changes in electrical potentials and currents produced in plants by various types of radiant energy. In their experiments it was found that marked changes in potential differences (voltage) were produced by ultra-violet and infra-red radiations and that the electric currents obtained in leaves, when an external but constant electromotive force was impressed, were increased by both these types of radiant energy. Furthermore, these changes in potential differences between the base and the tip of leaves were found to be associated very definitely with the phenomenon of growth. No changes in potential differences or in electric currents were produced by the visible portions of sunlight or various artificial sources of radiation.

The development of chlorophyll is dependent chiefly on the quality of the incident radiant energy, namely, the energy in the green region of the visible spectrum. Little chlorophyll is found in plants grown under filters which transmit infra-red or ultra-violet rays only. A comparison of the energy of the incident light transmitted by these filters and measured with thermopiles shows that a transmission of 5 per cent. of the green region (through a green filter) produces a greater amount of chlorophyll for each gram of plant than is produced by a transmission of 40 per cent. of energy in the yellow or red regions of solar radiation obtained through yellow and red filters.

CONCLUSIONS

(1) The ultra-violet and infra-red portions of sunlight are stimulating to germination and enhance growth and development.

(2) The green portion of the solar spectrum, which is its region of maximal energy, is inhibitory to the processes of germination and growth.

(3) The development of chlorophyll is enhanced under the yellowish-green, green and greenish-blue regions of the spectrum.

(4) The least development of chlorophyll occurs under the ultra-violet and infra-red portions of the spectrum.

CHARLES SHEARD,
GEORGE M. HIGGINS,
WILLIAM I. FOSTER
DIVISION OF PHYSICS AND BIOPHYSICAL RESEARCH AND DIVISION OF EXPERIMENTAL PATHOLOGY AND SURGERY, MAYO FOUNDATION, ROCHESTER, MINNESOTA

SOME PRACTICAL RESULTS OF AN X-RAY ANALYSIS OF COTTON FIBERS

WHILE it has been known for some time that cotton fibers yield a typical cellulose X-ray diffraction pattern, comparatively little work has been done with this material. The explanation of this lies in the fact that in ramie fibers, for example, there is a much more perfect orientation of the colloidal micelles parallel to the fiber axis than is true in cotton, which appears to have a spiral arrangement. Ramie fibers have, therefore, been practically exclusively used in the brilliant X-ray work which has led to a final analysis of the crystalline part of cellulose. It is now definitely known that cellulose belongs to the monoclinic system and that the unit cell dimensions derived from X-ray patterns are: $a = 8.3$, $b = 7.9$, $c = 10.3$ A.U. The last named is the identity period along the fiber axis, with a monoclinic angle $\beta = 84°$. This small unit cell contains four $C_6H_{10}O_5$ groups. It has been further demonstrated that cellulose is built from long primary valence chains of the dehydrated glucose molecules and that a bundle of these long chains constitutes the colloid micelle or crystal grain. The measurement of the breadth of the X-ray diffraction interferences has proved that in various samples the length of the micelles, which is the same as the length of the primary valence chains, lies between 150 and 500 A.U., and that the cross-section dimension of the micelle, which is determined by the number of chains in a bundle, lies between 20 and 50 A.U.

It is this complete structure of cellulose which enables explanation of the physical and chemical properties of cellulose fibers. Up to the present time all the X-ray work has been devoted to fundamental studies of cellulose and practically nothing has been done in the practical sense of following growth or in classifying fibers of a particular kind. In the X-ray laboratory of the University of Illinois extensive independent and cooperative studies are in progress on wood and on cotton fibers. The first results in comparative studies of cotton fibers have been so promising and have so far exceeded the expectations that it has seemed wise to report in a preliminary note these findings on structural changes during growth and on classification of mature fibers.

A series of developmental stages of the fibers of *Gossypium hirsutum* representing growth intervals of eighteen, twenty-one, thirty-five and fifty days respectively have been studied thus far, by means of the diffraction method, utilizing the copper $K\alpha$ radiation, the pinhold method and a bundle of parallel fibers as the specimen. The eighteen- and twenty-one-day samples represent the period of elongation in fiber growth. The thirty-five-day sample represents the early stages of wall thickening and the fifty-day sample the mature fiber at the close of its period of wall formation. The diffraction patterns for the four samples show a remarkable progression. In all cases the patterns indicate a crystalline condition which, however, is progressively more perfect with age. The eighteen-day sample pattern is distinguished by very broad and continuous rings indicating random orientation. The principal diffraction ring has a diameter of 4.05 cm. There is no evidence whatsoever of true fibering. The twenty-one-day sample pattern also shows continuous diffraction rings but these are sharper, indicating larger micellar size, that is, longer chains, and the diameter of the principal diffraction ring is 4.25 cm. The thirty-five-day sample pattern shows for the first time definite evidences of preferred orientation as indicated by greater intensity of the diffraction rings on the equator as compared with the poles of the pattern. The fibering, however, is still imperfect. The diameter of the principal diffraction ring is 4.50 cm. Finally, in the mature fifty-day fiber the pattern indicates the maximum degree of preferred orientation, the sharpest and narrowest diffraction maxima, indicating the final size of the micelles and a diameter of the principal diffraction ring of 4.60 cm. There has been thus a progression in these samples in fibering, in micellar size indicated by diffraction breadth and in the actual crystal unit cell dimensions as indicated by the interference ring diameters. The dimensions are largest for the youngest sample. This seems to indicate, therefore, a condition of intra-micellar swelling or of the fact that the primary valence chains are not oriented within the colloidal particle in a perfectly parallel fashion. It may also mean that the crystalline substance is not yet true cellulose. As the sample ages the diffraction ring increases in diameter, which means that the unit cell dimensions decrease until in the mature fiber the dimensions for ordinary cellulose are reached. It is evident that preferred orientation occurs some time between the twenty-first and thirty-fifth day, probably quite sharply. Further tests are now being made with samples showing finer gradation in growth.

Another series of samples of mature cotton fibers showing markedly different physical properties has been subjected to X-ray analysis and here again the diffraction patterns are equally striking in their differences. The samples consisted of a cotton of high quality, one whose fiber quality had apparently been lowered by adverse developmental conditions and a third which represented an inferior variety. In all three cases the diffraction rings have exactly the same measurements corresponding to true cellulose. The differences lie, first, in the degree of preferred orientation, and secondly, in the sharpness of the interference maxima. There is a marked difference in the degree of fibering which is maximum in the case of the first sample and minimum in the third. For example, the cords of the arcs on the diffraction rings produced by fibering have the following lengths: first, 2.8 cm; second, 3.25 cm; third, 3.8 cm. This gradation is exactly the same as that displayed by the qualitative differentiation. Furthermore, an examination of the sharpness of interferences indicates that the chain lengths in the colloidal micelles are greatest in the first sample and least in the third. Therefore, satisfactory physical properties are unquestionably connected with colloidal size greater than a critical value and in the best possible arrangement of these micelles with respect to the fiber axis itself. While these samples represent perhaps extreme conditions it seems very probable that it will be possible to classify cotton within much narrower limits and that the X-ray method will, therefore, prove an indispensable new tool both for specification and research in the cotton industry. A continuation of these studies in a quantitative manner is in progress.

GEORGE L. CLARK
LUCY W. PICKETT
DEPARTMENT OF CHEMISTRY,
UNIVERSITY OF ILLINOIS

WANDA K. FARR
DIVISION OF COTTON MARKETING,
U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF AGRICULTURAL ECONOMICS

BOOKS RECEIVED

DARROW, FLOYD L. *The New World of Physical Discovery.* Pp. 371. 14 illustrations. Bobbs-Merrill. $3.50.

DAY, ALLAN R. *Inorganic Qualitative Chemical Analysis.* Pp. ix + 197. 15 tables. Chemical Publishing Company. $2.75.

DE BEER, G. R. *Embryology and Evolution.* Pp. viii + 116. Illustrated. Oxford University Press. $2.00.

DENSMORE, FRANCES. *Pawnee Music.* Pp. xviii + 129. 8 plates. Songs. Smithsonian Institution.

FLINT, H. T. *Wave Mechanics.* Pp. ix + 117. 19 figures. Dutton. $1.25.

GIBBS, R. W. M. *The Adjustment of Errors in Practical Science.* Pp. 112. 43 figures. Oxford University Press. $1.75.

GUYER, MICHAEL F. *Animal Micrology.* Pp. xi + 289. 74 figures. 14 tables. University of Chicago Press. $3.00.

HEYL, PAUL R. *New Frontiers of Physics.* Pp. xi + 170. 11 figures. Appleton. $2.00.

HOLGATE, THOMAS F. *Projective Pure Geometry.* Pp. ix + 286. 146 figures. Macmillan. $3.00.

JOHNSON, JOHN C. *Educational Biology.* Pp. xx + 360. 123 figures. Macmillan. $3.00.

KAY, GEORGE F., and EARL T. APFEL. *The Pre-Illinoian Pleistocene Geology of Iowa.* Pp. 304. 66 illustrations. Iowa Geological Survey. Vol. XXXIV.

KLIGLER, ISRAEL J. *The Epidemiology and Control of Malaria in Palestine.* Pp. xv + 240. 32 figures. 19 charts. 22 maps. University of Chicago Press. $5.00.

MARMER, H. A. *The Sea.* Pp. x + 312. 45 figures. Appleton. $3.00.

PLANT, L. C. *Agricultural Mathematics.* Pp. ix + 199. 22 figures. 4 tables. McGraw-Hill. $2.50.

TAYLOR, GRIFFITH. *Antarctic Adventure and Research.* Pp. xi + 245. 34 figures. Appleton. $2.00.

UNITED STATES NAVAL OBSERVATORY, *Publications of.* Second series. Volume XII. Pp. ix + 592. 11 plates. 23 tables. United States Government Printing Office.

VON DER OSTEN, H. H., and ERICH F. SCHMIDT. *The Alishar Hüyük Season of 1927.* Part 1. Pp. xxii + 284. 251 illustrations. 5 plates in color. 22 maps. 2 tables. University of Chicago Press. $8.00.