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SOME CONSIDERATIONS ON CELLULOSE FIBRIL ORIENTATION IN GROWING CELL WALLS

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The following mathematical treatment demonstrates that various patterns of fibril texture in primary cell walls may be accounted for, merely by assigning appropriate — and by no means improbable — values to certain parameters.

Assume the cell wall to have axial symmetry, and assume its thickness t to be small compared with the diameter b (Fig. 1).

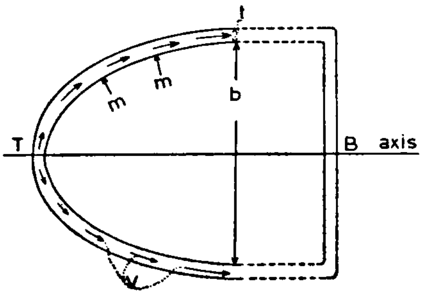

Fig. 1

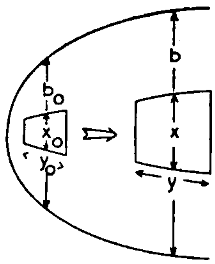

Fig. 2

The growth process is schematized as a stationary flow of incompressible cell wall material m being continuously deposited onto the inner face of the tip, and proceeding, from the moment it has been deposited, in the direction indicated by the arrows V inside the cell wall. For convenience's sake, we shall consider the tip T as fixed, so that in our picture the basal part B of the cell moves away from T with the growth velocity. Further, at any section S at a given distance from T, the cell wall material of all layers between the inner and outer face of the cell wall will be supposed to move with equal velocity, say v cm/sec.

Now, what we want to investigate, is the change in orientation of a fibril from the moment it is deposited until eventually it leaves the growth zone. Obviously this depends on the deformation of a certain volume element of cell wall material (in wich the fibril is situated), while it is shifting from the extreme tip towards the base of the growth zone (Fig. 2).

It is readily seen that dimensions in the transverse tangential direction (x) will vary as b. On the other hand, meridional dimensions (y)

within a small flowing volume element are proportional to the flow velocity v. For, since the flow is stationary, which means that the velocity at a given point is the same at any moment, two flowing points will pass through any section S with the same time interval, independent of the site of S. Hence if two points are close together, their interdistance (measured along the meridian) must remain proportional to v.

Consider a volume element with initial dimensions, diameter and velocity $x_0, y_0, b_0,$ and v_0, then at any later stage

$$\frac{\text{transverse dimension } (x)}{\text{meridional dimension } (y)} = \frac{x_0 b}{b_0} \Big/ \frac{y_0 v}{v_0} = \frac{x_0 b}{y_0 b_0} \cdot \frac{v_0}{v} \qquad (1)$$

The velocity v can be expressed in more essential variables as follows: Consider the volume E of cell wall material deposited in the unit of time onto the inner face of the cell wall between T and the cross section S (Fig. 3). This volume of cell wall material has to pass through the section S also in the unit of time. Since the area of this section is πbt, we obtain for the velocity $v = E/\pi bt$. Writing the initail values of the variables with the suffix $_0$, substitution in equation (1) yields

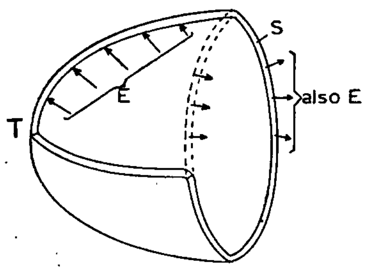

Fig. 3

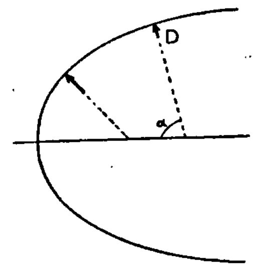

Fig. 4

$$\frac{\text{transverse dimension } (x)}{\text{meridional dimension } (y)} = \frac{x_0 b}{y_0 b_0} \cdot \frac{E_0}{\pi b_0 t_0} \Big/ \frac{E}{\pi bt} = \frac{x_0 E_0}{y_0 b_0^2 t_0} \cdot \frac{b^2 t}{E}$$

Now this means that the fibrils will retain their orientation throughout if b^2t/E is constant. With t constant, this will apply if the amount of cell wall material deposited between T and any section S is proportional to b^2, or, otherwise stated, if the quantities D deposited onto a unit area of the inner face of the cell wall are proportional to cos α (Fig. 4) (Compare Houwink and Roelofsen (1954), Fig. 16a. (This represents the probable way of growing of a root hair).

Obversely the change in fibril orientation observed in various plant cell walls may be explained either by a changing thickness of the cell wall ($t \neq t_0$) or by E/b^2 not having a constant value, or by both these causes. For instance, if t is constant, but E/b^2 increases from T towards the base of the growth zone, axial extension of the fibril layers will prevail (Compare Houwink and Roelofsen (1954), Fig. 16b and c). This may apply with cotton.

Reference

Houwink, A. L. and P. A. Roelofsen, 1954. Acta Botanica Neerlandica *3*: 385