X. *On Craterostigma pumilum, Hochst., a rare Plant from Somali-Land. By*
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(Plates XXXIV. & XXXV.)

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IN May 1897 a number of living plants collected in Somali-Land were received at the Cambridge Botanic Garden from Mrs. Lort Phillips, who presented them to this University. Among these was the following, and as it has flowered several times with us this summer, and has now (July 1898) ripened its first capsule of seeds *, we are able to give a fairly complete account of it even from the comparatively small quantity of material at our disposal.

It is a herbaceous perennial, the general habit, size, and mode of flowering of which remind one of a *Pinguicula*, though it is very different in details, as will be shown (Pl. XXXIV. fig. 1): but perhaps its most striking feature is the roots, to which our attention was drawn by Mr. Lynch long before the plant flowered; these are bright coral-red or scarlet, like vermilion sealing-wax, and present a startling contrast to the black soil used when repotting the plants.

Various suggestions have been entertained as to the best mode of growing the plant; on the whole it seems to do best in the Water-lily House, close to the glass.

The external features of the adult flowering plant may be described as follows:—

Roots numerous, fibrous, rather thick, and slightly branched, arising from the under-side of the rhizome and the bases of older leaves; white when young, the older ones scarlet with white tips. (Figs. 1 & 2, Pl. XXXIV.)

Stem a short, red, oblique or horizontal, creeping, subterranean rhizome, giving off roots below and rough with crowded leaf-scars above. It is terminated by a rosette of leaves at the surface of the ground, and gives off similar rosettes as lateral buds or offsets from the axils of the lowermost leaves. These offsets afford a ready means of vegetative propagation, soon forming rhizomes $\frac{1}{2}$ to 1 inch long, like the parent stem. (Fig. 2.)

Leaves few, simple, entire, exstipulate, sub-opposite, and crowded into radical rosettes, the internodes being practically obsolete. Lamina rhomboid-oval, and often slightly oblique, obtuse, about 1–1½ inches long; tapering below into a short, broad, flat petiole with a wide insertion, but not sheathing. Margins ciliate, especially when young. Venation somewhat like that of *Plantago*; principal ribs about 7 to 9, thick and

* These have now germinated (March 1899).

prominent beneath, longitudinal and nearly parallel, but converging above and below, and running close together down the petiole, where they are red; smaller veins numerous and reticulate, but sunk and hardly visible in the thick, almost fleshy, lamina. Upper surface of lamina bright green, glabrous, and minutely punctate; lower paler green, finely pilose, streaked with red at the base.

Flowers complete, hermaphrodite, zygomorphic, and solitary, each on an axillary scape; peduncle about $1\frac{1}{2}$ to 2 inches long, leafless, cylindrical, stiff, and erect.

Calyx regular, tubular-campanulate, erect and persistent, about $\frac{1}{4}$ inch long, 5-toothed and slightly 5-ribbed, shortly pilose; the teeth obtuse ciliate. Not winged or appreciably plicate. (Fig. 12, Pl. XXXIV.)

Corolla gamopetalous, hypogynous, bilabiate. Tube erect, blue, half as long again as the calyx; limb obliquely horizontal, and consisting of a large, patent, flat, equally three-lobed lower lip, white with blue patches and veins, and a much smaller oblong upper lip, scarcely notched at the tip. Æstivation imbricate, the upper lip external, the right-hand lobe of the lower lip internal and overlapped by the median and left-hand lobes; tube not folded. (Figs. 4-7.)

Stamens 4, didynamous, and with no trace of a fifth; inserted at the throat. The anterior pair longer, their free, white, straight, slender filaments converging forward and upward, and each springing at an acute angle from a yellow, prominent, cushion-like, basal insertion running obliquely across the base of the lower lip and nearly meeting its fellow (figs. 8 & 9); each stamen thus bears a curious resemblance to the leg of an insect. The posterior pair just within the tube, with much shorter filaments inserted directly into the base of the upper lip and converging forwards. Anthers of each pair somewhat connivent, two-lobed and two-celled, and dehiscing by longitudinal slits. Pollen simple.

Ovary superior, of two antero-posterior carpels, two-celled, the posterior chamber the larger; ovoid and completely enclosed in the tube; terminating in a long, thin, exserted style, expanding above to a two-lipped stigma, irritable to contact. (Figs. 6 & 7.) Placentation axile. Ovules small, numerous, anatropous. (Fig. 10.)

Fruit a capsule, cylindric-ovoid, twice the length of the calyx, which it distends and partially splits. Dehiscence septicidal and septicfragal, by two vertical valves. (Fig. 12.)

Seeds small, numerous, brown, pitted. Embryo straight, or nearly so, in the axis of a cartilaginous endosperm stored with aleurone. (Figs. 13 & 14.)

The germination is epigeal, the slender hypocotyl carrying the two small oval cotyledons some millimetres above the soil. The first pair of leaves are minute and opposite, and bear numerous hyaline hairs. The red colour appears in the primary roots when only 10-15 mm. long.

The habit and inflorescence of the plant have striking superficial resemblances to those of a *Pinguicula*; the venation is somewhat like that of a *Plantago*, while the corolla reminds one of some *Lobelias*, and the two-lipped stigma of that of a *Mimulus*.

Analysis of the above characters clearly places this plant in Scrophulariaceæ, and in the tribe Gratioleæ of the Antirrhinoideæ. This tribe contains a good many genera and numerous species of tropical and sub-tropical plants; and among these is the small genus

Craterostigma, founded by Hochstetter ('Flora,' Jahrg. xxiv. p. 668) in 1841 on the two Abyssinian plants *C. plantagineum* and *C. pumilum*, and it is with the latter that our plant agrees.

Of the three or four species comprised in *Craterostigma*, only one has the flowers solitary, viz. *C. pumilum*, Hochst., and it comes from Abyssinia or Somali-Land.

On reference to the Kew Herbarium we found that *Craterostigma pumilum*, Hochst., has inflorescences which are usually branched and bear about three to five flowers with bracts—an umbellate cyme apparently; but on the same sheet is a specimen with single flowers marked *Torenia auriculæfolia*, Domb., and the closest examination shows no other differences between it and the several-flowered *Craterostigma pumilum*, Hochst., and leads to the conviction that the Kew authorities are right in merging Dombrain's plant in Hochstetter's species. Moreover, there can be no doubt that Dombrain's plant is the same as ours, especially after consulting his figure in 'The Floral Magazine,' 1871, p. 534; but as he gives no botanical description and no figure or mention of the red roots or details, we think it worth while to offer our results.

On the same Kew sheet also there are some multi-flowered specimens collected by Mrs. Lort Phillips, and all the specimens on this sheet show by the red stains that the roots were coloured as in our specimen. The same is true of *C. plantagineum*, Hochst., a much more hairy form, evidently very close to *C. pumilum*, and coming from the same region. The dried herbarium specimens of *C. pumilum* also look more hairy than our fresh plant.

The question arises whether the single-flowered (*auriculæfolium*) form is a constant variety of *C. pumilum*, or merely a more poorly-grown plant: some of the Kew specimens with several flowers are as small as the one-flowered form. We have been unable to detect any bracts on the inflorescence of our Cambridge plant, and Dombrain's figure shows no traces of them.

INTERNAL STRUCTURE.

Root.—A transverse section through the root (Pl. XXXIV. fig. 15) shows the usual structure of a central stele surrounded by cortex. The cortical cells are arranged with great regularity in radial rows, and between them are equally symmetrical inter-cellular spaces, which, in section, are of quadrangular form, and contain a peculiar red colouring-matter. The spaces are in many cases almost as large as the cells, and generally occur throughout the cortex, but are absent from the piliferous layer and the cells immediately internal to it.

When highly magnified (Pl. XXXV. fig. 16) the spaces are seen to be due to the splitting of the middle lamella at the points where four cells would be in contact. Where the walls of adjacent cells are united one to another they are flat, but where they limit a space they project into it, so that, in transverse section, the cells approximate to the form of a square with rounded angles, while the spaces are quadrangular with convex walls. On account of the regularity of the arrangement of the cells, the spaces between them are also very uniform in shape and size.

In thick sections, less highly magnified, the colouring-matter appears to be lying freely in the spaces; but on closer examination it is seen to consist of minute rounded granules or drops, closely packed on the outer walls of the cells to which they are attached.

The cells of the piliferous layer are thin-walled, with the exception of a few of rather smaller size in which the outer wall is thickened (Pl. XXXV. fig. 18). On most of the roots there are extremely few root-hairs.

A radial longitudinal section shows that the intercellular spaces form passages bounded by cells which appear to lie in rows and to have a more or less moniliform outline (Pl. XXXV. fig. 18).

In oblique tangential sections the spaces between the cells in one plane appear to alternate with those separating the cells which lie immediately below. In such a section the colour is seen lying on the surfaces of the walls, and the large amount of it is very striking.

The colouring-matter is not present between the two outer rows of cells, even where the cells of the piliferous layer and that immediately within it are not in uninterrupted contact with one another.

It has been said (p. 343) that the ends of the larger roots and of some of the smaller ones are colourless. A longitudinal section in this region shows that, although the spaces are continuous almost to the apex, the red granules usually end some distance behind the tip, in most cases suddenly. Near the end of some roots the colour is present in patches separated from one another by areas free from granules.

The cells of the cortex in the root contain considerable numbers of colourless bodies, which are evidently leucoplasts (leucolecites). With iodine they become purple owing to the presence of starch, and are therefore to be regarded as amyloplasts.

If a plant be taken out of the ground and placed in water with its roots exposed to the action of light, the leucoplasts become green, *i. e.* they are changed into chloroplasts (chlorolecites).

The Stele.—There is nothing specially noteworthy, as departing from ordinary types, in the stele. In the centre are thick-walled sclerenchymatous fibres, in many cases still retaining their cell-contents. They are surrounded by about six groups of xylem, alternating with as many groups of phloem, separated from one another by small parenchymatous cells, the whole being enclosed by a not very definite pericycle and endodermis (Pl. XXXV. fig. 17). Immediately beyond the endodermis are cortical cells separated by spaces containing the colour-granules.

A longitudinal tangential section near the outside of the stele shows, even in extremely small roots and in fresh or hardened material, a central group of elongated thin-walled cells with very sinuous longitudinal walls. The most external of these cells, on each side, have always their inner walls sinuous and their outer walls smooth. These cells may perhaps be regarded as endodermal (*cf.* De Bary, 'Comparative Anatomy of the Phanerogams and Ferns,' fig. 50, p. 123).

The Leaf.—A transverse section near the base of the leaf consists of rounded cells of approximately equal size, separated from one another by very irregular spaces

(Pl. XXXV. fig. 22). Some of these spaces are mere points, others are so large that the cells are attached to one another, laterally, by very small surfaces.

From the underside of the leaf, through about half or two-thirds of its entire thickness, the spaces are lined with red granules. The extreme irregularity in the size and form of the spaces in the leaf is shown in Pl. XXXV. fig. 22.

In a longitudinal section the cells appear in rows, which in some parts are in contact, but in others separated by spaces of variable width, and tapering to a point where the cells of adjacent rows are still united. As in the transverse section, the spaces vary greatly in size and form, some appearing as small lenticular slits.

Transverse Section of the Lamina.—The red colour is absent from the upper part of the leaf, which in section differs little from the ordinary bi-facial type (Pl. XXXV. fig. 21).

On the upper side the epidermis consists of larger cells than on the lower. Stomata and glands are present on both surfaces, but they are more numerous on the under side. The palisade parenchyma consists of about four rows of cells, which are only slightly elongated. The cells of the spongy parenchyma are rounded, and connected with one another by elongated processes, bridging over the intercellular spaces.

A surface view of the epidermis shows the stomata and the glands. Seen from above the epidermal cells appear rounded and have undulating walls. The stomata are of the usual type (Pl. XXXV. fig. 23). Round the glands the epidermal cells are somewhat pyriform, with their narrow ends near the gland and their broad ends directed away from it, so that they form a kind of rosette. The reason of this arrangement is that the glands are sunk into pits. It is these pits which cause the punctate appearance of the leaves to which reference has already been made (p. 344). The glands themselves (Pl. XXXV. fig. 24) show a circular head, sometimes divided by one or two cross-walls into two or four smaller cells, containing dense granular protoplasm.

In vertical section (Pl. XXXV. fig. 25) the glands are almost identical in appearance with the hydathodes of *Piper nigrum*, described and figured by Haberlandt ('*Physiologische Pflanzenanatomie*,' 2nd edition, p. 420) and which also occur in depressions in the leaves. They are divided into three parts, called by Haberlandt the head, the stalk, and the foot. According to Haberlandt, the protoplasmic head functions as a peculiar water-gland. The stalk represents the mechanical apparatus of the whole organ, as it is provided with a thick ring of cellulose, which keeps a passage for the water always open and of a uniform diameter. The foot, which connects the gland with the adjoining epidermal cells and with the underlying tissue, is usually thin-walled. We have been unable to discover, in any of the glands of *Craterostigma pumilum* which we have examined, the ring of cellulose which Haberlandt describes and which was distinctly visible in the stalk-cell of the hydathodes of *Piper nigrum*, in sections which were cut for the sake of comparison with *Craterostigma*.

Whether the gland acts as a plug, when the depression deepens as the leaf dries, cannot be determined with certainty, but it appears to be probable.

Many of the epidermal cells contain one, or sometimes two bodies, which are more or less club-shaped (this varying somewhat in shape and size) and resemble cystoliths. Each is attached to the outer wall of the cell by a short stalk, which is in some cases very

slender, in others relatively thick (Pl. XXXV. figs. 25 & 26). In sections stained with gentian violet and eosin these bodies take up the eosin.

A transverse section of one of the large vascular bundles near the base of the leaf consists of vertical rows of vessels separated by parenchymatous cells. In longitudinal sections these vessels are seen to be spiral. Below the xylem is the phloem with its parenchyma, the whole being surrounded by an endodermis and a pericycle. The latter is interrupted on either side in the region of the phloem. No trace of internal phloem could be found; the bundles are strictly collateral. The smaller vascular bundles are very peculiar (Pl. XXXV. fig. 27). Among the large number of leaf-sections which we have examined, only one showed ordinary spiral tracheides. Their place seems to be taken by thin-walled tracheides with numerous transverse shelf-like rings or spiral thickenings.

Transverse sections show that the bundles consist of one or more rows of about three or five tracheides. Above each row of tracheides is usually a single cell as large as or larger than the tracheides in diameter, but thin-walled and without transverse thickenings. Below the tracheides, in all but the very smallest veins, are a few elements of phloem. The whole is surrounded by cells arranged in a manner which suggests a sheath. Beyond them are the ordinary parenchymatous cells of the leaf.

In longitudinal section the transverse thickenings are seen to be so numerous that the tracheides appear to be cut up into segments, square, or even broader than they are long. Between the ordinary spiral tracheides or vessels of the larger veins and the peculiar square elements are transitional forms consisting of shelf-like spirals which are more or less broken up.

The *Stem* is either a short thick root-stock or a creeping rhizome. It consists of a central pith surrounded by a relatively thick mass of xylem and a not inconsiderable phloem. The cortex contains numerous very large and irregular intercellular spaces, which, except near the central stele and the path of the adventitious roots, are lined with the red granules. The cortical cells, like those of the root, contain numerous leucoplasts (Pl. XXXV. fig. 20). The bundles are open and collateral, and there is a slight cambium. Surrounding the phloem is a fairly well-marked endodermis. But the vascular cylinder of the stem is much broken up by the large number of adventitious roots which arise in it and make their way through the cortex to the exterior.

The Red Colouring-matter *.—Owing to the scarcity of the material, we have only been able to examine the colouring-matter microchemically and with the aid of polarized light.

The colouring-matters of plants have been investigated by various observers, among others by Courchet ("Recherches sur les Chromoleucites," *Annales des Sciences Naturelles*, série 7, p. 263). According to this author, all colouring-matters other than chlorophyll and a few of very rare occurrence may be divided into two main groups: I. the *cyanic series*, and II. the *xanthic series*.

* Reddish colouring-matters are not uncommon in roots, but they are frequently confined to the sap, or are in hue, abundance, solubility, and other ways very different from the case we are considering. The reader may consult, e. g., Hildebrand, *Ber. d. deutsch. bot. Gesellsch.* 1883, Bd. i. p. xxvii, and Ascherson, *ibid.* p. 498.

I. The cyanic series has for its type the red substance occurring in solution, and includes the blue, violet, and "carmine red" colours derived from it. The colours in this series all become red with acids and blue with alkalies.

II. The type of the xanthic series is the solid yellow colouring-matter either contained in or derived from plastids (leucites), together with orange-yellow, orange-red, and brick-red solid pigments.

When treated with *concentrated* sulphuric acid, these bodies all become indigo-blue of varying degrees of brightness. With iodine they all take on a green colour. All of them are insoluble in water.

The pigments of the xanthic series may be further divided into two groups with reference to their behaviour towards other reagents:—

a. Yellow pigments (xanthin of some authors).—These, according to Courchet, are never crystalline, nor can crystals by any means be obtained artificially from their solutions. They are slightly soluble in chloroform, benzine, and ether, but most soluble in alcohol. Before becoming blue with concentrated sulphuric acid they pass through an intermediate green stage, which may be due to a mingling of the pigment which has become blue with that which is still yellow.

β. Orange-yellow and orange-red pigments may be amorphous, or in the form of crystallites or crystals. They are most soluble in ether, benzine, and chloroform, and less so in alcohol. With concentrated sulphuric acid they pass through a violet or violet-red phase, probably on account of the mixing of blue and red colouring-matter.

These differences may be tabulated in the following way:—

<i>Yellow Pigments.</i>	<i>Orange-yellow and orange-red.</i>
Non-crystalline.	Amorphous, crystallites, or crystals.
Slightly soluble in { chloroform. benzine. ether.	Most soluble in { chloroform. benzine. ether.
Most soluble in alcohol.	Less soluble in alcohol.
With concentrated sulphuric acid, first green, then blue.	With concentrated sulphuric acid, first violet or violet-red, then blue.

The colouring-matter of the flowers of *Aloë* is so peculiar in its reactions that it was placed by Courchet in a group by itself. It occurs in the form of chromoplasts (chromo-leucites) consisting of a coloured stroma, which is apparently homogeneous and contains very distinct pigmentary granules. With concentrated sulphuric acid the colour changes into a greenish yellow, but there are slight differences in this reaction due to the original colour and to the physical condition (whether crystalline or amorphous) of the pigment. Alkalies cause the formation of orange-coloured drops. In ether and chloroform the colour is almost insoluble; in alcohol it is very soluble, and forms a solution which Courchet describes as "currant-red."

The reactions of the red colouring-matter in the root of *Craterostigma* in some respects resemble those of the pigments of the xanthic group, in others those of the colour in *Aloë*-flowers, while in others again they are peculiar.

For the sake of comparison we have examined microchemically the colouring-matters in various plants in which they are present in a solid form and which have not been mentioned by Courchet. Some of these give the reactions which, according to Zimmermann ('Botanical Microtechnique,' translated by Humphrey, 1893, p. 101), are characteristic of carotin, and which also agree with those of Courchet's xanthic series. Carotin, the name originally given to the yellow colouring-matter first obtained from the roots of the cultivated carrot, is now proved to be more widely distributed, and to occur not only in many plants but in some animals (*cf.* Zopf, "Zur Kenntniss der Färbungsursachen niederer Organismen," Beiträge zur Physiologie und Morphologie, 1892 and 1893). It is supposed by some authors to be identical with that which has received the following names, as well as many others—chlorophyll-yellow, xanthophyll, erythrophyll, chrysophyll, etc., and to which is due the colour of leaves in autumn. The characteristic reactions of carotin with iodine and with concentrated sulphuric acid are those which distinguish the xanthic series as a whole. With regard to its behaviour towards alcohol, ether, benzine, and carbon bisulphide it in some respects resembles the yellow pigments, and in others the orange-yellow and orange-red colours which form the two divisions of Courchet's xanthic series.

By way of control experiments, we have compared the various reactions of the colouring-matter in the root of *Craterostigma* with those of the carotin in the flowers of *Tropæolum majus*, Linn.

Among other plants of which we have examined the colouring-matter for the sake of comparison was *Chamædorea Sartorii*, Liebm., which has thick floral axes coloured bright orange-red. The colouring-matter occurs as red granules in certain of the plastids which have also a coloured stroma. It is chiefly confined to a broad band of cells near the periphery, while those lying more internally contain chloroplasts. The cells in the centre of the axis are colourless.

In many of its reactions the colour in *Chamædorea* resembles carotin, but in some it is like the colour in the roots of our plant. Though many of the reactions of the latter are peculiar, yet on the whole they show a marked resemblance to those of the colouring-matter in the flowers of *Aloë*. For the sake of comparison with Courchet's results for *Aloë* and with our own for *Craterostigma*, we have examined microchemically the colour-bodies in *Gasteria*, a genus closely allied to *Aloë*. The results of a comparison of the solid colouring-matters contained in the flowers of *Tropæolum majus*, the floral axis of *Chamædorea Sartorii*, and in the flowers of *Gasteria formosa*, Haw., with that in the root of *Craterostigma pumilum* are summarized in the accompanying Table (p. 352) and may now be discussed.

The reactions of the red colour of the roots of *Craterostigma* with iodine and with concentrated sulphuric acid separate it at once not only from carotin, but from the whole xanthic series. With iodine the colour is not dissolved, but turns dark brown. With concentrated sulphuric acid the colour also at first becomes brown and then dissolves, forming a yellowish-brown fluid, but leaving an insoluble residue consisting of colourless granules.

Perhaps the most curious reaction, and one which suggests those of the cyanic series,

is the behaviour of the red colour of our plant towards potash. The colour first becomes a reddish purple and then a dull purplish or inky blue, but the pigment does not dissolve. The contents of the cell also take on the same colour. With nitric acid the colour dissolves and forms a fluid which is coloured brownish pink. With acetic, chromic, and hydrochloric acids the colour remains unchanged. In alcohol the pigment is extremely soluble and forms a red solution with a yellowish-brown or pink-brown tint. The colour is also very soluble, and forms a red solution, in ether; but in benzol, carbon bisulphide, and chloroform it is only slightly soluble.

The results we obtained with *Gasteria* are essentially the same as those which Courchet got with *Aloë*.

The colouring-matter in *Chamædorea Sartorii* in many of its reactions resembles carotin, but in some of those in which it differs it behaves like the colour in *Craterostigma*. Both are extremely soluble in alcohol, whereas carotin is only slightly soluble. But in *Chamædorea* this solution is followed by the formation of a finely divided yellow precipitate. Both are very soluble in ether, and only slightly so in benzol and carbon bisulphide.

The reactions of the colour in *Craterostigma* all differ markedly from those of carotin; among these the different behaviour of the two bodies towards concentrated sulphuric acid and towards iodine are specially noteworthy. In no single reaction does the red colour behave exactly like carotin. On the whole, though some of the reactions differ considerably, it is much more like that of *Gasteria* (or *Aloë*) than any other with which we have compared it.

With concentrated sulphuric acid *Gasteria* becomes first orange, then greenish yellow, fading into pale yellow and quickly becoming colourless. The changes of colour are so various and so rapid that it is extremely difficult to distinguish one from another and to observe their sequence. With iodine the colour becomes a pale yellowish brown. These reactions seem to be essentially the same as those which occur when the red colour in *Craterostigma* is treated with the same reagents. The difference is of degree rather than of kind, and may be due to the fact that the original colour of *Gasteria* is pale pink and of *Craterostigma* a deep but bright red.

With alcohol both are very soluble and form pink or red solutions. Both are only partly and slowly soluble in benzol, carbon bisulphide, and chloroform, with which they form pink or red drops of fluid. They differ, however, in their solubility in ether. The red colour dissolves readily, the pigment in *Gasteria* is almost insoluble. Potash, which with carotin and the colour in *Chamædorea* gives no reaction, affects, but in different ways, both the colour in *Craterostigma* and in *Gasteria*. That in the former rapidly becomes reddish purple, then a dull blue, while that in the latter slowly changes to a yellowish brown.

Hydrochloric acid with the red colour in our plant gives no reaction, but it changes that in *Gasteria* into orange, which becomes yellow and then fades away.

With nitric acid the red colour dissolves and forms a brown-pink solution, while that in *Gasteria* behaves essentially like carotin and the colour in *Chamædorea*; the colour first becomes yellowish, and then rapidly disappears. Carotin takes on a blue, and the

REAGENT.	COLOUR-BODIES IN			
	<i>Tropeolum majus.</i>	<i>Chamaedorea Sartorii.</i>	<i>Gasteria formosa.</i>	<i>Craterostigma pumilum.</i>
Iodine.....	Greenish or greenish-blue.	Blue-green.	Yellow-brown.	Brown.
Concentrated sulphuric acid	Violet, then indigo-blue.	Blue.	Orange, greenish-yellow, fading to pale yellow, becoming colourless.	Brown; then dissolves, and yellow-brown fluid is formed. Insoluble residue.
Water.....	Insoluble.	Insoluble.	Insoluble.	Insoluble.
Alcohol	Almost insoluble.	Soluble; yellow fluid formed, then yellow precipitate.	Very soluble; pink solution.	Soluble, forming red fluid.
Ether	Slightly soluble.	Very soluble; yellow drops of fluid formed.	Slowly soluble; orange drops.	Very soluble, forming a red solution.
Benzol	More soluble.	Partly and slowly soluble.	Slowly soluble; orange-pink drops formed.	Partly and slowly soluble; red solution formed.
Carbon bisulphide	Easily soluble.	Insoluble.	Slowly soluble; pink drops.	Partly soluble; red drops formed; colourless granules left.
Chloroform.....	Easily soluble.	Soluble; bright reddish-yellow solution.	Slowly soluble; orange-pink drops.	Slowly soluble; bright reddish-brown fluid.
Potash, 5% solution	Insoluble.	Insoluble.	Slow change to yellow-brown.	Reddish purple, then dull inky purple.
Acetic acid, 1% solution	Insoluble.	Insoluble.	Insoluble.	Insoluble.
Chromic acid, 1% solution	Insoluble.	Insoluble.		Insoluble.
Hydrochloric acid	Insoluble.	Bluish-green.	Orange; yellow, fading into very pale yellow.	No visible reaction.
Nitric acid	Blue, immediately becoming colourless.	Blue-green, rapidly fading into yellow and becoming colourless.	Yellowish, rapidly becoming colourless or almost colourless.	Soluble; brown-pink solution.

colour in *Chamædorea* a blue-green colour before becoming yellow, and, according to Courchet, that in *Aloë* also first becomes green. This reaction is a very remarkable one to watch, as the change is so rapid that, as the reagent penetrates the tissues, a wave of colour passes over the field, changing and disappearing as soon as it is formed.

Optical Properties of the Pigment.

The granules were examined by means of polarized light, both in the fresh plant and in the residue which remained after evaporation of the alcoholic extract. The granules thus obtained differed little, if at all, from those in the fresh root. Owing to their extremely small size, nothing definite could be determined about them, but they appeared not to be crystalline*.

We do not think that the colouring-matter occurs in drops in the plant, because the solid granules which are obtained from the alcoholic extract seem to be identical with those in the fresh tissues.

We have also applied the tests for tannin, but with negative results.

We therefore regard the evidence as being against the possibility of the colouring-matter being an oily or resinous body in drops, and it is certainly against its being a crystalline substance allied to carotin. It appears to be present in the form of rounded non-crystalline granules which may possibly be resinous, and which in their micro-chemical reactions most closely resemble the colouring-matter in the flowers of *Aloë*.

When the plant is placed with its roots in water and exposed to the action of light, the red colour, even after an interval of some weeks, changes very little. And this apparent fading may be due to the change of the leucoplasts into chloroplasts, and the consequent influence on the colour of the root as a whole; in solution, however, the colour slowly fades in the light.

The place of origin of the pigment may now be considered. Courchet has shown that solid pigments are usually, if not always, formed by plastids; and this fact, taken in connexion with the presence of such plastids in the tissues which contain the colour, points to the origin of the pigment in these bodies, although we have never seen any of the colouring-matter within the cells of our plant.

Any suggestion that the granules may be bodies foreign to the plant, and of the nature of bacteria, is rendered impossible on account of their complete solubility in more than one reagent, and also because they occur in spaces which are usually closed and have therefore no connexion with the exterior.

The excretion of colouring-matter by both plants and animals is not an uncommon phenomenon. Such cases of the excretion of carotin are recorded by Zopf. Zimmermann ('Botanical Microtechnique,' English edition, p. 112) mentions the excretion of colouring-matter (which may be crystalline or, more rarely, amorphous) by various lichens.

As to the possible uses of the pigment we can offer no definite suggestions. It may

* The colouring-matter of *Aloë*, which resembles that in our plant, also occurs in distinct granules which are non-crystalline, and it has not yet been obtained in a crystalline form.

be that the colour is merely incidental, and that it is the granules themselves which are of use to the plant.

In discussing the uses of carotin to the plants in which he found it, Zopf suggests three possible functions for the colour:—

- (1) That it is a protection against light;
- (2) That it protects the plant against the attacks of plant-eating animals;
- (3) That it is a reserve material.

The first hypothesis is untenable in the case of our plant, because the colour occurs in those parts of the plants which are not exposed to the light.

The second suggestion was abandoned by Zopf because, in the case of carrots, carotin is no protection from the attacks of snails and other animals.

The third suggestion seems to us to be extremely improbable, especially as the colouring-matter is produced in such large quantities in the intercellular spaces in perfectly active organs. And, as we find no evidence of resorption, it may be taken to be an excretion.

It may be that some of the peculiarities of the colouring-matter in our plant are due to its environment*. In this connexion Zopf's work on *Trentepohlia Iolithus*, Wallr., an alga growing on bare rocks, is interesting and suggestive. In this plant, which is alternately dried up by sun and wind and brought into a resting condition, and supplied with water by rain and dew and so enabled to grow, the reserve materials take the form of oil-drops and of included crystals of carotin, *i. e.* of bodies which are insoluble in water.

It may be that a reserve material which is insoluble in water would be more stable and less liable to be influenced by metabolic changes dependent upon fluctuations in the amount of water present in the plant, especially if, as is the case in *Craterostigma*, it is placed outside the cells.

But it is difficult on any hypothesis but that of excretion to account for the position of the granules outside the cells.

EXPLANATION OF THE PLATES.

PLATE XXXIV.

- Fig. 1. Whole plant, about natural size, showing leaf-rosette and red roots springing from the short root-stock (also red), one fully-expanded flower and two from which the corolla has fallen.
- Fig. 2. A stolon with three buds, somewhat enlarged.
- Fig. 3. Cross section of a bud, slightly magnified, showing sub-opposite leaves.
- Fig. 4. Flower-bud viewed (*a*) from the side, (*b*) from below—anterior view, (*c*) from above—posterior view.
- Fig. 5. Corolla seen from (*a*) the side, (*b*) above, and (*c*) below.

* We believe that our plant comes from a rocky region, where it would be exposed to periodic droughts.

- Fig. 6. A flower from which the corolla has fallen, showing persistent calyx and style.
 Fig. 7. Vertical section of ovary in the antero-posterior plane, showing superior position, large axile placenta, and terminal style. At (b) a lateral, and (c) front view of lipped stigma.
 Fig. 8. Corolla dissected open from above and the posterior lobe removed: natural size.
 Fig. 9. Corolla laid open from below, magnified.
 Fig. 10. Transverse section of ovary and calyx, magnified.
 Fig. 11. A young capsule, projecting beyond the persistent calyx.
 Fig. 12. Ripe capsule opening by two valves, septicidal and septifragal.
 Fig. 13. Ripe seed, showing the pitting.
 Fig. 14. Longitudinal median section of seed, showing nearly straight embryo in axis of endosperm.

PLATE XXXV.

- Fig. 15. Transverse section of root, showing central stele, and cortex with the large regular intercellular spaces filled with the red pigment. The two outer layers have neither spaces nor pigment. Low power.
 Fig. 16. Portion of above, more highly magnified (Zeiss D), showing pigment lining walls of spaces.
 Fig. 17. Transverse section of stele of root, with six xylem-strands, endodermis, pericycle, &c., of normal type.
 Fig. 18. Radial longitudinal section of outer root-cortex and piliferous layer, showing intercellular spaces and pigment—cf. fig. 19—and the peculiarly thickened outer cell-walls of some of the cells of the piliferous layer.
 Fig. 19. Tangential oblique section of cortex of root, showing peculiar appearance caused by the arrangement of the intercellular spaces.
 Fig. 20. Transverse section of the rhizome, showing central stele, origin of roots, and oblique sections of vascular strands to the leaves. The intercellular spaces of the outer cortex are filled with the red pigment, except just below the epidermis.
 Fig. 21. Part of transverse section through lamina of leaf, showing differences between upper and lower epidermis, and the feebly differentiated palisade-tissue. Stomata and glands occur both above and below.
 Fig. 22. Transverse section through base of leaf, showing the pigmented intercellular spaces in lower portion only.
 Fig. 23. A stoma in vertical section.
 Fig. 24. Two of the glands, seen from above.
 Fig. 25. A gland and its pit in vertical section: in one of the epidermal cells a cystolith-like body.
 Fig. 26. Section of epidermis, showing two cystoliths.
 Fig. 27. Section across a small vein of leaf.
 Fig. 28. Longitudinal section of small vein of leaf, showing the peculiar short tracheidal elements with shelf-like thickenings.