the light nuclei. This is all basic information without which it will be hard to refine the nuclear physics of the problem.

On the side of theoretical astrophysics, models for stellar evolution need to be taken further, and the evolutionary path of a star after it leaves the red giant configuration must be understood. This involves computational programs on the best automatic computers, such as the one devised by Hoyle for an IBM 704. The problem of handling instabilities in the evolutionary path remains to be solved. On the observational side, more work on the determination of abundances in stars is needed. At present, there has been much qualitative examination of spectra but very little spectroscopic analysis to give quantitative results. More studies of old stars, preferably members of clusters that can actually be dated by the position of the break-off from the main sequence, will be very valuable.

Galactic evolution is one of the subjects where interesting new developments may come soon. This embraces study of the structures, spectra, and distribution of galaxies, as well as theoretical work. When it is remembered that so well-known a feature as the arms in spiral galaxies are still imperfectly understood theoretically, it will be seen how much work still remains to be done in this field.

Astrophysics is the only branch of physics in which we cannot make experiments, but can only observe. It is a science also in which the conditions are always more extreme than any attainable in terrestrial laboratories and the time scales are unimaginably longer. Perhaps its fascination lies in this very aspect, that it challenges man's imagination to the utmost.

References and Notes

1. H. E. Suess and H. C. Urey, *Revs. Mod. Phys.* 28, 53 (1956).
2. R. A. Alpher and R. C. Herman, *Revs. Mod. Phys.* 22, 153 (1950).
3. *Ylem* is an obsolete word for primordial matter.
4. F. Hoyle, *Monthly Notices Roy. Astron. Soc.* 108, 372 (1948); H. Bondi and T. Gold, *Monthly Notices Roy. Astron. Soc.* 108, 252 (1948).
5. G. R. Burbidge and F. Hoyle, *Nuovo Cimento* 4, 558 (1956); M. Goldhaber, *Science* 124, 218 (1956).
6. J. L. Stebbins and A. E. Whitford, *Astrophys. J.* 108, 413 (1948).
7. A. E. Whitford and A. D. Code, "Annual Report of the Washburn Observatory," *Astron. J.* 61, 352 (1956).
8. M. Ryle and P. Scheuer, *Proc. Roy. Soc. (London)* A230, 448 (1955); B. Y. Mills and O. B. Slee, *Australian J. Phys.* 10, 162 (1957).
9. M. L. Humason, N. U. Mayall, A. R. Sandage, *Astron. J.* 61, 97 (1956).
10. A. R. Sandage, *Astrophys. J.* 127, 513 (1958).
11. It should be remembered that the age of the universe can be derived from these figures only after a particular cosmological model is specified. For example, for the Einstein-de Sitter case, the age is two-thirds of the figure given.
12. R. d'E. Atkinson, *Astrophys. J.* 73, 250, 308 (1931).
13. H. A. Bethe, *Phys. Rev.* 55, 434 (1939).
14. C. F. von Weizsäcker, *Physik Z.* 39, 633 (1938).
15. F. Hoyle, *Monthly Notices Roy. Astron. Soc.* 106, 343 (1946).
16. E. E. Salpeter, *Astrophys. J.* 115, 326 (1952); F. Hoyle, *Astrophys. J. Suppl.* 1, 121 (1954).
17. C. W. Cook, W. A. Fowler, C. C. Lauritsen, T. Lauritsen, *Phys. Rev.* 107, 508 (1957); W. A. Fowler, *Sci. Monthly,* 84, 84 (1957).
18. A. R. Sandage, in *Stellar Populations,* D. J. K. O'Connell, Ed. (Vatican Observatory, Vatican City, 1958), p. 41.
19. E. M. Burbidge, G. R. Burbidge, W. A. Fowler, F. Hoyle, *Revs. Mod. Phys.* 29, 547 (1957).
20. A. G. W. Cameron, *Phys. Rev.* 93, 932 (1954); *Astrophys. J.* 121, 144 (1955); see also J. L. Greenstein, *Modern Physics for Engineers,* L. Ridenour, Ed. (McGraw-Hill, New York, 1954), p. 267.
21. W. A. Fowler, G. R. Burbidge, E. M. Burbidge, *Astrophys. J.* 122, 271 (1955).
22. P. W. Merrill, *Science* 115, 484 (1952); *Publs. Astron. Soc. Pacific* 68, 70 (1956).
23. E. M. Burbidge and G. R. Burbidge, *Astrophys. J.* 126, 357 (1957).
24. G. R. Burbidge, F. Hoyle, E. M. Burbidge, R. F. Christy, W. A. Fowler, *Phys. Rev.* 103, 1145 (1956); W. Baade, G. R. Burbidge, E. M. Burbidge, F. Hoyle, R. F. Christy, W. A. Fowler, *Publs. Astron. Soc. Pacific* 68, 296 (1956).
25. E. M. Burbidge and G. R. Burbidge, *Astrophys. J. Suppl.* 1, 431 (1955); *Astrophys. J.* 122, 396 (1955); *Astrophys. J.* 124, 130, 655 (1956).
26. W. A. Fowler, G. R. Burbidge, E. M. Burbidge, *Astrophys. J. Suppl.* 2, 167 (1955); E. M. Burbidge, G. R. Burbidge, W. A. Fowler, *Proc. Stockholm Conf. Cosmical Magnetism 1956,* in press.
27. A. B. Severny, *Astron. Zhur.* 34, 328 (1957); L. Goldberg, O. C. Mohler, E. Muller, *Astrophys. J.* 127, 302 (1958).
28. A. J. Deutsch, *Astrophys. J.* 123, 210 (1956); J. A. Crawford, *Astrophys. J.* 121, 71 (1955).
29. J. W. Chamberlain and L. H. Aller, *Astrophys. J.* 114, 52 (1951); E. M. Burbidge and G. R. Burbidge, *Astrophys. J.* 124, 116 (1956); M. and B. Schwarzschild, L. Searle, A. Meltzer, *Astrophys. J.* 125, 435 (1957).

Long-Term Fallout

A summary of measurements made through June 1957 by the gummed-film network of the AEC is presented.

Merril Eisenbud and John H. Harley

Several papers have described the phenomena of long-range fallout and the methods by which it is routinely monitored (*1*). This paper presents estimates of strontium-90 deposition and external gamma dose which were obtained from the world-wide gummed film network of the U.S. Atomic Energy Commission through June 1957. Results for the continental United States and other stations are tabulated in Table 1; results for the worldwide network are mapped in Fig. 1. In addition, the estimates of strontium-90 deposition as obtained by the gummed-film method are compard with measured values obtained by sampling with open pots.

Because of their mass, it is not practical to present the detailed analytical results in this article (*2*). This presentation, therefore, is limited to a condensation of the cumulative fallout observations.

Sampling and Measurement

A primary technique in studying long-range fallout is the measurement of the rate of deposition and the cumulative deposit per unit area. For this purpose, three types of samples are currently used: soils, pots or funnels, and gummed film.

Soil samples represent the accumulated fallout at a given location, but these samples require tedious radiochemical analyses for the determination of specific isotopes. Moreover, soil sampling does not permit one to estimate the external gamma dose delivered by the isotopes because of difficulty in analysis and uncertainty in the time of fallout.

Open samplers, such as pots or fun-

The authors are on the staff of the Health and Safety Laboratory, New York Operations Office, U.S. Atomic Energy Commission.

nels, permit collection of individual rainfalls or weekly or monthly deposits, from which strontium-90 and other isotopes may be determined directly by radiochemical analyses. Gamma emitters may be evaluated by spectroscopy.

The principal advantage of the gummed-film method, in addition to its simplicity, is that it permits daily sampling. This is important for the estimation of gamma dose.

There can be no absolute sampling procedure for fallout deposition because the deposition in a given situation will be influenced by the type of surface. However, to permit some basis of comparison, the collection performance of the gummed film has been studied in relation to the collection performance of pots.

In earlier reports, it has been shown that the gummed film, under conditions of moderate rainfall in a temperate climate, yields fallout samples with an overall efficiency of about 63 percent compared with the values from high-walled pots. In regions where much of the fallout occurs with snow, the gummed-film method may grossly underestimate the true fallout values. Despite this objection, the gummed-film technique has proved to be desirable because of the simplicity with which daily samples can be accumulated from a large number of widely scattered locations.

Since late 1954, the computation of strontium-90 from the total beta activity of the gummed-film samples has become increasingly difficult because the computed values are sensitive to the assumed age of the debris. The accumulation of long-lived fission products in the stratosphere and the greater frequency of weapon tests has greatly complicated the problem of assigning an age to the

Table 1. Strontium-90 deposition and cumulative gamma dose as estimated by gummed-film measurements through June 1957.

Station	Sr^{90} (mc/mi^2)	External γ dose (mrad)*
Outside continental United States		
Alaska		
Anchorage	12	20
Fairbanks	15	26
Juneau	16	30
Nome	9	17
Argentina		
Buenos Aires	9	18
Australia		
Sydney	6	17
Bermuda	21	43
Bolivia		
La Paz	9	22
Canada		
Churchill, Manitoba	6	11
Edmonton, Alberta	18	33
Goose Bay, Labrador	13	29
Moncton, New Brunswick	13	25
Montreal, Quebec	16	33
Moosoonee, Ontario	13	29
North Bay, Ontario	17	34
Ottawa, Ontario	12	25
Regina, Saskatchewan	13	27
Seven Islands, Quebec	12	27
Stephenville, Newfoundland	20	42
Winnepeg, Manitoba	23	45
Ceylon		
Colombo	9	29
Costa Rica		
San Jose	7	17
Ecuador		
Quito	5	14
Ethiopia		
Addis Ababa	11	21
French West Africa		
Dakar	12	22
Germany		
Rhein Main	15	27
Greenland		
Thule	9	15
Hawaii		
French Frigate Shoals	21	42
Lihue	18	38
Hilo	30	59
Honolulu	16	34
Iceland		
Keflavik	21	36
Italy		
Milan	13	23
Japan		
Hiroshima	19	36
Misawa	20	39
Nagasaki	21	41
Tokyo	23	43
Liberia		
Monrovia	10	19
Malaya		
Singapore	7	23
Mexico		
Mexico City	16	39
Morocco		
Sidi Slimane	18	30
New Zealand		
Wellington	5	10
Nigeria		
Lagos	8	14
Norway		
Oslo	13	23
Pacific Ocean		
Yap, Caroline Islands	17	52
Guam, Caroline Islands	78	160
Truk, Caroline Islands	33	87
Ponape, Caroline Islands	41	140
Canton Island	7	23
Iwo Jima	36	170
Johnston Island	30	65
Koror, Palau Island	14	44
Manila, Philippine Islands	17	48
Midway Island	19	36
Noumea, New Caledonia	8	20
Wake Island	22	45
Panama Canal Zone	9	22
Puerto Rico		
San Juan	15	29
Saudi Arabia		
Dhahran	15	28
Scotland		
Prestwick	18	30
Thailand		
Bangkok	10	39
Tripoli		
Libya	24	41
Union of South Africa		
Durban	4	8
Pretoria	10	19
Continental United States		
Albuquerque, N.M.	45	150
Atlanta, Ga.	20	41
Billings, Mont.	26	58
Binghamton, N.Y.	13	25
Boise, Idaho	27	44
Boston, Mass.	20	69
Cape Hatteras, N.C.	14	29
Chicago, Ill.	22	50
Cleveland, Ohio	25	65
Concord, N.H.	11	26
Corpus Christi, Tex.	12	25
Dallas, Tex.	25	60
Des Moines, Iowa	27	63
Detroit, Mich.	22	49
Grand Junction, Colo.	39	160
Jacksonville, Fla.	13	30
Knoxville, Tenn.	18	45
Las Vegas, Nev.	23	66
Los Angeles, Calif.	11	20
Louisville, Ky.	24	54
Medford, Oreg.	13	23
Memphis, Tenn.	24	75
Miami, Fla.	16	37
Minneapolis, Minn.	25	51
New Haven, Conn.	20	43
New Orleans, La.	28	64
New York, N.Y.	28	54
Philadelphia, Pa.	19	39
Pittsburgh, Pa.	26	46
Rapid City, S.D.	18	45
Rochester, N.Y.	19	37
Salt Lake City, Utah	54	180
San Francisco, Calif.	14	23
Scottsbluff, Neb.	38	73
Seattle, Wash.	19	34
Tucson, Ariz.	25	49
Washington, D.C.	18	35
Wichita, Kan.	25	62

* The tabulated values are calculated infinity exterial gamma dose in millirad. The probable exposure to the population, allowing for shielding and weathering, is approximately 10 percent of this value.

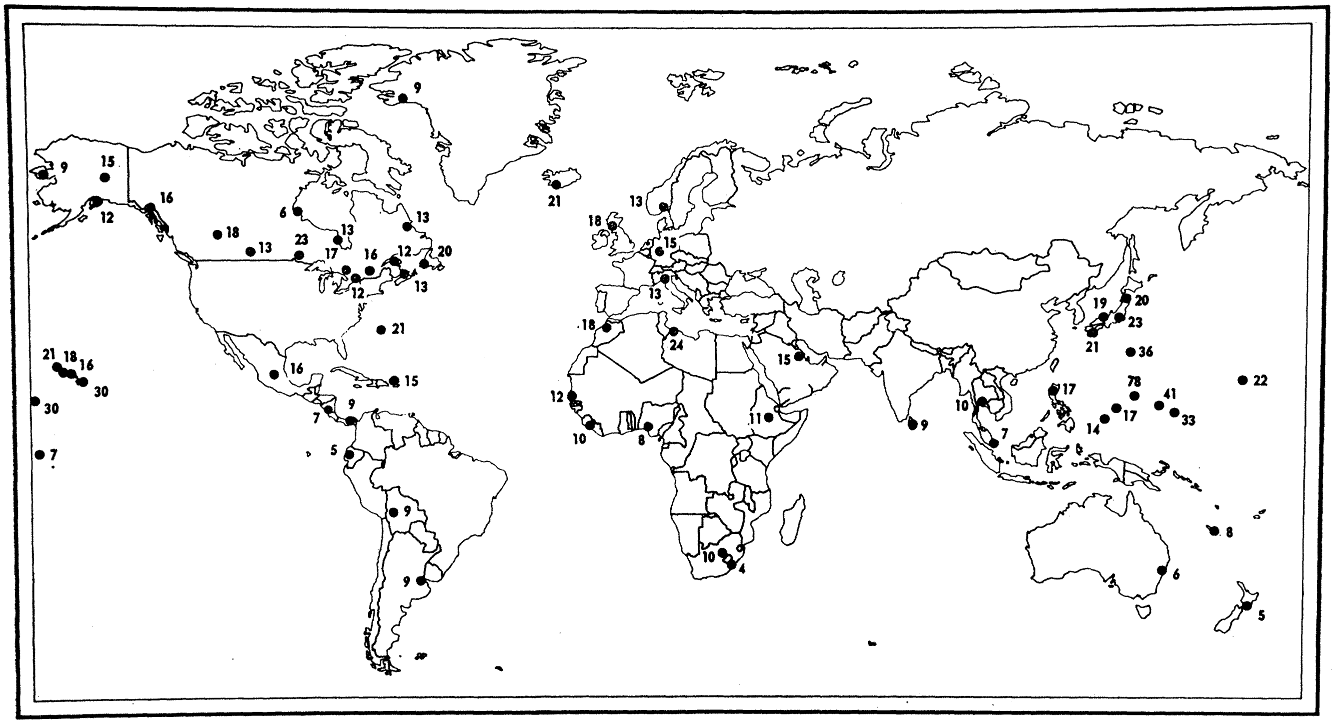

Fig. 1. Calculated cumulative strontium-90 fallout in millicuries per square mile as of June 1957.

debris. However, a method of computation has been devised by which the latter difficulty can be minimized.

Methods of Computation

The adhesive-coated films, which have been exposed for 24 hours, are shipped to the U.S. Atomic Energy Commission's Health and Safety Laboratory in New York. The total beta activity of the ashed samples is measured and corrected by the 63 percent efficiency factor. The strontium-90 component of the fallout is calculated from modified Hunter and Ballou (3) ratios. In addition, an estimate of the infinity external gamma dose in air is made from the beta activity (4).

The original calculations of strontium-90 deposition from measurements of total beta activity on ashed gummed-film samples were performed as follows:

1) The activity measured on a given sampling day was attributed to the test immediately preceding that sampling day.

2) The measured activity on the counting day was extrapolated to a fixed day by the formula

$$A = A_1 t^{-1.2}.$$

3) The strontium-90 fraction of the total beta activity on this day was taken from modified Hunter and Ballou curves.

4) The strontium-90 activity values for the individual days were summed by months, and these sums were added for the desired period of accumulation.

The assignment of activity on a given day to the most recent test was a reasonable approximation during the period of tropospheric fallout. The deviations between gummed-film estimates and radiochemical analyses became larger as the contribution from stratospheric fallout increased. To improve the estimation of strontium-90, a system was devised which takes stratospheric debris into account. Tests of this simplified model yielded values that are in good agreement with computations from more complex models. This method, which has been applied to data subsequent to May 1956, is as follows:

1) Estimates of the yields of total fission products and of strontium-90 are obtained for each weapon test.

2) The total fission-product yield for each test is added to the calculated fission-product residue from previous tests. (The $t^{-1.2}$ law is used for decaying total fission product activity.)

3) The strontium-90 activity from each test is added to the accumulated strontium-90 activity from previous tests.

4) For each sampling day, the stron-

Table 2. Comparison of strontium-90 estimates from gummed-film with radiochemical analysis of monthly pot collections.

Period of observation	Total Sr^{90} (mc/mi^2) Film	Total Sr^{90} (mc/mi^2) Pots	Ratio film/pot	Monthly ratios Low	Monthly ratios High	Film/pot mean
		New York City				
5/56–6/57	12.3	13.7	0.90	0.32	2.2	1.1
		Pittsburgh				
5/56–6/57	12.1	10.6	1.14	0.62	2.5	1.2
		Chicago				
12/56–6/57	6.3	4.6	1.37	1.0	1.9	1.4
		Salt Lake City				
12/56–6/57	15.1	9.1	1.66	1.1	3.3	1.8
		Los Angeles				
12/56–6/57	3.5	3.1	1.13	0.78	2.4	1.4
		Hiroshima				
10/56–6/57	5.6	3.7	1.51	0.82	3.7	1.7
		Nagasaki				
8/56–6/57	6.7	5.5	1.22	0.64	5.5	1.6

tium-90/total-fission-product-activity ratio is calculated.

5) Each day's measured beta activity is converted to strontium-90 activity by use of this factor.

This method of calculation would give high strontium values for locations near test sites on days of high fallout. This is caused by the attribution of activity to the total accumulated pool of fission products rather than to the immediate burst which caused the fallout. This can be corrected by treating these few cases individually.

The major approximations of this technique are as follows:

1) Tropospheric and stratospheric debris enter a pool which contributes to the fallout at each location.

2) The mixed fission products from each detonation decay according to the $t^{-1.2}$ law.

3) The relative tropospheric and stratospheric depletion rates are not considered at this time.

The only practical means of evaluating the new calculation technique is by comparison with radiochemical analyses of open samplers. During the period from May 1956 to June 1957, several locations had parallel sampling units for at least part of the time. These data are shown in Table 2, in which it is shown that the gummed-film system, together with the above-mentioned method of computation, yields estimates of strontium-90 deposition which tend to be higher than the estimates derived by radiochemical analyses of pot samples. The mean ratio of strontium-90 estimated from gummed-film to pot analyses is 1.45, with a maximum ratio of 1.66 at Salt Lake City and a minimum of 0.90 in New York City.

The calculation of external gamma dose is less sensitive to variations in the source of fallout. In addition, it appears that the important gamma dose from fission products is from internal cesium-137 rather than from the external gamma radiation from distributed fission products after suitable allowance for shielding and weathering.

Conclusions

The range of values for strontium-90 deposition through June 1957 in the United States is 11 to 54 millicuries per square mile, which is somewhat higher than other large land areas of the world. Excluding the United States, deposition in the Northern Hemisphere averages 16 millicuries per square mile, about twice the average for the somewhat fewer values reported in the Southern Hemisphere.

The calculated external gamma doses given in Table 1 are estimates of the infinity doses and have not been corrected for shielding and weathering. Our best estimate of the actual external dose to the population is approximately 10 percent of the tabulated values. The dose may actually be lower, but a factor of 10 is a conservative estimate of the effect of shielding and weathering.

References and Notes

1. W. F. Libby, *Proc. Natl. Acad. Sci. U.S.* **42**, 365 (1956); ———, *ibid.* **42**, 945 (1956); Joint Committee on Atomic Energy Hearings, "The Nature of Radioactive Fallout and Its Effects on Man" (Government Printing Office, Washington, D.C., 1957); M. Eisenbud and J. H. Harley, *Science* **117**, 141 (1953); ———, *ibid.* **121**, 677 (1955); ———, *ibid.* **124**, 251 (1956).

2. We wish to acknowledge the continued cooperation of the U.S. Weather Bureau in the collection of gummed-film samples. The computations and data handling were performed by Dr. A. E. Brandt and Dr. George D. Diehl of the Biometrics Branch of the Health and Safety Laboratory.

3. H. F. Hunter and N. E. Ballou, *Nucleonics* **9**, No. 11, C-2 (1951).
4. N. A. Hallden and J. H. Harley, *AEC TISE Rept. No. NYO-4859* (1957).

News of Science

Excerpts from the Summary and Conclusions of the Report of the United Nations Scientific Committee on the Effects of Atomic Radiation

In estimating the possible hazards of ionizing radiation, it is clearly necessary to know both the levels of such radiation received by man and his environment from various sources, and the present and future effects likely to be produced thereby. It is of particular importance to assess the effects of radioactive fallout from nuclear weapons, since this source of general environmental contamination is of recent origin, has been of uncertain significance, and has led to concern in the minds of many people. All sources of radiation must, however, be reviewed for a complete evaluation of the situation.

The Committee, aware of the complexity of this task, knows that our present information about radiation levels and effects is inadequate for an accurate evaluation of all hazards, and that many of the estimates will necessarily be approximate or tentative.

The physical characteristics of ionizing radiation, and the amounts of human exposures to it, are at present more accurately known than its biological consequences, especially where small doses and dose rates are concerned. In the present chapter, therefore, we review first the amounts of radiation received by man, both in regard to the exposure of individuals and of whole populations, and in respect to present and possible future levels. We then attempt to estimate the biological effects of varying amounts of radiation of different types, and to evaluate the hazard resulting from certain sources of particular significance.

. . . In view of the complex nature of the subject, individual sentences or assessments may easily be misunderstood unless related to the context of the report as a whole. . . .

Radiation from Natural Sources

The radiation received by man from natural sources varies somewhat from place to place according to the local radioactivity of the earth's surface; and that of only occasional populated areas exceeds the average by a factor of 10. Studies on populations living in these areas are of extreme interest for the development of our knowledge on the effects of small doses of radiation. The contribution from cosmic rays differs at different altitudes and geomagnetic latitudes. That from the normal radioactive potassium and carbon content of the body is about the same in different people, but the radiation due to radium, thorium and their decay products varies