IV.—*On the Crystals in the Testa and Pericarp of several Orders of Plants, and in other parts of the order Leguminosæ.*

By George Gulliver, F.R.S.

Plate XLIV.

Sect. I.—Crystals in the Testa and Pericarp.*

Interest of these Crystals.—Microscopists have of late been so much interested by the markings on the surface of seeds, that for specimens of them we see many advertisements; and, indeed, these pretty and attractive objects are now familiarly known and much prized for the microscopic cabinet. But their value might be much increased were the examination of them carried a little deeper into the texture of the seed-coat and extended to its immediate coverings; and the present notice is intended to show that the crystals which constantly abound in one or other of these parts in many plants, and are as constantly absent from the same parts in numerous other plants, afford really beautiful microscopic objects, which may prove good characters in systematic botany. Some of them, too, have the advantage of being easily prepared and preserved, as anyone may learn in the gooseberry, elm, black bryony, and the geraniums.

The inquiry concerning the distribution of the crystals may afford, also, additional means of illustrating the life history of plants, still so miserably defective in our books of descriptive botany; and no doubt when these crystals have been sufficiently studied they will supply instructive characters. We may expect that those botanists who will not undertake the inquiry may contemn it by the general and true remark that such crystals occur in numberless plants; but this is no answer to the particular and rational question as to the orders or species which are or are not characterized by certain saline crystals in the fruit or other parts of

EXPLANATION OF PLATE XLIV.

All the objects are drawn to the scale of which each division represents $\frac{1}{4000}$th of an English inch.

Figs. 1, 2, 3, and 7.—Crystals in the pericarp and testa: Fig. 1, in the pericarp of *Geranium Robertianum;* Fig. 2, in the testa of the same; Fig. 3, in the pericarp of *Geranium phæum;* Fig. 7, four crystals from the testa of *Tamus communis.*

Fig. 4.—Crystals in the sutural margin of the pod of *Lathyrus odoratus.*

„ 5.—Crystalline fibres from the leaf of *Mimosa pudica.*

„ 6.—Crystalline fibre from the leaf of *Phaseolus multiflorus.*

„ 8.—Crystalline tissue in the membranous part between the nerves of the calyx of *Trifolium pratense.*

„ 9.—Crystals in the nerve of the same calyx.

„ 10.—Four chains of crystals in the liber of *Mimosa pudica* with a row of five parenchyma-cells to the right.

* Read to the last meeting of the British Association at Bradford.

the plant. Many of the raphides and different forms are figured, after my old and extensive researches, in 'Science Gossip' for May, 1873. In the 'Quarterly Journal of Microscopical Science,' July, 1873, I have given an engraving of the crystals in the testa of the elm; and now is to be added a notice of similar crystals in the same part or its covering of other plants.

How to find the Crystals.—These crystals are most easily found in the seed-coat or pericarp, while it is yet somewhat soft and transparent before it acquires hardness and opacity by perfect ripeness. The thinnest possible sections are to be placed in a drop of water or glycerine on the object-plate, and firmly pressed down by the glass cover. Thus they may be examined first with an objective of half an inch focal length, and afterwards with deeper powers from $\frac{1}{8}$th to $\frac{1}{16}$th. This last will probably not work through glass covers of common thinness, but it may act satisfactorily when the focus is lengthened and the power increased by the immersion front. Another and easier plan, often very successful and always useful, is to mash up or comminute minute and thin fragments, by the point of a penknife, in a drop of fluid on the object-plate, by which means, and the aid of needles, some very suitable bits may be so divided and flattened as to show the crystals admirably.

Distribution and Size of the Crystals.—They occur regularly and constantly in the testa or pericarp of many plants, as I have witnessed, for example, in the orders Tiliaceæ, Aceraceæ (*Acer campestre* and *A. pseudo-platanus*), Geraniaceæ (Pelargonium, *Geranium phœum*, *G. pyreniacum*, *G. dissectum*, and *G. Robertianum*), Grossulariaceæ (*Ribes grossularia* and *R. rubrum*), Primulaceæ (*Anagallis arvensis*), Ulmaceæ (*Ulmus suberosa*), Dioscoreaceæ (*Tamus communis*), and some others. No doubt numerous additions to this list will be made by future observers. But though in the testa or pericarp of certain species of divers orders these crystals are constantly present, they are as regularly absent from other orders. Thus I have not yet found the like crystals in the testa of Umbelliferæ, Leguminosæ, and many other sections of the British flora; and yet similar crystals abound in the pod and other parts of leguminous plants. The crystals in the testa or ovary of Compositæ I have figured in the number of 'Science Gossip' above cited.

Though the crystals are often plainly seen, they are not always easily found. In the horned poppy they are obscure and only about $\frac{1}{8000}$th of an inch in diameter; and in the maple and sycamore the crystals often occur in isolated patches, or so scantily as to escape notice. The crystals in the gooseberry and the elm are about $\frac{1}{3000}$th of an inch in diameter, and so very distinctly and regularly studded, each within a plain cell, throughout the testa as to present an appearance of crystalline tissues, forming very pretty microscopic spectacles; while in the red currant the crystals are scarcely half the size, and by no means readily distinguishable. In the black bryony (Plate XLIV., Fig. 7) they are beautiful and large, about $\frac{1}{1500}$th of an inch in diameter, thickly set at regular distances throughout the testa. And as this plant, like other Dioscoreaceæ, abounds in true raphides, it affords a good instance of their occurrence with other saline crystals in the very same species. So, too, raphides and long crystal prisms may occur in single plants of certain Pontederaceæ and Liliaceæ; and the short prismatic crystals (Plate XLIV., Figs. 1, 2, and 3) in the fruit of Geraniaceæ are very different forms from the sphæraphides which are so common in the calyx of the same order. Many similar examples to the same effect are recorded in my former memoirs on plant-crystals.

It is hoped that this communication may induce microscopical observers, both neophytes and experts, to pay some attention to a branch of phytotomy which has been too much neglected. The pursuit might prove pleasing and instructive, as well to those who are so frequently inquiring for "good microscopic materials," as to botanists with the higher aim of expounding the life-history and natural characters of the manifold members of the vegetable kingdom.

Sect. II.—Crystals in Leguminosæ.*

Name of the Crystals.—As they mostly belong to one or more of the prismatic systems, and are seldom twice the length of their breadth, we may provisionally call them *short prismatic crystals*, some specific term being needful to distinguish them from raphides, and from the other long or acicular forms which I have always called crystal prisms. It should be borne in mind that raphides, regularly having rounded shafts and tips, have not the figure of prisms; that the long crystal prisms, on the contrary, though often as thin as raphides, have distinct faces and angles; and that the objects now to be described under the name of *short* prismatic crystals are very different in shape from either raphides, long crystal prisms, or sphæraphides.

How to find the Short Prismatic Crystals.—This may be done after the manner recommended in Sect. I. Of Leguminous plants the novice may commence his examinations in the leaves of the common white or Dutch clover, or of *Mimosa pudica*, and the young pods of the garden pea (*Pisum sativum*); taking care to look especially at the fibro-vascular bundles, alongside of which the crystals occur abundantly in strings of cells. To facilitate their exposure those bundles may be dissected from the surrounding parts, and then cut or scraped into thin shavings, or mashed into fragments, in a drop

* The substance of this section was orally communicated, with drawings, and extemporaneous demonstrations in the fresh plants, to the East Kent Natural History Society, Oct. 2, 1873.

of water or glycerine on the object-plate. Thus the crystals will be quickly and easily found; and in the fibrous bundles of the sutures of the green pea-pod, they may often be detached by comminution of the part from their seat, so as to be made to roll over and display their forms in the microscopic field of vision. Not so in the tough inner skin of the pod-valve of this plant, among the fibres of which the crystals are thickly studded, and so firmly fixed in and hidden by this dense tissue, as not to be easily seen therein or detached therefrom. But by drying it, and then scraping it with a knife in a drop of turpentine, the texture is made more transparent, and some of the crystals may be found floating freely and separately around; and indeed plant-crystals, often but dimly seen through thin fragments of the tissue in water, occasionally in the dry state become plainly visible when treated with turpentine or oil of cloves. Other means of detaching the crystals from, or exposing them in, their seat will, of course, be tried by the practical phytotomist; and to this end boiling in water or in a strong solution of caustic potass will frequently prove more or less efficacious. The alkali sometimes facilitates the separation or isolation of the tissues or cells, so as to show them very advantageously. For example, by this treatment two layers may be plainly demonstrated in the seed-coat of Tamus; one layer composed of parallel fibres about $\frac{1}{2000}$th of an inch in diameter; and another layer of roundish or polygonal cells, each containing one of the crystals (Plate XLIV., Fig. 7). And of these may be made and easily preserved novel and beautiful microscopic preparations.

Composition of the Crystals.—They appear to consist chiefly of oxalate of lime. In none of many trials did the crystals dissolve with effervescence in acids; though the carbonate of that earth is not uncommon as the main constituent of plant-crystals, as I infer from the experiments I have made on the rhombohedral or some such forms in Cactaceæ, and on the sphæraphides which are often either abundant or deficient in the leaves of Urtica. It is well known that the leaves of Bryonia are studded with scabrous tubercles, and to be regretted that of the intimate nature of these no information is given in the books of descriptive botany. Each of these "asperities" or "callous points" is about $\frac{1}{114}$th of an inch in diameter, and composed of many smooth, hyaline, round, or oval granules, the mean size of which is about $\frac{1}{666}$th of an inch; and they are soluble with brisk effervescence in dilute acids.

Form, Size, and Situation of the Crystals.—In the leaves and other parts of Leguminosæ the crystals are much of the same size and shape as already described in the testa of many other orders. But the figure and size are so variable, even in one plant, as to defy precise and intelligible definition. The mean diameter of the crystals is about $\frac{1}{3000}$th of an inch; and in the garden pea they run much larger. As to form, they are both simple and compound; they generally belong to one or other of the prismatic systems, and among them may be seen rhombs, cubes, tetrahedrons, lozenge-shapes, parallelopipeds, and hexagonal prisms. The crystals are often hemiedral or unsymmetrical, and indeed as frequently so irregular in outline as to present it curved or broken, quite unlike that of a regular saline crystal, and resembling a starch granule, or contracted at the sides like a dice-box, or, more rarely, bulging there like a rolling-pin or skittle. Such forms, by the tests of acids and iodine, are easily distinguishable from starch; and none of them are ever so elongated as the objects which, under the name of crystal prisms, I have long since distinguished from raphides. In Leguminosæ the crystals are commonly in strings of cells, with one crystal, rarely two or more, in the centre of each cell; and thus is formed a system of crystalline fibres, running parallel, as already mentioned, to the fibro-vascular bundles (Plate XLIV., Figs. 4, 5, and 6). But not always thus; for in many instances the crystals are regularly dotted throughout a membranous part, as may be well seen, for example, between the nerves of the calyx of Trifolium (Plate XLIV., Fig. 8), and so presenting a pretty form of a crystalline tissue.

Confusion of Terms and Vagueness of Knowledge.—So common are minute crystals of one form or other in flowering plants, as to have arrested the attention of the earlier observers; but the knowledge we at present possess of the distribution in the vegetable kingdom of the crystals depicted in Plate XLIV., is still but little in advance of what it was at the time of Schleiden's 'Scientific Botany.' This frequent presence of such crystals in one or other part of numerous widely different orders of plants, and the still further confusion arising from the misuse of terms, has made more difficult the discovery of any rule concerning the occurrence of any special form of crystals in particular parts of the frame of the species of the manifold vegetable genera or orders. All microscopic crystals in them, of what form soever, were confused together, under the name of raphides, up to the advent of my researches; and are still too often so confounded, to the obstruction of botanical science, even by some of the most eminent botanists. Thus, in the latest edition of Henfrey's 'Course of Botany,' the subject is perfunctorily and erroneously treated; and in the recent and much-esteemed 'Treasury of Botany' there is no notice whatever of either crystal prisms or sphæraphides, and only the word raphides occurs, with this definition: "Crystals of various salts formed in the interior of plants by the combination of vegetable acids with alkaline bases." Thus we still have sad work in books of high pretensions; and the more so as there is to be found in older and popular dictionaries, making no point of botany, shorter and more accurate definitions, as may be seen, for example, in Ogilvie's edition, published in 1859, of 'Webster's English Dictionary.' Perhaps some knowledge of the subject may become popular, now that it has been illustrated by figures in 'Science Gossip' for May, 1873. But very little seems to be known about the short prismatic crystals; for, in the last July 'Quarterly Journal of Microscopical Science,' we find Professor McNab, of Dublin, announcing the discovery, in Germany, of "numerous crystals of calcium oxalate in the bracts of Medicago, Trigonella, and Pocockia."

The Short Prismatic Crystals in Leguminosæ.—But these crystals, so far from being confined to those plants, and still less to their bracts, commonly occur abundantly in the calyces, leaves, bracts, pods, and other parts of numerous species of the order. I have found the crystals thus in Medicago, Melilotus, Trifolium, Lathyrus, Pisum, Vicia, Onobrychis, Phaseolus, Mimosa, Chorozema, Robinia, and many other members of the same order. In these the crystals were always present; but not so in a few examinations made of some species of a few more genera, including Ulex, Genista, Lotus, and Acacia, in which the crystals were either very scanty or wanting. In the leaves of Wistaria I found sphæraphides with the short prismatic crystals. Thus, so far as these researches have gone, it appears that these last-named crystals are very beautiful, and common, but not universal, in leguminous plants.

Multitude of these Crystals.—In the course of these examinations, a remarkable abundance of starch in the trefoils, and in the other leguminous plants which are most relished by ruminant and other animals, was so apparent as to arrest the attention. But the quantity of the short prismatic crystals was a much greater novelty and surprise. In a bit, only $\frac{1}{70}$th of an inch in length, of the midrib of a leaflet of clover, I have counted ten chains, each containing twenty-five of the crystals; and thus, there being 250 of them in view in that $\frac{1}{70}$th of an inch of the midrib, an inch thereof would contain no less than 17,500 of the crystals, without reckoning the number in its branches and in the two other leaflets, or elsewhere. And, by a like observation, no less than 21,000 of the crystals were reckoned in one inch of the sutural margin of a single valve of one pea-pod; so that, multiplying this number by 12, the average length of each of the four separate sutural margins of the full-grown pod being three inches, we have in those sutures alone the amazing number of 252,000 of the crystals!

Significance of these Crystals.—Professor Rollestone has somewhere made a remark to the effect that structures which, from their minuteness, or obscurity of function, appear insignificant or useless, may in reality rise in connection with this fact into the more importance. Here we have crystals in cells, organized structures of great beauty, regularity and constancy, and moreover most marvellously numerous in the plant. And will any physiologist now maintain, as often has been maintained, that such structures are mere freaks of nature, of no relation to or value in the life and use of the species? Though we cannot at present see the full meaning, some partial gleams of it may appear, and prove good suggestions for future researches. Probably the earthy salts, stored as we have seen in various parts of the plant, may be needful for the preservation of the fertility of the earth, by being regularly restored to it in the fallen leaves. And when we consider the importance of lime in the economy of animals, we may well admire this one of several sources by which, as we now see, nature has so abundantly provided this earth in that very provender on which many animals greedily feed. Has any chemist ever determined the percentage of lime, and starch and its derivatives, in the leguminous plants used as fodder for ruminant and other animals, and the relation of such constituents to the value of such food? What are their absolute and relative quantities in a truss of clover or saintfoin? Surely questions of this rational sort will have to be solved, sooner or later, in the interest of scientific agriculture. Though the present is but a very fragmentary contribution to the life history of the vast order of leguminous plants, it is novel, and may, when further extended, lead to curious and useful results. We can now perceive some of the significance of these crystals. But why they should be constantly present in certain parts of the structure of one plant or group of plants, and as regularly absent from the same parts of others; why, instead of the form of shapeless precipitates, the lime should occur in crystals within beautifully-organized cells, arranged with exquisite regularity, we can nowise understand. Here science is still in complete darkness, utterly unable to see the cause of these phenomena. And if so as regards such lowly objects, we may derive from them—and their number is legion—lessons of humility, which should not be without use to those philosophers who believe themselves able to unveil, by mere physical inquiries, the mysteries of the highest creation.