Johnson bill through Congress; of how he was foiled in this by some of the scientists; and of his embittered efforts to take revenge. Such a history will examine carefully whether these things were related to the doings of the House Committee on Un-American Activities in 1948 and 1949, which deprived this country of the services of so many brilliant young American scientists.

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Radionuclides and Bone Cancer

A serious error exists in J. G. Kaplan's recent letter (*1*). It was stated that the Russians had observed bone cancers developing in dogs about 3 years after the injection of 0.1 microcurie of strontium-90 per kilogram. Actually, the radionuclide used in these Russian studies was not strontium-90, as erroneously reported by Engstrom *et al.* (*2*), but the much more dangerous thorium-228 (*3*).

The injected amounts of strontium-90 which it has been proved cause bone cancer are much higher than 0.1 μc/kg. Finkel (*4*) found that the incidence of osteogenic sarcomas in 90 mice injected with 44 μc of strontium-90 per kilogram was somewhat higher (6 percent) than that in 150 controls (2 percent), but the probability of this being due to chance occurrence was 20 to 30 percent. In a current study in our laboratory, 60 beagles have been injected with from 0.5 to 100 microcuries of strontium-90 per kilogram. Thus far only one dog, injected with 94 μc/kg, has developed a bone tumor. These results do not imply that lesser amounts of strontium-90 are without effect. However, they do illustrate the enormous difficulty in experimentally determining the consequences of very small injections of strontium-90, such as 0.1 μc/kg.

The maximum permissible body burdens of strontium-90 and radium-226 should be set so as to give the same probability (or improbability) of causing undesirable effects. If the ratio of these limits is based on the observed biological effects of strontium-90 and radium-226 in experimental animals, the maximum permissible body burdens, for occupational workers, of 2 microcuries of strontium-90 and 0.1 microcurie of radium-226 correspond fairly well.

In view of Kaplan's opinion of the "obvious impertinence" of physicists in biological questions, it seems strange that he would base the heart of his argument on the theoretical calculations of Rolf Björnerstedt, who is a physicist.

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3. R. Björnerstedt, in a letter (9 July 1959) citing results reported in *Conference on the Remote Consequences of Injuries Caused by the Action of Ionizing Radiation*, F. G. Krotkov *et al.*, Eds. (State Med. Lit. Press, Moscow, 1956).
4. M. P. Finkel, *Science* **128**, 637 (1958).

Meteorology for Non-Science Majors

There is general agreement that all college students should have an experience in science before they receive their diplomas. Very rarely, it seems, is meteorology recommended as one of the courses the student should take to satisfy his science requirement. This is regrettable in view of the fact that meteorology has within it all the elements which a science course for the non-science major should have.

Of course there are reasons for the present situation. People have been concerned about the weather since "the year 1," yet the problems involved in making enough observations of the atmosphere to find out what is going on and then devising ways of handling and digesting the masses of data have been so immense that modern meteorology can be considered a rather young branch of science.

Despite the vast meteorological training program of World War II, only a small percentage of these trained men went back into academic life after the war, and of those who did, only a fraction found academic positions in which it was possible to teach meteorology.

The professional academic meteorologist still finds it difficult to disengage himself from the stereotype of the fumbling-bumbling weatherman fostered by the cartoonists in the public press. And his timid dean hesitates, on the basis of scientific respectability, to encourage development of a course in which (he opines) the subject matter is more of an art than a science.

Despite difficulties such as these, meteorology does seem to be coming of age as a valid academic subject studied by many more than just a few specialists. It is of this that I wish to speak, stating what appears to be a case for meteorology.

If a student who is a non-science major is to have only a fleeting experience of science, we first might ask what elements his experience should contain. Certainly his science course should have high interest value; it should leave him with an increased understanding of science; it should illustrate general principles in such a way that their broad applicability may be perceived; it should give him accurate information about the way in which science relates to human activity; it should have maximum carry-over value with respect to situations which he will encounter in later years; and, finally, it should not involve just an accumulation of facts—it should be developed around an integrative theme which provides coherence and continuity. How does meteorology rate according to these several criteria?

1) Every person lives out his life at the bottom of the "sea of air and water vapor" which produces the weather. The weather is of great interest to everyone because it necessarily affects everyone. Therefore it seems to make very good sense for an educated person to have an understanding of the circumstances under which the several phenomena—wind, cloud, rain, lightning, and so on—are produced, and the reasons for them.

2) Meteorology has high carry-over value. The person who learns to identify clouds and to read these "signposts of the sky" will have gained access to a source of lifelong enjoyment denied to other people. Each hour of each day holds interest for one who has become familiar with clouds and their portent.

3) Meteorology is a subject which beautifully illustrates general physical principles. In discussing energy and its transformations, an instructor can start with mass-energy transformations which take place in the sun's interior, lead the student through application of radiation laws across 93 million miles of space to the outer edge of the earth's atmosphere, follow the diminution of the solar beam through the atmosphere, apply the laws of motion to illustrate how the atmospheric circulation is maintained, and so forth.

4) In meteorology, excellent examples of the way pure science relates to human activity are legion. For example, the tornado represents concen-

trated atmospheric violence which often results in deaths and heavy property damage. When we combine the increased understanding of the dynamics of storms of this type (as provided by meteorological research) with the research efforts in electron physics which produced radar and television, and then use radar for storm detection and television to inform the populace about the progress of a storm, death and destruction are reduced to a minimum.

Meteorology should be much more widely offered, and students who are non-science majors should be encouraged to take this course as a satisfying means of completing their physical-science requirement.

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Arctic Waters

Regarding the report entitled "Tritium tracer in Arctic problems," by Giletti and Kulp [*Science* **129**, 901 (1959)] and the subsequent exceptions taken by Barnes and Coachman [*Science* **130**, 273 (1959)], I am not sure whether I am lessening or adding to the confusion with the following remarks, but there are some factors very pertinent to the matter which I feel should be brought out.

As Barnes and Coachman pointed out, the curves in Giletti and Kulp's Fig. 1 do not agree with the reference (*6*) cited in the figure's caption. The figure presents temperature-depth curves for "Icicle" stations, 2, 5, 10, and 11. The first two curves were derived not from reference *6* but rather from reference *5*, cited in the text [namely, L. V. Worthington, *Woods Hole Oceanog. Inst. Tech. Rept. 53-92* (1953)]. The other two curves were drawn from data gathered by Goldstein in 1955. I am not aware that the curves from the last two stations have appeared in previous literature, but the data received some small distribution.

Barnes and Coachman have used a bottom temperature read from the curve for station 11 to show that this water, if it were a mixture of Atlantic water and arctic surface water as proposed by Giletti and Kulp, was at best only 20 percent arctic and 80 percent Atlantic water. Giletti and Kulp replied that this accorded with their theory.

I should like to point out two items. First, the bottom temperature shown in the station-11 curve is actually an extrapolated value, the deepest observation having been made 22 meters above the bottom. This extrapolated bottom temperature is about +0.1°C; the deepest observation shows a temperature of +0.21°C. I am not sure that other extrapolators would have drawn the curve in quite the same manner as it appears in the Giletti and Kulp report.

The second item is, I believe, the crux of the matter. The tritium sample which led Giletti and Kulp to their conclusions was collected at a depth of 400 meters at a location very close to station 11. Therefore it would seem to be only proper to use the interpolated 400-meter temperature of +0.35°C given by Giletti and Kulp for station 11 in carrying out the computations proposed by Barnes and Coachman for figuring the percentages of Atlantic and arctic surface waters.

If this is done, we find that if surface water having a temperature of −1.9°C (which it would have if the salinity concentration were to be raised the requisite amount by freezing) is mixed, in