barren for 3, 4.5, 4.5, 5, and 6 years, respectively. Hence in these seven instances, at least, it appears that the steroids not only did not damage the ovaries but, on the contrary, may have been helpful in the relief of sterility (*7, 8*).

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6. J. Rock *et al.*, in G. Pincus, Ed., *Recent Progress in Hormone Research, Proc. 1956 Laurentian Hormone Conf.* (Academic, New York, in press), vol. XIII.
7. This investigation was aided by grants from the Planned Parenthood Federation of America, Inc., and G. D. Searle & Co. The compounds used were contributed by G. D. Searle & Co. and the Chemical Specialties Co., Inc.
8. We are grateful to Luigi Mastroianni, Jr., and John V. Kelly, for their valuable clinical assistance.

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Aftereffect in the Degradation of Cellulose and Pectin by Gamma Rays

Desoxyribonucleic acid is degraded by x-rays, and after the termination of irradiation a further degradation occurs (*1*). The latter phenomenon has been called an "aftereffect." Similarly, an aftereffect has been observed in the irradiation inactivation of trypsin (*2*), pepsin (*3*), and bacteriophage (*4*). The present communication (*5*) describes an aftereffect in the degradation of cellulose and pectin by gamma rays.

Solka Floc (Brown Company BW-200), which is a purified wood cellulose containing approximately 99.5 percent alpha-cellulose, and NF Citrus Pectin, a highly purified product used for pharmaceutical purposes, were chosen for these studies. The air-dry samples were reduced to lower moisture contents by being placed over phosphorus pentoxide in a desiccator which was evacuated by a Hyvac oil pump for periods up to 120 hours. Moisture contents were determined by the loss in weight at 70°C for 6 hours at 100 mm pressure. Samples that were heated were not used in further studies.

Solka Floc and pectin were placed in screw-cap glass vials and exposed to gamma radiation from cobalt-60. The dosages were controlled by placing the samples at fixed distances from the source for known periods of time, as has been previously described (*6*).

An estimate of the degradation of these samples was obtained from solution viscosity measurements in Ostwald-Cannon-Fenske viscometers at 25°C for cellulose and 30°C for pectin. Cellulose solutions were made up in cuprietheylenediamine which was 0.5*M* with respect to copper and in which the ratio of ethylenediamine to copper was 2/1 (*7*). Intrinsic viscosities were obtained by plotting n_{sp}/C as a function of the concentration, C (0.250, 0.125, and 0.0625 g/100 ml), and extrapolating the lines to zero concentration. Relative viscosities were determined for pectin at a concentration of 0.100 g/100 ml in a solution containing 0.2 percent Calgon and 0.8 percent sodium chloride and adjusted to *p*H 6.0 (*8*). In order to determine the primary effect of radiation, the viscosities of the irradiated and control (unirradiated) samples were measured as soon as possible after the end of irradiation. The solid samples were stored in vials at room temperature until they were needed for subsequent viscosity determinations.

Cellulose (*9*) and pectin (*8, 10*) are known to be degraded by ionizing radiation, and the extent of degradation (percentage change in viscosity) as measured immediately after the irradiation is proportional to the log of gamma-ray dosage (*8, 11*). To our knowledge, no aftereffect has been described for any polysaccharides.

The results in Fig. 1 were obtained on cellulose and pectin at moisture contents of 0.32 percent and 0.75 percent, respectively, irradiated in air. The degradation continued in the solid (dry) samples beyond that indicated by solution viscosities determined as soon as practicable after irradiation. With both polysaccharides, the aftereffect continued for at least 2 weeks, after which it became difficult to distinguish between small changes and experimental variations. In the specific instances illustrated, the aftereffect amounted to 106 percent and 25 percent of the primary effect for cellulose and pectin, respectively. The apparent dissimilarity is in part due to the fact that the particular dosage for cellulose (103.5×10^3 r) is much smaller than that for pectin (2030.0×10^3 r) so that in the case of cellulose the primary effect was relatively small. Thus, for example, at 552.3×10^3 r the aftereffect for cellulose was 59 percent of the primary effect.

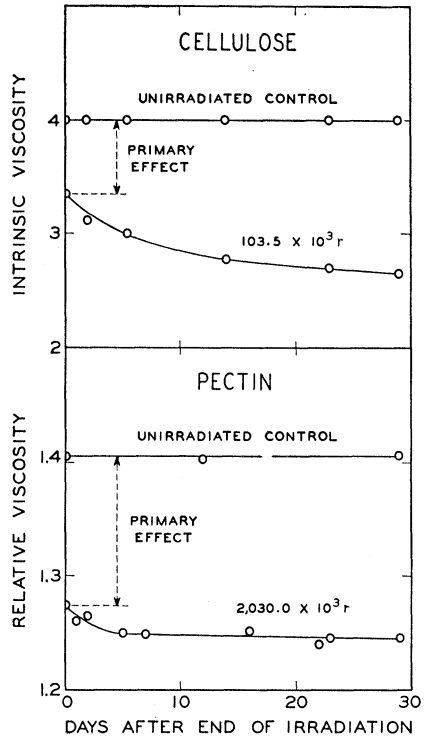

Fig. 1. Changes in solution viscosities of cellulose and pectin irradiated and stored in the solid (dry) state at room temperature. The primary effect is the change induced in the viscosity of the original sample by gamma rays and ascertained as soon after the end of irradiation as practicable (within 5 hr). The aftereffect is the change that occurs after the first viscosity measurement on irradiated samples.

The phenomenon reported here is unique in that the aftereffect occurred in solid (dry) samples, whereas those previously reported (*1–4*) involved substances irradiated in the presence of water. In fact, cellulose and pectin samples of various moisture contents were investigated and the aftereffect was observed only in the afore-mentioned samples which were of the lowest moisture levels studied.

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Armed Forces and has been assigned number 657 in the series of papers approved for publication. The views or conclusions contained in this report are those of the authors. They are not to be construed as necessarily reflecting the views or endorsement of the Department of Defense. The technical assistance of Marcia Davidson, Miles Connor, and Leon Lind is gratefully acknowledged.

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Radiostrontium Fallout from Continuing Nuclear Tests

In spite of widespread comment on the problem of the fallout of radiostrontium from testing thermonuclear weapons, confusion persists in the public mind and perhaps among many of the readers of *Science* as well regarding the relationship of Sr^{90} accumulation on the ground to such factors as assumed mean storage time in the stratosphere and the rate of testing of thermonuclear weapons. Libby's recently published report on the AEC's studies of the Sr^{90} problem (*1*) was not addressed to the effects of continuing weapons tests. Yet his conclusions have recently been quoted in the press as if they were valid if tests continue provided only that test rates remain unchanged.

Libby's analysis considered essentially the question whether nuclear weapons tests to date may have committed us already to an intolerable accumulation of Sr^{90}. Happily they have not. Speaking to that point, the meteorologists on the National Academy of Sciences study of the biological effects of atomic radiation stated, "At present, the amount of Sr^{90} in the stratosphere from nuclear weapon tests is far too small to approach maximum permissible concentration even if it all were to be deposited now. However, if the testing programs of the several countries producing thermonuclear weapons were to intensify, stratospheric storage time may become a critical item in terms of hazard to mankind. For this reason, a continuing program to investigate this phenomenon is needed, including actual measurements of the radioactivity in the stratosphere and improved and more representative methods of observing fallout" (*2*, p. 60).

The consequences of continued tests can be discussed in terms of a simple mathematical model which is generally accepted by Libby and others in this country as well as in England (*3*). Assume that Sr^{90} is introduced at a constant rate n into the stratosphere, where it is immediately mixed uniformly over the entire globe. According to British data, mixing is evidently reasonably rapid (*3*, p. 11). Assume further that fallout occurs at a rate $R = kQ$, where Q is the instantaneous stratospheric storage and k is the reciprocal of the mean stratospheric storage time.

Accumulated radiostrontium on the ground, M, can then be shown to be

$$M = \frac{n}{\lambda}\left[\frac{k}{k+\lambda} + \frac{\lambda}{k+\lambda}\, e^{-(k+\lambda)t} - e^{-\lambda t}\right] \quad (1)$$

where λ is the radioactive decay constant of radiostrontium. If the constants are expressed in years and the rate of testing is expressed in terms of millicuries of Sr^{90} per square mile of the earth's surface introduced per year into the stratosphere, M is given in terms of millicuries of Sr^{90} per square mile at t years. When $t = \infty$

$$M_{\max.} = \frac{nk}{\lambda(k+\lambda)} \quad (2)$$

and the maximum accumulation of fallout is seen to be proportional to the test rate.

Using Libby's best estimate for the mean stratospheric storage time of 10 years and a conservative estimate of the test rate corresponding to the introduction of 2.5 mc/mi² yr, per year as a reasonable value for n, the maximum accumulation of radiostrontium would be about 80 mc/mi². Libby, *considering only the Sr^{90} produced up to 1955*, predicted maximum fallout of less than one-tenth this amount. The two figures should not be confused.

It is not yet known what fraction of the total radiostrontium produced from a thermonuclear weapon reaches the stratosphere and becomes involved in the fallout process discussed here. For this reason, we do not know how to interpret available data on test rates and accumulation of Sr^{90}—for example, whether little has reached the stratosphere and has subsequently fallen out again relatively quickly or whether much has entered the stratosphere but has been held back by a long storage time. It cannot be said with much confidence, therefore, what rate of weapons testing would result in a given accumulation of Sr^{90}.

Assuming a 10-year storage time and a continuing test rate about twice that mentioned in a previous paragraph (corresponding to estimates made by Stewart, Crooks, and Fisher in the United Kingdom), the Sr^{90} accumulated on the ground after about 35 years would be 80 mc/mi². This would correspond to about 0.14 MPC (maximum permissible concentration) unit in the soil. According to Libby (*4*), Sr^{90} levels in soils are converted to levels in bones of young children at about 70 percent efficiency. This reduces the figure for levels in young children after 35 years of continuous tests to about one-tenth the permissible levels as established for *occupational* exposures. The concentration would not fall much below 0.07 MPC unit even if storage time were found to be 20 years instead of 10. Recently committees of the National Academy of Sciences (*2*, p. 39) and the British Medical Research Council (*5*, par. 281) have expressed their belief that only 0.1 MPC unit or less should be permitted for the population at large. In fact, the British report stated (*5*, par. 360) "So far as radioactive fallout may affect the individual, we believe that immediate consideration would be required if the concentration of radioactive strontium in bone showed signs of rising greatly beyond that corresponding to one-hundredth of the maximum permissible occupational concentration." The rate of introduction of Sr^{90} into the stratosphere assumed here is close to that estimated by Libby for the past three years. On the assumptions made here, therefore, a long-term test program could conceivably reach or exceed the levels of Sr^{90} considered safe for the whole population.

There is little reason to hope that what may be learned about storage time, k, will change this situation much. We must hope that new information may allow us to increase the maximum permissible concentration of radiostrontium in the bodies of the people of the world, that means may be found to decrease the input of Sr^{90} to the stratosphere from tests, or, preferably, that a new attitude among the people of the world will permit us to lower the test rate, n.

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10 September 1956