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FROST PLANTS: A RESUME.

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PROF. LESTER F. WARD'S observations on the "Frost Freaks of the Dittany," in the *Botanical Gazette* for April, 1893, obtain more than a passing interest, since the phenomenon recorded—ever but little noticed, and recently almost forgotten—illustrates one form of the action of the woody tissues, and the medullary rays, in the movements of water in the plant stem.

Since the article mentioned and the accompanying cut may not be accessible to all of the readers of *Science*, it may be pertinent to say that the frost phenomena of this and other plants consist principally of the formation of very thin sheets of crystals of ice on the sides of the stem near the ground. These crystals are attached only by one edge, and extend their length of several inches out into the air in a sinuous or scroll-like form. The interpretation of the facts affording this phenomenon seems to the author to be of such importance as to justify their presentation here.

The first observation recorded is that of Stephen Elliot, who "notices a remarkable protrusion of icy crystals from the stems *Couyza bifrons*" (now *Pluchea bifrons*). (1824. Sketch of the Botany of South Carolina and Georgia, Vol. 2, p. 322.)

Sir John F. Herschel notices a similar occurrence on the stalks of the thistle and heliotrope, in the *London and Edinburgh Philos phical Magazine* (1833. 3d series, Vol. 2, p. 110).

Prof. S. R. Rigaud notices the analogous formation of ice crystals on a newly-built stone wall, in the same journal (l. c. p. 190).

The frost freaks of the dittany were first noticed by Dr. Darlington in his "Flora Cestrica" (1837. p. 350). In his description of the *Cunila Mariana* (the dittany) he says: "In the beginning of winter, after a rain, very curious and fantastic ribands of ice may often be observed attached to the base of the stems of this plant, produced, I presume, by the moisture from the earth rising by capillary attraction, and then being gradually forced out horizontally through a slit by the process of freezing The same phenomenon has been noticed in other plants." Referring to Helianthemum Canadense, he says: "Prof. Eaton and Dr. Bigelow have noticed the formation, in freezing weather, of curiously curved ice crystals near the root of H. Canadense" (l. c. p. 314).

Prof. John Leconte made a study of the frost-phenomena of *Pluchea bifrons* and *P. camphorata Decand.*, in November and December, 1848, along the coast of South Carolina and Georgia. The results of his observations, and a consideration of the results of some of the preceding workers, are given in the Proceedings of the A. A. A. S. for 1850, under the title of "Observations on a Remarkable Exudation of Ice from the Stems of Vegetables, and a Singular Protrusion of Icy Columns from Certain Kinds of Earth During Frosty Weather."

The frost phenomena noted by these several observers on the various plants agree in their general features, and it is only necessary to present the conclusions reached by Leconte in his lengthy and detailed consideration of the subject. The points which appear to be well established are:

1. The ice crystals on any plant are in the form of sheets, one to five in number, about three or four inches in width, and extending one to five inches from the plant.
2. The crystals are attached in longitudinal lines, following the medullary rays, in the portion of the stem immediately above the ground, around which they are arranged symmetrically or unsymmetrically.
3. The crystals appear to have their origin at the outer surface of the fibro-vascular ring, and protrude through slits in the bark, which has been ruptured in their formation. If the bark is strong enough to resist this rupture, the ice extends around the plant in the form of a thin layer of ice between the wood and bark.
4. When the crystals did not extend into the woody ring, they might appear in the same position several days in succession: if, however, the crystals extended through the wood along the rays, the wood split apart in the freezing, and no more crystals could be formed at that place.
5. The stems had ceased growing and were in all stages, from almost green to entirely dead; in all cases the stems were more or less saturated with water. The phenomena is entirely physical: similar formations are exhibited by certain soils.
6. The crystals are formed in the greatest profusion immediately after rainfall, and at a temperature slightly below 30° F.

All of these conclusions are fully warranted by the facts recorded, but when Professor Leconte sought an explanation of the actual movement of water in the plant stem necessary for the formation of the crystals, he was, of course, limited by the somewhat crude knowledge of plant anatomy current at that time. His reasoning that plants to show frost phenomena must be annual and herbaceous is entirely at fault, since the very plants upon which he worked are described by many botanists as biennials, as well as Helianthemum, on which the phenomenon is most frequently noticed. Again, while herbaceous stems doubtless furnish these crystals in greater profusion, the stem of Helianthemum is very woody and hard, with a relatively small section of pith. He reasons that the water "is drawn upward through the highly porous pith, while the wedge-shaped medullary rays secure the mechanical conditions necessary for the projectile force in the proper direction."

Of course, the water is drawn upward through the vessels near the pith, and is conducted laterally by the medullary rays. That the fluid does take this course in the dead stems was proven by the author, by allowing them to absorb and carry up colored solutions. It appears that the water is taken up by the simple saturation of the roots from the charged soil, without the intervention of the special activity of the root hairs, as is shown by the fact that plants dug up and replanted, which

would destroy the larger number of the root hairs, still formed crystals as usual. Then root pressure must be entirely wanting, as well as osmotic activity in plants at this stage. Neither can the elevation of the water be due to "negative pressure," since the portion of the stem above the crystal-forming part may be split, or broken, or cut entirely away, without affecting the formation of the crystals.

Capillary force is the only means by which the water may be carried from the ground up through the plant to where it forms crystals. The constant absorption and evaporation by the dessicating tissues limit the region of saturation and confine the formation of crystals to the basal portion of the stems. The size and arrangement of the medullary cells favor the lateral conduction of the water by reason of their greater capillary power. The portion of water at the peripheral ends of the rays is frozen and in expanding is forced outward. The portions which replace it are in turn frozen, and the successive increments thus formed give the length and account for the perpendicular striations of the ice riband. This is suggested by Professor Leconte, though he compares the whole ray with the capillary pores of the soil in its action. A temperature of several degrees below freezing point is necessary to overcome the capillary force, and freeze the water in the rays, which results in the splitting of the stem.

So far as can be learned from an examination of the stems of the "frost plants," the only structural conditions necessary are large and numerous vessels, thin-walled medullary cells in a well marked ray, and a bark easily split longitudinally. The category of plants furnishing these conditions is by no means small. And it seems highly probable that frost phenomena may be exhibited by any of these plants which may pass through the death stage at the season affording the necessary conditions of temperature and moisture.

I am indebted to Prof. Lester F. Ward for some of the references given above, as well as for other helpful suggestions.

QUANTITATIVE COMPARISONS: A COMMON ERROR OF LANGUAGE.

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IN expressing the degrees in which any object—using the word in its broadest or metaphysical sense—possesses a certain attribute or characteristic there must be understood a unit of comparison or measurement. To be comprehensible, this unit must be subject to the associative law of mathematics; that is to say, if subtracted from itself the remainder must be nothing, or the zero of the scale of comparision, if added to itself the sum must be twice itself, and if from the unit—supposed positive—there be subtracted a quantity greater than itself, the remainder must be negative. These facts, which seem so axiomatic as to make their statement superfluous, are frequently overlooked even by some eminent speakers and writers.

If we say that A is twice as long as B, we make B the unit of comparison and affirm that the length of B is contained twice in that of A, or, no length being the zero of linear measurement, the length of B is one unit and that of A is two units. Similarly, if we say that A is three-halves longer than B we have:

Length A = length B + 3/2 length B = 5/2 length B;

and if A is three-halves shorter than B we have:

Length A = length B − 3/2 length B = − 1/2 length B.

Now such a negative can occur only as indicative of reversed direction or position relative to the zero, and when no direction or position is assumed as positive the negative, as well as its imaginary roots, expresses the impossible. For example, when we say it is twice as far from A to B as from A to C, we have no reference to the positions or directions of the lines A B and A C, but only to their relative lengths, and a negative expression under these conditions is impossible in any system of mathematics.

A photographer advertised that by an improved process he could take pictures thirty times quicker than by the old process. Here, if T is the time required by the old process and T′ the time required by the new process, we have:

$$T' = T - 30\,T = -29\,T;$$

the negative T being the algebraic expression for "less than no time." Granting the claim of the advertisement, it necessarilly follows that the passage of time could be stopped or reversed at our pleasure and the rapidity of its backward flight would be determined only by the number of photographs taken by the new process in a unit of time. Amateur photographers will doubtless be pleased to know that they have the fountain of eternal youth so easily within their reach! It is true, however, that if an arbitrary assumption be made in regard to the zero of the scale of "quickness" the claim of the advertisement may be verified. For example, if we agree to take one second, s, as the zero of measurements, all increments constituting slowness and all decrements quickness, Q, then if T = 59/60 s we have Q = 1/60 s and Q′ = 30/60 s, whence

$$T' = T - Q' = 29/60\ \text{s};$$

so that the time by the new process would be nearly half the time by the old process. But the "thirty times quicker" was doubtless intended to mean one-thirtieth of the time, and so was a notable example of an unsuccessful and absurd attempt to make a quantitative statement.

A more remarkable example, because it occurred in a carefully written essay by an eminent scientist describing a variable star, is as follows:

"On April 27 it had become invisible in the great telescope. It was then one hundred and sixty thousand times fainter than it was at the time of discovery."

Now it is evident what would be meant by saying that it was one hundred and sixty thousand times brighter at one time than another, because brightness is an essentially positive quality whose quantity is dependent upon if not proportional to the amount of luminous energy eminating from the body; but faintness is a negative quality expressing only the absence of brightness; hence if there was no lack of brightness in the star when discovered, faintness at any other time could not be expressed comparatively by using any positive factor however large.

Considering the quotation grammatically the star is said to be "fainter" in the comparative degree; hence it is evident that it was first faint in the positive degree, and since no unit of faintness is used in photometry we can only assume that the brightness of the star in its positive condition of faintness as observed at discovery is the unit of comparison; hence when it was one hundred and sixty thousand times fainter it must have been (160,000−1) times less bright than an invisible body—since the latter, without luminous energy, has no brightness and presumably one unit of faintness.

After the author of the statement quoted has shown that 160,000 times fainter is equivalent to 1/160,000 as bright, which is doubtless what he meant, I will show that a liability of $1.00 is the same thing as assets of $159,999.00; and such a blessed discovery for insolvent debtors and their creditors would have so many degrees of brightness as to quite outshine any variable star!