west of the new exposure at station No. 1, and the gravel-till contact is estimated, from the large-scale topographic map, to be about 780 feet above tide. This is about 130 feet above the stream bed of Sangamon times—a fact which explains the well-drained profile that is so colorful.

In 1920 one of us (M.M.L.) observed and described in notes a nearly vertical ledge of ferruginous glacial conglomerate in an abandoned gravel pit in the east valley wall of the present Rock River (SE¼ NW¼ NW¼ sec. 7, T. 44N, R. 2E) about 4½ miles north of the pit described by Bretz. As exposed, this ledge was 10 feet high and 7 to 8 feet thick, the lower part being surrounded by fresh Farmdale till. One 3-foot bed was so firmly cemented that when it was struck with the hammer the fracture went through the pebbles rather than around them. Clearly the cementation took place prior to the Farmdale glacial invasion, with cement that resulted from the weathering of the gravel. The elevation of the ledge is estimated roughly at 750 feet.

Also in 1920, in a new western addition to Rockford, a basement excavation for a house and a nearby open cistern were observed which showed 1 to 1½ feet of reddish sand and gravel beneath 2½ to 3¾ feet of partly weathered till and 4½ feet of weathered loess. The till, now known to be Farmdale, contained a 3-inch lens of the older reddish sand. The driller of a well 12 feet away had just struck rock at 23½ feet; he reported that the red sand and gravel is 4 feet thick and that a "grayish pebbly hardpan" lies beneath; this might well be Illinoian till.

Almost equally significant was the finding of fragments of ferruginous glacial conglomerate on the surface of an esker 3½ miles west of Rock River in the north half of section 21, township 45N, range 1E, and on a knoll at the center of the east line of section 32, township 45N, range 1E.

These phenomena, each striking in itself, show conclusively that the Rockford area was glaciated twice, once by the Illinoian and later by the Farmdale. We have already shown (*7*) that the Farmdale drift sheet extends west to Freeport and that the Illinoian drift extends to the Driftless Area.

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18 JANUARY 1963

References and Notes

1. F. Leverett, in "The Illinois Glacial Lobe," *U.S. Geol. Surv. Monograph No. 38* (1899).
2. W. C. Alden, in "The Quaternary Geology of Southeastern Wisconsin," *U.S. Geol. Surv. Profess. Papers* **106** (1918).
3. M. M. Leighton, in "Itinerary State Geologists' Conference on the Loess Deposits" (1947).
4. ———, in "Basis of Subdivisions of Wisconsin Glacial Stage in Northeastern Illinois" (guidebook, Illinois and Indiana Geological Surveys Joint Geological Field Conference) (1953), p. 8.
5. P. R. Shaffer, *Science* **119**, 693 (1954).
6. ———, in "Farmdale Drift in Northwestern Illinois," *Illinois State Geol. Surv. Rept. Invest.* **198** (1956).
7. M. M. Leighton and J. A. Brophy, *J. Geol.* **69** (Jan. 1961).
8. J. E. Hackett, *Illinois State Geol. Surv. Rept. Invest.* **213** (1960).
9. J. H. Bretz, *Illinois State Geol. Surv. Bull.* **43C** (1923).

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Ependymal Cilia: Distribution and Activity in the Adult Human Brain

Abstract. *Examination of 150 to 200 samples of the ependymal lining of the ventricles of nine adult human brains obtained 2½ to 6 hours post-mortem revealed cilia in at least 20 separate sites in the four ventricular cavities. In seven of the brains ciliary motion was evident, and in two of these it was widespread and rapid. It seems likely that the adult human ventricular ependyma is ciliated throughout. Currents having distinct patterns are induced in the ventricles of animal brains by ciliary motion, and such currents probably exist in man. A local mechanism for the rapid movement of cerebrospinal fluid is therefore present.*

Little consideration has been given to the ciliated ependymal cells in man in recent years although the literature before 1900 contains numerous references to them (*1*). Most of the earlier accounts refer only to ciliated ependymal cells in human embryos, although the first description of them by Valentin (*1*) describes them in the adult. Modern textbooks generally refer only to "patches" of cilia in the adult human (if they are mentioned at all) but recognize a fully ciliated ependyma in the human embryo. Crosby, Humphrey, and Lauer (*2*) do acknowledge that "it is not rare" to find such patches at various stages after birth. It is, however, implicit in the brevity of these modern accounts that the matter is of little consequence.

Since experience in our laboratory and the accounts of Stoklasa (*3*), Chu (*4*), and others indicated to us that there is a widespread occurrence of cilia in the ventricular systems of many species, a fundamental difference in primates, including man, seemed unlikely. An investigation of the distribution of ciliated cells in the ependyma of man was therefore undertaken. Nine adult human brains were obtained at autopsy and examined from 2½ to 6 hours after death. They were immersed in mammalian Ringer's solution as soon as practicable after removal. Small pieces of ependyma were removed by curved corneal scissors held parallel to the ependymal surface in order to obtain a specimen with a thin edge; these specimens were then examined in the fresh state with water immersion lenses.

In the nine brains examined within this time period cilia were found in numerous places in each of the four ventricular cavities and were always present in any given area selected for examination. In seven of the brains, cilia which were still beating were found at one or more sites, and in the two best specimens of the series cilia which were still beating with a rapid and uniform motion were found in at least 10 separate areas in each brain. (Motion pictures of ciliary movement in the human brain were taken.)

Correlations between quality of preparation on the one hand and elapsed time after death or cause of death on the other are difficult to make in this short series. However, the two brains in which ciliary motion was uniform, widespread, and rapid were from cases of sudden, accidental death in individuals without known disease. They were examined 2½ and 3 hours after death. Moreover, the ependymal cilia from a patient with hepatic cirrhosis showed no movement when examined 3½ hours after death. With the exception of one case of drowning, the remaining cases were from patients with chronic systemic disease. These observations suggest that severe systemic disease may be a more important factor in disturbing ciliary activity in supravital preparations of human ependymal cilia than elapsed time after death. However, we have no experience with long periods of elapsed time after death in cases of sudden accident in healthy individuals.

Cilia have been found in the following sites in one or more of the brains examined, and in most instances, in all of them: floor of the rhomboid fossa in several different places, obex, ven-

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*).

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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.
6. We are indebted to the department of pathology of the Medical College of South Carolina for its cooperation in these studies.

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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,