NOTES.

THE EFFECTS OF TROPICAL INSOLATION.—In my paper with this title, published in the September number of the *Annals*, I notice that, when speaking of the movements of the sensitive leaflets, I omitted to refer to Oltmann's researches on this subject. Oltmann¹ was the first to show that in *Robinia* it is the pulvini which are directly stimulated to movement by a change in the intensity of the illumination. The observations I have made in Java and Ceylon are of interest as corroborating and extending the results obtained by Oltmann, and later by Macfarlane², on this particular point.

ALFRED J. EWART.

MASON COLLEGE, BIRMINGHAM.

THE TENSILE STRENGTH OF CELL-WALLS.—Some time ago I estimated the osmotic pressure in the leaf-cells of several plants to range between 20–30 atmospheres (or 200–300 grs. per sq. mm.)³. It seemed to me of interest to ascertain what coefficient of safety was allowed by the plant to meet these high pressures. This may be done by determining the tenacity or tensile strength of cellulose, and estimating the stress in the cell-wall while the cell is distended by these pressures.

The first was ascertained directly by weighing a single hair or fibre, detached from the surface of the seed of *Gossypium*, until it broke. From the breaking weight and the area of cross-section of the fibre, its tenacity may be obtained.

I applied the weight by slowly filling with water a light paper

¹ Oltmann, *Flora*, 1892, p. 234.

² Macfarlane, *Bot. Centralblatt*, 1895, I, p. 136.

³ Notes from the Botanical School, Trinity College, Dublin, No. 2, May, 1897.

[*Annals of Botany*, Vol. XI. No. XLIV. December, 1897.]

bucket attached to the fibre. The attachment was effected by gluing the end of the fibre to a fine wire-handle on the bucket.

To quote an example of one of these observations: the bucket suspended from a fibre, as described, was slowly filled with water. When the increasing weight parted the fibre, the bucket together with the water weighed 7.817 grs. Microscopic measurement showed that the greater diameter of the fibre was 0.0192 mm., and the lesser 0.0078 mm. As the fibres are roughly rectangular in section, the area of cross-section equalled 0.00015 sq. mm. inclusive of the lumen of the cell, which, however, is very small.

From this it follows that the breaking stress was not less than 52,000 grs. per sq. mm.

Another experiment gave the weight of bucket and water sufficient to break another fibre as 8.500 grs. But in this case the cross-section of the fibre was 0.0137 mm. $\times$ 0.0168 mm. It follows that the breaking stress was greater than 37,000 grs. per sq. mm.

It is evident from the nature of the method that these figures only fix a minor limit to the tenacity of cellulose. The breaking stress of cellulose must be as great or greater than 52,000 grs. per sq. mm. For it is impossible to determine the cross-section exactly at the point of fracture, and it has been my practice to estimate the section at the narrowest place above the fracture; but of course this is not the smallest cross-section, supposing the fibre to be homogeneous. It seems indeed that the figures are much below the true breaking stress, and that fracture occurs at a point in the fibre weakened by some flaw. This may be demonstrated by taking one of the parts of a fibre, which originally parted under a stress, say, of 3 grs., and testing it in the same manner as before. It will then be found to support a greater weight: probably of 10 grs. or even 12 grs. One fibre, .017 $\times$.018 mm., broke on the first trial at 8.500 grs., second at 12.552, third at 16.267, and fourth at 18.200 grs. The final result gives a tenacity of 60,000 grs. per sq. mm.

Hence we may safely assume that the tenacity of cellulose is greater than 50,000 grs. per sq. mm., which is about equivalent to thirty tons per square inch, and also about the same as the tenacity of Aluminium bronze¹.

The tenacity given for Red Pine² is 9,100 grs. per sq. mm.; but

¹ Numerical Tables and Constants, S. Lupton. Macmillan, 1896, p. 17.

² Loc. cit.

the actual area of woody wall in a section of Pine, would scarcely amount to more than about 0.2 of the cross-section; so that the absolute tenacity of the substance of the walls of the tracheides probably approximates closely to that of the fibre of *Gossypium*.

Now with regard to the stress actually obtaining in the cell-walls of the leaf. It will be convenient, in treating of the stresses, to regard the cells as cylinders. This assumption is justified by the consideration that it is probably only the cell-walls of the cylindrical cells of the leaf, e.g. those of the palisade-tissue and those forming sheath surrounding the bundles, which are exposed to this stress; for it seems probable that the walls of the irregularly stellate cells of the spongy parenchyma are not exposed to any great distending forces, otherwise they would assume a spherical contour; unless, indeed, we attribute great rigidity to their cell-walls. The apparent paradox, that these cells contain a pressure of 20-30 atmospheres, while there is no stress in their walls, is explained by the fact that it is an osmotic pressure, and is not exerted on the enclosing membrane unless there is fluid enough present to distend that membrane. This consideration would also lead to the conclusion that the rigidity of leaves is due only to the cylindrical and more spherical cells, and that those cells with re-entrant angles are not normally in a state of turgor.

When a cylinder is exposed to internal pressure, the stress in the wall tending to rupture it may be obtained in the following way: the total disruptive force equals the internal pressure acting over an area equal to the length multiplied by the diameter of the cylinder. This force is exerted on an area of cellulose equal to the thickness of the cell-wall multiplied by twice the length and twice the diameter of the cylindrical cell. Thus—

$$\text{Stress per sq. mm. of cellulose} = \frac{P \cdot l \cdot d}{2 (l + d) t}.$$

Where P=osmotic pressure, l=length, d=diameter of cell, and t=thickness of cell-wall.

In *Cytisus Laburnum* the cylindrical palisade-cells are about .06 mms. long, about .0175 mms. diameter, and their cell-wall is .001 mms. thick. The stress per sq. mm. in their cell-walls is consequently

$$\frac{300 \times .06 \times .0175}{.155 \times .001} = 2,032 \text{ grs.}$$

R r

In *Helianthus multiflorus* a cell from the same tissue measures very closely the same ; so that in these two instances we see that the walls of the cells of the palisade-parenchyma, so far as they are exposed to disruptive forces, are stressed far below the experimentally derived tenacity of cellulose. In fact there is a coefficient of safety amounting to 25.

The dimensions of the cylindrical cells of the sheath are the following :—

Cytisus Laburnum, length = .100 mm., diameter = .030 mm.

Helianthus multiflorus, length = .108 mm., diameter = .018 mm.

These are the maximum dimensions observed. The thickness of the walls in each case is about .001 mm.

It results from these figures that if the pressure is 300 grs. per sq. mm. that cell-walls of *Cytisus Laburnum* will be subject to a stress of less than 3,500 grs. per sq. mm. This leaves a coefficient of safety of at least 14.

It has been noticed as probable that the walls of the cells of the spongy parenchyma do not, under normal circumstances, sustain any appreciable stress. But even if it is assumed that their cellulose membrane is sufficiently rigid to maintain its irregular shape when exposed to these high internal pressures, it is easily shown that the stress in the cell-walls does not rise above 1,500 or 2,000 grs. per sq. mm.

So it appears that the wall of every cell of the leaf is amply strong to sustain the high osmotic pressures which are demonstrable as giving rigidity to the leaf, and that, so far as the strength of the cell-walls is concerned, much higher osmotic pressures than those actually observed might exist in the cells of the leaf.

H. H. DIXON, Dublin.

STRUCTURE OF CODIUM.—Two years ago, in the month of April, I gathered some material of *Codium tomentosum* near Ventry, Co. Kerry. In sections prepared from this for teaching purposes, I was struck by the peculiar appearance of the club-shaped ends of the ramifications of the coenocyte. Sections 10 μ thick, stained with Delafield's Haematoxylin, showed in many of the branches of the coenocyte a stout axial strand of a violet substance. The strand is thin and more delicate in the narrow interweaving parts of the coenocyte, and thickens gradually as it passes out into the enlarged

Dixon, Henry Horatio. 1897. "The tensile strength of cell-walls." *Annals of botany* 11, 585–588. <https://doi.org/10.1093/oxfordjournals.aob.a088673>.

View This Item Online: <https://www.biodiversitylibrary.org/item/233542>

DOI: <https://doi.org/10.1093/oxfordjournals.aob.a088673>

Permalink: <https://www.biodiversitylibrary.org/partpdf/318486>

Holding Institution

Smithsonian Libraries

Sponsored by

Biodiversity Heritage Library

Copyright & Reuse

Copyright Status: Not in copyright. The BHL knows of no copyright restrictions on this item.

This document was created from content at the **Biodiversity Heritage Library**, the world's largest open access digital library for biodiversity literature and archives. Visit BHL at <https://www.biodiversitylibrary.org>.