to the various colors used on the disc are far from representing percentages of pure spectral hues. The actual percentage transmission of spectral red, for example, from the "Red" disc is lower than that from the "Yellow" disc. To the eye, of course, the differences in reflection of light of these wave lengths appears extreme in the opposite direction. By means of the ratio $\frac{I_{6500}}{I_{5000}}$ the different appearances to the eye of these two discs is more satisfactorily represented. Similarly the ratio $\frac{\text{"Red"}}{\text{"Yellow"}}$ as determined by color disc analysis is found to bring out better the apparent striking color differences of two soils.

G. B. BODMAN

DIVISION OF SOILS,
UNIVERSITY OF MINNESOTA

SPECIAL ARTICLES

LIVING CELLS TWO AND A HALF CENTURIES OLD

RESEARCHES dealing with the growth and hydrostatics of trees and other massive plants have led to a consideration of the activities of living cells in the interior of large stems. Rigidity and other mechanical features of tree-trunks are such that living cells in layers a year old can not grow or divide and hence the existence of a living cell in layers 50 or 100 years old may be taken as an example of a protoplast which has carried on an individual existence for that length of time. In many trees all living cells perish when the splint or sap wood of which they form a part is converted into heartwood. A notable case was recently described in SCIENCE in which medullary cells of the redwood remained alive in the heartwood attaining an age of over a century.[1]

Professor Faul has recently called attention to the work of J. H. White in which tyloses were seen in heartwood of beech, maple, oak and other trees in regions invaded by *Fomes applantus*. It is implied that these formations take place only in living cells and that their development was induced by the penetrating fungus. The case seems to call for a more detailed examination. Now that the existence of living cells in heartwood and in old wood has been rescued from the negations of widely used text-books it is highly probable that numerous additional examples will be found.[2]

Our quest for other examples of long-lived cells has had for its chief purpose the determination of the progressive changes in protoplasts which attain great age and to appraise the conditions endured. A desert tree *Parkinsonia microphylla*, which has been used for tests in conduction and growth has yielded results of interest in this matter.

This bean tree is a prominent member of the desert flora of the southwest and because of its smooth green bark is known as "Palo verde." Despite the fact that its growth in thickness is at an extremely low rate, 0.2 to 0.6 mm annually, the trunk is soft and brittle, losing 45 per cent. of its dry weight in two days in the drying oven at 100° C. Bark and wood are heavily loaded with crystals, mostly calcium carbonate. The ash constitutes as much as 3.4 per cent. of the dry weight.

Sections of stems 10 cm in diameter and over 75 years old, first examined, showed occasional living ray-cells near the center and also a number of tracheids in which the nucleus and cytoplasm were plainly in a normal and active condition.

An older excentric trunk which stood in a leaning position showed sound moist wood in the flank which was 9 cm in thickness. Several counts of layers by Dr. Forrest Shreve gave a basis for the estimate that the age of the trunk might be safely taken as between 275 to 300 years old. Living ray cells and tracheids could be seen in sections near the center without staining and with a dry objective. We have no hesitancy in announcing that these elements may be safely considered as having an age of over 250 years.

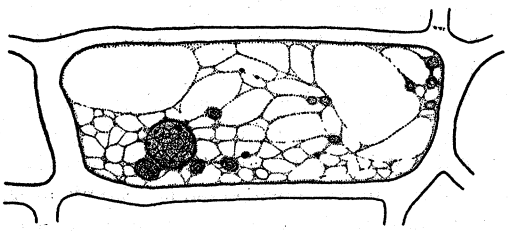

FIG. 1. Ray cell of Parkinsonia over 250 years old. Reticulum of nucleus and cytoplasm well defined.

Macroscopically the stele of *Parkinsonia microphylla* presented a nearly uniform light straw color sometimes with a small central core of heartwood (duramen). In other words, sapwood (alburnum) made up almost the entire mass of wood. Elements of the xylem consisted of tracheids typical in shape; coarsely pitted vessels; elongated thick-walled cells with blunt ends, and short prosenchymatous cells in vertical rows near the medullary rays.

The tracheids composed by far the greatest part of the xylem. They measured approximately 20 microns in length. Those laid down at the end of the growing season in the oldest wood near the central pith had walls averaging 4 microns when measured between lumina of two tracheids, while those formed in spring and summer and measured in the same way averaged 3 microns in thickness. Comparative measurements of tracheids in xylem formed in recent years was 3.2

[1] MacDougal, D. T., and G. M. Smith, SCIENCE 66, 456–457. 1927.

[2] Faul, J. H. "Living Cells in Heartwood," SCIENCE 67, 296. 1928.

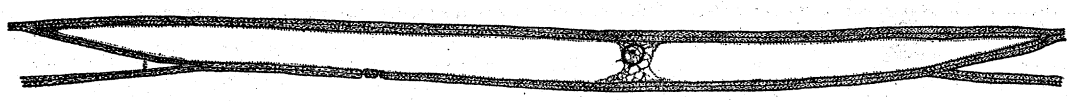

FIG. 2. Tracheid of Parkinsonia over 250 years old. Nucleus plump and normal.

microns for those laid down in the fall and 4.2 microns for those formed in spring and summer.

Living tracheids are numerous, even in the oldest part of the stem. Part of an annual ring in one bundle consisting of 120 tracheids showed nuclei and more or less cytoplasm in approximately 50 per cent. of the tracheids. Likewise many of the medullary ray cells were living. Nuclei in both tracheids and ray cells were large, well-rounded and clearly showed a reticulum. One to three nucleoli were present.

The vessels or tracheae were coarsely pitted and few in number. Some of them contained a substance which stained brown with Haidenhain's iron-alum haematoxylin. Otherwise they were not unlike those found in woody dicotyledonous plants.

Elongated cells with coarsely pitted end walls and abundant pits in lateral (radial) walls were found near the rays but extended vertically. Frequently this type of wood cell contained living contents. It appeared to be a transition between tracheid and trachea.

The prosenchymatous cells, apparently formed by the transverse division of a xylem parenchyma cell early in the development of the wood, usually contained cubical or six-sided crystals. Many of these cells were alive and contained cytoplasm in contact with crystals in various stages of development.

In previous discussions attention was called to the fact that cells attaining great age were of the thin-walled parenchymatous type. Later Dr. F. H. Long prepared a manuscript now ready for publication in which epidermal cells, including stomata of the tree-cactus of Arizona, are shown to attain an age of over a century.

The preceding paragraphs record the existence of ray cells of the thin-walled type in Parkinsonia and also of typical tracheids with heavy walls in parts of trunks formed over two and a half centuries ago. No observations have been made as to the length of the period of enlargement of these elements, but as the season's growth of this desert tree is completed within the brief period of the summer rains it may safely be taken to be something less than a week. Existence is continuous for 12 or 13 thousand weeks, thus setting a new high ratio between the developmental period and the period of mature existence.

Heartwood is not always formed in Parkinsonia, the vessels are large and the protoplasmic strands connecting neighboring cells are well defined and numerous. By this arrangement the innermost cells are much more closely connected with the surface layers of the trunk than in the redwood or the central parts of other trunks.

The cells capable of attaining great age appear to lose their embryonic character very early. At the same time surfaces of wounds of this tree dry out so quickly that rarely is any notable callus formation found. The living cells of the trunk endure a range of temperature higher than those to which trunks of mesophytic trees are subject. The actual range, however, may be not nearly so great as those attained by cells in flattened stems in cacti in which mid-day temperatures of over 50° C. are common.

The gases in the vessels and intercellular spaces of trunks of Parkinsonia are extractable at about the same rate as in Quercus. Samples taken from bores extending 10 to 12 cm or to the center of trunks at 0.3 to 0.4 atm showed never less than 1 per cent. carbon dioxide and the proportions in some cases were as high as 16 per cent.

The above notes are intended as an announcement of the discovery of living cells older than those noted in any record in which estimates of age have been included. Elements of Parkinsonia, including ray cells and tracheids, have been found near the center of a trunk nearly three centuries old. The appearance of the nuclei and cytoplasm is not widely away from that of young cells and it may be safely predicted that the examination of older trees would reveal living elements of even greater age.

The long-lived cells endure a wide range of temperatures and the gases in the vessels which are dissolved in their sap are very high in carbon dioxide. Mineral elements of which calcium is the chief component accumulate in the wood so that the ash constitutes 3.4 per cent. of the dry weight. The ash of beech wood forms but 0.355 per cent. of its dry weight. The caenocytic arrangement of the living cells is so marked as to suggest that the connections afforded by the heavy connecting protoplasmic threads may be important as conductive organs maintained between the deeply lying old protoplasts and the surface layers.

D. T. MACDOUGAL,
J. G. BROWN

LABORATORY FOR PLANT PHYSIOLOGY,
CARNEGIE INSTITUTION OF WASHINGTON
AND UNIVERSITY OF ARIZONA