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CONTENTS.

On the Continuity of Protoplasm through the Cell Walls of Plants.

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Sachs, in 1863, proved the continuity of protoplasm from cell to cell through sieve plates, and in 1880 made the remarkable statement that this continuity was universal in plants. He said, "Every plant, however highly organized, is fundamentally a protoplasmic body forming a connected whole, which, as it grows on, is eternally clothed by a cell membrane, and internally traversed by innumerable transverse and longitudinal walls."* Considering the difficulty of successfully demonstrating the continuity of protoplasm in many parts of plants, more especially

*Walter Gardiner, in Philosophical Transactions of the Royal Society of London, Vol. 174, p. 817.

where the cell walls are thin, and with a view to finding which plants of those accessible to most students in our country are most suitable for the purpose, we began the work by examining the cortical layer of one or more species of about seventy-five genera of native and cultivated exotic trees and shrubs. Without going into details in regard to all the various methods which have been tried by Sachs, Gardiner, and others, we will merely state that at first beginning, a thin fresh tangential section was made with a razor and at once a drop of strong sulphuric acid from a glass rod was placed upon it. After one to three minutes, depending on the thickness of the cell walls of the specimen examined, the sections were rapidly washed in water, and stained with iodine or analine blue.

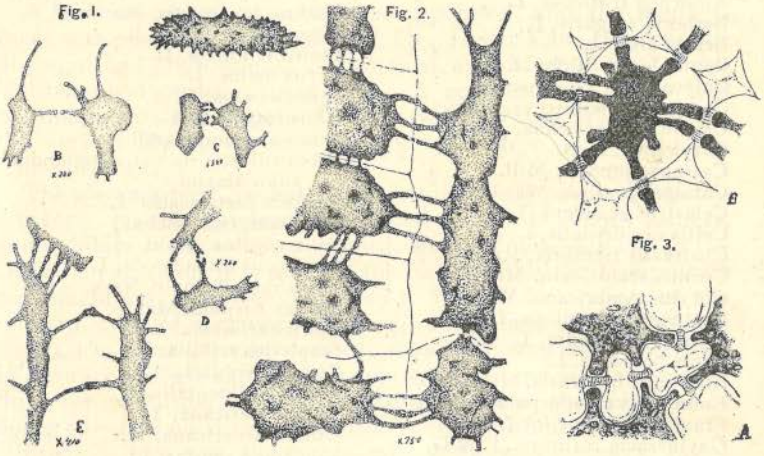
Chloriodide of zinc was also tried. But the most satisfactory results were obtained by placing a thin section in a solution of iodine, until it turned brown. Then wash, and then run strong sulphuric acid under the cover-glass, and soon, again, draw out the acid, replacing it by water. After washing well, mount in glycerine and color with green or blue analine.

In these experiments, a great deal of time and labor for weeks may here be passed over by a mere mention of the fact, calling it "dead work." Now for the results: The large masses of protoplasm in all the cells properly treated were very pronounced, and from each mass extended arms or strands in every direction. Each arm in a cell exactly approached and met or seemed to *almost* meet one from an adjoining cell. In some places, in every species examined, a continuous strand seemed to extend from one cell to the next one, but this was very likely due to some imperfect work in making the experiment. In most instances there was a light line, through which the connection could not be successfully traced. At this place the tips of the strands were swollen and between them a light, hazy look was very common.

The question to be demonstrated was the presence of delicate threads of protoplasm passing from the swollen tip of one strand to the swollen tip of a contiguous strand in the next cell. In the cells of the endosperm of palms the walls are very thick, and the space between the tips of contiguous strands rather prominent; but in the cortical layer of our woody plants the cell wall is rather thin, and the space between the tips of the strands is a very narrow one. To trace threads across this narrow passage is difficult and often unsatisfactory, as the threads are very short. We employed a Spencer's one-eighteenth-inch immersion objective.

Among the most satisfactory of the many specimens of cortex examined was that of the common lilac, where the sections were taken from large-sized twigs two to three years old. *Viburnum opulus* (snow ball) was much the same. In specimens of our hawthorns the strands were slender and longer, but the threads joining their tips showed very well. Perhaps the best one of all was taken from the cortex of *Alnus glutinosa*. Here the

strands are of good size. At the middle lamella the connecting threads of protoplasm are three to seven or more in number, and bulge outward, the whole somewhat resembling a barrel in shape. Unfortunately a drawing of the alder was mislaid. The drawing of the endosperm of *Heterospathe elata*, a palm seed (Fig. 3), has been copied from the work of Mr. Gardiner, and very closely resembles that of the alder, above referred to. In A is seen endosperm of *Heterospathe elata*, showing threads of the tips of four contiguous strands. The middle lamella is but little developed; in B, ripe endosperm of *Phœnix dactylifera* after treatment—one cell, with parts of several others. The strands of protoplasm extending out from the central mass in the cells of *Amelanchier* (Fig. 1) are often forked near the tips.



The specimen is one of the best examined. The cells are not large, but are comparatively long, and having exceedingly long protoplasmic strands. From one cell (A) many pointed strands of protoplasm seemed to radiate in all directions, their form of cells were numerous, and in some cases strands extended to other cells. The peculiar point illustrated by B, C, D, and E is the forked appearance of protoplasmic strands at the point of junction between the cells. Here in many cases the connection seems to be broken, but in above, as in E, exceedingly fine threads apparently unite the two strands. The middle lamella is easily seen in this specimen, and it is here where we always find the break, if any, in the connecting strands.

In *Cratægus* (Fig. 2) the continuity is very pronounced. The middle lamellæ are distinct. At the middle lamella there is a difference apparently in the strands of protoplasm. Strands do not appear as dense at this point as elsewhere. Strands in all

cases come to the middle lamella at the same point as those of the neighboring cells.

In the thick-walled cells of the ripe endosperm of many palms, Mr. Gardiner demonstrated that extremely delicate threads not only passed from tip to tip of the strands of protoplasm, but through the thick walls as well.

We give the names of those examined:

SECONDARY CORTEX.

Acer platanoides, L.
Æsculus glabra, Willd.
Ailanthus glandulosus, Desf.
Alnus glutinosa, Gaert.
Amelanchier Canadensis, T. & G.
Amorpha fruticosa, L.
Berberis vulgaris, L
Betula alba, L.
Betula lutea, Michx, f.
Calycanthus Floridus, L.
Caragana arborescens, Lam.
Carpinus Americana, Walt.
Carya alba, Nutt.
Castanea pumila, Mill.
Catalpa speciosa, Warder.
Celastrus scandens, L.
Celtis occidentalis, L.
Cladrastis tinctoria, Raf.
Cornus stolonifera, Michx.
Corylus Americana, Walt.
Cratægus tomentosa, L.
Cytisus laburnum, L.
Dirca palustris, L.
Elæagnus hortensis, Marsch.
Euonymus atropurpureus, Jacq.
Fraxinus sambucifolia, Lam.
Gaylussacia resinosa, T. & G.
Gordonia, sp.
Gymnocladus Canadensis, Lam.
Hamamelis Virginiana, L.
Hydrangea paniculata, Siebold.
Ilex verticillata, Gray.
Juglans nigra, L.
Lonicera sempervirens, Ait.
Maclura aurantiaca, Nutt.
Magnolia acuminata, L.
Menispermum Canadense, L.
Negundo aceroides, Moench.
Philadelphus coronarius, L.
Picea nigra, Link.
Pinus strobus, L.
Populus alba, L.
Prunus Americana, Marshall.
Prunus Virginiana, L.
Ptelea trifoliata, L.
Pyrus malus, L.
Quercus alba, L.
Rhus capallina, L.
Ribes aureum, Pursh.
Ribes rubrum, L. var. subglandulosum, Maxmi.
Robinia pseudacacia, L.
Rosa setigera, Michx.
Salix cordata, Muhl.
Sambucus Canadensis, L
Sassafras officinale, Nees.
Smilax hispida, Muhl.
Spiræa trilobata, L.
Staphylea trifolia, L.
Syringa vulgaris, L.
Thuya occidentalis, L.
Tilia Americana, L.
Ulmus Americana, L.
Viburnum opulus, L.
Vitis riparia, Michx.
Xanthorrhiza apiifolia, L' Her.
Xanthoxyllum Americanun, Mill.

ENDOSPERM.

Iris versicolor, L.
Phœnix dactylifera, L.

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Glue Without Heat.—Dissolve 50 parts of barium chloride in 750 parts of cold water. Put into it 13 parts of gelatine or glue. Let it stand 12 hours. Precipitate the baryta with sodium sulphate.

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Liquid Paraffin dissolves camphor. The solution becomes perfectly limpid with a little heat.