tricular surface of the anterior medullary velum, fastigium, several levels of the aqueduct of Sylvius, several places in the third ventricle [including the hypothalamic sulcus, supraoptic recess, infundibular recess, lateral (thalamic) wall, and margin of the foramen of Monro] and several places in the lateral ventricle [including the head of the caudate nucleus, floor of the posterior horn, calcar avis, lateral wall of the temporal horn, and surface of the hippocampus]. These observations suggest strongly that the ependyma of the adult human brain is completely ciliated and demonstrate that lack of cilia in any given part of the ventricular system is exceptional.

Strong currents which are induced by cilia are under study in the ventricular cavities of rats and mice. These initial studies show distinct patterns of currents which tend to keep the cerebrospinal fluid in constant motion. In the fourth ventricle this motion is toward the lateral apertures and roof. Since ciliary activity is prominent in the ventricles of man as well as rats, mice, and other animals, it seems probable that such currents are present in the adult human also. A mechanism is present, therefore, for the rapid movement of cerebrospinal fluid by local mechanical means (*5*).

W. CURTIS WORTHINGTON, JR.
ROBERT S. CATHCART, III
Medical College of South Carolina, Charleston

References and Notes

1. G. Valentin, *Repertorium f. Anat. u. Physiol.* **1**, (1836); H. Luschka, *Die Adergeflechte des menschlichen Gehirns* (Reimer, Berlin, 1855); F. Leydig, *Lehrbuch der Histologie des Menschen und der Thiere. Mit zahlreichen Holzschnitten* (Meidinger, Frankfurt am Main, 1857); Studnička, *Untersuchungen über den Bau des Ependyms. Anat. Hefte* (1900); A. Kölliker, *Manual of Human Microscopical Anatomy,* trans. by G. Busk and T. Huxley, J. DaCosta, Ed. (Lippincott, Grambo, Philadelphia, 1854).
2. E. C. Crosby, T. Humphrey, E. W. Lauer, *Correlative Anatomy of the Nervous System* (Macmillan, New York, 1962).
3. L. Stoklasa, *Anat. Anz.* **69**, 525 (1930).
4. H-Y. Chu, *Am. J. Physiol.* **136**, 223 (1942).
5. Supported by U.S. Public Health Service grants B-3937 and H-4176.
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Chronic Gamma Radiation Affects the Distribution of Radial Increment in Pinus rigida Stems

Abstract. *Exposure of pitch pine trees to chronic ionizing radiation at rates between 1 and 5 roentgens per day for several years causes reduction of radial increment throughout the stem, the reduction being most ponounced near the base of the tree. Both the size of the tree crown and climate influence the severity of the effect, trees with large crowns showing little effect at low exposures except in years of environmental stress.*

Meristematic tissues are well known to be more sensitive to damage from ionizing radiation than differentiated tissues. Recent work on primary meristems has shown damage in *Taxus* buds at exposure rates as low as 3.75 r/day after total exposures of less than 100 r (*1*). Secondary meristems appear to be affected somewhat differently, although these effects have been less well defined. The present study was planned to utilize the marks of annual xylem growth in pitch pine, a highly radiosensitive species, to determine the effects of long-term chronic gamma irradiation on the pattern of radial growth along the bole (*2*). The experimental trees had been irradiated chronically for about 9 years at the edge of a gamma radiation field at Brookhaven National Laboratory. Exposure rates varied from year to year, but the trend was from low levels of approximately 0.1 r/day in the earlier years to higher levels in later years. Maximum rate for any tree was 5 r/day. Controls were nonirradiated trees from similar stands remote from the gamma source.

Trees were felled and a cross section was taken from each internode. Ring widths were measured along three radii in each cross section. The measurements for each ring were averaged and plotted on a graph in which the ordinate was the position along the stem and the abscissa was the width of the ring. Such a graph shows the "type one sequence" of Duff and Nolan (*2*), called more simply "oblique sequence" by Mott, Nairn, and Cook (*3*). Identification of false annual rings produced by a second flush of growth was facilitated by recognition of key years of high or low growth. In certain instances it was necessary to follow individual rings on longitudinal sections to ascertain whether the rings had been produced throughout the length of the stem. By combination of these techniques it was possible to identify rings positively from one internode to another through the stem and to correlate diameter increments among trees. This method showed clearly that reduced, discontinuous, or missing rings are common in the basal sections of irradiated trees and much less common in nonirradiated controls (Fig. 1).

Once the correlation of annual increments between internodes and among trees had been completed, diameter growth along the entire stem of a tree for any year could be plotted. Comparing in this way the increment of control trees and experimental trees prior to irradiation, it was clear that there had been no substantial differences in diameter growth: in favorable years both groups of trees had added 2.0 mm or more of radial increment throughout their lengths; in unfavorable years both added about half that radial increment, but the reduction was most pronounced at the base of the tree. After commencement of irradiation in 1951 the experimental trees produced no annual increments or reduced or incomplete increments in the lower one-third of their stems, while control trees added an increment throughout their lengths. The effect of continued irradiation with sublethal levels was a substantial reduction of radial increment at the base of the tree first and reduced increment at the top, a pattern described by Farrar (*4*) and Duff and Nolan (*2*) as characteristic of suppressed or otherwise stressed trees.

The parallel between radiation effects and stress effects on radial growth led to examination of increments produced in years of high and low stress. These years were defined as years in which control trees produced near-minimum and near-maximum increments in diameter. In years of low stress, control trees produced radial increments between 1 and 2 mm in width throughout the length of the stem; the pattern in years of high stress was similar except that the total increment was less. In irradiated trees equal in age to the controls, growth in diameter prior to irradiation paralleled that of control trees. After commencement of irradiation in 1951, however, the increments at the base of the tree dropped sharply,

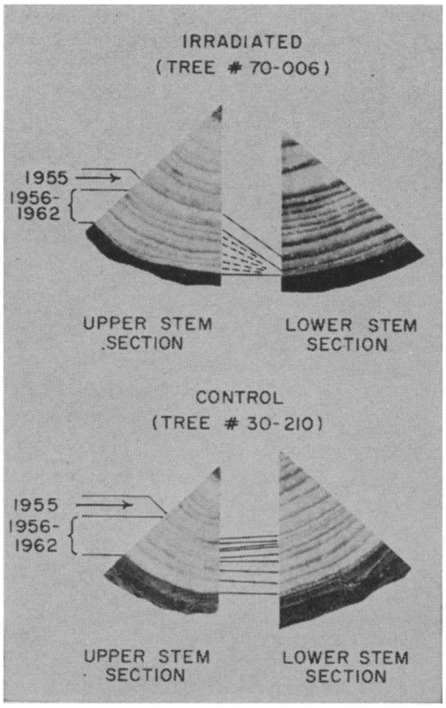

Fig. 1. Diameter increments of upper and lower stem sections from control and irradiated trees. The irradiated tree was receiving 3.0 r/day in 1955 and 4.4 r/day in 1961, when diameter growth ceased at the top of the tree.

the greatest drop occurring in years of high stress. In years of low stress recovery occurred, even when total exposure had increased in the interim. This relationship simply emphasizes the importance of environmental conditions in controlling the intensity of the radiation effect.

We also examined trees growing under different environmental conditions,

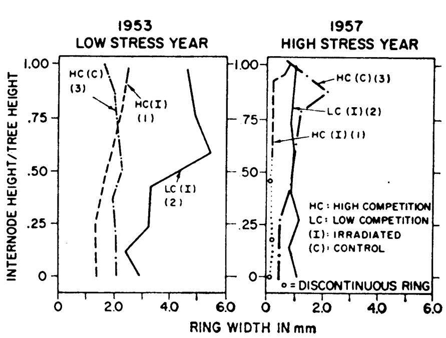

Fig. 2. Effect of "environmental stress" and "competition" on reaction to exposure to ionizing radiation. Environmental stress was assumed to be a measure of climate; competition, a measure of size of the tree crown. Exposures of irradiated trees were: tree No. 1; 1953: 2.8 r/day and 442 r total; 1957: 3.2 r/day and 3193 r total. Tree No. 2; 1953, 2.5 r/day and 395 r total; 1957: 2.7 r/day and 2815 r total.

arbitrarily recognizing two conditions which were called "high" and "low competition." Trees in the woods and with crowns extending one-third or less of the total length of the stem were said to be growing under high competition; trees along the margin of the woods or in the open and with living branches extending two-thirds or more the length of the stem were said to be growing under low competition. Radial increments of such trees differed by a factor of approximately 2, as shown in the graphs for 1953, a year of low stress (Fig. 2). In years of high stress, however, the tree with low competition produced a small radial increment throughout its length, despite a total exposure of 2815 r. The tree in the woods, exposed to about 3200 r, produced only discontinuous rings throughout more than half its length and a very small increment at the top of the tree, while a nonirradiated control, also under high competition, produced an increment throughout its length.

From these observations it is clear that the effect of ionizing radiation on radial growth is highly dependent on the size of the tree crown and on environmental conditions during irradiation. A tree with a large crown extending throughout most of the length of the stem may show little or no effect from low-level exposures even in years of environmental stress, while trees in the forest and with small crowns respond to total exposures as low as 2 r/day by failure to add radial increments in the lower part of the bole. This observation suggests that the primary site of damage lies in the crown and not in the stem, and agrees with other observations (*1*, *5*) which indicate that buds are probably the sites most sensitive to radiation damage. Since cambial activity appears to be initiated by auxin movement from these buds (*6*) damage to the sites at which auxin is produced may cause failure of initiation of cambial activity at points most distal from the buds. Such an effect would be confounded in this study with effects due to reduced production of carbohydrates by the radiation-damaged crown.

A second conclusion is that the interaction of ionizing radiation and stress in producing variations in the severity of the reduction in growth emphasizes the general principle that less than optimum conditions for one factor or set of factors may alter the tolerance of an organism for another factor, in this case ionizing radiation. It is quite probably true, therefore, that the interaction of ionizing radiation with the stresses normally exerted on plants in natural arrays will produce effects at lower radiation exposure levels than those necessary to produce the same effects in the laboratory or under controlled environment conditions (*7*).

G. M. WOODWELL
LEE N. MILLER
Biology Department, Brookhaven National Laboratory, Upton, New York

References and Notes

1. J. P. Miksche, A. H. Sparrow, A. Rogers, *Radiation Botany* **2**. 125 (1962).
2. G. H. Duff and N. J. Nolan, *Can. J. Botany* **31**, 471 (1953).
3. D. G. Mott, L. D. Nairn, J. A. Cook, *Forest Sci.* **3**, 286 (1957).
4. J. L. Farrar, *Forestry Chron.* **37**, 323 (1961).
5. L. W. Mericle, R. P. Mericle, A. H. Sparrow, *Radiation Botany*, in press; J. Read, *Radiation Biology of* Vicia faba *in Relation to the General Problem* (Blackwell, Oxford, 1959).
6. P. R. Larson, in *Tree Growth*, T. T. Kozlowski, Ed. (Ronald Press, New York, 1962).
7. Research carried out at Brookhaven National Laboratory under the auspices of the U.S. Atomic Energy Commission. We are grateful for the able assistance of Eric Klug, Terry Lee Lyon, Miss Mary Hertenstein, and Mrs. John Greenlaw.

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Estradiol: Evidence for its Direct Effect on Hypothalamic Neurons

Abstract. *When estrogen has been implanted in the arcuate nucleus of the hypothalamus of the rat, the size of the nucleoli of the neurons in this nucleus decreases, as determined by measurement of the mean diameters. These changes are accompanied by atrophy, similar to that caused by hypophysectomy, of the ovaries and uterus of the female or testes and accessory glands of the male.*

According to recent reports estrogen-sensitive centers are present within the hypothalamus (*1*, *2*), and highly localized implants of crystalline estradiol-17β result in the appearance in the gonads of atrophic changes similar to those caused by hypophysectomy. It was inferred that certain brain centers were operative in a feedback mechanism that monitored the amount of estrogen in the circulation and could influence the rate of release of gonadotrophin from the pituitary. This observation made further analysis of serial sections of the brain important,