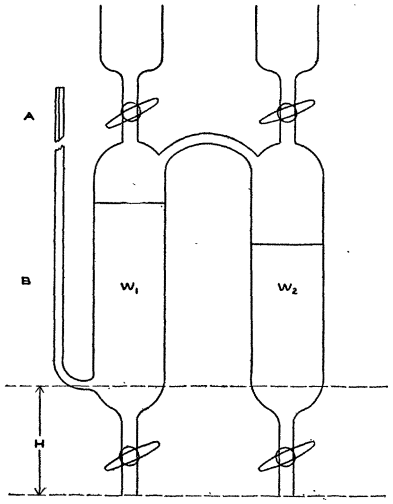

FIG. 1.

independent of density or viscosity is shown in Fig. 1. The system W_1, W_2 with the intervening air space acts as a balance so that if W_1 becomes momentarily lighter than W_2 owing to the liquid having run out faster, it necessarily slows up and W_2 speeds up until the weights are again equal. By the use of a side arm B the hydrostatic head is made equal to H until the level of W_2 reaches that point. It is preferable that the liquid in W_1 be the less viscous since air bubbles pass through it. W_1 may be used as a control liquid only and not one of those to be used for experimentation.

The rate of flow is governed by the capillary A. If the flow is to be varied a number of capillaries of different lengths or bore may be kept in hand so that by means of rubber connections the rate may be quickly changed.

Fig. 2 shows results of an experiment in which glycerine of specific gravity 1.25 and water at 1.0 and of viscosities 4.9 and 0.0089, respectively, were used as the liquids.

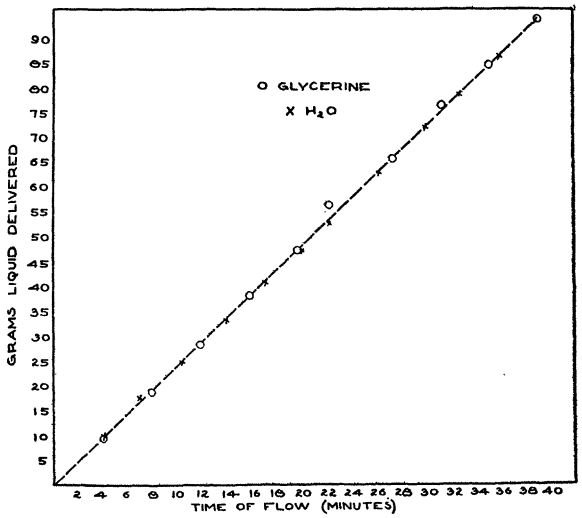

FIG. 2.

Obviously by similar air connections any number of added tubes containing liquids or solutions may be used. The rate of flow is not governed by either the shape or dimensions of the container, since it is dependent only on H and the capillary A. The same holds true for the temperature of the system above H so that the solutions may be at different temperatures and yet give equal rates of flow in weights per unit time.

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SPECIAL ARTICLES

THE SPIRAL GROWTH OF SINGLE CELLS

IT is clear that all cases of spiral growth or movement in organisms are not produced by the action of the same factors, even though it is possible in a general way to describe the twisted or helical forms of growth as due to the resolution of two growth vectors, one longitudinal and one rotational. Whatever may be the ultimate explanation of twisting of such complex structures as trees, it is exceedingly interesting that spiral structure is exhibited by so many single plant cells. The spiral layers of the walls of wood cells, the coiled chloroplasts of *Spirogyra*, the whole organization of the coenocytic cells of *Chara* and *Nitella* and the spiral growth of the fungus *Phycomyces* may be taken as examples. It remains to be shown, of course, whether the spiral form of multicellular plants is referable in some way to the spiral growth of their cellular components. At the moment the need is for an analysis of the cause of spiral growth in the simplest cells available.

The only living plant cell in which it has been possible to measure simultaneously growth and twisting about the long axis is the coenocytic spore-bearing cell of *Phycomyces*, where Oort[1] found at 17.5° C. an average rate of elongation of 39μ/min. and an average rate of rotation of 3.7° per minute. For cells of diameter 114μ, the angle which the main direction of growth makes with the longitudinal axis of the cell (therefore the inclination of the spiral, and the angle at which micellae are incorporated into the chitinous

[1] A. J. P. Oort, *Proc. Acad. Sci. Amsterdam*, 34: 564, 1931.

wall) is on the average about 6°. It has frequently been suggested[2,3,4] that the direction of protoplasmic streaming determines the orientation of spiral structure in the cell wall. Oort and Roelofsen[5] found that in the lower, non-growing part of the sporangiophore of *Phycomyces* spiral protoplasmic streaming indeed occurred, but were not able to observe oriented streaming at the actual zone where growth took place.

In an attempt to learn something about the nature of the "rotational vector" in the growth of cells of this type, the rates of elongation and of rotation of sporangiophores of *Phycomyces* were determined at 15° C. and at 25° C. The temperature coefficients for this interval were in 5 cases as follows: Q_{10} growth = 1.1, 1.1, 1.2, 1.6, 1.1; Q_{10} rotation = 2.5, 3.0, 2.4, 2.5, 1.6. Taken at their face value, these results indicate that the forces involved in twisting the cell have a significantly higher temperature coefficient than those concerned with its elongation. As a necessary consequence, moreover, the angle which the spiral makes with the long axis of the cell is greater at the higher temperature. For the five cells mentioned, the angles at 15° C. were 3.3°, 5.6°, 8.6°, 6.3° and 9.3°; at 25° C. these angles were, respectively, 10.8°, 15.6°, 15.6°, 11.6° and 11.1°. It is evident, therefore, that the steepness of the growth spiral is not structurally fixed, but that it can be (reversibly) altered by change of temperature. This supports the view that the spiral form of growth in these cells is indeed due to the resolution of two vectors.

Raising the temperature of the cells above 25° C. further increases the rate of rotation up to about 27.7° C. At this temperature rapid elongation of the cell continues, but rotation is greatly diminished in rate, frequently abolished altogether, or occasionally *reversed in direction*. No mention has been made so far of the direction of rotation. Oort[6] found that the majority of the cells grew upwards in the form of a "right-handed" spiral. This corresponds to what we call a left-handed thread on a screw. In the studies which are described here, most of the cells from a totally different stock of the same strain of fungus showed similar "right-handed" spiral growth.

The question as to what determines the direction of spiraling of cells or organisms is possibly a separate problem. It has frequently been approached by conducting a survey, sometimes extending into the cosmos, of the direction of spiraling found in nature.[7,8,9] Unfortunately, no satisfactory general explanation is forthcoming. The abolition of spiral growth or its reversal in *Phycomyces* by change of temperature suggests that relatively homely factors may control the direction as well as the magnitude of the process. The rapidity with which changes in the angle of spiraling may come about seems to argue against any interpretation in terms of altered proportions of different types of isomeric molecules. It is possible that the direction in which the protoplasm streams orients molecules which are being built into the wall,[10] and that at the higher temperatures the streaming protoplasm reaching the growing zone is not stably oriented. The suggestion that the rotational vector in spiral growth is streaming protoplasm is not intended to explain one unknown in terms of another: we know that there is movement and consequently force in protoplasmic streaming. If this idea were correct it would remain to discover what kinds of forces are at work in initiating and maintaining protoplasmic movement, but two problems would have been united. The experimental results briefly reported here show how relatively simple factors may profoundly modify the magnitude and direction of the rotational vector in spiral growth and suggest the value of experiments designed to test the rôle of protoplasmic streaming.

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EFFECT OF FLOWER PRODUCTION ON RATE OF GROWTH OF VEGETATIVE SHOOTS OF LONGLEAF PINE

WHILE working in a young stand (about 25 years old) of longleaf pine (*Pinus palustris* Miller) on April 8, 1931, I noticed a remarkable variation in the length of the terminal shoots. A close examination revealed that invariably those shoots which bore staminate strobili were short, while those which bore pistillate strobili or no strobili at all were quite long. The question suggested itself whether the production of the strobili may have had some influence on the rate of growth of the terminal shoots. Accordingly, 15 trees were numbered, and on each of these 10 to 20 terminal shoots were tagged with metal tags at different parts of the tree for a permanent record. The length of each shoot was measured from the base to the tip and the sex and number of strobili on each were recorded. On September 11 of the same year, the marked shoots were remeasured. The results appeared quite significant, suggesting a problem that has not yet received sufficient attention.

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