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Strontium-90 in Man

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Radioactive fallout at great distances from atomic explosions produces both internal and external hazards to the human race. The external hazards result from the interaction of gamma rays in the environment on the genes of individuals, which produces an increased mutation rate. The increase in normal gamma background owing to fallout is very small, so far, and it is being carefully monitored (*1*). The tolerable level of external gamma radiation for genetic effects is not well defined (*2*). The internal hazard is primarily the development of bone cancer, because of the presence of strontium-90 (half-life 28 years). Libby (*3*) has discussed the general problem of strontium-90 in fallout and has presented considerable data (*4, 5*) on the concentration of this isotope in various parts of the chain from the atmosphere to man.

This article (*6*) summarizes the results obtained at Lamont Geological Observatory on the strontium-90 content in man (based on a world-wide sampling network) and attempts to evaluate the potential hazard. The work presented here is a part of a more comprehensive study of the geochemistry and biochemistry of strontium-90 that has been in existence at Lamont for several years (*7, 8*). The first experimental verification of measurable quantities of strontium-90 in animal bone, milk products, and soil was made at Lamont in August 1953 following the prediction by Libby, Eisenbud, and others in July 1953 (*9*) that it might be found in detectable quantities if low-level techniques were employed.

At the present time strontium-90 can be found in all human beings, regardless of age or geographic location, provided that a sample of adequate size is available. As is shown here, these quantities are small compared with the maximum permissible concentration (MPC) (1.0 millimicrocuries of strontium-90 per gram of calcium) established by the National Committee on Radiation Protection (*10*). However, the existence of measurable quantities makes it possible to analyze the present distribution of strontium-90 with regard to age, sex, diet, geography, and time. Such information is fundamental for making predictions about the probable effects of future nuclear explosions.

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Dispersal

The route of strontium-90 from the time of fission to its uptake in human bones is known in broad outline. The explosion releases the strontium-90 into the air, where it is then carried for great distances. Eventually it is transported to the soil and becomes a part of the base-exchangeable alkaline-earth-metal ions in the upper few inches. Since plants take up this radioactive strontium along with their necessary calcium, human beings ingest strontium-90 from vegetables and milk products.

Kiloton explosions produce debris mainly in the lower atmosphere (troposphere), from which the strontium-90 is deposited in a few weeks (*5*). This debris is deposited in a restricted latitude. Thus the Nevada test series distributed strontium-90 largely over a narrow latitude band in the Northern Hemisphere, with a higher concentration in the United States than elsewhere. Megaton weapons, on the other hand, appear to put most of their strontium-90 into the stratosphere, where it is more or less uniformly distributed with respect to latitude. It then passes very slowly (about 10 percent per year) back into the troposphere (*4*), from which it is rapidly washed out. Megaton explosions, therefore, tend to equalize the world-wide fallout pattern. The local distribution will be modified by rainfall, vegetation cover, and topography, but the latest total fallout data (*1*) support a rather homogenous distribution that shows maximum variations of only a factor of 3 at the longitudes of Africa and New York. The distribution in the Northern Hemisphere remains higher than that in the Southern Hemisphere, because of the kiloton shots from the Soviet and United States test sites.

It is now reasonably well established (*5*) that the scavenging action of rain is responsible for most of the deposition of tropospheric debris. Experiments made at this laboratory during the past 6 months confirm this conclusion. Other experiments at Chicago (*11*) and at Lamont (*8*) indicate that at least 60 to 70 percent of the strontium-90 which has fallen out in the United States is in the soluble form and is therefore available to plants. It is suspected that the megaton debris from the Pacific tests has a higher fraction of soluble strontium-90 than debris from other tests, but this remains to be confirmed. About 80 percent of the strontium-90 is found in the upper 2 inches of the soil, but in some cases detectable amounts may be carried down as far as 12 inches (*8*), because of the type of soil, topography, and drainage pattern. Measurements of the soil and plant content of strontium-90 per gram of available calcium in 1953 (*4*) can be interpreted as meaning that some plants have significant surface retention of strontium-90, or that the concentration of strontium-90 per gram of calcium in the 0- to 2-inch interval is not representative of the true environment of the roots. As the ground becomes progressively more contaminated with strontium-90, however, the surface effects become obscured. Thus, on the East Coast of the United States during the Nevada tests in the spring of 1955, the surface fallout of strontium-90 was only a very small fraction of the total strontium-90 in the plants (*8*).

The total fallout of strontium-90 was

estimated by Libby (*5*) at the end of 1955 to be about 13 millicuries per square mile in the upper midwestern region of the United States. The soil data of Hardy and Morse (*4*) suggest an average of about 15 millicuries per square mile for the United States. On the basis of the fallout of mixed fission products and an estimate of strontium-90 fractionation at long distances from test sites, Eisenbud and Harley (*1*) calculated a fallout of 13 millicuries per square mile for the United States in late 1955. By comparing the average total fallout on gummed paper for the United States in the fall of 1955 (*1*) with that for the world, a world-wide average deposition of strontium-90 on the soil of 8 millicuries per square mile can be calculated.

The amount of strontium-90 in the soil which gets taken up by the plant depends on the root depth, the calcium content of the soil, and the biological fractionation factor. Menzel (*12*) has shown that strontium is discriminated against by a factor of about 1.4 when it goes from soil to plant. The calcium content of the soil varies greatly. Values of 0.4 to 40 milliequivalents of exchangeable calcium per 100 grams of soil are common. Further, as noted in a foregoing paragraph, the concentration of strontium-90 drops rapidly with depth. These factors make it possible for the concentration of strontium-90 per gram of available calcium to vary by a factor of more than 100 for a given amount of fallout. Since the biological hazard may be stated in terms of concentration of strontium-90 per gram of calcium, it is clear, then, that merely to consider average values of strontium-90 in soil is not sufficient. Thus, although the fallout of strontium-90 per square foot in the New York area in 1955 varied by a factor of 7 (144 to 1010), the range in micromicrocuries of strontium-90 per gram of available calcium exceeded a factor of 40 (6 to 250) (*8*).

Biochemical Considerations

Most people in the United States obtain their calcium through milk products. Here, fortunately, there is a discrimination factor of 7 against strontium from the plant that the cow consumes to the milk produced, according to experiments by Comar (*13*).

Regardless of the dietary source (milk products, vegetation, meat, or water), strontium-90 will follow calcium in the body, but it is discriminated against in going from the intestines to the blood by a factor of 2 to 3 (*14, 15*). Studies on human beings who have been given intravenous tracer doses of strontium-85 and calcium-45 simultaneously show that strontium is also discriminated against in the process of bone deposition. This, together with the fact that the body preferentially excretes strontium, results in a progressive enrichment of the bone in the calcium isotope following a single administration of the two tracers, the experimentally determined factor being 2.0 at 1 month and gradually increasing (*16*). On constant dietary intake, it would appear that an equilibrium enrichment of about 3 would be obtained in going from blood to bone, so that the total discrimination against strontium in going from the food to bone is about 8.

Appreciable local variations in strontium-85 content per gram of calcium occur in individual bones after a single dose. The "hot spots" that appear on autoradiographs are probably of less consequence in the case of strontium-90 than they are in the case of radium, because the dimension of these localizations is usually much less than the range of the beta particle that is emitted from the strontium isotope. Table 1 shows that real differences in strontium-85 content per gram of calcium exist among the various bones of a particular skeleton. Although the data shown are for an individual who died 39 days after administration, the ratios proved to be relatively uniform for seven other cases ranging from 3 hours to 125 days.

From the unpublished data of Trotter on the weights of individual bones in the human skeleton and from information on the percentage of calcium in the bones and the distribution of strontium-85, it is possible to calculate the total skeletal load of strontium-90 from any given bone. The bone most frequently obtained at autopsy is the rib. It may be noted from Table 1 that the concentration of strontium-85 per gram of calcium in the rib is twice that of the average body. Other bones frequently received in the world-wide survey are femur and vertebrae, which contain 0.72 and 4.2 times the average strontium-85 concentration of the whole skeleton, respectively.

These are the primary concepts and data that must be used in interpreting the world-wide human assay.

Table 1. Relative size of bone and distribution of strontium-85 in human skeleton.

Bone	Percentage of skeleton (dry wt)*	Percentage of calcium of skeleton	Percentage of Sr^{85} per gram of calcium†
Long bones‡	52.5	57.9	0.0187
Femur	18.7	20.6	0.0219
Humerus	6.9	7.6	0.0171
Radius	2.3	2.5	0.0170
Skull and mandible	17.9	19.7	0.0094 (skull)
Rib	5.7	6.3	0.0618
Vertebrae	8.6	7.1	0.128
Sternum	0.3	0.2	0.138
Weighted average			0.0303

* Data kindly supplied by Mildred Trotter, Washington University School of Medicine.
† Data from Schulert, Laszlo *et al.*, giving concentrations 39 days after administration of isotope. Other data taken from 3 hours to 125 days after administration of isotope show similar relative distribution of strontium-85.
‡ All the limb bones plus the pelvis. In averaging, it was assumed that the three analyzed are representative of the total.

Sampling

Autopsy samples of human bones were obtained from 17 stations in a world-wide network (*17*) (Fig. 1). To date, more than 1500 samples have been received, and about 600 analyses have been made; the bulk of the samples have come from about ten stations. The size of sample ranged from 1 to 200 grams of wet bone. An attempt was made to get as wide a geographic and dietary distribution as possible, but the distribution was necessarily limited by our contacts with physicians in certain centers. Future sampling will utilize a wider network, and considerable use will be made of integrated samples.

The bones employed were usually ribs, but those from Germany were femur shafts, and those from Switzerland, England, and Denmark were vertebrae. In all cases the entire rib, shaft, or vertebrae section was ashed and analyzed to avoid local variations that do appear both laterally and vertically in the bone.

The early results suggested that there was negligible strontium-90 in persons over 40 years of age; hence, sampling was concentrated in the younger age groups. It is clear that this is no longer true and that a broader spectrum is now desirable.

A few samples of adult bone measured at Lamont and many stillborns analyzed at Chicago (*4*) date as early as 1953, but for most localities the samples were procured in 1955, so that a clear definition of the rate of change of strontium-90 concentration cannot yet be made.

Analysis

The radiochemical procedure (*18*) consists briefly of ashing the bone, dissolving in hydrochloric acid, precipita-

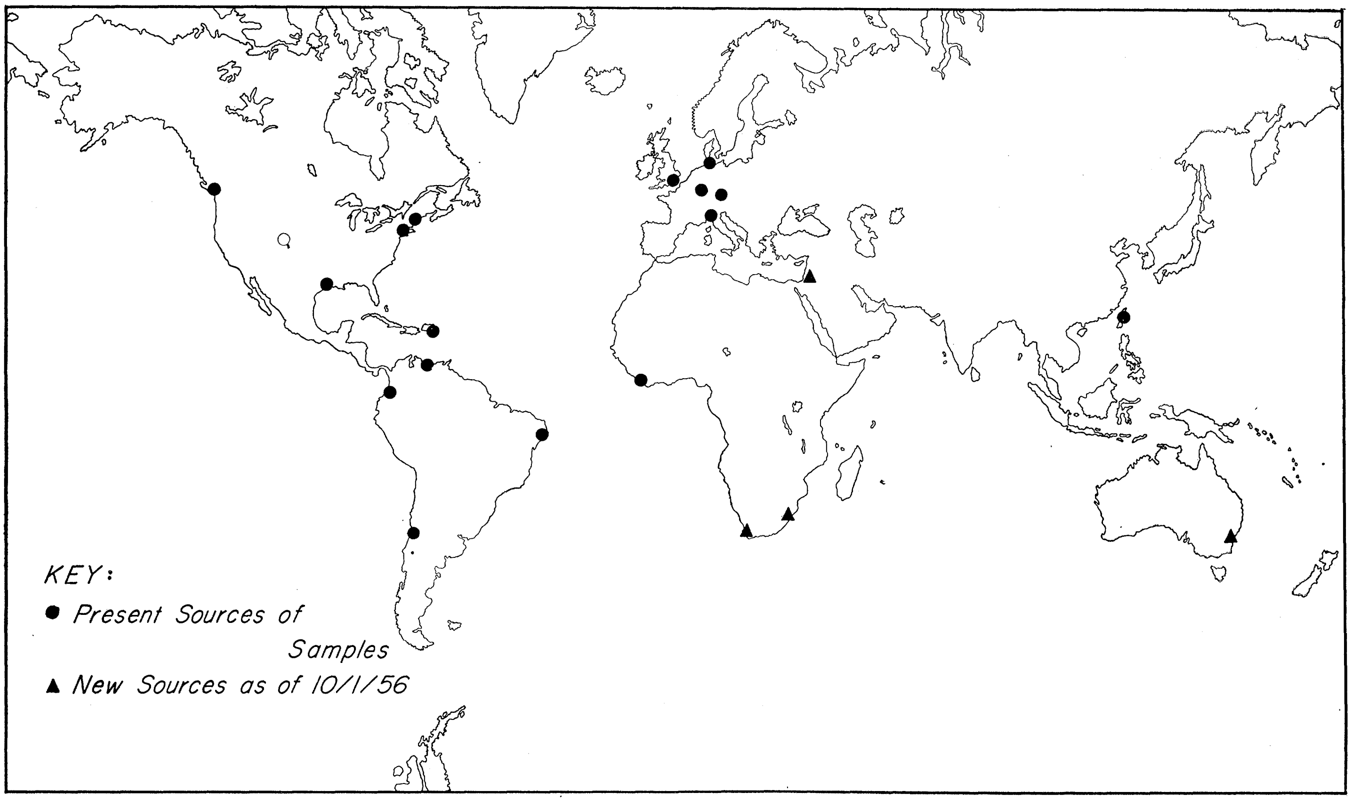

Fig. 1. World-wide network for collection of human bone samples. The triangles indicate new stations for which data are not yet available.

ting calcium oxalate, igniting to calcium oxide, resolving in hydrochloric acid, adding nonradioactive yttrium carrier, and milking the yttrium-90 daughter of strontium-90 as the oxalate. Usually the first milking brings down some foreign activities so that a second one is required for the quantitative assay of yttrium-90. Purity is checked by monitoring the decay of the yttrium-90 precipitate. The yttrium oxalate precipitate is counted in a convenient low-level system that has been described elsewhere (*19*). This procedure makes it possible to determine less than 1 disintegration per minute of the strontium-90 sample. At the level of 10 disintegrations per minute, per sample, the precision is a few percent. Even at low levels of activity, the variation in the individual samples is considerably larger than the experimental error.

The data reported in this paper were obtained at the Lamont Observatory and at two commercial laboratories: Isotopes Incorporated, Westwood, New Jersey; and Nuclear Science and Engineering Corporation, Pittsburgh, Pennsylvania.

Results

All of the analyses of strontium-90 in human bone reported in this study are summarized by locality in Fig. 2. The results are given in micromicrocuries of strontium-90 per gram of calcium. The dashes mean that the sample contained equal to, or less than, this amount. The error in a determination is generally less than 20 percent, but for a few of the very small samples or those with only a few hundredths of a micromicrocurie of strontium-90 per gram of calcium, it may be considerably higher.

Table 2 shows the averages for all localities broken down into age groups. All values in this table are normalized to an average skeleton, using the aforementioned factors. The weighted averages for each age group were calculated for each continent and for the world. Finally, a total maximum world average of the concentration of strontium-90 in the human skeleton was obtained. The average deviation for a given age group and locality was commonly around 50 percent. All samples whose analyses were reported as "equal to or less than x" have been assumed to contain x micromicrocuries of strontium-90 per gram of calcium for the purposes of this averaging. Thus Table 2 actually represents the maximum average strontium-90 content. For most localities, however, this makes little difference, because the number of such analyses was small or the analyses were in the range of low concentration. In the case of Chile and Brazil, however, the actual average concentration is probably about 25 percent lower than this maximum value.

One sample with very high concentration of strontium-90 was not included in the average. This sample was from Vancouver, British Columbia (49 years; tibia), and it had a concentration of 6.6 ± 0.3 micromicrocuries of strontium-90 per gram of calcium. This would give a skeletal average of about 9.1 micromicrocuries of strontium-90 per gram of calcium. Analytic error owing to contamination appears unlikely, since other samples that were processed at the same time showed very low activity.

Discussion

From the analytic data shown in Fig. 2 and Table 2, the following tentative conclusions may be drawn.

1) The present world-wide average content of strontium-90 in man is about 0.12 micromicrocuries per gram of calcium, or 1/10,000 of the presently accepted maximum permissible concentration.

2) The averages for the different continents are surprisingly similar, indicating that already the stratospheric drip of strontium-90 from megaton explosions is swamping the local concentrations from both the Nevada and the Soviet test sites. There is evidence, however, that Chile and Brazil have clearly lower concentrations than those localities in the Northern Hemisphere for which a large number of samples are available. The close similarity between Houston, Texas, and Bonn, Germany, for which good sampling is available, emphasizes that

the differences as a function of longitude in the Northern Hemisphere are small. Since Taiwan has appreciable fallout from Pacific and Soviet tests (*1*), it is not surprising that its values are similar to those for North America.

3) There is clearly an age effect, at least in the first 20 years. Young children have 3 to 4 times more strontium-90 per gram of calcium, on the average, than adults. This effect reflects the larger proportion of active bone in children.

4) As was expected, the average strontium-90 content of human bone does not vary from one locality to another more than the average concentration of mixed fission products (*1*). For identical periods of time there is a fair correlation between these two factors for the 17 localities that were sampled for human bone.

5) By averaging all samples from persons above 10 years of age, a large enough set is available for comparison between localities. In North America, for exam-

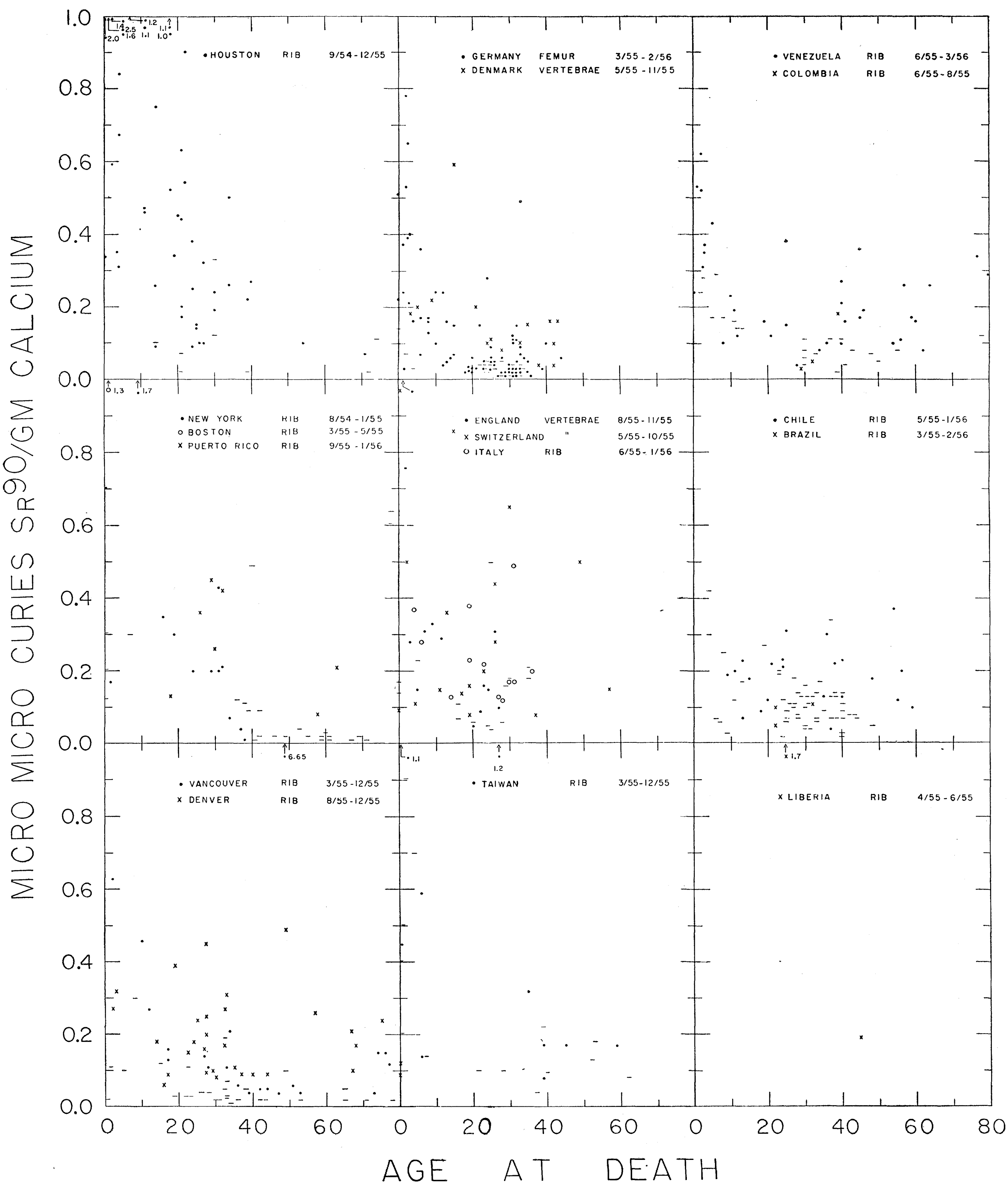

Fig. 2. Strontium-90 content of human bone in 1955.

ple, it is readily seen that the concentration in Vancouver is essentially the same as that in Houston, whereas the concentration in Denver is definitely lower (despite its proximity to Nevada). The New York average is not strictly comparable; it is low because samples from individuals 40 to 60 years of age comprised half of the total. These are the only ones in the table that were obtained in the spring and fall of 1954. At that time the strontium-90 content of adult bone was distinctly lower than it was in late 1955. (Note that the concentration in New York City milk had increased at least by a factor of 2 toward the end of 1955 from the level in 1954 (*4*).

6) There are large deviations from the mean in the strontium-90 content in individuals of a given locality. The average deviation for most 10-year-age sets is about 50 percent. Figure 3, a log normal plot of the North American samples, illustrates that some individuals may have at least 10 times the average concentration. This is most probably related to diet.

An attempt was made to find the time-dependence of the strontium-90 contamination in human bone. The major difficulty is the limited time interval over which samples have been taken (mainly 1955). The New York samples of the spring and summer of 1954 in the older adults (40 to 60 years) were definitely lower (the average was less than 0.01 micromicrocurie of strontium-90 per gram of calcium) than in areas of similar total fallout in 1955—for example, Puerto Rico and Denver (averages were 0.14 and 0.08 micromicrocurie of strontium-90 per gram of calcium, respectively). Here an increment of 0.1 micromicrocurie of strontium-90 per gram of calcium, per year is evident. It now appears that stillborns may have a higher concentration than the average of the mother skeleton, at least during this early period of nonequilibrium. The Chicago data (*4*) suggest a 1953 stillborn average of about 0.12 micromicrocurie of strontium-90 per gram of calcium; this climbed to 0.17 by the spring of 1954. Six samples from Chile gave about 0.35 in mid-1955. The values for the comparable mother skeletons would have been 0.03 micromicrocurie per gram in Chicago in 1954 and 0.07 micromicrocurie per gram in Chile in 1955.

The samples from Germany were of sufficient size and number to make possible a significant comparison between the periods March to September 1955 and October 1955 to January 1956. The biggest difference was observed in the youngest age group, whose members would be the most sensitive to change in the strontium-90 concentration of the diet, because of their rapid growth. For the 0 to 9 age group, the averages were 0.21 and 0.34 micromicrocurie of strontium-90 per gram of calcium for March to September 1955 and for October 1955 to January 1956, respectively. A major increment in the known bone data should be observed in the present winter 1956–57 collection.

The average American obtains about 80 percent of his calcium from dairy products and the remainder mainly from vegetation (*20*). In 1955 the strontium-90 concentration in milk in the United States was about 3.5 micromicrocuries per gram of calcium (*4, 5*). During the same period, field vegetation averaged about 20 micrimicrocuries per gram of calcium (*5, 8*) so that the *average* human population in the United States probably had a diet of about 7 micromicrocuries of strontium-90 per gram of calcium. Using the discrimination factor of 8 between diet and human bones, an equilibrium concentration of

Table 2. Average strontium-90 content in man 1955. (All values in micromicrocuries of strontium-90 per gram of calcium, normalized to the average whole skeleton. The numbers in parentheses give the total number of samples in the category.) The world average for all ages and locations is 0.12 micromicrocuries per gram of calcium; the average, including one sample of high value, is 0.14; and the world average for all samples assuming "equal to or less than" values are zero is 0.10.

Location and sample	Age at death								Average 10–80
	0–4	5–9	10–19	20–29	30–39	40–49	50–59	60 →	
				Europe					
Germany (femur)	0.44(12)	0.25(6)	0.14(13)	0.065(33)	0.085(29)	0.14(2)			0.085(77)
Switzerland (vertebrae)	0.13(3)		0.068(6)	0.076(3)	0.088(2)	0.12(1)	0.036(1)		0.076(13)
England (vertebrae)	0.19(3)	0.060(4)	0.048(2)	0.026(9)					0.032(11)
Denmark (vertebrae)	0.044(1)	0.052(2)	0.14(1)	0.029(4)	0.024(3)	0.029(4)			0.036(12)
Italy (rib)	0.18(1)	0.14(1)	0.10(4)	0.10(6)	0.11(7)				0.11(17)
Average	0.33(20)	0.15(13)	0.11(26)	0.06(55)	0.085(41)	0.08(7)	0.04(1)		0.078(130)
				North America					
Texas (rib)	0.49(13)		0.22(9)	0.14(17)	0.12(8)	0.13(1)	0.05(1)		0.15(36)
Denver (rib)	0.12(5)	0.085(5)	0.09(11)	0.075(9)	0.09(4)	0.13(1)		0.07(7)	0.085(32)
New York City (rib)	0.44(2)	0.16(3)	0.17(2)	0.10(2)	0.075(8)	0.005(4)	0.01(4)		0.06(20)
Boston (rib)	0.40(2)								
Vancouver (tibia)	0.46(2)		0.28(5)	0.10(4)	0.066(11)	0.06(5)	0.06(3)	0.092(7)	0.10(35)
Puerto Rico (rib)	0.06(1)		0.065(1)	0.21(2)	0.13(3)	0.15(2)	0.04(1)	0.16(6)	0.14(15)
Average	0.41(25)	0.12(8)	0.17(28)	0.12(34)	0.09(34)	0.07(13)	0.02(9)	0.10(20)	0.11(138)
				South America					
Colombia (rib)				0.016(1)	0.04(5)	0.04(1)			0.035(7)
Chile (rib)	0.15(1)	0.06(5)	0.075(7)	0.07(16)	0.06(22)	0.05(10)	0.10(4)		0.065(59)
Brazil (rib)	0.21(1)		0.14(1)	0.055(1)	0.055(1)	0.05(3)			0.06(12)
Venezuela (rib)	0.19(10)	0.11(4)	0.08(4)	0.085(4)	0.04(6)	0.085(10)	0.065(6)	0.105(6)	0.075(39)
Average	0.19(12)	0.085(9)	0.08(15)	0.07(27)	0.055(34)	0.065(24)	0.08(10)	0.105(6)	0.065(117)
				Africa					
Liberia (rib)				0.83(1)		0.093(1)			
				Asia					
Taiwan (rib)	0.34(5)	0.16(3)	0.25(1)	0.33(2)	0.08(7)	0.055(3)	0.08(3)		0.12(16)
				World-wide					
Average	0.31(62)	0.14(33)	0.12(70)	0.09(118)	0.08(106)	0.07(47)	0.06(22)	0.09(26)	

about 0.9 micromicrocurie of strontium-90 per gram of calcium would be predicted for the average American. The actual concentration in 1955 was probably about 0.3 for young children and 0.1 for adults. These lower values reflect the time required for bones to equilibrate with the strontium-90 calcium ratio in the diet.

An estimate of the world-wide burden can be made by assuming that the average total strontium-90 fallout was 8 millicuries per square mile in 1955, and that the average amount of exchangeable calcium is 75 grams per cubic foot (*4*). Thus, if half of the fallout is in the upper 1 inch of soil, which contains 6 grams of calcium per square foot, an average concentration of about 25 micromicrocuries of strontium-90 per gram of calcium would be available to grains and grasses. Using a soil/plant fractionation of 1.4 and a plant/milk fractionation of 7, the average world-wide concentration of strontium-90 in milk would be about 25 micromicrocuries per gram of calcium, and in vegetation about 18 micromicrocuries per gram of calcium. Assuming that 80 percent of the world-wide dietary calcium comes from milk products—as is true for the average American diet (*20*)—the predicted concentration of strontium-90 in the diet would be about 5 micromicrocuries per gram of calcium. This in turn would yield a predicted value of 0.6 micromicrocurie per gram of calcium for the average man when equilibrated with the fallout that existed at the end of 1955. The major uncertainties in the calculation are the source of calcium in the average world diet, the average calcium content of the soil, root depth, and possible direct foliar uptake.

In terms of hazard to man, there are two problems to be considered: (i) the average value for the world population and (ii) possible maximal concentrations. Locations near atomic test sites are not included in these considerations.

With regard to the strontium-90 burden of the population of the world in the fall of 1955, it can now be said that this is reasonably well known (0.12 micromicrocurie per gram of calcium) and that this burden is very small compared with the maximum permissible concentration (1/10,000).

The matter of predicting the maximum average human burden that will ultimately be occasioned from atomic explosions through the fall of 1956 involves several factors. The average burden will be determined by the average strontium-90/calcium ratio in the diet at equilibrium. Thus, if the fall 1955 concentrations in the diet were maintained, the average human being at *all* ages would reach a maximum of about 0.6 micromicrocurie of strontium-90 per gram of calcium. This would be the result of a world-wide fallout of about 8 millicuries per square mile by the end of 1955 (*1*). From the end of 1955 to the fall of 1956, another 2 millicuries per square mile would appear world-wide from stratospheric fallout. An additional 8 millicuries per square mile has fallen out since 1955 from high-yield weapons that have deposited all of their debris in the Northern Hemisphere (*5*). Libby (*5*) states: "In fact, we estimate at the present time that the total stratospheric reservoir, counting all sources, is about the same as it was 2 years ago—that is, 12 millicuries of strontium-90 per square mile, or the equivalent of 24 megatons of fission products calculated as a uniform world-wide distribution." Taking decay into account, a total quantity of 26 millicuries per square mile would be available in the United States for equilibration with the human skeleton by 1970. Thus, from explosions that have already occurred, the average human bone in the United States should contain about 2 micromicrocuries of strontium-90 per gram of calcium by 1970, whereas the world-wide average concentration should be about 1.3. This will have been the result of about 50 megatons of fission. On this basis, 35,000 megatons of fission would be required to bring the average concentration in the world's population up to the maximum permissible concentration.

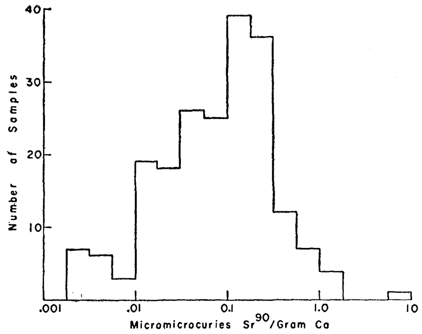

Fig. 3. Distribution pattern of strontium-90 in human bone in North America.

The most important problem lies with individual variation. By direct experiment, it has been found that the distribution curve is quite sharp (Fig. 3 and Table 2). Although food grown in restricted areas of low available calcium content could have 10 to 100 times the mean, it is clear that the general mixing of food sources in the diet of an urban population would make it impossible for most people of the world to exceed the average concentration of strontium-90 by more than a factor of 10.

The theoretical estimation of the maximum concentration of strontium-90 that some individual or a small group of individuals might receive at long distances from atomic test sites is a complex problem involving a number of parameters that are at present subject to large uncertainties. The highest concentrations will be found in isolated individuals who obtain their total food supply from a restricted area that has very low available calcium in the soil (*21*).

Summary

The world-wide average strontium-90 content of man was about 0.12 micromicrocurie per gram of calcium (1/10,000 of the maximum permissible concentration) in the fall of 1955. A few values as high as 10 times the average have been obtained.

This value is in accord with the predicted value based on fallout measurements and fractionation through the soil-plant-milk-human chain.

With the present burden of strontium-90, this average level should rise to 1 to 2 micromicrocuries of strontium-90 per gram of calcium by 1970.

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Science, Ethics, and Politics

Albert Szent-Györgyi

We are often told that science has no moral content. Certainly, if I measure the respiration of a tissue, I have little to do with morals or ethics, but on the same ground one could deny a religious content to the Holy Communion, drinking wine and eating bread not being, in themselves, religious acts. If there should be a Creator, then scientific research would be tantamount to worship, there being no greater compliment to a creative artist than an effort to understand his work.

The scientist is searching for truth, for truth's sake, and, if it is found, he processes it without fear of consequences. This demands the highest ethical standards and brings him into line with the religious and moral leaders of mankind. What the scientist really wants to know are the internal laws that hold the universe together with all that is in it. Morals are the laws that hold human societies together. So science is not devoid of relations to ethics and morals.

Moral Law

Morals are practical prescriptions that tell us how to live to be able to live together. The moral outlook of a scientist has to be wider than that of the average, simply because his society is wider, not being limited by time or space. The community in which I live has Galileo, Newton, and Lavoisier as its active members, and I cannot help feeling more affinity to Chinese or Indian scientists than I do to my own milkman.

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As to politics, up till lately, there was no need for the scientist to take cognizance of its existence. However, lately, politics has penetrated not only into science but also into the private lives of individuals, forcing the scientist, too, to make a stand. That science, in certain countries, is dictated by political dictators is so crude a matter that it demands no discussion.

A subtler question may be asked about the aims of science. The main driving force of researchers is mostly some sort of a curiosity, the gratification of a mental need, which makes research a selfish occupation. However, from a higher point of view, scientific research is one of the human efforts aimed at elevating man. Within the last decade, science has created the most powerful tools, which, like any tools, can be used for construction or destruction. The scientist cannot remain a neutral spectator and refuse all moral responsibility when he sees the politician run away with these and turn them into tools of destruction.

We all have the bad luck to be born in an age of a moral crisis, and, according to Dante, the hottest places in Hell are reserved for those who remained neutral at times of a moral crisis. So we all have to take a stand, simply as human beings. Humanity has its well-established moral code on which human relations are based. It is these moral laws that enable man to live in a society, and the problem is whether these morals apply only to the individual or also to groups of men, whether crimes which are punished by death in one country should be suffered to be practiced on a big scale as a routine by governments in another country, being "internal affairs." This is more than an ethical problem. As a society could not exist without a moral convention among its members, so countries cannot exist, side by side in peace, without a moral code. I am deeply convinced that this is the simple root of all our political troubles, the whole political superstructure being but a "pseudo-problem."

One Moral Code

I also believe that there cannot be two moral codes, an individual one and a political one. There is but one, and this one is very deeply written into our minds by our education. It is so deeply engraved that we see no need to restate it every time we make any agreement, and we tacitly suppose all written agreements to be based on this unwritten moral code. For instance, if we make an alliance, we see no need to state explicitly that it is made so that we may help one another and not to enable us to stab our ally in the back, as we were advised to do by Lenin.

It is natural that any system can achieve a great temporary advantage by rejecting the moral code that is written so deeply in its adversary's mind that he will believe and fall, over and over again. How often the world believed, *ad nauseam,* when Hitler called every demand his last one. The Hungarians fell for the famous "salami technique" (one slice at a time). We saw just the other day, how, with a boring repetition, all leaders of a revolution could be trapped and marched to jail by an invitation to a "discussion."

There is but one moral code, and, if any government rejects it inside its borders, it will reject it in its international relations as well and create disorder. The question is whether any deviation from moral convention should be suffered by the rest of mankind. There are international laws to control pestilence, for fear that that pestilence may spread across borders. Why not the same for moral pestilence?

Political Questions and the Individual

For most of my colleagues, these questions may seem so crude, and the an-