Letters

Hazards from Isotopic Tracers

There is an aspect of the use of radioisotopes as tracers which needs to be called to the attention of some of those people using them. This is, that the degree of hazard involved, both to the investigator and to any volunteer subjects, can depend to a great extent on the chemical form in which the isotope is used, and that, to a large degree, the present guides for estimating this hazard are inadequate.

The immediate example is the rapidly growing use of tritiated thymidine and other nucleic acid precursors. The estimates of the hazard from tritium are based on the assumption that it is used in the form of tritiated water. In this case, it is estimated that tritium distributes uniformly through about 50 liters of water in the "standard man," and that it turns over with a biological half-life of 19 days [see "Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water," *Natl. Bur. Standards (U.S.) Handbook No. 52*]. Under these conditions, it is estimated that a steady burden of 10 mc of HTO in the body, or of 200 μc per liter of drinking water, would deliver 300 mrem per week. If one considers the "integral dose" from a single intake of HTO, the estimate is that about 1 c is required to deliver a total dose of 100 rem [see, for example, K. Z. Morgan, in *Proc. 1st Intern. Conf. on the Peaceful Uses of Atomic Energy* (1956), vol. 13, p. 139]. On this basis, the Atomic Energy Commission now allows the sale of 250 μc of tritium without a specific license. In the form of tritiated water, swallowed or inhaled all at one time, this quantity would deliver between 20 and 35 mrem, a reasonable risk indeed for an investigator.

One is also permitted, however, to buy 250 μc of tritiated thymidine without a specific license. The experimental results obtained so far, with this and other isotopic tracers, show that in some organisms thymidine goes largely, if not exclusively, into deoxyribonucleic acid (DNA) and that it stays there with little if any turnover. This points up the fact that investigators need to take considerable precaution in handling the material. One can estimate that the human body contains 50 to 100 g of DNA, or, say, 1000 times less DNA than it does water. The biological half-life may be very long, depending on the cells and tissues most actively synthesizing DNA, and it is conservative to estimate a half-life of 190 days or more—perhaps years? If all the radiation were concentrated in the DNA itself, 250 μc of tritium could deliver to the "genestuff" a dose 10,000 to 100,000 times greater than that from an equal quantity in the form of tritiated water.

Other factors affect this estimate, however. The first is that, in fact, the ionizations are spread through a somewhat larger volume than just the DNA (most of the ionizations being within 1 or 2 μ of their origin), so that the dose (ionizations per unit volume) is lower. A more correct estimate, then, is that the chromosomes or entire nuclei are being irradiated, and the dose may be 10 to 50 times less than that estimated above. The second factor—namely, the fact that a small fraction of the body cells are most actively synthesizing DNA (for example, the germ lines, bone marrow, spleen, and so on)—works in the opposite direction. If these cells pick up most of the tritium, the dose may be increased by a factor of 10 or more—not to mention the fact that these cells are more radiosensitive than others. The last consideration is that only a fraction of the thymidine will be incorporated into DNA—depending on the route of intake, somewhere between 1 and 50 percent (?).

Putting all these factors together, one estimates that under various conditions tritiated thymidine can deliver a dose to the chromosomes of radiosensitive cells from 50 to 50,000 times greater than that delivered by an equal activity of tritiated water. The upper limit corresponds to about 5 r per microcurie ingested. In view of the unusual difficulty of monitoring tritium contamination, it seems clear that great care needs to be taken by anyone who wants to use tritium in the form of thymidine.

The foregoing estimates are very uncertain, and the information is not yet available to improve them. Similar considerations apply to any other specialized metabolite; much more information is needed about the fates of isotopic tracers. Frequently the investigators who use them are best qualified to determine these fates, and it is to be hoped that they will do so and make the information available to guide others.

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Survival

In a letter headed "Darwin and Pandora's box" [*Science* **128**, 424 (1958)], H. K. Livingston discusses the analogy between the death of the individual and the extinction of species, with reference to the concept of immortality. He asserts that "one consequence of the understanding gained from our concept of evolution is the knowledge that species become extinct—not just occasional species, as an odd incident, but all species, inevitably, as part of the order of things." This statement can hardly be supported by direct observational evidence; indeed, there are many species alive today with fairly remote origins, and we really do not know whether there is an upper limit to the "life-time" of a species. George Gaylord Simpson [*The Meaning of Evolution* (Mentor, New York, 1951), p. 76] has considered this problem:

"Is extinction the fated end of all groups of organisms, as death is of each individual organism? There are in the world today a large number of types of organisms that arose so long ago that the great majority of their early contemporaries have long been extinct. . . . Among these Methuselahs . . . are . . . *Sphenodon* (surviving almost unchanged from Jurassic to Recent) or the opossum (Cretaceous to Recent). The invertebrates, older to begin with and generally slower in evolution, provide still more striking examples. The little sea shell *Lingula* is amazingly like its Ordovician ancestor of 400,000,000 years or so ago, and an oyster of 200,000,000 years or more in the past would look perfectly familiar if served in a restaurant today."

Simpson points out the special circumstances which have allowed these types to continue so long, and adds: "The fact that extinction has not occurred for these animals during their exceptionally long histories does not permit the conclusion that their extinction will never occur and that they are, in literal fact, immortal. . . . It must be concluded that material racial immortality is impossible. The time will come when all life ends." Here he adds a footnote: "The fantasy of transfer to other planets is not impossible although it is hardly imminent. This might postpone but could not avoid the inevitable end."

Inasmuch as any cosmic catastrophe, such as a radical change in the luminosity of the sun, is not expected for several billion years, it appears to be possible, if not probable, that *Homo sapiens* or his descendents might survive on this planet for a period of time comparable to the interval during which life has existed. By that time, "the fantasy of transfer to other planets" should be a practicality; if the steady-state view of the universe is the correct one, there should then be no "time . . . when all life ends."

As for the problem of surviving for the next few billion years on this planet, it is tempting to extend the analogy between the life of the individual and the life of the species. Just as man's intelligence has allowed him to extend the life of the individual, it can be hoped that his intelligence, used wisely, can prolong his existence as a species—perhaps indefinitely.

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