not fit down into the opening as far as it did initially. Thus, when potassium was added to the potassium-depleted mica and the mineral heated to 300°C to collapse the d_{001} to a minimum value, it was found that the d_{001} increased from 9.96 to 10.00 Å.

The implications of this relationship include the possibility of interpreting past history of micaceous minerals such as illite by careful measurements of the d_{001} values. For example, a value of 10.0 Å or greater for a mica might indicate that potassium had been removed to the point of producing a decrease in the *b*-dimension; subsequent resaturation with potassium in a new environment produces a mineral with a d_{001} value greater than that of the initial material (*13*).

ALLAN F. BURNS
JOE L. WHITE
Department of Agronomy, Purdue University, Lafayette, Indiana

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11. Delamica is a delaminated $2M_1$ muscovite obtained from English China Clays Lovering Pochin and Co., Ltd., St. Austell, Cornwall, England.
12. Silversheen mica is a $2M_1$ muscovite obtained from the Harwick Standard Chemical Co., Akron, Ohio.
13. This report is journal paper No. 2005 of the Purdue University Agricultural Experiment Station, Dept. of Agronomy, Lafayette, Ind. Supported by grant NSF G6063 from the National Science Foundation, made through the Purdue Research Foundation (PRF 2007).

25 October 1962

Lichens in a Greenhouse

Abstract. *The discovery of the first species of lichen capable of tolerating cultural conditions in greenhouses opens the possibility for conventional physiological experiments in this group of plants.*

In the temperate world greenhouses provide tropical habitats that are quickly infested with lower plants. Aside from the notorious cryptogamic pathogens that attack the greenhouse crops, an impressive array of saprophytic fungi, mosses, liverworts and algae of all sorts are the uninvited but usually harmless guests in all long-established greenhouses. Yet it has always been noteworthy that none of the some 20,000 known species of lichens seem to participate in this heterogeneous, synthetic flora. The lichen's apparent aversion for greenhouse life is doubly demonstrated by the regular failure of collected specimens to survive when brought inside for scientific or ornamental purposes. A vigorous and extensive growth in greenhouses—whether spontaneous or induced—has never been reported for any lichen species. Yet just such a development of one species can be seen in Paris.

This French lichen is crustose and grows over the plant debris used as a medium for culturing orchids in the two houses devoted to those plants in the Jardin des Plantes of the Muséum National d'Histoire Naturelle. It is always sterile and the thallus is whitish or pale green, disorganized in structure and mealy in texture, resembling coarse soredia. The hyphae are 2.5 to 4.0 μ in diameter. The algae are unicellular and globose; they measure 8 to 21 μ in diameter, and they belong to the genus *Trebouxia* (*1*). The general habit of the lichen resembles that of the imperfect species *Lepraria aeruginosa* (Wigg.) Sm., which is common in western Europe. But apparently the species in the greenhouse in Paris should neither be identified with this *Lepraria* nor indeed with any other of the common imperfect lichens of Europe. The notion that it might be one of these species can almost surely be ruled out, both because this lichen produces the depsides atranorin and stictic acid (*2*) and because it seems to be restricted to the greenhouses in Paris. The common European imperfect lichens have not been reported to elaborate these substances (although it must be admitted little at all is known of their chemistry). Furthermore, if it were simply a question of a local species that "came indoors," it should occur in greenhouses in many places in Europe, while in reality it appears to be unknown outside the conservatories of the Muséum National. A more plausible explanation is that it is a tropical imperfect species (or in any event a tropical species that does not fruit under these greenhouse conditions) that was accidentally introduced with the orchids themselves and that has since flourished in its new home (*3*).

Emile Manguin, director emeritus of the greenhouses of the Muséum National, told me that to his knowledge the lichen has been present there for at least 30 years. It grows in hundreds of pots over the mixture of polypody (*Polypodium vulgare*) fiber and various species of mosses used as a culture medium for the orchids. The growth rate is apparently rapid, at least from the lichenological point of view, since the lichen must be scraped off the surface of the medium about every 6 months. It is removed because it prevents the gardeners from telling when the plants need watering and not because it directly harms the orchids. And it might be added that the lichen also withstands both the extremely calcareous water of Paris as well as the badly contaminated atmosphere of the center of the city.

The real importance of the discovery of the spontaneous occurrence of lichens in glass houses, however, goes far beyond its mere immediate botanical curiosity. Experiments in the biology of the lichens have never progressed very far because most isolated fungal components are hard to culture and because attempts to grow the complete lichen in greenhouses and growth chambers have all failed. But it would appear that at last the perfect experimental subject has been found. And to increase the subject's attractiveness, it produces two substances, atranorin and stictic acid, which could well be called typical of that odd group of natural products —the extracellular, water-insoluble lichen constituents or "lichen acids"— that are almost entirely restricted to the lichens (*4*). In recent years the lichen substances have been used more and more as taxonomic criteria in the classification of this group of plants, and of course many critical questions about their suitability as such criteria have been raised (*5*). Lichenologists have regretted that they could not conduct experiments to determine the extent to which the environment affects (or does not affect) the qualitative and quantitative production of these unique compounds. But the substances produced by the modest lichen growing in Paris must surely be elaborated along the same biochemical pathways and subject to the same environmental influences as these substances are when they are produced in such well-known, conspicuous, and highly evolved genera as *Cladonia, Parmelia* and *Usnea.* Perhaps the lichenologist can at last solve some of his puzzles by studying this little French weed that finds the greenhouse so congenial (*6*).

WILLIAM LOUIS CULBERSON
Department of Botany, Duke University, Durham, North Carolina

References and Notes

1. The generic identification of the algal component was made by Dr. Vernon Ahmadjian of Clark University.
2. The microchemical and chromatographic determinations of these substances were made by Dr. Chicita F. Culberson, Lichen Chemistry Laboratory, Duke University.
3. Most of the specimens of orchids in this collection were gathered in the former French colonies and sent to Paris for culture rather than being propagated in France.
4. Book-length summary: Y. Asahina and S. Shibata, *Chemistry of Lichen Substances* (Japan Society for the Promotion of Science, Tokyo, 1954).
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6. The observations reported here were made while I held a grant from the National Science Foundation.

29 October 1962

Spiral Flow in Rivers, Shallow Seas, Dust Devils, and Models

Abstract. *Spiral flow has been observed in meandering rivers, braided rivers, very shallow sea water, model experiments, and dust devils. Experimental work also produced standing spiral waves and spouts of water. Many observed spirals reversed direction from time to time. Geometry of the system, roughness, and turbulence are perhaps dominant in the control of spiral flow.*

Spiral flow, a common phenomenon in fluid motion, has been somewhat neglected, perhaps because it is not easily observed. The purpose of this note is to call attention to a wide range of situations where spiral flow has been reported.

Leliavsky (*1*) has summarized the findings of several workers who have related spiral flow to stream meandering. Einstein and Harder (*2*) described a circulatory motion in stream bends, in which the surface water tends to move toward the outside (concave) bank and the bottom water tends to move toward the inside (convex) bank. I have performed a series of model experiments (*3*) which appear to establish a sequence as follows: roughness, turbulence, spiraling, meandering. I have, moreover, observed the same general circulation patterns in small- to medium-sized natural rivers. This sequence is thought to apply also to oceanic currents such as the Gulf Stream, and to atmospheric currents such as the jet stream, except that in atmospheric currents roughness is not necessary to produce turbulence.

Hugh Casey (see *4*) produced several simultaneous adjacent spiral cells in a relatively wide, shallow experimental flume. One of these spiral cells was primary, inducing the formation of two immediately next to it, which in turn induced two others. Van Straaten (*5*) described ripple-mark-like features which may have been formed in the same way as the long, parallel ridges left by the scouring action of Casey's multiple spirals. Stokes (*6*) reported similar ridges ("rib and furrow") from lithified sediments. I have observed the same phenomenon on modern tidal flats and in various shallow-water currents (*7*). Jordan's large symmetrical sand waves may have had a similar origin (*8*). Bagnold (*9*) described a similar mechanism in connection with the growth and dissipation of sand dunes or ridges.

Some of the experiments (*3*) already referred to resulted in distinctive stream sedimentation. This finding led to the conclusion that multiple spiral cells, if large enough, create a complex of more-or-less diamond-shaped bars which, taken together, make the braided pattern. Bars of this type formed where several conditions were maintained: ample bed material of sand size; great mobility of bed material (that is, in rivers, very little clay to act as a binding agent), and therefore high width-depth ratios; and proper size of the system (widths of about 1 m to 1 or more km). Smaller systems carrying silt were also braided. Where materials were mobile and coherent (rather than mobile and loose) and abundant, and the system was large, meandering resulted. Where materials were abundant, mobile, and coherent and the system was small, "rib and furrow" or "spiral flow" ridges resulted. Where mobile bed materials were not abundant but roughness was much the same throughout and walls were rigidly fixed, a system of standing waves arose. The use of tracers made verification of spiral flow possible.

Kennedy and Fulton (*10*) have described a series of experiments in which helical overturn seems to be related to water depth.

If a large tub, filled with water, is allowed to stand and then is drained from the bottom, a helix develops in the drain, as is well known. Theoretically this helix should rotate according to the Coriolis principle (Ferrel's law), hence in a single direction. If the tub is large enough, this result can be obtained. With smaller tubs (that is, 1 m across), a helix appears in the drain but its directional properties do not relate clearly to the earth's rotation. In several hundred trials recorded, all in the United States, the rotation was counterclockwise in 58 percent of the trials, clockwise in 42 percent. These figures are not, however, stable; at one time late in the series of experiments the ratio of the percentages was almost 1 : 1. More interesting was the fact that, with a single tub, about 10 percent of the trials produced no spiral; about 25 percent produced one spiral, about 25 percent two and about 25 percent three successive spirals, and about 5 percent four, about 5 percent five, and about 5 percent six successive spirals. These successive helices could be distinguished from each other by the fact that, except in about 2 percent of the instances, the direction was reversed from one spiral to the next. The tentative conclusion drawn was that bottom roughness, turbulence, and width-depth ratios controlled the spirals. Sibulkin (*11*) has also described reversals in the bathtub vortex.

A series of seven dust devils (whirlwinds), which I sighted quite by accident during field work one dry summer, passed close enough for me to determine rotation directions with certainty. Of these, two showed counterclockwise rotation and four showed clockwise rotation. The seventh passed directly overhead, picking up paper trash in large quantities so that detailed air-current directions could be noted. As it approached, it changed direction from counterclockwise to clockwise; it reversed direction once again before passing out of sight. For the seven dust devils, clockwise rotation was observed in five instances, counterclockwise rotation in four.

The reversing dust devil altered only one obvious feature: ground roughness, in the form of trees and houses. It is concluded, tentatively, that roughness was responsible for the reversals. These events were reported formally at the national meeting of the Ameri-