sideration of significant personnel needs. Second, the Institution of Professional Civil Servants, a staff association that is officially recognized by the Treasury and by the departments, acts as a representative spokesman and negotiator for the scientific staff as a whole or for individual scientists, on any policy, practice, or problem requiring top-level decision by the head of the department, by the Treasury, or by Parliament. If necessary, the Institution of Professional Civil Servants may carry a case beyond the Minister to an arbitration tribunal set up in the Ministry of Labour. Third, the national and departmental Whitley Councils on which representatives of the employees—the "staff side"—and the representatives of top department management—"the official side"—meet to discuss and to decide on policies and practices affecting more than one occupational class of the civil service provide a clearing house for problems.

5) The tax-free substantial lump-sum payment at retirement and the noncontributing retirement system effective after 10 years of service at age 60 create a strong incentive for senior scientists to remain in the service.

6) Full recognition and use is made of policies covering fellowships, training at government expense at universities, encouragement of attendance at professional meetings, and paid advertising of vacancies in newspapers and journals.

7) The establishment of a policy that individual scientists with creative research talent may rise to top positions without administrative or supervisory responsibilities and assignment of complement for that purpose is an excellent incentive.

8) The interdepartmental scientific panel, which is composed of top scientists and establishment officers of the administrative class who represent their departments, as well as representatives of the Treasury, in overseeing the welfare of the scientific civil service and in promoting acceptance of government-wide policies that will improve the service is a major factor in assuring continuity of progressive policies.

Although the purpose of this report is to suggest that British experience might include concepts applicable to the management of scientists in the United States, it may be relevant to point out certain disadvantages from the American point of view of the British scientific civil service. These should, of course, be evaluated in the light of the very marked cultural differences between the two nations.

1) The promotion rate is considerably slower than it is in the United States. It is considered that an outstanding scientist will reach the grade of principal scientific officer in his early 30's or from 10 to 15 years after his entrance in the service two grades below.

2) The stratification among the three classes in the scientific service is sharply defined and reflects to some extent the national educational system. Opportunity for mobility upward toward the scientific officer class is limited, although it should be noted that the normal educational qualifications are waived in the cases of those who are promoted from class to class.

3) The rigid maximum age limit for entry into the scientific officer class makes it impossible, except in special cases, for individuals over 31 with the necessary scientific attainments to obtain permanent posts in the government service. However, as has already been noted, they may obtain temporary appointments and have the benefits of a special contributory super-annuation scheme. There are no such restrictions with regard to the other two (lower) classes, but it will be evident that there is a marked tendency in the United Kingdom to expect the young scientist to decide very early where his career lies and not to give him any great facilities for changing to government service after he has reached the age of 31.

4) The salary scales for the top positions in the scientific class are not at a parity with top positions in the administrative class. This places the scientific civil service in a position secondary to that of the administrative class in the civil-service structure and culture.

In summary, there are many areas in the management of scientific personnel where the British have made valuable progress to be noted by other public civil-service systems that employ scientists. In common with the public service in other countries, many pressing problems constantly face them in their struggle to obtain and keep a fair share of creative scientific talent in the face of a national shortage of supply. The British civil service is alert to this challenge and continuously strives to meet it through a personnel system that features careful selection, professional development, and development of trust on the part of those who are members of the service in the major administrative decisions as made by their fellow scientists.

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Uptake and Turnover of Calcium-45 by the Guppy

Harold L. Rosenthal

The possible contamination of marine and fresh water supplies with radioactive materials was forcefully indicated following the 1954 atomic bomb tests carried out in the Pacific islands. Although the prospect of wartime contamination from detonation of atomic weapons is remote, accidental pollution of water supplies may occur during efforts to dispose of radioactive by-products from peacetime usage of radioactive materials. Contamination of water supplies may also result in the accumulation of radioactivity in food fishes. Such accumulation may adversely effect the nutritional economy and medical status of the world's population.

Andrews (*1*) has recently indicated that if the fission products of a nominal atomic bomb were mixed into the water of Lake Mead, an individual would have to drink 50,000 cubic feet of water to reach the tolerance value for strontium-90. However, if one assumes that fission products from waste effluents or bombs are not evenly distributed but may be concentrated in relatively local areas of the oceans or of bodies of fresh water for a given period of time, an entirely differ-

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ent situation may occur. It is conceivable that migratory fishes such as salmon, tuna and others may accumulate sufficient radioactivity in one area and transport this activity to another area some distance from the original source of contamination. Furthermore, fishes are able to concentrate and retain radioactive nuclides in their tissues (*2–5*) for various lengths of time, depending on the nuclide and its physicochemical and biological half-life. The tremendous increase in the production and use of radioactive materials has accentuated the need for information concerning this problem. Although various investigations have been carried out and have appeared as reports of the U.S. Atomic Energy Commission (*2–4*), few articles are available in the formal literature (*5*).

In conjunction with other studies (*6*), it was necessary to obtain information concerning the rate of uptake of calcium-45 from water, and the rate of turnover of this nuclide by the guppy, *Lebistes reticulatus*. The data I have obtained may be of interest to a wide segment of the scientific community, and they form the basis for this article.

Experimental Detail

Normal, wild-type, adult male guppies were obtained commercially, and lordotic guppies were raised in our laboratory (*7*). The fish averaged about 125 milligrams in weight (70 to 230 milligrams), and they were approximately 3 to 8 months old. The animals were fed commercial dried food supplemented daily with frozen brine shrimp and tubifex worms when available. The temperature of the aquariums was maintained at 22° ± 3°C (*7, 8*).

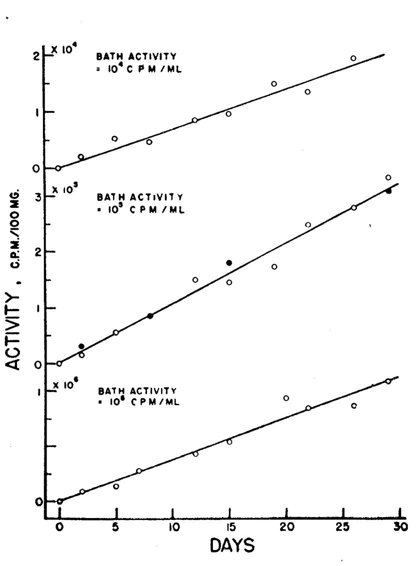

Fig. 1. Uptake of calcium-45 by wild-type *Lebistes* versus days in water containing the isotope. Open circles represent two to four fish; closed circles, five to six fish.

For analyses of radioactivity, fish were removed with a net, sacrificed by immersion in boiling water for 1 minute, rinsed with tap water, blotted on cellulose tissue, and weighed to the nearest milligram. In some experiments, tissues were obtained by dissection with needles, and the representative tissues were weighed to the nearest 0.01 milligram (Roller Smith 25-milligram torsion balance). The fish or tissues were digested in 0.25 to 1.0 milliliters of nitric acid for 1 to 2 hours with the aid of steam at 100°C. The digests were diluted with 1 to 10 milliliters of distilled water, and 100-microliter aliquot portions were plated in desicoted stainless steel cups, dried slowly, and counted in a windowless gas-flow counter. A sufficient number of counts were taken to assure a statistical error below 5 percent. Appropriate corrections for self-absorption, when necessary, were made by weighing dried aliquot portions of the digests and by reference to a previously determined standard curve. Corrections for physicochemical decay were made in the usual manner. The efficiency of the counter was such that 1 millicurie of calcium-45 yielded approximately 10^9 counts per minute. The calcium-45 was obtained from Oak Ridge National Laboratory in the form of carrier-free calcium chloride.

Uptake of Calcium-45

The rate at which guppies take up calcium-45 was determined by placing 10 to 12 male fish in glass aquariums containing 500 milliliters of the isotope. At this population density, the quantity of radioisotope removed from the water by the fish was sufficiently low so that no changes in the concentration of radioisotope in the water could be observed. In order to compensate for physicochemical decay of the isotope and to replace water lost by evaporation, distilled water was added three times weekly in such a way that the isotope activity varied less than ± 5 percent during the experimental period.

The results obtained from these experiments (Fig. 1) demonstrate the rapid incorporation of radioactivity in the body of the fish. This incorporation was linear during the 29-day experimental period at all concentrations thus far tested. The rate of accumulation of calcium-45 is consistent and reproducible. Thus the results of a second experiment (closed circles) repeated about 4 months later with water containing 10^5 counts per minute, per milliliter of calcium-45 are identical with the results of the first experiment. Each open circle represents average data obtained on two to four fish; the closed circles describe data from five to six fish. Since some radioactivity might adhere to the mucoid substance

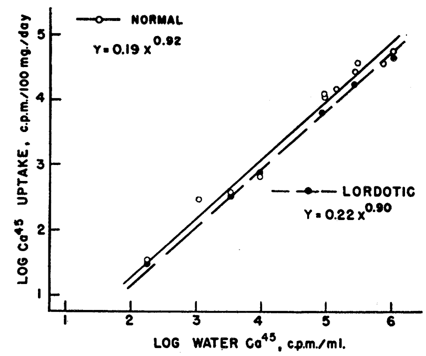

Fig. 2. Rate of uptake of calcium-45 by *Lebistes* versus activity of the water in which they were maintained. Each point represents data obtained on six to 30 fish in 12 experiments.

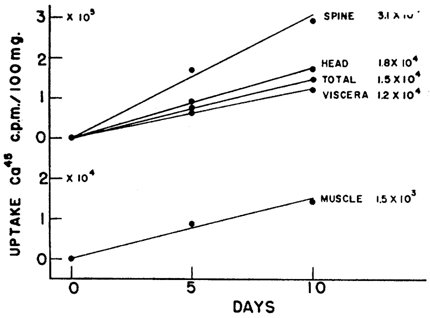

Fig. 3. Uptake of calcium-45 by various tissues from wild-type *Lebistes* versus days in water containing 1.8×10^5 counts per minute, per milliliter. Values for each tissue represent rate of uptake of calcium-45 in terms of counts per minute, per 100 milligrams, per day.

covering the surface of the fish by adsorption, the quantity of nuclide adsorbed in this manner was determined by analyzing fish that had been dipped in the experimental aquariums for 1 to 2 minutes. Although the adsorbed activity was relatively low, ranging from 0 to 5 times more than that absorbed by the undipped controls, all data were corrected for this activity.

The linear relationship between the amount of calcium-45 taken up by the body of the fish and the time in which the fish were immersed in radioactive water of constant activity appears to be in contrast with the reports of Lovelace and Podoliak (*5*) and Prosser *et al.* (*2*). These investigators studied, respectively, the uptake of calcium-45 in trout and of strontium-89 in goldfish, and concluded that the rate of uptake of isotopes from water decreases with time. However, these authors plotted their data logarithmically. When their data are replotted in the form presented in this article, it is found that their data are consistent.

The concentration of calcium-45 used in these experiments during the short, 29-day experimental period had little, if any, adverse effect on the fish. Although occasional fish died during the experimental period, these losses were entirely consistent with our experience and were to be expected. Since the relationship of rate of uptake with time is linear, many later experiments were performed during a shorter, 10-day period, which was long enough for the fish to accumulate sufficient activity for analysis.

The rate of accumulation of calcium-45 by the total body of both the lordotic and the wild-type guppy is related to the concentration of isotope in the water in which they swim (Fig. 2). When the logarithm of the rate of uptake of the isotope (counts per minute, per 100 milligrams, per day) is plotted against the logarithm of the specific activity of the external medium (counts per minute, per milliliter), it can be seen that the experimental data are adequately described in the form of logarithmic equations for both strains of fish. The lines of the graph were fitted to the experimental data by the method of least squares. It is evident that the slopes of the lines for both strains of fish are the same. However, unpublished data show that the rate of uptake of calcium-45 by the lordotic guppy is significantly lower than the rate for the wild strain. The relationship between the rate of uptake of calcium-45 and the concentration of nuclide in the external medium is essentially in agreement with Prosser's data (*2*) but differs from the data of Lovelace and Podoliak (*5*). The latter authors concluded that the uptake of calcium-45 from water is independent of the concentration of the isotope in the external medium. Apparently, the interpretation made by these investigators is based on insufficient data, for the experimental concentration differences of the water were too small to yield unequivocal data.

The various organs of the body such as the spine, head, viscera, and muscle also take up isotope in a linear fashion, but the rate of uptake differs for each organ as shown in Fig. 3. The spine, containing the highest concentration of calcium, accumulated calcium-45 at a rate that is twice as great as the rate of uptake for the total fish. Muscle tissue, however, accumulated the isotope at a rate that is one-tenth that for the total fish. The difference in the rate of uptake of spine and muscle appears to be consistent with the calcium concentration of the two tissues, for the spine contains about 12 times as much calcium as muscle tissue on a dry-weight basis (*9*).

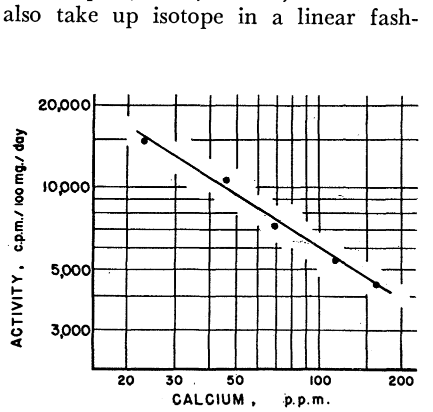

Fig. 4. Activity of calcium-45 incorporated by wild-type *Lebistes* versus concentration of inactive calcium contained in the water. Each point represents rate of uptake determined on five to six fish. The water contained 1.4×10^5 counts per minute, per milliter (see Fig. 3).

Table 1. The uptake of calcium-45 by wild-type *Lebistes* of different ages. The water contained 10^5 counts per minute, per milliliter. The numbers in parentheses indicate the range of weight.

Age (day)	No. of fish* (pair)	Weight (mg)	Relative uptake† ± standard error‡
1	6	6.7 (5.4 to 7.5)	0.923 ± 0.004
20	5	13.2 (9.7 to 16.3)	0.921 ± 0.009
43	6	24.2 (15.9 to 38.9)	0.912 ± 0.007
78	9	85.1 (66 to 106)	0.888 ± 0.010
Adult (male)	8	113.1 (65 to 162)	0.793 ± 0.006

* Each pair represents an experimental animal and one dipped momentarily as its control.
† Relative uptake = log [(uptake in count/min, per 100 mg, per day)/(water activity in count/min, per ml)].
‡ Standard error = $[\Sigma d^2/n(n-1)]^{1/2}$.

On the other hand, the visceral organs accumulate the isotope at approximately the same rate as the total body. The relatively high rate of incorporation by the viscera in comparison with the rate of incorporation by muscle is presumably the result of the greater proportion of blood in visceral tissue which is in equilibrium with the absorption mechanism in the gills (*10*). Since the visceral tissues include the intestinal tract, it is possible that some of the activity was owing to activity in the intestinal contents and the feces.

The rate of uptake of radioactive calcium-45 depends to a considerable extent on the concentration of inactive calcium present in the water, as is shown in Fig. 4. These data were obtained by placing fish in water containing added amounts of neutral calcium chloride and the same amount of radioactive calcium-45. After a 10-day experimental period, the fish were sacrificed, and the rate of uptake determined. It can be seen that increasing the inactive calcium concentration decreases the rate of incorporation of calcium-45 by the total body of the fish in a manner consistent with a logarithmic function.

The effect of age on the rate of uptake of calcium-45 from water was determined by isolating pregnant female guppies until young were produced. When the young reached the required age, they were placed in water containing calcium-45 for 3 days, and the rate of uptake of the isotope by the fish was determined in the usual way.

Since sexual dimorphism does not become apparent in guppies raised under the conditions existing in this laboratory until 60 to 90 days of age, all young up to 43 days of age were considered to be male guppies. However, the 78-day-old guppies were selected when possible, and they represent the male sex for the most part. It is apparent (Table 1) that the rate of uptake of calcium-45 by young guppies is constant during the first 20 days of life but greater than the rate of uptake by adults. After the initial phase, the rate of uptake gradually decreases to that of the adult. Since the newborn guppy (*8*) contains less calcium (0.4 percent of wet weight) than the adult male (1.14 percent wet weight), the greater rate of uptake during the initial phases of growth corresponds to the period of maximal calcification of mineralized tissues.

Turnover of Calcium-45

The rate of turnover of calcium-45 was studied by placing fish in water containing isotope at a concentration of approximately 2×10^5 counts per minute, per milliliter for 10 days in order to incorporate sufficient isotope for analysis. The fish were then transferred to conditioned isotope-free water at a density of 20 fish per gallon, and they were transferred to new water at 3-hour intervals during the first day, at daily intervals for the next 4 days, and at 5-day intervals thereafter. All data have been corrected for natural decay of the nuclide.

The loss of radioactivity (Fig. 5) from the total fish may be divided into three major components that are adequately described by first-order reactions varying from very fast to very slow. The first rapid component, with a biological half-life of 3 days, represents loosely bound calcium-45 derived from soft body tissues and body surfaces of the fish. A second component, with a biological half-life of 137 days, presumably represents more tightly bound calcium-45 in muscle and connective tissues. A very slow third component represents calcium-45 which is incorporated in bone and other osseous tissues such as the scales, fin rays, and so forth. This component has a biological half-life of at least 300 days. Other components with longer half-lives may be present. The short experimental period does not permit a better approximation, but it has not been possible to maintain the animals for a longer length of time under the experimental conditions used.

In some experiments, the loss of calcium-45 from viscera, muscle, head, and spine was determined as shown in Fig. 6. It is apparent that visceral tissues lose most of the calcium nuclide during the first few days. The rapid loss corresponds to the first short half-life component illustrated in Fig. 5. However, small amounts of the isotope were still present in the viscera after the fish had been in isotope-free water for 40 days. Since the visceral tissues include the intestinal tract, the residual radioactivity may represent calcium ion which is being excreted. Muscle tissue loses radioactive calcium more slowly than the viscera and apparently corresponds to the second component ($T_{½} = 137$ days) discussed in the preceding paragraph.

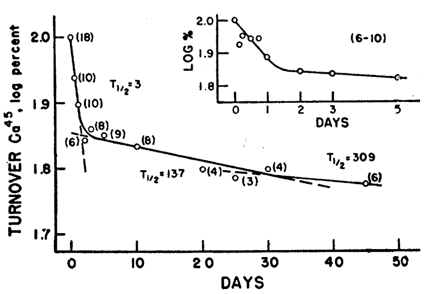

Fig. 5. Turnover of calcium-45 by wild-type *Lebistes* versus days in water containing no isotope. The figures in parentheses indicate number of fish averaged from four experiments. The inset depicts an expanded representation during the first 5 days. Fish contained about 10^5 counts per minute, per 100 milligrams on day zero of turnover.

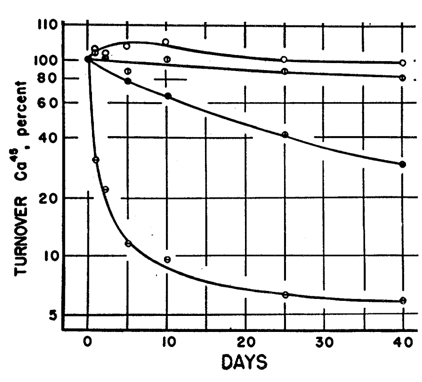

Fig. 6. Turnover of calcium-45 by various tissues from wild-type *Lebistes* versus days in water containing no isotope. Each point represents average data on four to 10 fish from four experiments. ○, spine; ⦶, head; ●, muscle; ⊖, viscera. Fish contained about 10^5 counts per minute, per 100 milligrams on day zero of turnover.

Table 2. Distribution of calcium-45 in tissues of wild-type male *Lebistes*. The numbers in parentheses indicate number of fish analyzed.

	Uptake ± standard error (10 days)		Turnover ± standard error (40 days)	
	Body weight (%)	Distribution (%)	Body weight (%)	Distribution (%)
Carcass	100.0 ± 7.26 (15)	100.0 ± 2.92 (15)	100.0 ± 4.02 (7)	100.0 ± 5.43 (8)
Head	19.7 ± 0.42 (14)	21.3 ± 1.12 (14)	19.1 ± 1.09 (7)	34.4 ± 2.08 (7)
Viscera	12.7 ± 0.49 (14)	7.3 ± 0.48 (14)	11.6 ± 0.32 (6)	0.5 ± 0.04 (5)
Muscle*	40.0 (14)	3.7 ± 0.31 (14)	40.0 (5)	2.6 ± 0.46 (5)
Spine	2.8 ± 0.15 (14)	6.2 ± 0.36 (14)	2.8 ± 0.21 (7)	19.4 ± 1.04 (7)
Remainder†	24.8 ± 0.44 (13)	61.5 ± 2.32 (13)	26.5 ± 1.02 (8)	43.1 ± 2.38 (6)

* Muscle tissue estimated to comprise 40 percent of body weight. † Calculated by difference.

In contrast to viscera and muscle, the spine continues to incorporate calcium-45 for the first 10 days the fish are placed in inactive water. The additional calcium-45 is presumably obtained from redistribution of the isotope from tissues in which it is only loosely bound. Thereafter, the rate of calcium turnover is exceedingly slow. An approximation of the biological half-life of the calcium-45 of the spine estimated from the last 15 days of the experiment is about 600 days or more. The head, consisting largely of osseous tissues, behaves in a fashion similar to the spine but with some of the characteristics of softer tissues.

Distribution of Calcium-45

The distribution of calcium-45 in various tissues at the end of 10 days of uptake from isotopic water and after 40 days turnover is shown in Table 2. The differential accumulation of the isotope in osseous tissues is evident. Thus, the spine, which comprises only 2.8 percent of the body weight, accounts for 6.2 percent of the total body radioactivity after 10 days of uptake and 19.4 percent of the total activity after 40 days of turnover. On the other hand, muscle tissue comprises about 40 percent of the body weight but contains only 3.7 percent of the total body activity after 10 days of uptake. The viscera, however, accumulate a good deal of the isotope which is turned over at a very rapid rate, as has been shown. The data shown in Table 2 are necessarily arbitrary because it was necessary to assume that muscle comprises 40 percent of the body weight. The remainder of the fish includes the scales, skin, fins, and ribs, and amounts to about 25 percent of the body weight. Since most of this residue is composed of osseous tissues, it is not surprising that this tissue accumulated about 62 percent of the total activity in the body of the animals. The distribution of calcium-45 in muscle tissue of *Lebistes* is similar to the distribution of this isotope in muscle tissue of the salt-water *Tilapia* (*11*).

Conclusions

It is apparent from these studies that fish accumulate considerable quantities of calcium-45 and other radioactive nuclides (*2–5*) from the water in which they swim. Many radioactive elements such as calcium-45, carbon-14, strontium-90, and others become fixed in osseous tissues and may remain in these tissues for a long time. Although this article deals only with calcium-45, a relatively short-lived isotope ($T_{½} = 163$ days), bone seeking elements with longer half-lives, such as strontium-90, ($T_{½} = 25$ years), may remain in osseous tissues in significant quantities throughout the life of the fish. With incorporated calcium-45, however, natural decay of the nuclide would remove about 75 percent of the activity in a year.

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