The 'Droppers' of Tulipa and Erythronium.

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With Plates XXXI and XXXII.

I. Introduction.

In the course of Miss Ethel Sargant's examination of monocotyledonous seedlings, she noticed in the Tulip and Dog's Tooth Violet the peculiar descending stolons known to gardeners as 'droppers.' These seemed to show features of some interest, and since the question lay outside the main line of her research, she proposed to me early in 1902 that I should find out what work had been done on the subject, and try to investigate it further. I am indebted to Miss Sargant not only for suggesting this research, but also for handing over to me her *Tulipa* and *Erythronium* seedlings, and allowing me to examine her preparations of these genera. I have also to thank Mr. R. I. Lynch, M.A., of the Botanic Garden, Cambridge, and Mr. E. Aveling Green, of Berrystead, Beds, who have been most generous in supplying me with material and information. This investigation has been carried out in the laboratory of University College, and I have much pleasure in acknowledging the kind help I have received from Professor F. W. Oliver, especially in connexion with the literature.

II. The Movements of Bulbs in the Soil.

(a) *Migration.*

A great drawback of the vegetative reproduction so characteristic of bulbous plants is that it tends to overcrowding. The lateral bulbs are produced close together, and have no opportunity of colonizing fresh soil. This is got over in certain special cases by the replacement of sessile by stalked bulblets. De Vriese[1] records cases in which *Ixia lutea* and *carminosa* produced their lateral bulblets at the end of stalks from 1 to 15 centimetres

[1] W. H. de Vriese, Bydrage tot de Morphologie der Bollen, Tydschr. v. Natuurlyke Geschiedenis, Leiden, 1841.

long. Tristan[1] mentions that stalked bulblets occur in *Allium vincale.* Some Snowdrops (*Galanthus nivalis*), sent me by Mr. Aveling Green, show a similar adaptation in a very striking fashion. In *Galanthus* the growth is monopodial, the flower being produced laterally, and in these specimens the axis had elongated greatly, carrying the new bulb some little distance from the parent (e. g. Fig. 1). Mr. Aveling Green tells me that 'where they have been growing for some years in a mass, the under ones have tried to get along under the mass, and to find a way up and form a second bulb.' I have also seen exactly the same elongation of the axis in a specimen of the Snowflake (*Leucojum aestivum*), by which the new bulb was carried upwards until its base was 5·5 centimetres above the base of the parent bulb. After examining it, I came across a figure and description by Irmisch[2] of a precisely similar case in another species, *L. vernum.*

(b) *Descent.*

To each perennial plant a certain definite depth in the soil appears to be specially appropriate, and if it is disturbed it makes efforts to return to this particular level[3]. Massart[4] records a most interesting series of culture experiments on about 200 perennial species, which were planted, some at the normal level, some too deep, and some too shallow. The plants were very successful in bringing back their winter buds to the normal level by curvature of rhizomes, elongation of internodes, and so on.

To bulbous and tuberous plants a certain depth in the soil must be even more important than to ordinary perennial species, since they want protection for their succulent tissues from animals and from frost. The need for descent into the soil is especially urgent in the case of the seedling, since here the young plant starts at the surface of the ground instead of at the level of the parent bulb or corm. The commonest method of descent into the soil is by means of contractile roots[3], which are shown specially well in the *Crocus.* Here, as each successive daughter corm is formed above the parent, the need for descent is particularly obvious. The contractile root is 'always present in the young seedling, and occasionally reproduced in after years. . . . I fancy I have noticed it to be found more frequently in old Crocus bulbs when they have been brought near the surface in the process of digging a bed.'[5] The contractile roots of *Scilla*

[1] M. de Tristan, Histoire des developpemens de quelques gemmes bulbifères, Mém. du Mus. d'Hist. Nat., 1823, T. x, p. 51.

[2] M. Irmisch, Zur Morphologie der monokotylischen Knollen und Zwiebelgewächse, Berlin, 1850, p. 101, and Pl. VII, Figs. 10, 11, 12.

[3] F. W. Oliver, The Depth in the Soil at which Plants Occur, Jr. Roy. Hort. Soc., April, 1898, vol. xxi, p. 486.

[4] J. Massart, Comment les plantes vivaces maintiennent leur niveau souterrain, Bull. de la Soc. Roy. de Bot. de Belge, T. xli, 1902–3.

[5] C. Wolley Dod, Gardeners' Chronicle, 1886, p. 626.

have been investigated by Mr. Woodhead [1], both as regards their behaviour and internal structure.

Among the Lilioideae we meet with a great range of bulb structure. Perhaps the most primitive type of bulb is that of such a plant as the White Lily, in which the scales are obviously leafy, the outer ones being actually formed from the bases of the foliage leaves. A slightly more advanced stage is reached in the Turk's Cap Lily (*Lilium Martagon*), in which there are no ground leaves, and so all the bulb leaves, not merely the inner ones, take the form of specialized scales. A much more sophisticated type is that of the so-called 'tunicate bulb,' in which each scale leaf is a closed sheath, with only a small opening at the top. The most specialized methods of descent into the soil with which we are acquainted are met with in *Scilla*, *Tulipa*, and *Erythronium* among the Lilioideae, and *Gagea* among the related Allioideae, all of which have tunicate bulbs. The curious behaviour of the Wild Hyacinth is described by Rev. C. Wolley Dod as follows:—'The smallest bulbs, which I take to be the produce of the seed shed eighteen months before, in the July of the previous year, are at a depth of one or two inches, and the size of a small pea; the two-year-olds are at an average depth of four inches, and at least 70 per cent. of them are curiously elongated, being three times as long as broad. Those three and four years old—for I think some rest contented with the depth reached in the third season's growth, and some take another dive in their fourth season—are six or seven inches deep. Thus the crown of the new bulb is, on an average, 1½ inch below the base of the old one, and I feel no doubt that it is formed where it is found.' Mr. Woodhead [1] has published a full and interesting account of the life history of the Wild Hyacinth, and the structure of the curious elongated bulbs by which it lowers itself into the soil.

The most highly specialized method of descent, that by 'droppers,' is discussed in detail in the following sections.

III. Tulip 'Droppers.'

Tulip growers have long been familiar with 'droppers' ('sinkers' as they are called in Holland), and a good many accounts of them and references to them occur in horticultural and botanical literature; but it will be convenient to leave the discussion of these until after the description of my own observations.

(a) *The Non-Flowering Tulip.*

Fig. 2*a* shows a typical, immature, non-flowering plant of *Tulipa saxatilis*, in the state in which it would be found about March. The

[1] T. W. Woodhead, Notes on the Bluebell (*Scilla festalis*, Salisb.), The Naturalist, Feb. and March, 1904.

description of it applies in all essentials to the two other species of which I have had material at this stage, namely, *T. sylvestris* and *T. praecox*. The small bulb is clothed externally by a brown scale leaf. A single foliage leaf comes out of the top of the bulb, whilst a whitish stolon—the 'dropper'—and a crop of adventitious roots emerge below. If the brown scale leaf is removed, a second, and sometimes a third, scale leaf are disclosed, differing from the first in being white and succulent, but resembling it in the 'tunicate' form (Fig. 2 *b*). There may be one or more buds in the axils of the scale leaves. On removing the scale leaves and buds, the only thing left is the dwarf stem, to which are attached the roots, foliage leaf, and dropper; it is found that the latter is actually a continuation of the base of the foliage leaf (Fig. 2 *c*). It emerges from the bulb by boring its way through the scale leaves enclosing it. Sections show that the dropper is not a solid structure but a hollow tube, containing in its swollen tip a small bulb (Fig. 2 *d*). Hairs grow from the inner epidermis into the cavity of the dropper tube. The length of the dropper may be very great; a bulb of *T. sylvestris*, dug up in the middle of April, possessed one which measured $9\frac{3}{8}$ inches. Later in the year the parent bulb will be found to be dead and withered, its stored nourishment and the food manufactured by the foliage leaf having passed down the dropper into the young bulb at the tip. Eventually the dropper itself shrivels and disappears, leaving the new bulb free below.

The most reasonable view as to the morphological nature of the dropper is that it is partly foliar and partly axial, and this conception of it is confirmed by the anatomy. As the foliage leaf is tubular at the base, an axillary bud would necessarily be completely enclosed by it. The dropper is simply formed by the downward elongation of the leaf base fused on the adaxial side with the stem rudiment (Fig. 3). The tubular nature of the dropper seems to be merely a further step in the tendency to marginal fusion which is characteristic of all tulip leaves. This is shown not only in the 'tunicate' scale leaves and the bases of the ordinary foliage leaves, but also in the peculiar abnormal leaves, known as 'ascidia,' which are occasionally mentioned in the literature [1]. A complication, which has not yet been referred to, is the presence of small droppers from the axillary buds. These commonly terminate upwards in a rudimentary foliage leaf without a blade (Fig. 6 *d*). They occur chiefly in non-flowering garden Tulips, presumably forms of *T. Gesneriana*. Occasionally droppers of very curious form are found. In one specimen of *T. praecox*, I met with a dropper which, instead of running downwards, doubled sharply on itself,

[1] Germain de Saint-Pierre, Bull. de la Soc. Bot. de France, i, 1854, p. 63. Penzig, Note di teratologia vegetale, Malpighia, 16, 1902, p. 168. Miss T. L. Prankerd, B.Sc. has kindly shown me a photograph and water-colour sketch of the bulb of a pink-flowering Tulip bearing a short tubular leaf, the upper part of which was pink in colour like the flower.

and emerged from the top of the bulb side by side with the foliage leaf to which it belonged. Its tip, which was coiled like a ram's horn, contained the usual small bulb, and, in addition, there was a second one growing outside.

Since the dropper is neither purely axial nor purely foliar the question arises as to whether its region of greatest growth will be at the base as in leaves, or immediately behind the apex as in roots. To decide this, two bulbs of *T. sylvestris* were grown as water-cultures, and when they had each produced a dropper $\frac{3}{4}$ inch long, the foliage leaf and dropper in one case were divided with lines of Indian ink into zones of $\frac{1}{8}$ inch, and in the other into zones of $\frac{1}{6}$ inch. After a few days it was found that in each the growth of the leaf was much greater in the lowest zone, and that of the dropper in the zone next behind the apex. So the growth of the dropper resembles that of the root.

I have examined the vascular transition from leaf to stem and dropper by means of serial sections (cf. Figs. 4 *e*, *f*, *g*, *h*, and Fig. 5 *b*), and also by placing the whole transition region in concentrated carbolic acid kept at a temperature just above its solidifying point. This produces sufficient transparency to allow the veins to be followed under the dissecting microscope. Fig. 2 *e* and Figs. 6 *f*, *g*, *h*, were drawn from such preparations. In *T. saxatilis* and *T. sylvestris* both these methods have been used for comparison, but in *T. praecox* the carbolic method only, and in *T. Clusiana* sections only have been employed. The anatomy is essentially the same in all four species. In general terms we may say that the bundles on the side of the cylindrical leaf base remote from the midrib run straight down to form the vascular system of the corresponding abaxial side of the dropper. The midrib and main laterals on the other hand run directly down into the stem rudiment, but each before entering it gives off a branch to supply the adaxial side of the dropper. These two sets of foliar bundles form a complete ring round the dropper. Complications are sometimes introduced by bundles starting from the stem rudiment which run a little way up into the leaf and then suddenly dive down into the dropper, or dip down into the dropper and then rise at a sharp angle into the leaf. The midrib and the main laterals of the leaf enter the dwarf stem in a crescent, but soon arrange themselves in a circle. From the side of this towards the dropper, two or more bundles as a rule send branches into the dropper, which course down its adaxial side outside the foliar vascular ring. The orientation of the bundles on the adaxial side of the dropper is very variable. The foliar bundles are inclined to place themselves so as to form, with the axial bundles, a more or less complete ring. In the dwarf stem the bundles, as we pass downwards, become concentric by the creeping of the xylem round the phloem and then fuse into an irregular plexus, which ultimately divides up completely to form the vascular systems of a crop of 3- to 5-arch adventitious roots (Fig. 5 *b*).

The droppers of *T. sylvestris* may sometimes be used for ascent, instead of descent, for Oliver (l. c.) records that when the bulbs are planted at a depth considerably below their normal level the droppers may curve upwards.

(b) *The Flowering Tulip.*

The flowering Tulip differs from the immature plants described in the last section in that the foliage leaves are produced on the flowering axis instead of growing directly from the bulb. It is obvious from this that the main bulb cannot produce a dropper as there are no ground leaves of which it can be a continuation. However, the axillary lateral bulbs sometimes produce droppers which terminate upwards in rudimentary (or occasionally normal) foliage leaves (Fig. 11).

(c) *The Seedling Tulip.*

By Miss Sargant's kindness I have been able to examine the seedlings of an unnamed species of *Tulipa* from Calcutta (Fig. 9 *a*). From the seed a long slender cotyledon emerges carrying at its tip the radicle and plumule. This tip dips down into the earth, and from it the main root and first adventitious root arise. But the shoot instead of emerging here as usual, remains inside the cotyledon tip, and by the continued elongation of the latter is carried down into the ground for some distance below the point of origin of the roots. The cotyledon thus forms a dropper to lower the first plumular bud well into the soil. I have followed the relation of the vascular system of cotyledon, dropper, and roots by means of serial sections. Miss Sargant[1] has already recorded that the transition from stem to root in this species is of the normal Tulipeae type, of which she figures *Fritillaria imperialis* as an example.

In *Fritillaria* dropper formation does not occur, so perhaps it will be well (since the dropper is the organ with which we are especially concerned) shortly to describe and figure the transition phenomena in *Tulipa* sp. (Calcutta). The cotyledon contains a pair of bundles which at the base approximate to form a double bundle with one protoxylem group (Fig. 9 *b*). The two phloem groups continue directly into the phloem groups of the diarch main root. The protoxylem group broadens into a flat plate at right angles to a line joining the centre of the two phloem groups, and the extremities of this plate form the protoxylem groups of the root. The dropper is supplied by a branch from each of the constituent bundles of the double bundle (Fig. 9 *c*). These two branches unite to form a V-shaped double bundle which presently gives off two laterals (Fig. 9 *e*). The first adventitious root arises opposite the dropper and a little below it (Fig. 9 *d*).

[1] E. Sargant, A Theory of the Origin of Monocotyledons founded on the structure of their Seedlings, Ann. of Bot., vol. xii, Jan. 1903, Pl. III, and p. 23.

(d) *The Life History of the Tulip as described in the Literature.*

The history of a garden Tulip, from the seedling stage described in the last section up to the time when it produces its brilliant parti-coloured flowers, is a very long one. For about six years [1] the seedlings do not bloom, but each season they produce a single foliage leaf above ground and a dropper below. 'The usual game of "droppers" goes merrily on, till the young bulbs feel, that if they drop any deeper, there will be suffocation through their leaves never reaching the surface alive—and they will take care not to incur this [2].' The first flowers produced are as a rule self-coloured, and the plants at this stage are known in England as 'breeders,' and on the Continent as 'Couleurs,' 'Espectanten,' or 'Muttertulpen.' After two or three years [3] the flowers may 'break' into different colours, but this process does not necessarily occur so soon. Some mother-tulips, which have been known in the self-coloured form for fifty years or more, may still occasionally 'break [4].' A change of situation, especially into a warm soil, is said to encourage 'breaking [5].' Rarely the first flowers produced by a seedling may be 'broken,' but where this occurs they do not 'break' according to the florist's rules of beauty, their colours being mixed and wanting in clearness. Sometimes 'broken' Tulips return to the plain colours of the 'breeders.' The great Haarlem bulb growers, E. H. Krelage and Sons, write to the Gardeners' Chronicle [6], 'There are a great number of varieties of Tulips, among which is a form of atavism. Occasionally some specimens lose their character and return to a form of tulip with narrow flowers, and mostly of one colour only. These Tulips are known in Holland as "thieves," and are always taken out and thrown away as of no value. We have for some years planted these variations separately and found them constant.' Solms-Laubach [4] has observed that such Tulips are especially liable to produce droppers.

Tulip droppers seem to have been repeatedly rediscovered, judging by the curiously scattered and disconnected references to them which occur in the literature. Besides the notices of them which occur in the papers of Horner, Oliver, Solms-Laubach, and Hall, already quoted, we find that de Vriese [7] refers to them in 1841, and Krünitz [8] five years later describes them as bulbs growing at the ends of root fibres. A case of droppers from the lateral buds of a mature Tulip is commented on by a writer in the Gardeners' Chronicle in 1866 [9], and another by Masters [10] in 1869. The

[1] J. G. Krünitz, Oekonomisch-technologische Encyklopädie, Berlin, 1846. And P. Miller, The Gardener's and Botanist's Dictionary, 1807.

[2] Rev. Francis D. Horner, The Florist's Tulip, Jrn. R. Hort. Soc., Jan. 1893.

[3] Krünitz, loc. cit., and A. D. Hall, The English or Florist's Tulip, Jrn. R. Hort. Soc. Sept. 1902.

[4] Solms-Laubach, Weizen und Tulpe, Leipzig, 1899.

[5] A. D. Hall, loc. cit.

[6] Gardeners' Chronicle, 1881, prt. ii, p. 182.

[7] W. H. de Vriese, loc. cit.

[8] Krünitz, loc. cit.

[9] Gardeners' Chronicle, 1866, p. 386.

[10] Masters, Vegetable Teratology, 1869.

droppers of *Tulipa sylvestris* are described in more than one place in the Gardeners' Chronicle [1] by correspondents who failed to recognize their true nature. Germain de St. Pierre [2] in 1870 and Loret [3] in 1875 refer to them as foliar structures, and compare them with the curious bulb-bearing leaves of certain species of *Allium.*

But by far the most important contribution to the subject antedates most of these references by many years. It is that of Thilo Irmisch [4] on the morphology of monocotyledonous bulbs and tubers published in 1850. This is a very valuable book, giving an accurate and exhaustive account of naked eye observations on the development and structure of bulbs. Some parts of the rather lengthy preface show that in spite of the mass of detail with which Irmisch dealt, he kept his attention fixed on the larger issues. He says, for instance, that 'Systematic Botany . . . especially in the case of the so-called higher plants, will have to rest upon comparative morphology, as Systematic Zoology has comparative anatomy for its essential basis,' and he adds 'It would rejoice me greatly if my observations should be found not useless as material for a scientific systematic treatment of (of course) only an extremely small number of plant species.' Irmisch's descriptions and figures of the immature Tulip-bulb and its dropper are so good that they may be felt to render the present paper unnecessary. My excuse is that Irmisch's work seems unfamiliar to many botanists, and that in his account of the droppers (which is confined to those of *T. sylvestris*) he does not figure the seedling or the flowering bulb, and he leaves the anatomy out of consideration. In his own words 'The morphology of fully developed plants like the comparative anatomy of fully developed animals will generally lead to sure results without reference to knowledge of tissues. Still cases arise in which the knowledge of the anatomical structure of a part will be valuable for the determination of its morphological significance.' As a matter of fact my examination of the anatomy has simply confirmed Irmisch's view as to the morphology of the dropper, namely, that it is formed partly of an elongation of a portion of the axis and partly of an invagination of the sheathing or dorsal surface of the leaf.

IV. Erythronium 'Droppers.'

Irmisch [5] has given a full illustrated description of the structure and development of the bulb of *Erythronium Dens-canis* in which the seedling

[1] Gardeners' Chronicle, May and Sept. 1888.

[2] Germain de Saint-Pierre, Nouveau Dictionnaire de Botanique, Paris, 1870.

[3] Loret, Sur les bulbes pédicellés du *Tulipa silvestris*, Bull. de la Soc. Bot. de France, T. xxii, 1875, p. 186.

[4] T. Irmisch, Zur Morphologie der monokotylischen Knollen und Zwiebelgewächse, Berlin, 1850, p. 57, and Plate V, Figs. 12–22.

[5] Th. Irmisch, Beiträge zur vergleichenden Morphologie der Pflanzen, Abhandl. der Naturforsch. Gesellsch. zu Halle, Bd. VII, Heft iii, 1863, p. 184.

possesses a well-marked dropper; in the succeeding years, however, the outgrowth is so rudimentary as scarcely to deserve the name. The structure of the bulb closely resembles that of the Tulip, and the non-flowering plant produces annually a single foliage leaf. Asa Gray[1] refers to the 'subterranean runners' of *E. americanum* and *E. albidum*, and figures another species *E. propullans*, in which a similar structure arises from a point some little distance *above* the parent bulb. It would be interesting to know what the exact morphology is in this case. F. H. Blodgett[2] gives a very telling series of figures of *E. americanum*, illustrating the five-year cycle from seed to flowering plant, and showing the amount of dropping that occurs each season. My Figs. 7 and 8 show two stages in the development of a young dropper in this species.

I have examined the seedling structure of another species, *E. grandiflorum*, by means of serial sections through the transition region of a seedling nineteen days old (Fig. 10). Miss Sargant[3] has already mentioned that *E. Hartwegi* has three bundles in the cotyledon which form a triarch root according to the first type of transition described by V. Tieghem. In one of the two seedlings of *E. grandiflorum* which I sectioned, the cotyledon near its base contained a midrib with two laterals, and immediately inside the midrib there was a small inverted bundle (Fig. 9 *b*). The laterals and the small inverted bundle pass down directly into the dropper and have no bearing on the symmetry of the root. The phloem mass of the midrib runs straight down to form one of the phloems of the triarch root. The xylem of the midrib gives rise to two of the xylem poles of the root, while the third, as well as the two remaining phloem groups, are supplied partly by it and partly by the chief bundle of the dropper (Fig. 9 *d*). The latter is a double bundle with a single xylem group and two phloems, and occupies the position in the dropper corresponding to that of the midrib in the leaf. There are six bundles in the transverse section of the dropper (Fig. 9 *e*): the midrib which connects with the root, the two laterals which are continuous with the laterals of the cotyledon, the small inverted bundle which also continues right into the cotyledon, and one bundle on each side arising as a branch of the cotyledon midrib. By the outward migration of the small inverted bundle a ring of bundles is formed in the dropper in place of the comparatively leaf-like arrangement in the cotyledon. The second seedling which I cut differed from this one in the absence of the small inverted bundle.

[1] Asa Gray, A New Species of *Erythronium*, Amer. Nat., 1871, p. 298.

[2] F. H. Blodgett, Vegetative Reproduction and Multiplication in *Erythronium*, Bull. Torrey Bot. Club, xxvii, p. 305.

[3] E. Sargant, loc. cit.

V. Gagea 'Droppers.'

The droppers of *Gagea arvensis* are figured by Irmisch [1]. They recall those of *Tulipa* and *Erythronium*, but are exceedingly short, so that the new bulb is carried a very little distance down into the ground.

VI. Summary.

The power of lateral migration to prevent overcrowding, and of descent into the soil for protection against frost, drought, and animals, is possessed in some degree by many bulbous plants. The most specialized methods of downward migration are those of certain 'tunicate' bulbs, *Scilla*, *Gagea*, *Tulipa*, and *Erythronium*. The last three produce the structures known as 'droppers.' In *Tulipa* and *Erythronium*, with which we have been particularly concerned in this paper, the immature bulb each year produces a single foliage leaf continued at the base into a hollow tube, the 'dropper,' enclosing a bulb at its tip. Irmisch's interpretation of this as partly axial and partly foliar is borne out by its anatomy. The region of greatest growth in the dropper is immediately behind the apex, showing that this foliar-axial organ has become root-like in more than mere externals. Both immature and flowering Tulips may produce droppers from lateral buds. *Tulipa* and *Erythronium* are much alike in almost every point, including the structure of the bulb and the external morphology of the seedling, and they are regarded by systematists as closely related, but the type of seedling anatomy in the two genera is curiously different. *Tulipa* conforms to the normal Tulipeae type, while *Erythronium* is aberrant. In the latter genus there are at least three bundles in the cotyledon, and this is correlated with a triarch root, while *Tulipa* has only two bundles in the cotyledon together corresponding to the midrib of *Erythronium*, and a diarch root. The triarchy of the *Erythronium* main root may possibly be connected with the fact that the plant depends on it alone for some time, whereas in *Tulipa* a second root is produced almost immediately.

Note. Since the above paper was written my attention has been called to an important treatise in Danish by Christian Raunkiær, 'De Danske Blomsterplanters Naturhistorie,' Bd. I, Copenhagen, 1895–9. The author figures and describes external views and dissections of immature dropper-bearing plants of *Tulipa sylvestris*. He also figures a case of elongation of the axis in a bulb of *Galanthus nivalis* (Fig. 104 F) similar to that shown in my Fig. 1. He further describes and figures the peculiarities of bulb formation in a number of species of *Gagea*.

September 17, 1906.

[1] Th. Irmisch, loc. cit., 1850, Pl. IV, Figs. 22, &c.

EXPLANATION OF PLATES XXXI AND XXXII.

Illustrating Miss A. Robertson's paper on the 'Droppers' of *Tulipa* and *Erythronium.*

f. = foliage leaf; *d.* = *dropper*; *d.b.* = tip of dropper containing bulb; *d.w.* = dropper wall; *sc.* = scale leaf; *l.b.* lateral bulb; *st.* = dwarf stem; *v.b.* = vascular bundle; *m.r.* = midrib; *d.m.r.* = dropper mid-rib; *d.v.b.* dropper vascular bundle; *x.* = xylem; *ph.* = phloem; *r.* = main root; r_1. = first adventitious root; *adv. r.* = crop of adventitious roots; *c* = cotyledon.

PLATE XXXI.

Fig. 1. Bulb of *Galanthus nivalis* (June, 1903) showing prolongation of axis, and formation of new bulb some little distance from parent (Nat. size).

Fig. 2. Non-flowering plant of *Tulipa saxatilis* (March, 1902).

Fig. 2 *a*. Whole plant (¾ nat. size).

Fig. 2 *b*. Bulb with outer scale leaf removed (Nat. size).

Fig. 2 *c*. Bulb with inner scale leaf and axillary bulb removed, showing continuity of base of foliage leaf and dropper (Nat. size).

Fig. 2 *d*. Longitudinal section of tip of dropper showing bulb (slightly enlarged).

Fig. 2 *e*. Transition region of foliage leaf, stem, and dropper in carbolic acid to show veining (slightly enlarged). Three main veins run up the back of the leaf from the stem base. The bundles supplying the adaxial side of the dropper all arise as branches from these three.

Fig. 3. Diagram to represent the mode of origin of the dropper of *Tulipa* by invagination of the tubular base of the foliage leaf fused on one side with an outgrowth from the stem. The stem is distinguished by cross-hatching.

Fig. 4. *Tulipa Clusiana* (December, 1903).

Figs. 4 *a*, *b*, *c*, *d*. Stages in the dissection of the bulb (Nat. size). Fig. 4 *d*. shows a small dropper forming the continuation of the foliage leaf. Also a lateral bud.

Figs. 4 *e*, *f*, *g*, *h*. Diagrams of sections cut at the levels marked by these letters in Fig. 4 *d*. The bundles are not yet completely differentiated into xylem and phloem (× 13 *circa*).

Fig. 4 *e*. Section at the level at which the tabular cavity of the leaf base opens to the exterior.

Fig. 4 *f*. Section near top of lateral bulb.

Fig. 4 *g*. Section through attachment of lateral bulb. Bundles are passing from the stem into the dropper.

Fig. 4 *h*. Dropper free from stem. Note circle of bundles on adaxial side. Bundles in stem rudiment are becoming irregular.

Fig. 5. *Tulipa saxatilis* (March, 1902).

Fig. 5 *a*. Central part of bulb showing rudimentary stem to which is attached base of foliage leaf, dropper, and adventitious roots (Nat. size).

Fig. 5 *b*. Section at the level marked *B* in Fig. 5 *a*, showing dropper and bases of numerous 3- to 5-arch adventitious roots, embedded in the rudimentary stem.

Fig. 6. *Tulipa praecox* (March, 1902).

Figs. 6 *a*, *b*, *c*, *d*, *e*. Dissection of bulb by removal of successive scale leaves. This bulb has a dropper in connexion with its foliage leaf, and also a second dropper from a lateral bulb. The second dropper is slightly connected with the outer tissues of the first.

Figs. 6 *f*, *g*, *h*. Three views of the transition region of the leaf and main dropper in carbolic acid (slightly enlarged). Five veins on the midrib side of the leaf run straight into the stem rudiment, and four veins on the sheathing side run straight into the abaxial side of the dropper. The fifth vein on the sheathing side of the leaf connects with an arch from the stem rudiment, and does not continue down into the dropper. Some veins come straight from the stem rudiment and run down into the back of the dropper which is also partly supplied by branches from the five main leaf veins.

Fig. 6 *k*. Apex of second dropper in carbolic acid (slightly enlarged).

Figs. 7 and 8. *Erythronium americanum.*

Figs. 7 *a* and *b*. Young bulb (February, 1904). Fig. 7 *b*. Longitudinal section showing lateral bulb within the tubular base of the foliage leaf which will later form a dropper.

Fig. 8. Older bulb (April, 1904). Two droppers have grown out.

PLATE XXXII.

Fig. 9. *Tulipa sp.* (Calcutta).

Fig. 9 *a*. Seedling (Nat. size).

Figs. 9 *b, c, d, e*. Transverse sections showing the vascular connexion of cotyledon, main root, and dropper (× 146).

Fig. 9 *b*. Cotyledon near base showing two bundles with a common protoxylem group. Outer parenchyma and epidermis omitted.

Fig. 9 *c*. A little lower than Fig. 9 *b*, showing a branch going off to the dropper from each limb of the double bundle.

Fig. 9 *d*. Diarch root on the right formed from the main part of the cotyledon double bundle, and dropper vascular system on the left formed from the two branches named *d. v. b.* in Fig. 9 *c*. These at first unite into a V-shaped double bundle, which in this section is beginning to divide up. On the right the first adventitious root is coming off.

Fig. 9 *e*. Dropper and root quite separate. The vascular system of the dropper now consists of a midrib and two laterals.

Fig. 10. *Erythronium grandiflorum.*

Fig. 10 *a*. Seedling. *s* = seed. (Nat. size.)

Figs. 10 *b, c, d, e*. Transverse sections showing relation of vascular system of cotyledon, root, and dropper. Outer parenchyma and epidermis omitted. *i. v. b.* = inverted vascular bundle; l_1 and l_2 = lateral bundles (× 146).

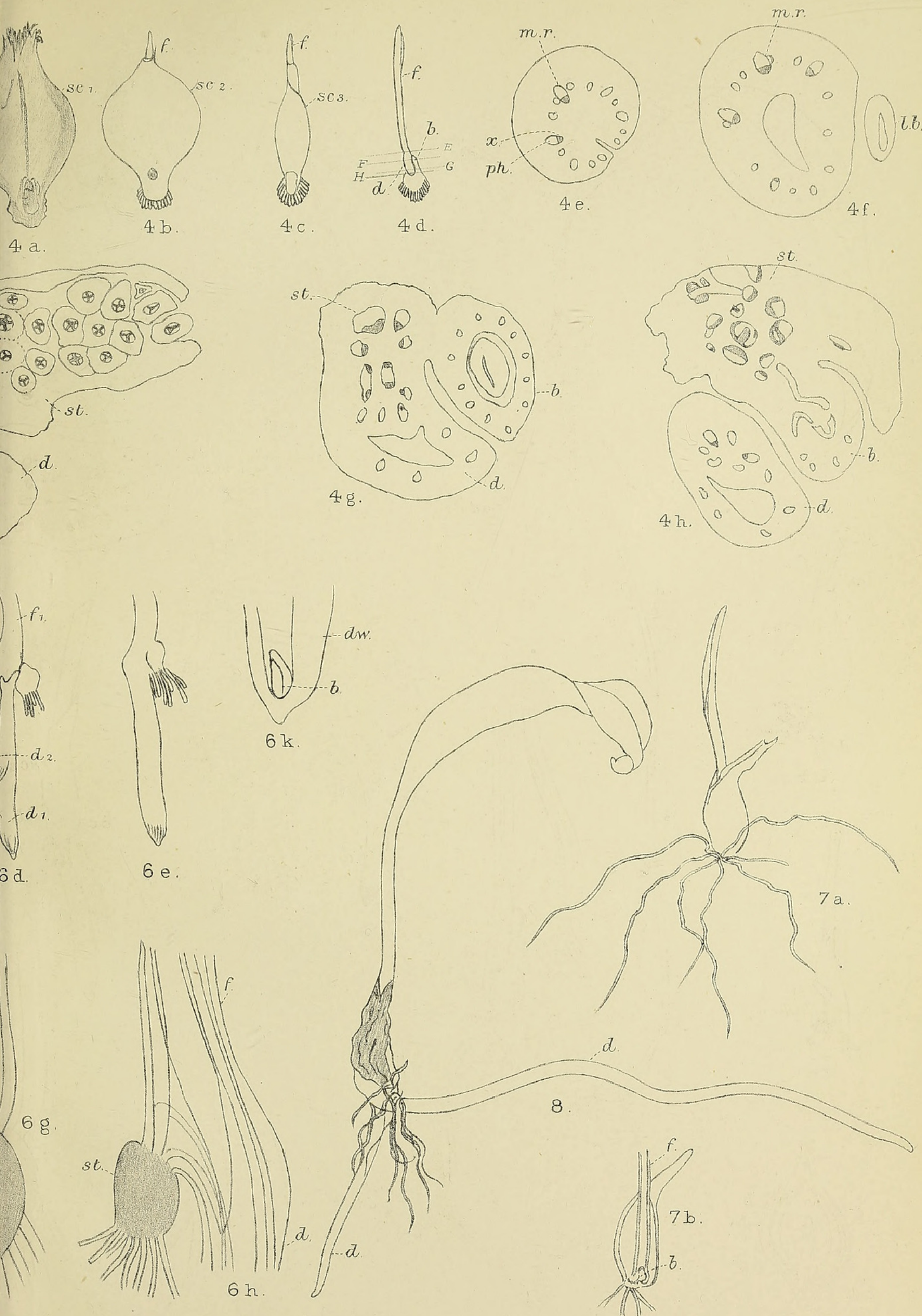
Fig. 10 *b*. Near base of cotyledon.

Figs. 10 *c* and *d*. Transition region. *d.m.r.* = dropper mid-rib.

Fig. 10 *e*. Triarch root completely formed to the right and dropper vascular system to the left. *r. c.* = root cylinder.

Fig. 11. *Tulipa sp.* (*Gesneriana ?*). Flowering tulip with a dropper from one of its lateral bulbs (July, 1906). *f. st.* = flowering axis. ($\frac{1}{3}$ nat. size.)

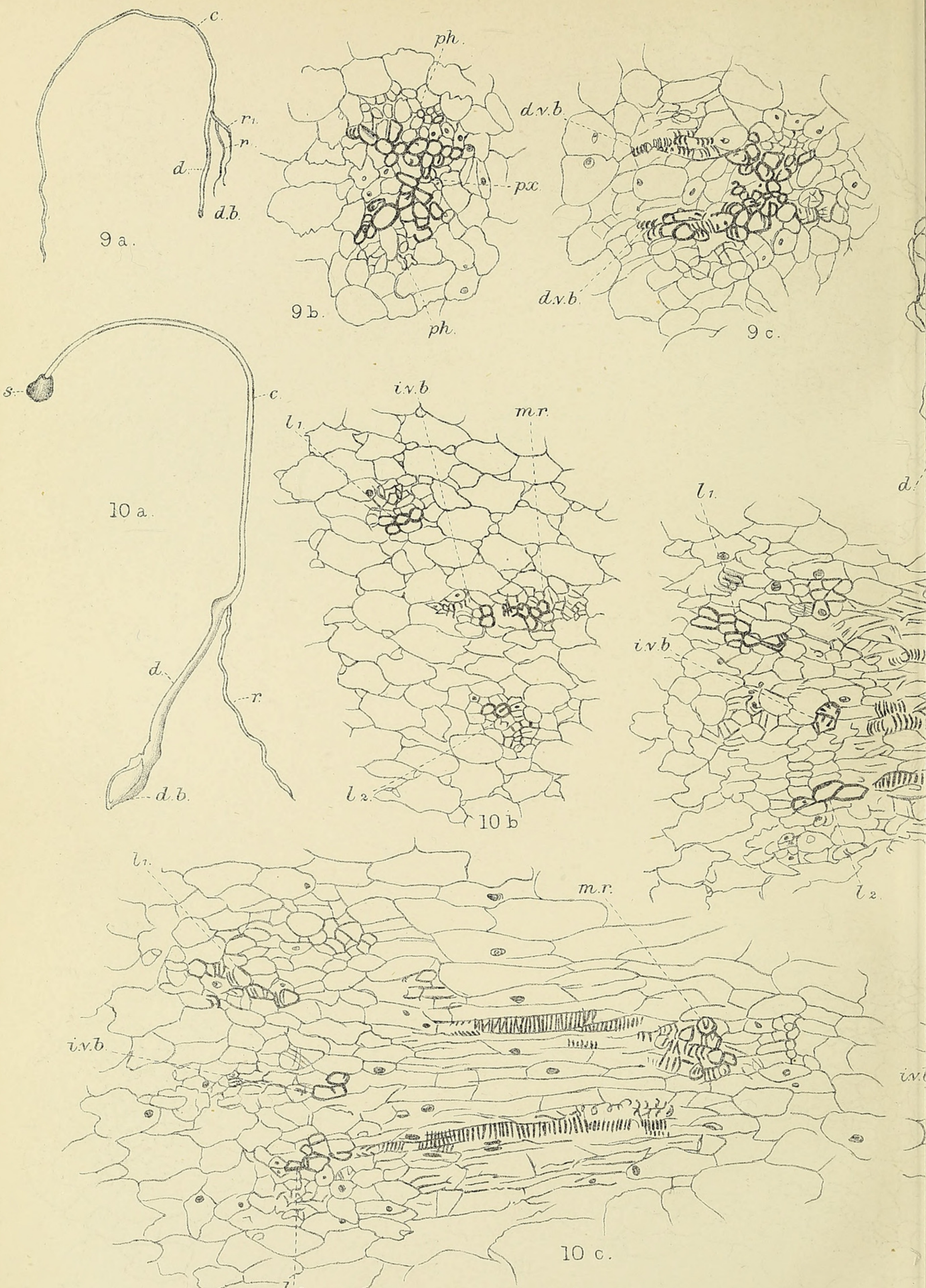
ROBERTSON DROPPERS OF TULIPA AND ERYTHRONIUM.



Huth. lith. et imp.

A. R. del. Huth. lith. et imp.

ROBERTSON — DROPPERS OF TULIPA AND ERYTHRONIUM.



A.R. del.

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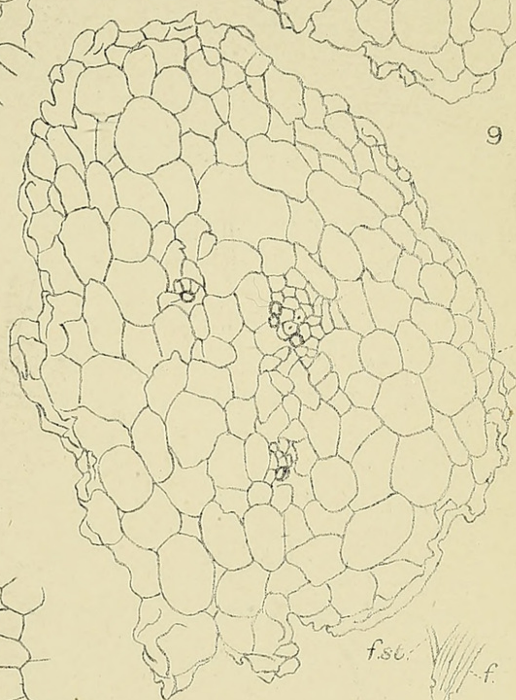
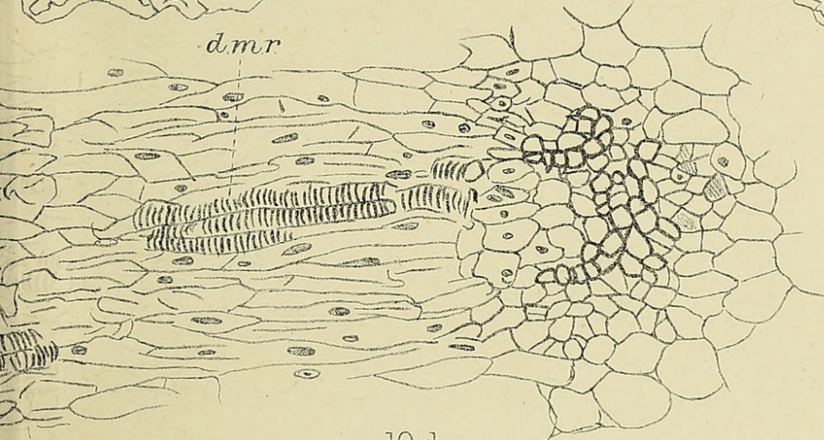
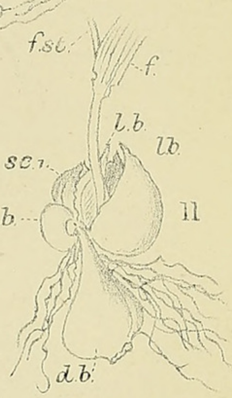
9 d.

9 e.





10 d.



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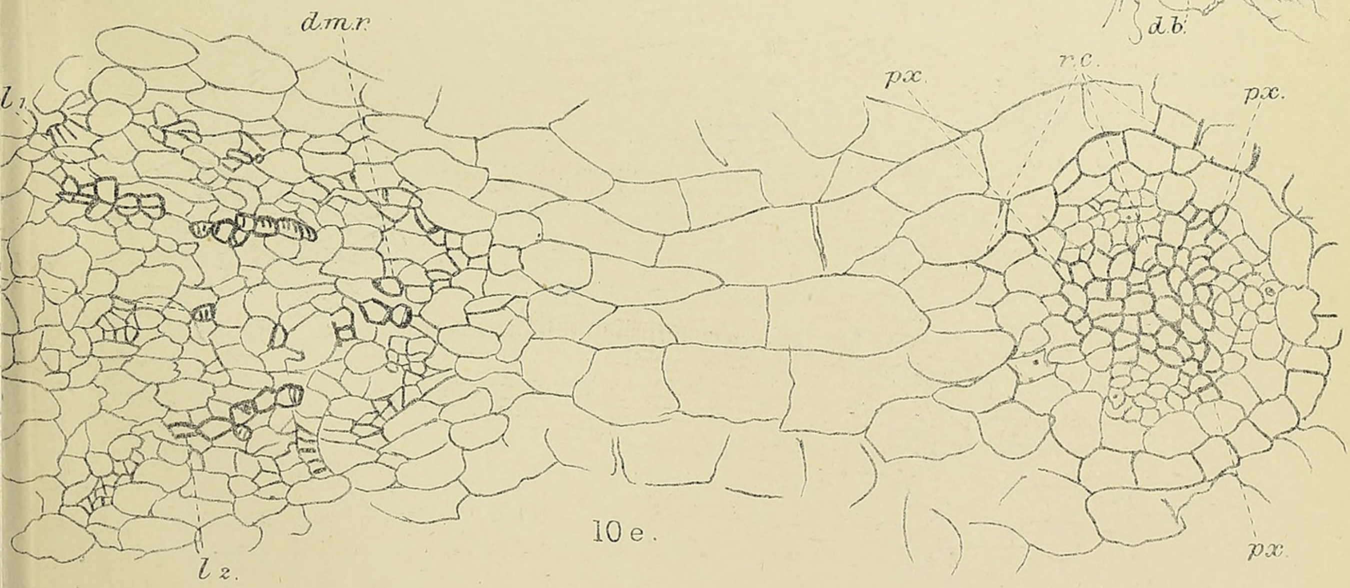
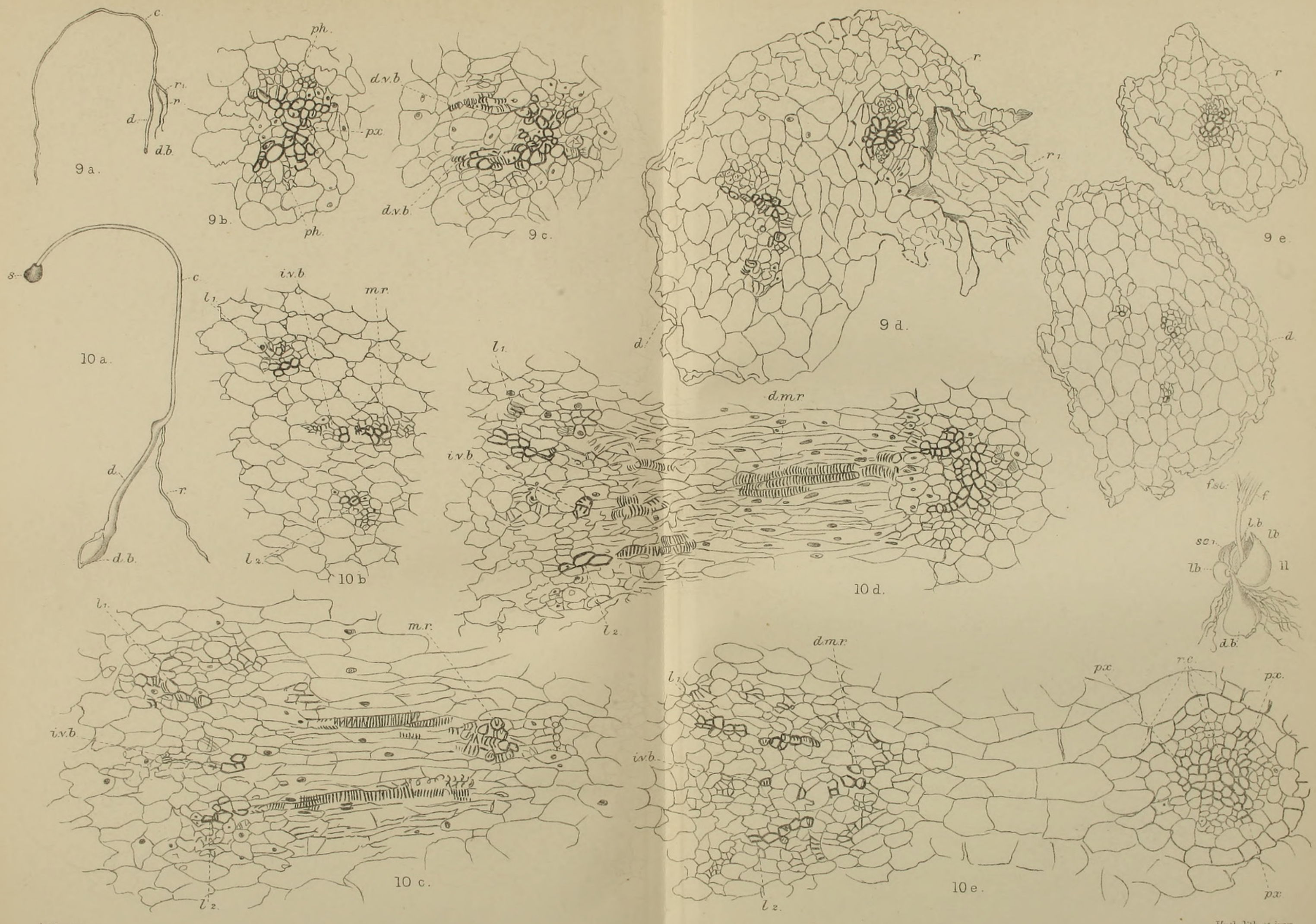


10 e.

Huth. lith. et imp.



A. R. del.

Huth lith et imp.

ROBERTSON – DROPPERS OF TULIPA AND ERYTHRONIUM.