast Cancer is due to the high level of interest in that specific cancer. The inclusion of a row for "whites only" has a purpose too.

The "Whites Only" Rows in Box 2

Some readers may wonder whether the correlations we have uncovered in Chapters 6 through 21 are somehow based on the geographic distribution of white and black "races." We have explored that possibility. All the work presented in Chapters 6 through 19 was done also for "whites only." The correlations are very similar, as indicated in Box 2 for All-Cancers (and Breast Cancer), for the 1940-1940 analyses. Since "whites only" account for the overwhelming share of cancer-deaths in 1940, and our "whites only" analyses so closely mirror our "all-race" analyses, we have assurance that the correlations we uncovered are NOT somehow due to the geographic distribution of "blacks." Even if the correlations had differed appreciably, Hypothesis-1 refers to cancer mortality for the United States as a WHOLE, and requires use of the "all-race" data.

The Initial Correlation: 1921 PhysPops with 1940 Cancer MortRates

Box 2 shows that even the 1921 PhysPops have a statistically significant correlation with the 1940 MortRates. (The X-Coef/SE ratio is 2.0 or higher.) How can the 1921 PhysPops correlate as well as they do, with the 1940 cancer MortRates, when Figure 5-A shows (a) that radiation given during 1921 contributes only ONE of the 40 "cancer boxes" in the column which depicts delivery of radiation-induced cancer during 1940, and (b) that the overwhelming share of radiation-induced cases delivered during 1940 is coming from radiation received in years before and after 1921?

The answer is this. The correlation is biologically reasonable BECAUSE the 1921 PhysPops are almost certainly correlated with earlier PhysPops (which we do not have) and are definitely correlated with later PhysPops. In Chapter 3, our Table 3-C shows the correlations between the 1921 PhysPops and the later 1923, 1925, 1927, 1929, 1931, 1934, 1936, 1938, and 1940 PhysPops.

2c. Explanation of the Tightening PhysPop-MortRate Correlations

While the 1921 PhysPops already correlate rather well with the 1940 cancer MortRates, the post-1921 PhysPops correlate even better with the 1940 cancer MortRates (Box 2). Why better?

Biology and demography combine to provide the explanation.

- It is a biological fact that medical radiation received not only before 1921, but also AFTER 1921, has an impact on the 1940 cancer MortRates (Chapter 2, Part 8).

- It is a demographic fact that PhysPop proportions (dose proportions) changed among the Nine Census Divisions between 1921 and 1940. If the 1921 PhysPop values had persisted WITHOUT change in proportion until 1940, those unchanged PhysPop proportions would have "driven" the nine cancer MortRates of 1940 into proportions somewhat DIFFERENT from the proportions actually observed in 1940 among the Nine Census Divisions.

But in the real world, between 1921 and 1940, the "spread" among the PhysPop values grew (Table 3-A). In 1921, (Pacific PhysPop / SouthAtlantic PhysPop) produced the biggest ratio: (165.11 / 110.32) = 1.50. In 1940, (MidAtlantic PhysPop / EastSouthCentral PhysPop) produced an appreciably bigger ratio: (169.76 / 85.83) = 2.00. The Hi5/Lo4 ratio changed from 1.18 to 1.46 during those years. Variation in a cause produces variation in its effect, and it follows that the greater post-1921 spread in PhysPop would cause (biologically) a greater spread in the 1940 cancer MortRates than the 1921 PhysPops would cause.

Because the Observed 1940 cancer MortRates in the Nine Census Divisions are affected by post-1921 changes in the relative strength of the biological CAUSAL agent (PhysPop), it is not surprising that the post-1921 measurements of that agent correlate better with those MortRates than does the 1921 measurement. We would expect post-1921 PhysPops to explain the 1940 outcome better --- and they do.

2d. Visual Evidence: Radiation Driving x,y Datapoints into Line (Figures 22-A + C)

Box 2 shows that the R-squared values and the reliability of the slope (as measured by the X-Coef/SE) improve progressively as PhysPop approaches 1940. One can SEE the improvement in correlation, between 1921 and 1940, by comparing Figures 22-A and 22-C. The MortRates (y-values) for 1940 are identical in both graphs, of course. Only PhysPops (x-values) change --- and such changes cause the boxy symbols to move laterally but not vertically.

Figure 22-C depicts a much tighter dose-response than Figure 22-A, between PhysPops and the MortRates. All of the nine real-world datapoints in Figure 22-C lie close to the line of best fit. The cumulative consequences of 44 years of medical radiation have been gradually causing the x,y datapoints to line up in this way. The fact, that a cause drives x,y datapoints toward a line of best fit, is the essence of any prospective study which uncovers a linear dose-response.

2e. The Power of This New Carcinogen

After Roentgen's discovery of the xray in 1895, PhysPop became approximately proportional to the biological agent called medical radiation. The reality summarized in Box 1 is that this new carcinogen, medical radiation, had the power to make variation in the 1940 cancer MortRates, among the Nine Census Divisions, correlate almost perfectly and positively with variation in PhysPop. The goodness of the correlation says that the 1940 cancer death-rates were virtually set in concrete by PhysPop.

In striking contrast with the positive correlations in Box 1, Chapter 25 will reveal a significant but negative correlation between PhysPop and the 1940 MortRates from all NonCancer NonIHD causes of death combined.

• Part 3 Are the Negative Constants a Worry?

In our graphs, which are based on equations of best fit, the Constant (y-axis intercept) represents the value of the cancer MortRate when PhysPop equals zero. Biologically, there is no such thing as a cancer MortRate BELOW zero. Therefore, should we worry about the string of negative constants in Box 2 for All-Cancer, Males, and for Breast Cancer?

Those who work with numbers realize that a few "outliers" --- datapoints which are "way out of line" in a series of observations --- are capable of tilting a best-fit slope. In epidemiology, a few outliers are no justification for disbelieving the bigger picture.

Because records were not kept, no one can ever plot datapoints for PhysPop-MortRate pairs in 1900, by the Nine Census Divisions. We can never know the distribution out of which developed the distribution in Figure 22-A: 1921 PhysPops paired with 1940 cancer MortRates (male). It is likely that the outliers in Figure 22-A, which produce negative Constants in Box 2 for All-Cancers Male, would be traceable to a few pre-xray datapoints near the turn of the century. For both All-Cancers Male and for Breast Cancer, the negative Constants in Box 2 move inexorably toward positive values, with later PhysPop years.

3a. Demonstration That the Negative Constants Do Not Mislead about Correlation

We have explored what happens if we BANISH negative Constants from our analyses. This can be done in regression analysis by equations which provide the best-fit output after one forces the Constant to be ZERO. Setting the Constant equal to zero is equivalent to asking: How well do the observations fit the MX linear model instead of the MX + C linear model? (Chapter 5, Parts 5 and 6.)

Box 3 provides the answers in a form very easily compared with Box 2. Readers can see for themselves:

• - All-Cancers, Male: The R-squared values in every row are very nearly the same, whether the Constant is negative or zero. So the negative Constants have virtually no impact on the strength of the correlations. A comparison of Figure 22-A with Figure 22-B shows the very similar relationship, between the two different lines of best fit and the single set of boxy symbols (the real-world observed pairs of 1921 PhysPops with 1940 MortRates).

• - All-Cancers, Female: There were no negative Constants to consider. We show the effect, of forcing the positive Constants to equal zero, just to satisfy curiosity.

• - Breast Cancer: Forcing the line of best fit to go through zero makes the fit a little worse for a while --- as signaled by the lower R-squared values in Box 3 than in Box 2. By 1934, there is very little difference in R-squared values between the two types of regression analysis. So the negative Constants have virtually no impact on the strength of the correlations.

3b. A Dramatic Visual Contrast: Outliers Move into Line

Figure 22-A shows the 1940 cancer MortRates, male, regressed on 1921 PhysPops. It is obvious that there are two datapoints which are very much out of line. Mid-Atlantic lies far ABOVE the line of best fit, and East South Central lies well BELOW it. So the line of best-fit is steep enough to produce a negative Constant, by intersecting the y-axis (MortRate) below zero.

The contrast between Figure 22-A and Figure 22-C is easy to see. Of course, the MortRates (y-values) for 1940 are identical in both graphs. Because PhysPops (the x-values) DIFFER in the two graphs, the boxy symbols move laterally but not vertically.

The result: In Figure 22-C, the worst outliers are gone. The real-world observations (the boxy symbols) now lie close to the best-fit line, and the best-fit line has a new slope which makes the Constant POSITIVE. Box 2 confirms that the slope is less steep in Figure 22-C than in 22-A: The best-fit equation for Figure 22-C has an X-Coefficient of 0.7557, whereas the best-fit equation for Figure 22-A has an X-Coefficient of 1.0086.

• Part 4. An Extremely Large, "Blind," Prospective Dose-Response Study

In the world of medicine and pharmacology, the "gold standard" for establishing certain types of cause-and-effect is the "blind" prospective dose-response study. Although a dose-response can never prove causation in the STRICTEST definition of proof, it can provide circumstantial evidence "beyond a reasonable doubt" --- and all other things being equal, the larger is the study, the more reliable are the results.

As noted in Part 1b, we were not seeking additional proof that ionizing radiation is a cause of human cancer when we undertook the studies in this book. Additions are not needed. Instead, we undertook the work in order to evaluate Hypothesis-1. Nonetheless, it is well worth noting that in the process, we HAVE provided powerful additional proof.

Our combination of PhysPop with cancer MortRates, by Census Divisions, represents one of the largest "blind" prospective dose-response studies imaginable. Yet the prospective nature of our study would not be evident to readers if they focus only on the results of 1940 MortRates paired with 1940 PhysPops. And so we call attention to the dose-responses in Box 2, between the 1940 cancer MortRates and PhysPops of years EARLIER than 1940. The dose-responses become statistically significant when the ratio, X-Coef/SE, reaches about 2.0. Almost all results in Box 2 are considerably stronger than a ratio of 2.0.

The 1940 cancer MortRates in the Nine Census Divisions grew out of populations for whom the x-variable (PhysPop) was measured up to 19 years BEFORE measurement of the outcome (1940 cancer MortRates). Even in 1921, variation in PhysPop explains much of the variation in 1940 cancer MortRates.

Separately, Box 4 considers the 1940 NATIONAL cancer MortRates, and demonstrates that:

- The 1921 PhysPops predict the Observed National MortRates for 1940 quite well.
- The 1931 PhysPops predict the same rates even better.
- The 1938 PhysPops predict them better yet. Why improvement occurs is discussed in Parts 2c and 2d, above.

• Part 5. Fractional Causation: Why We Used 1940 PhysPops with 1940 MortRates

The fact that we used 1940 PhysPops with 1940 MortRates, in order to calculate Fractional Causation, deserves some comment here.

There is very probably no MINIMUM incubation-time (latency period) between time of irradiation and delivery of cancer (discussion in Chapter 5, Part 4). Nonetheless, there is almost always at least a year between DIAGNOSIS of a cancer, and DEATH from that cancer. Then why did we "mate" 1940 PhysPops with 1940 MortRates, when a 1940 change in PhysPop-proportions (compared with PhysPop-proportions in 1938) could have no biological impact on the 1940 cancer MortRates?

5a. Consequences of the Competing Alternatives

We were searching for the MAXIMUM detectable correlations remaining in the data, after operation of migration, changes in PhysPop proportions, and other entropic circumstances which conceal the true strength of a relationship (Chapter 5, Part 8). Regression analyses revealed that the very best correlations between PhysPop and All-Cancer MortRates, both for males and for females, occur when the 1940 PhysPops are the input for the x-axis. The improvement in correlation, produced by the 1940 PhysPops compared with the 1938 PhysPops, is in fact TRIVIAL --- as shown by the R-squared values and X-Coef/SE ratios in Box 2.

In order to avoid pairing 1940 cancer MortRates with PhysPops of the same calendar-year, we could have paired 1940 PhysPops with 1942 cancer MortRates --- but we don't have 1942 cancer MortRates by gender and Census Divisions.

The other alternative, in order to avoid same-year pairs, would have been to use the results from pairing 1940 cancer MortRates with the 1938 PhysPops, or the 1936 PhysPops. If we had chosen a pre-1940 set of PhysPops, the estimated Fractional Causation by medical radiation would have been HIGHER for both males and females, because for both genders, the Constants were LOWER in 1938 and in 1936 than in 1940 (Box 2). So our decision to use the 1940 PhysPops was in the direction of LOWER estimates of Fractional Causation. Our choice was also in the direction of somewhat tighter confidence-limits, because in 1940, the ratios of X-Coef/SE were somewhat higher than they were in 1938, for both genders (Box 2). Those who may prefer use of the 1936 or 1938 PhysPops of course can use them to obtain higher estimates of Fractional Causation. When the maximum correlation did occur with 1936 PhysPops (male Genital Cancers) or with 1938 PhysPops (female Breast Cancer), we have already used those pre-1940 PhysPops.

5b. What about Fractional Causation of Pre-1940 Cancer MortRates?

Hypothesis-1 embraces the entire Twentieth Century. Yet complete cancer MortRates for each state and gender are not available before 1940 (Chapter 4, Part 1). Then what can we say about Fractional Causation of 1910, 1920, 1930 cancer mortality by medical radiation? Only this:

- – In 1896, Fractional Causation by medical radiation was zero.

- – In 1940, the best estimates of Fractional Causation by medical radiation (Box 1) are about 90% for males, and 58% for females (or 75% for females, if Genital Cancers are excluded).

- – It follows that between 1896 and 1940, Fractional Causation of cancer MortRates by medical radiation had to rise, from zero percent, toward 90% (male estimate) and 58% (female estimate). It seems reasonable to suggest that by 1920 (the midpoint between 1900 and 1940), perhaps Fractional Causation was one-third of its 1940 value. This would mean that about 30% of the 1920 male All-Cancer MortRate was radiation-induced by physicians, and about 20% of the 1920 female All-Cancer MortRate was radiation-induced by physicians.

• Part 6. Ockham's Razor: The Law of Minimum Hypotheses

Every hypothesis in science is viewed in the light of a famous principle, which deserves explicit attention here.

6a. The Law of Minimum Hypotheses: "Ockham's Razor"

The Law of Minimum Hypotheses, in logic and science, has various formulations. One example: To explain a phenomenon, invoke only as many explanations as required. Or: Avoid fabricating many explanations if one suffices.

The Law of Minimum Hypotheses is also known as "Ockham's Razor," because it was stated (in Latin) by Wilhelm of Ockham in the Fourteenth Century: "Entities [explanations] should not be multiplied beyond what is needed."

6b. The Hypothesis under Examination: Size of Effect, Not Effect Itself

The hypothesis under examination here is that "Medical radiation is a highly important cause (probably the principal cause) of cancer-mortality in the United States during the Twentieth Century" (Hypothesis-1). The issue is the SIZE of medical radiation's impact on the total cancer MortRate. The OCCURRENCE of an impact is beyond doubt (Chapter 2).

Our findings, about the size of medical radiation's impact on the 1940 cancer MortRates, are summarized in Box 1. These findings are based on irrefutable, positive correlations between PhysPop and the 1940 cancer MortRates. We know of no basis for either speculating or assuming that the estimates in Box 1 are too high (Chapter 6, Part 4a).

Therefore, we remind readers of Ockham's Razor. There exists an IDENTIFIED and proven carcinogen which is proportional to PhysPop: Medical radiation. In Chapter 2, we summarized some of the facts about the manner in which xrays really have been used in medicine, and about the special biological properties of ionizing radiation. If one contemplates such facts, the findings in Box 1 seem of reasonable magnitude --- and not in need of additional explanations.

• Part 7. Comment on the Results So Far, and on a "Bonus"

The giant prospective study, presented in Chapters 6 through 21, evaluates the impact by 1940 of an event in history which will never recur: Introduction of ionizing radiation into United States medicine.

By 1940, population was about 132 million (Table 3-B). Unlike studies where almost an entire population is used to approximate a "control group," our study divides the entire population into nine groups --- ALL of which are exposed, because there is no Census Division where medical radiation is absent. Probably our study is one of the largest prospective dose-response studies ever conducted in this country.

Additionally, the databases we have used, by their very nature, exclude intentional bias. It deserves emphasis that the FIRST obligation of objective investigators is to assure that they are working with trustworthy data --- because even Einstein himself would produce false answers, if he were working with a tainted database.

The studies in Chapters 6 through 21 constitute some of the most powerful evidence ever assembled confirming that ionizing radiation is a potent cause of virtually all types of human cancer. We regard this confirmation as a "bonus" from the work, since our studies were undertaken for a different purpose: To test Hypothesis-1.

We would have liked to have had earlier cancer MortRates in every state, but the available data have clearly sufficed to address Hypothesis-1. We conclude that the findings strongly indicate that, during the first half of the Twentieth Century, medical radiation became a highly important cause (probably the principal cause) of cancer mortality in the United States.

>>>>>>>>>>

Box 1 of Chap. 22
Comparison of Results from Chapters 6 through 21.

Cancer	Col.A	Col.B	Col.C	Col.D	Col.E	Col.F	Col.G	Col.H
	Natl MR 1940	Share of ALL	PP-Year Constant	for Max	R-sq.	Ratio X-Coef. / SE	Best-Est. FracCausn	90% C.L. on Frac. Causation
All-Cancers								
Males: Ch6	115.0	All	11.6	1940	0.95	11.63	90%	74% - 99%
Females: Ch7	126.1	All	53.0	1940	0.86	6.58	58%	41% - 69%
Breast Cancer								
Females: Ch8	23.3	0.18	-2.2	1938	0.92	8.70	~100%	86% - ~ 100%
Digestive-System								
Males: Ch9	60.4	0.53	1.9	1940	0.91	8.30	97%	75% - ~ 100%
Females: Ch10	50.1	0.40	10.2	1940	0.76	4.64	80%	49% - ~ 100%
Urinary-System								
Males: Ch11	7.4	0.06	-2.8	1940	0.92	9.02	~100%	See Chap. 11 text.
Females: Ch12	4.0	0.03	0.6	1940	0.94	10.43	86%	68% - 95%
Genital			15.2					
Males: Ch13	15.2	0.13	3.2	1936	0.78	4.92	79%	52% - ~ 100%
Females: Ch14	32.1	0.25	29.1	1940	0.07	0.72	~0%	See Chap. 14 text.
Buccal-Pharynx								
Males: Ch15	5.1	0.04	-0.2	1940	0.72	4.28	~100%	61% - ~ 100%
Respiratory-System								
Males: Ch16	11.0	0.10	-5.1	1940	0.87	6.76	~100%	See Chap. 16 text.
Females: Ch17	3.3	0.03	0.1	1940	0.96	13.40	97%	83% - ~ 100%
"Difference" Ca.								
Males: Ch18	104.0	0.90	16.7	1940	0.93	9.97	84%	68% - 94%
Females: Ch19	122.8	0.97	52.9	1940	0.85	6.37	57%	40% - 68%
All-Except-Genital								
Males: Ch20	99.8	0.87	6.4	1940	0.95	11.16	94%	77% - ~ 100%
Females: Ch20	94.0	0.75	23.9	1940	0.87	6.77	75%	54% - 89%
All-Except-(Gen+Respy)								
Males: Ch21	88.8	0.77	11.5	1940	0.94	10.03	87%	70% - 97%
Females: Ch21	90.7	0.72	23.8	1940	0.86	6.54	74%	53% - 88%

- Col.A: National age-adjusted MortRates are deaths per 100,000 population.
- Col.B: Each entry is the ratio of 2 values from Col.A. Example: In 1940, Breast Cancer accounts for (23.3 / 126.1), or 0.18 of the female All-Cancer MortRate.
- Col.G: These percentages are best estimates (most likely values) of Fractional Causation by medical radiation of the corresponding 1940 National MortRate. Please see text (Part 1a of Chapter 22).
- When an entry of ~100% occurs in Column G, such a finding is fully consistent with the fact that cancers of these organs occurred before introduction of radiation into medicine. Other causes of such cancers (including radiation exposure from nature itself) have been operative both before and after the introduction of medical radiation. A finding, of ~ 100% Fractional Causation by medical radiation in 1940, means that by 1940, a very low fraction of such deaths would have occurred without medical radiation as a co-actor.

Related text = Part 1.

Box 2 of Chap. 22

Summary from Chapters 6, 7, 8: Regression Results 1921 Onward.

• Below are the summary-results for the 1940 MortRates regressed on PhysPops, by Census Divisions. For the 1940-1940 pairs, we also show the output when the analysis was done with data for "Whites Only" (Text, Part 2b).

ALL-CANCERS, MALE. From Chapter 6, Box. 1..

Part	PhysPop	R-squared	Constant	X-Coef	Std Err	X-Coef/SE
2a	1921	0.4630	-27.08	1.0086	0.4105	2.4568
2b	1923	0.5447	-24.83	1.0198	0.3524	2.8937
2c	1925	0.5943	-16.55	0.9879	0.3085	3.2024
2d	1927	0.7175	-20.94	1.0399	0.2466	4.2168
2e	1929	0.7596	-19.27	1.0351	0.2201	4.7032
2f	1931	0.7827	-10.40	0.9582	0.1909	5.0207
2g	1934	0.8718	-2.60	0.8903	0.1290	6.9009
2h	1936	0.9119	-1.42	0.8756	0.1029	8.5104
2i	1938	0.9407	3.05	0.8351	0.0792	10.5419
2j-->	1940 Max	0.9508	11.55	0.7557	0.0650	11.6275
Whites:	1940	0.9473	23.83	0.6740	0.0601	11.2146

ALL-CANCERS, FEMALE. From Chapter 7, Box 1..

Part	PhysPop	R-squared	Constant	X-Coef	Std Err	X-Coef/SE
2a	1921	0.3566	33.38	0.6497	0.3299	1.9695
2b	1923	0.4180	34.97	0.6559	0.2925	2.2423
2c	1925	0.4837	37.90	0.6542	0.2555	2.5609
2d	1927	0.6001	33.82	0.6981	0.2154	3.2407
2e	1929	0.6482	34.06	0.7019	0.1954	3.5916
2f	1931	0.6732	39.75	0.6524	0.1718	3.7978
2g	1934	0.7661	44.25	0.6127	0.1279	4.7888
2h	1936	0.8035	44.96	0.6034	0.1128	5.3509
2i	1938	0.8424	47.45	0.5801	0.0948	6.1177
2j-->	1940 Max	0.8608	52.98	0.5279	0.0802	6.5801
Whites:	1940	0.8638	51.35	0.5352	0.0803	6.6650

BREAST CANCER, FEMALE. From Chapter 8, Box 1......................................

Part	PhysPop	R-squared	Constant	X-Coef	Std Err	X-Coef/SE
2a	1921	0.5061	-10.94	0.2440	0.0911	2.6780
2b	1923	0.5784	-9.94	0.2432	0.0785	3.0991
2c	1925	0.6598	-8.63	0.2409	0.0654	3.6849
2d	1927	0.7673	-9.12	0.2488	0.0518	4.8040
2e	1929	0.8051	-8.58	0.2466	0.0459	5.3774
2f	1931	0.8203	-6.31	0.2270	0.0402	5.6519
2g	1934	0.8840	-4.03	0.2075	0.0284	7.3052
2h	1936	0.9005	-3.42	0.2014	0.0253	7.9604
2i-->	1938 Max	0.9153	-2.21	0.1906	0.0219	8.6965
2j	1940	0.9126	-0.12	0.1713	0.0200	8.5512
Whites:	1940	0.9184	0.3566	0.1683	0.0190	8.8740

Related text = Parts 2b + 2c.

Box 3 of Chap. 22

Companion for Box 2: Results When Negative Constants Are Banished.

• Below are the summary-results for the 1940 MortRates regressed on PhysPops, by Census Divisions, when the Constant is forced to equal Zero. Regressions are not shown. They use exactly the same input presented in Chapters 6, 7, 8. Although entries for (X-Coef/SE) below should not be compared with corresponding entries in Box 2, comparisons within each box are valid.

ALL-CANCERS, MALE...

	PhysPop	R-Squared	Constant	X-Coef.	Std Err	X-Coef/SE
2a	1921	0.4449	0	0.8100	0.0423	19.1511
2b	1923	0.5261	0	0.8330	0.0401	20.7611
2c	1925	0.5840	0	0.8597	0.0388	22.1842
2d	1927	0.6992	0	0.8754	0.0335	26.1476
2e	1929	0.7428	0	0.8827	0.0312	28.2985
2f	1931	0.7769	0	0.8767	0.0288	30.4032
2g	1934	0.8714	0	0.8702	0.0217	40.1186
2h	1936	0.9118	0	0.8647	0.0178	48.4724
2i	1938	0.9400	0	0.8583	0.0146	58.7986
2j	1940	0.9380	0	0.8414	0.0145	57.8434

ALL-CANCERS, FEMALE. ....

	PhysPop	R-Squared	Constant	X-Coef.	Std Err	X-Coef/SE
2a	1921	0.3053	0	0.8947	0.0347	25.7607
2b	1923	0.3498	0	0.9190	0.0345	26.6365
2c	1925	0.3845	0	0.9477	0.0346	27.3856
2d	1927	0.5114	0	0.9639	0.0313	30.7726
2e	1929	0.5507	0	0.9714	0.0303	32.0982
2f	1931	0.5157	0	0.9639	0.0312	30.9080
2g	1934	0.5189	0	0.9551	0.0308	31.0132
2h	1936	0.5316	0	0.9484	0.0302	31.4336
2i	1938	0.5043	0	0.9406	0.0308	30.5475
2j	1940	0.3607	0	0.9210	0.0343	26.8662

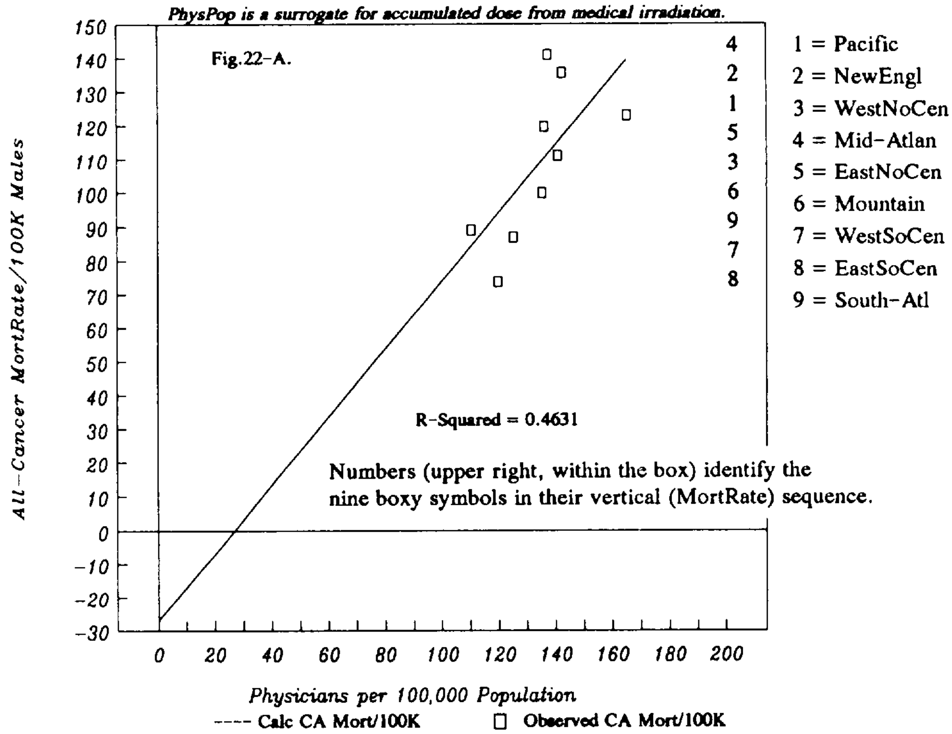
BREAST CANCER, FEMALE...

	PhysPop	R-Squared	Constant	X-Coef.	Std Err	X-Coef/SE
2a	1921	0.4506	0	0.1637	0.0097	16.8158
2b	1923	0.5229	0	0.1684	0.0093	18.0788
2c	1925	0.6080	0	0.1740	0.0087	19.9874
2d	1927	0.7024	0	0.1772	0.0077	22.9946
2e	1929	0.7427	0	0.1787	0.0072	24.7569
2f	1931	0.7804	0	0.1775	0.0066	26.8191
2g	1934	0.8635	0	0.1763	0.0052	34.0861
2h	1936	0.8847	0	0.1751	0.0047	37.1150
2i	1938	0.9079	0	0.1738	0.0042	41.5408
2j	1940	0.9126	0	0.1704	0.0040	42.6609

Box 4 is located after the Figures.

A.

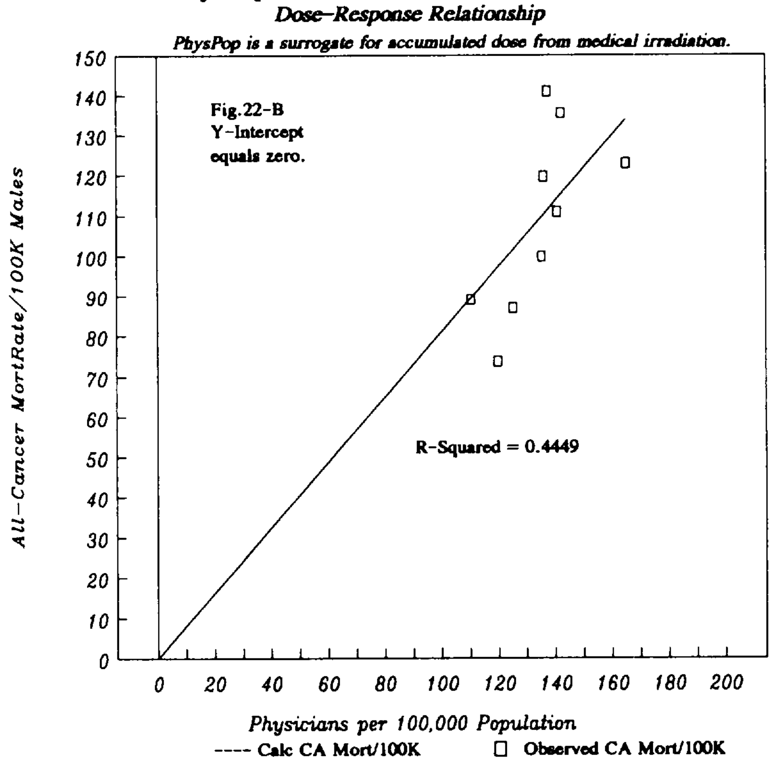
1940 All–Cancer Mortality–Rates versus
1921 PhysPop Values for the 9 Census Divisions, USA.
Dose–Response Relationship
PhysPop is a surrogate for accumulated dose from medical irradiation.



B.

Same as A, except line of best –fit has been forced to go through the origin.

1940 All–Cancer Mortality–Rates versus
1921 PhysPop Values for the 9 Census Divisions, USA.
Dose–Response Relationship
PhysPop is a surrogate for accumulated dose from medical irradiation.

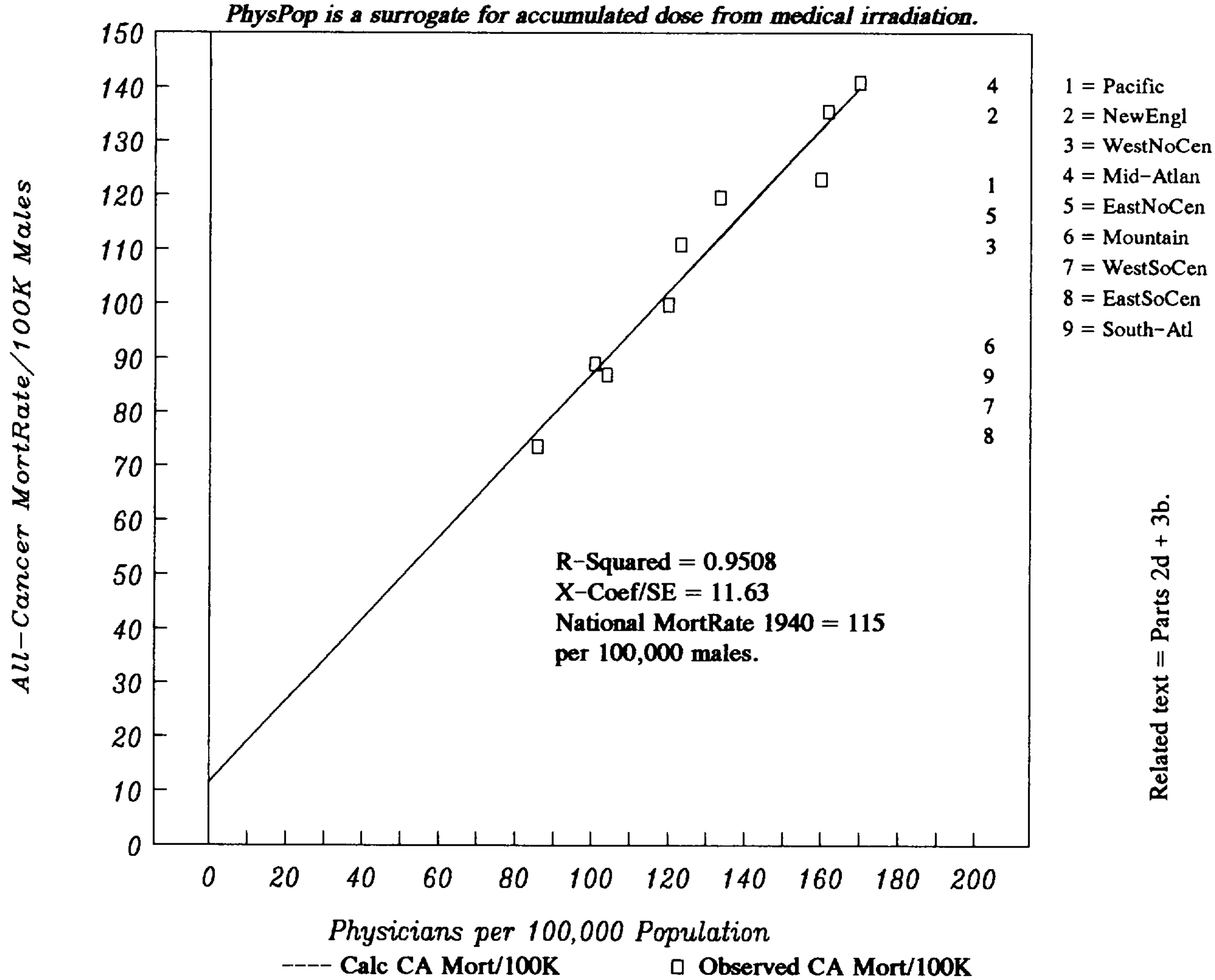


Related text = Part 3a.

1940 All-Cancer Mortality-Rates versus 1940 PhysPop Values for the 9 Census Divisions, USA.

Dose-Response Relationship

PhysPop is a surrogate for accumulated dose from medical irradiation.



Related text = Parts 2d + 3b.

On the X-axis, PhysPop values = Physicians per 100,000 Population in the Nine Census Divisions of the USA Population, Year 1940. This variable is a surrogate for accumulated radiation dose --- the more physicians per 100,000 people, the more radiation procedures are done per 100,000 people.

On the Y-axis, All-Cancer Mortality-Rate per 100,000 males = the reported rates in USA Vital Statistics for the Nine Census Divisions, Year 1940.

Figure 22-A, nearby, shows that the essence of the relationship between PhysPop and All-Cancer MortRates was already present by 1921. Indeed, the 1921 PhysPops predict the male's 1940 National All-Cancer MortRate quite well (text, Part 4 and Box 4).

Above, Figure 22-C shows that, by 1940, the tightness of the correlation had improved to near perfection (text, Parts 2d and 2e). Because the 1940 MortRates are the same in Figures 22-A and 22-C, only lateral differences occur in the positions of the nine boxy symbols.

Box 4 of Chap. 22

Comparison: Predicted 1940 National Cancer MortRates versus Observed Rates.

In the upper part of this box, we calculate the national PhysPop values for 1921, 1931, and 1938. We already know that for 1940, the national PhysPop value is 132.04 (Chapter 6, Box 4). Pop'n Fractions: Table 3-B.

(A) Census Division	(B) 1920 Pop'n Fraction	(C) PhysPop 1921	(D) 1921 Weighted PhysPop	(E) 1930 Pop'n Fraction	(F) PhysPop 1931	(G) 1931 Weighted PhysPop	(H) 1940 Pop'n Fraction	(I) PhysPop 1938	(J) 1938 Weighted PhysPop
Pacific	0.0529	165.11	8.73	0.0670	159.97	10.72	0.0739	157.62	11.65
New England	0.0703	142.24	10.00	0.0676	142.35	9.62	0.0641	154.08	9.88
West No. Centra	0.1192	140.93	16.80	0.1086	126.50	13.74	0.1027	124.95	12.83
Mid-Atlantic	0.2115	137.29	29.04	0.2146	140.82	30.22	0.2092	160.69	33.62
East No. Central	0.2040	136.06	27.76	0.2067	128.59	26.58	0.2022	131.98	26.69
Mountain	0.0317	135.38	4.29	0.0303	118.89	3.60	0.0315	119.88	3.78
West So. Central	0.0973	125.15	12.18	0.0995	105.95	10.54	0.0992	102.79	10.20
East So. Central	0.0845	119.76	10.12	0.0808	96.73	7.82	0.0819	88.21	7.22
South Atlantic	0.1287	110.32	14.20	0.1251	99.59	12.46	0.1354	99.26	13.44
Sums	1.0001		133.11	1.0002		125.30	1.0001		129.30

All the predictions below use the equation of best fit:
Cancer MortRate 1940 = (Xcoef * Natl PhysPop) + Constant.
The values for Xcoef and Constant come from Part 2 of Chapters 6, 7, 8.
For the zero-intercept calculations, Xcoefs and Constants come from Chapter 22, Box 3.

• - MALES, ALL-CANCERS.		PREDICTED	OBSERVED
1921 Best-Fit Eq. MALE MR 1940 =	(1.0086*133.11)+(-27.0754) =	107.2	.... Observed = 115
MALES All-Canc. w. zero intercept=	(0.8100*133.11) =	107.8	.... Observed = 115
1931 Best-Fit Eq. MALE MR 1940 =	(0.9582*125.3)+(-10.4041) =	109.7	.... Observed = 115
MALES All-Canc. w. zero intercept=	(0.8767*125.3) =	109.9	.... Observed = 115
1938 Best-Fit Eq. MALE MR 1940 =	(0.8351*129.3)+3.0512 =	111.0	.... Observed = 115
MALES All-Canc. w. zero intercept=	(0.8583*129.3) =	111.0	.... Observed = 115
1940 Best-Fit Eq. MALE MR 1940 =	(0.7557*132.04)+11.55 =	111.3	.... Observed = 115

• - FEMALES, ALL-CANCERS.		PREDICTED	OBSERVED
1921 Best-Fit Eq. FEM. MR 1940 =	(0.6497*133.11)+(33.3847) =	119.9	.... Observed = 126.1
FEMALES All-Ca. w. zero intercept=	(0.8947*133.11) =	119.1	.... Observed = 126.1
1931 Best-Fit Eq. FEM. MR 1940 =	(0.6524*125.3)+(39.754) =	121.5	.... Observed = 126.1
FEMALES All-Ca. w. zero intercept=	(0.9639*125.3) =	120.8	.... Observed = 126.1
1938 Best-Fit Eq. FEM. MR 1940 =	(0.5801*129.3)+47.4535 =	122.5	.... Observed = 126.1
FEMALES All-Ca. w. zero intercept=	(0.9406*129.3) =	121.6	.... Observed = 126.1
1940 Best-Fit Eq. FEMALE MR 1940 =	(0.5279*132.04)+52.984 =	122.7	.... Observed = 126.1

• - FEMALES, BREAST CANCER.		PREDICTED	OBSERVED
1921 Best-Fit Eq. FEM. MR 1940 =	(0.2440*133.11)+(-10.9421) =	21.5	.... Observed = 23.3
FEMALES Breast Ca w. zero intercept	(0.1637*133.11) =	21.8	.... Observed = 23.3
1931 Best-Fit Eq. FEM. MR 1940 =	(0.2270*125.3)+(-6.3107) =	22.1	.... Observed = 23.3
FEMALES Breast Ca w. zero intercept	(0.1775*125.3) =	22.2	.... Observed = 23.3
1938 Best-Fit Eq. FEM. MR 1940 =	(0.1906*129.3)+(-2.2092) =	22.4	.... Observed = 23.3
FEMALES Breast Ca w. zero intercept	(0.1738*129.3) =	22.5	.... Observed = 23.3
1940 Best-Fit Eq. FEMALE MR 1940 =	(0.1713*132.04)+(-0.1205) =	22.5	.... Observed = 23.3
FEMALES Breast Ca w. zero intercept	(0.1704*132.04) =	22.5	.... Observed = 23.3

Related text = Part 4.