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Studies on some Extranuptial Nectaries.

By

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With 3 plates

I. Introduction.

The first systematic study ever attempted upon the anatomy of the extranuptial nectary is that by Fuckel[1], who took the stipular nectary of *Vicia sativa* for his subject. Beginning with the year 1875, a series of investigations on the same subject with several species of plants was made by Poulsen[2], and since then, the subject has been treated by several botanists. Among the contributions on the subject in general, that of Morini[3] is regarded as one of the most valuable and contains some excellent illustrations. Delpino's[4] "*Piante Formicarie*" is also a complete work and treats of almost all the known cases of extranuptial nectaries. In the course of these studies, the attention of botanists was called to the relation of the nectary to insects and especially to

1) Fuckel. Flora. 1845.

2) Poulsen. Om nogle trichomer og nektarier. Vidensk. meddel. naturh. 1875.

3) Morini. Contribuzione all' anatomia ed alla fisiologia dei nettarii estranuziali. Bologna, 1886.

4) Delpino. Piante Formicarie. Bull. orto bot. Napoli. 1899, 1900, 1902, 1903.

the fact that ants are attracted by that organ, which circumstance tends to protect the plants from the injuries caused by the larva of certain insects. It has also been observed that even Hymenoptera are attracted by the nectaries. In tropical lands, the relation between ants and plants[1] is especially remarkable. As to the physiology of extranuptial nectaries, Bonnier[2] and Morini[3] may be mentioned as the first two early writers, who made investigations on the contents of the nectaries. They did not, however, show how sugar is formed in the nectary.

It is owing to Wilson's[4] researches, that we now know the cause of the secretion to be the local osmotic pressure, produced by the storage of sugar solutions in the tissues of the nectaries. Recently Haupt[5] carried on physiological experiments concerning the secretion of the nectary, and estimated the influence of warmth, moisture and sunlight on the secretory phenomena. He observed also the resorption of nectar in *Vicia faba*.

Lastly, on the development of extranuptial nectaries in general, we have had hitherto very few investigations, of which Correns'[6] paper on the *Dioscorea*-nectaries is worthy of mention.

With a view of throwing some light on the anatomy and physiology of extranuptial nectaries,[7] I have worked under the guidance of Prof. Miyoshi, during the academic year of 1904–1905,

1) Schimper. Die Wechselbeziehungen zwischen Pflanzen und Ameisen im tropischen America. Jena, 1888.

2) Bonnier. Les nectaires. Étude critique, anatomique et physiologique. Bull. de la soc. bot. de France. T. XXV, p. 262. 1878.

3) Morini. l. c.

4) Wilson. The causes of the excretion of water on the surface of nectaries. Untersuch. a. d. bot. Inst. in Tübingen. Bd. I, p. 8. 1881.

5) Haupt. Zur Sekretionsmechanik der extrafloralen Nektarien. Flora. Bd. 90, p. 1. 1902.

6) Correns. Zur Anatomie und Entwickelungsgeschichte der extranuptialen Nektarien in Dioscorea. Sitzungsb. d. k. k. Akad. d. Wiss. Bd. 97, Theil I, p. 561. Wien, 1888.

7) I use the term "extranuptial nectary" in the same sense, as did Knuth in his 'Blüthenbiologie."

mostly on material collected in the Botanic Garden of the Tokyo Imperial University, and I wish here to express my sincere thanks to him. The results are given in the following chapters.

II. Anatomy of some extranuptial nectaries.

A. Structure of extranuptial nectaries in general.

All the extranuptial nectaries, which I have studied, may be classified under two types: the first including the nectaries, which develop from epidermal cells; and the second, those which originate from a group of cells, both epidermal and hypodermal.

The first type.

a. Polygonum sachalinense.

Here we have the nectary in the form of a shallow elliptical basin of a slightly reddish colour. It is tolerably large, the longest diameter reaching sometimes 4 mm. It is composed of a group of glandular papillae, each of which consists of three parts, *viz.*, crown, style and base. The crown is built up of a bundle of narrow prismatic cells, regularly arranged in a single layer on the style cells; the number of the cells in each bundle varies from 16 upwards. The height of the cells is three or four times their diameter. Sometimes the cell is divided into two parts by a tangential wall.

The style cells are fewer in number than the crown cells, and lie close to one another. Each style cell is in shape a polyhedron, the upper wall of which is convex. The cuticle covering the whole surface of glandular papillae is slightly thickened around the style.

Immediately below each style cell and on the same plane

with the epidermis lie flattened basal cells, the number of which corresponds to that of the style cells. Adjoining the basal cells is the small-celled parenchyma, which is composed of only two or three layers of cells. The fibro-vascular bundle shows no direct connection with the nectarine tissue.

The crown is the true secretory epithelium, and the cells are filled with granular protoplasm, with numerous vacuoles which are rich in grape sugar. The style cells, on the contrary, contain little protoplasm with very large vacuoles, and a distinct nucleus. The basal cells, like the crown cells, are rich in plasmic contents and have a large and distinct nucleus. Fehling's solution gives copious brown precipitates in the cell.

The above description of the structure of the extranuptial nectary is applicable also to the case of *Polygonum cuspidatum*[1] and *P. multiflorum*.

Ipomoea Batatas has also similarly constructed extranuptial nectaries, which are situated on the under surface of the leaves along both sides of the origin of the leaf-veins. Here we see only one broad style cell and two basal cells in a papilla.

b. Osmanthus aquifolium.

The extranuptial nectaries are found on the under surface of leaf-blades, and are composed of a multitude of minute glandular papillae. The crown consists of two small cells and the style of a single cell only. The side wall of the style cell is remarkably thickened and cutinised forming a stout ring around the papilla so as to support the crown. The base is formed of two small cells which are rich in contents. There are several non-secretory papillae, intermingled with the glandular

1) Morini. l. c. p. 40.

papillae. The non-secretory papilla is composed of a set of long cells, which have a thick, cutinised outer wall, but contain no protoplasm.

Syringa amurensis var. *villosa* is remarkable for its having the style cell often divided by a tangential wall into two parts, the papilla consequently being somewhat elongated. The nectaries of *Ligustrum medium*, *L. ciliatum* and *L. lucidum*[1] belong to this type.

c. *Urena sinuata.*

The nectary is found on the prominent midrib and has a structure similar to that of *Hibiscus tiliaceus.*[2] The glandular papilla has only one style cell and two basal cells, and the bundle of crown cells is elongated in the vertical direction forming on the whole a kind of multicellular glandular hair.

Ipomoea paniculata[3] and *Erythrina Cristagalli*[4] are known to have a similar structure.

d. *Clerodendron trichotomum, Diervilla grandiflora, Callicarpa japonica, Tecoma grandiflora, Catalpa Kaempferi, Paulownia tomentosa.*

The extranuptial nectaries of this group differ from the foregoing type, and even among them some structural differences are to be noticed. These nectaries originate from a single epidermal cell, and develop into a complex form by a repeated division of that single cell. It may be remarked, that there exists a striking resemblance between the structure of the nectaries of this type

1) Morini. l. c. p. 38.
2) Morini. l. c. p. 44.
3) Ewart. On the leaf-glands of Ipomoea paniculata. Ann. of Bot. Bd. IX, p. 175. 1895
4) Morini. l. c. p. 45.

on the one hand, and that of some hydathodes[1] on the other.

The second type.

SUBDIVISION I.

Prunus yedoensis.

The extranuptial nectaries are found in pairs on the top of the petiole, just at the base of the leaf-blade. They are cup-shaped and show sometimes a bright red colour on the surface. The secretory layer consists of a row of prismatic cells, which, gradually lessening in height, pass into epidermal cells. The cuticle is found above the secretory epithelium.

Just below the secretory epithelium, several layers of sub-glandular cells are found. The main body of the disk is composed of an anastomosing system of conducting parenchyma and ground parenchyma. The conducting parenchyma is arranged just below the layer. The extranuptial nectaries of *Mallotus japonicus*, *Idesia polycarpa*, *Excoecaria japonica*, *Aleurites cordata*[2] and *Prunus persica* have a similar structure, while those of *Sapium sebiferum* and *Populus tremula* var. *villosa* may better be included under the following type, as their secretory epithelium consists not of a single row, but of several rows of cells.

SUBDIVISION II.

a. Luffa cylindrica.[3]

The extranuptial nectary has several secretory layers, in which the secretory cells are regularly arranged in a row. There exists, just below the secretory epithelium, a certain layer of small

1) Koorders. Ueber die Blüthenknospen-Hydathoden einiger tropischen Pflanzen

2) Groom. On the extrafloral nectaries of Aleurites. Ann. of Bot. Bd. 8, p. 228. 1894.

3) Archangeli. Altre osservazioni sopra alcune Cucurbitacee e sui lovo nettarii. Bull. soc. bot. ital. p. 198. 1899.

cells, which corresponds to the style cells in the extranuptial nectary of *Clerodendron trichotomum.*

b. Cassia sulfurea.

A single nectary of a spherical form, acute at the top and green in colour, is found on the rachis between the lowest leaflets. The whole surface of the spherical body is provided with several layers of secretory epithelium, and is protected by the cuticle. The outermost layer of the secretory epithelium consists of elongated cells of different heights, arranged somewhat regularly. Chlorophyll is found in the secretory epithelium. Subglandular cells are deficient. The space inside of these layers is filled with the ground parenchyma and fibro-vascular bundles.

c. Viburnum dilatatum.

Minute nectaries are found on the underside of the leaves. The cells which line the surface of each nectary are broad in shape and cutinised on the outer wall. Beneath this layer, there are five or six layers of small elongated cells, arranged in a form radiating from the centre of the nectarine surface. These cells may be regarded as the secretory cells. The fibro-vascular system is connected with the base of the nectary by the conducting parenchyma. The secretory cells are surrounded by a number of large parenchymatous cells which have wide intercellular spaces between them.

Viburnum japonicum, V. opulus[1] and *Diospyros morissiana* have similarly constructed nectaries.

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1) Thouvenin. Observations sur les glandes petiolaires du Viburnum opulus. Rev. gén. bot. Bd. XV, p. 98. 1903.

B. Size of extranuptial nectaries.

The following table shows the sizes of the fully developed nectaries, in the plants which I studied.

(Name of plant)	(Longer diameter)	(Shorter diameter)
Polygonum sachalinense.	3.0 mm.	2.0 mm.
Polygonum cuspidatum.	3.0 „	2.0 „
Prunus yedoensis.	2.5 „	2.0 „
Prunus Laurocerasus.	2.3 „	1.5 „
Idesia polycarpa.	2.0 „	0.7 „
Aleurites cordata	1.5 „	1.0 „
Viburnum opulus.	1.5 „	0.7 „
Mallotus japonicus	1.5 „	1.0 „
Clerodendron trichotomum.	0.75 „	0.75 „
Viburnum japonicum.	0.7 „	0.5 „
Ligustrum lucidum	0.7 „	0.45 „
Syringa amurensis var. *villosa*	0.7 „	0.45 „
Viburnum dilatatum.	0.5 „	0.45 „
Diospyros Lotus.	0.5 „	0.35 „
Callicarpa japonica.	0.4 „	0.4 „
Diervilla grandiflora.	0.3 „	0.2 „
Paulownia tomentosa.	0.3 „	0.3 „
Catalpa Kœmpferi.	0.2 „	0.2 „
Tecoma grandiflora	0.2 „	0.2 „

C. Structure of the secretory organ.

We shall here describe the nectary in its parts, *viz.*, cuticle, secretory layer, subglandular layer, vascular system, and also the conspicuous cell contents, i. e. crystals and anthocyan.

a. Cuticle.

In most cases the cuticle forms a simple coating to the

outer wall of the epithelium; but in the nectaries of the second type it is sometimes found penetrating between the secretory cells so as to cover their longitudinal walls. When the secretory epithelium has stored up plenty of nectar substance, the cuticle is separated from the underlying cellulose-layer and is raised up from the latter. The space thereby produced between the cuticle and the cell-wall, is filled up with successive secretions of the secretory epithelium so as to cause the swelling of the cuticular membrane. I met with this phenomenon very often on the microtome section of the extranuptial nectaries of *Diospyros morissiana*, *Cassia occidentalis* and *Idesia polycarpa*.

Under favourable external circumstances and also under the one-sided osmotic pressure[1] exerted by the subglandular tissue, the elasticity of the cuticle is overcome, resulting in the rupture of the membrane and the extrusion of the fluid on the surface of the nectary. Thus the secreting phenomenon is caused. After the first ample secretion, the nectaries in most cases remain inactive and produce no more nectar; the regeneration[2] of the cuticle takes place only with some species of *Prunus*. From the fact that the cuticle is often ruptured by the force of the secreting fluid, it must be supposed that the membrane is impermeable.[3] But there are cases[4] in which the cuticle remains uninjured throughout the secreting period.

The nectar must then be secreted through the cuticle; in other words, the latter must be permeable. In fact, the cuticle is thinner on the surface of the nectary (generally about 7–3 μ)

1) Wilson. l. c.
2) Pfeffers. Pflanzenphysiologie. II Aufl. Bd. I, p. 265.
3) Wilson. l. c.
4) Koorders. l. c

than in any other part of the plant. The cuticle[1] no doubt allows, in certain instances, of the secretion of the nectar through its substance.

b. Secretory layer.

The cells of the secretory layer are generally of an elongated prismatic form, and are compactly set together. They are rich in granular protoplasm and numerous vacuoles. Chlorophyll grains are lacking in the fully developed nectaries, except in the case of *Cassia sulfurea* and *C. occidentalis*. Sugar is commonly found in the cells of the secretory layer, while fat and tannin are rarely present. Nuclei with nucleoli are fairly distinct, especially in the younger stages, and are always found near the centre of the cells.

After the secretion of the nectar, the secretory cells shrink, but after a few days often recover their original condition.

c. Subglandular layer.

This layer is found under the secretory layer of the nectaries of the second type only, and its physiological significance is the same as that of the basal cells of the nectaries of the first type; it also resembles them in its morphological characters. The subglandular layer has no intercellular space, and the cells themselves are generally smaller than the neighbouring parenchymatous cells. The nucleus is comparatively large and the chlorophyll grains are often found in the cell, as is the case with *Prunus yedoensis*, *Idesia polycarpa*, *Viburnum japonicum*, etc.

The function of this layer is evidently to cause the osmotic pressure from inside, necessary to the secretion of the nectar.

d. Vascular system.

1) Kroemer. Wurzelhaut, Hypodermis u. Endodermis der Angiospermen-Wurzel. Bibliotheca Botanica. Bd. XII, Heft 59. 1903.

A vascular system[2] is found in nectaries of the second type. The fibro-vascular bundles coming from beneath spread out in the ground parenchyma of the nectary, and are connected with the subglandular tissue by means of the conducting parenchyma. The constituent elements of the greater part of the fibro-vascular bundles end bluntly in the assimilatory tissue of the nectary.

The nectar, secreted under favourable conditions for twelve hours, amounts to such a quantity, as almost to equal the volume of the nectary itself. It is obvious that the secreting layer must have derived from the inner tissues the water necessary to form the entire mass of the nectar. It seems, however, that the vascular system does not supply water directly to the secreting epithelium; for I severed the midrib of the leaves of *Prunus Laurocerasus* at a point, near the nectary, so as to cut off the nectary from direct connection with the main vascular system, and repeatedly washed off the nectar from the nectarine surface, but the operation did by no means affect the quantity of the secretion.

With *Viburnum japonicum*, I obtained the same results.

e. Crystals.

Cells containing crystals of calcium salts (i. e. mostly oxalate, sometimes carbonate) were present in large numbers in the nectaries of most of the plants which I studied. These cells are larger than the ground parenchymatous cells and are distributed along the water-passage.

f. Anthocyan.

The extranuptial nectaries of *Impatiens balsamina* and *Prunus cerasus* have a beautiful red colour owing to the presence of anthocyan in their secretory cells. The nectary of *Sapium sebiferum* has a bright red colour only in the younger stages; but in the case

2) Ewart. l. c.

of *Viburnum japonicum*, red anthocyan is found in the surrounding tissues of the nectaries, but only when they have become old.

Idesia polycarpa has petiolar nectaries, of which those situated at the upper part of branches, and so exposed to the sun, become in consequence red; while those borne on the lower shaded leaves retain the green colour.

The extranuptial nectaries of *Vicia faba* and *V. sativa*, when they are cultivated in diffuse light, take no reddish hue, and even in direct sunlight, all their younger nectaries have a green colour. The green nectaries produce the same amount of nectar as the red ones do, as I have proved in the case of *Vicia faba*, *Idesia polycarpa* and *Prunus yedoensis*. So far as I could see, ants[1] showed no preference as to the colour of the nectaries, visiting the red and green ones with equal frequency.

D. Classification of some extranuptial nectaries.

The first type.

a. *Polygonum sachalinense; P. cuspidatum; P. cuspidatum*, forma *Meigetsuso; P. multiflorum; Ipomoea Batatas.*

b. *Ligustrum ciliatum; L. medium; L. lucidum; Osmanthus aquifolium; O. fragrans; Syringa amurenis* var. *japonica; S. vulgaris; Sterculia platanifolia; Hibiscus rosa-chinensis*

c. *Hibiscus tiliaceus; Urena sinuata.*

d. *Diervilla grandiflora; D. japonica; Clerodendron trichotomum; Callicarpa japonica; Tecoma grandiflora; Catalpa Kaempferi; Paulownia tomentosa; Vicia faba; V. sativa.*

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1) Conf. Machiatti. Ufficio dei peli, dell'antocianio, e dei nettarii estranuziali dell' Ailanthus grandulosa. Bull. soc. bot. ital. 1899.

The second type.

Div. I. *Prunus yedoensis ; P. macrophylla ; P. Laurocerasus ; Aleurites cordata ; Excoecaria japonica ; Mallotus japonicus ; Sapium sebiferum ; Merculiaris leiocarpa ; Idesia polycarpa ; Populus tremula* var. *villosa.*

Div. II.

a. *Luffa cylindrica.*

b. *Cassia sulfurea ; C. occidentalis.*

c. *Viburnum dilatatum ; V. Opulus ; V. japonicum ; Diospyros Lotus ; D. morissiana ; Impatiens balsamina ; Ailanthus glandulosa ; Sambucus racemosa.*

E. Secreting season.

April : *Sambucus racemosa ; Prunus yedoensis ; Viburnum dilatatum ; V. japonicum ; Vicia faba.*

May : *Vicia sativa ; Prunus persica ; P. communis ; Excoecaria japonica ; Sapium sebiferum ; Viburnum Opulus ; Idesia polycarpa ; Sterculia platanifolia ; Polygonum sachalinense ; P. cuspidatum* forma *Meigetsuso ; Syringa vulgaris ; S. amurensis* var. *villosa.*

June : *Aleurites cordata ; Hibiscus tiliaceus.*

September : *Urena sinuata ; Cassia sulfurea.*

October : *Luffa cylindrica ; Osmanthus aquifolium.*

Each nectary has its own secreting season, and in most cases the secretion has certain relations to the flowering season. Sometimes the secretion occurs simultaneously with the development of the young slender leaves.

III. Physiological experiments.

For the secretion of the nectar, the external circumstance

are of slight value compared with the inner conditions of the nectary. When the plant is growing vigorously and its nectaries are fully developed, the secretion may occur by mere chance. Generally speaking, the external conditions favourable to the life and growth of the plant itself, promote at the same time the secretion of the nectar.

The mechanism of the secretion of the nectar has recently been studied by Haupt,[1] who found that light, heat and moisture are the conditions which principally modify the secretion. I have also made some experiments on these conditions, the results of which may briefly be described as follows.

a. Influence of moisture.

Moisture is one of the conditions most favourable to the secretion of the nectar, and its influence seems to be more or less direct. Dry atmosphere is in all cases unfavourable to the secretion.

In open air, nectaries are found to secrete more nectar in warm damp weather than on dry windy days. When a plant, the nectaries of which are inactive in the open air, is put under a moist bell-jar, the secretion often takes place. For this experiment I took the following plants: *Prunus Laurocerasus; P. yedoensis; P. persica; Idesia polycarpa; Mallotus japonicus; Aleurites cordatus; Diospyros Lotus; D. morissiana; Viburnum Opulus; V. japonicum; Diervilla grandiflora; D. floribunda; Ligustrum japonicum; L. lucidum; Polygonum cuspidatum; P. sachalinense; Sterculia platanifolia; Callicarpa japonica.*

Cut twigs of *Prunus Laurocerasus*, put in a water bottle and held under a bell-jar in moist air, continued to secrete the nectar during the three weeks—from April 21st to May 10th, the washing of the nectary being repeated daily. Neither the quantity of the nectar, nor the sugar in it, decreased throughout the experiment.

1) Haupt, l. c.

Only towards the end of the fourth week, did the leaves become yellowish, and the nectar decrease in quantity. Finally the leaves withered and fell.

During the experiment, when I took the plant out of the moist bell-jar and put it in dry atmosphere, I noticed that the secretion stopped at once, but began again on being replaced in moist air.

Under the same conditions, *Prunus yedoensis* and *P. persica* were observed to secrete the nectar very copiously four times; and *Viburnum japonicum* five times. Among the nectaries of the first type, *Polygonum sachalinense*, *P. cuspidatum*, *Ligustrum medium* and *L. lucidum* did not secrete at all, when once washed out, though I treated them carefully and kept them under favourable conditions. *Vicia faba*, *V. sativa* and *Diervilla grandiflora* secreted the nectar only twice under the same treatment.

Vicia faba, which is active in secretion under normal conditions, did not secrete, when put in a small dry chamber, the air in which was kept dry by means of calcium chloride. With *Viburnum japonicum*, *V. opulus* and *Idesia polycarpa*, I obtained exactly the same result.

In general the nectaries of the second type are more vigorous in the secretion of nectar than those of the first type. This difference in secretion, between the nectaries of the first type and those of the second, chiefly depends upon their different structures.

b. Influence of temperature.

The influence of temperature on the secretion of the nectar, within the range of 15°–25° C. is not remarkable and seems to have merely an indirect effect, in so far as it affects the plant itself. In estimating the influence of temperature, it is necessary to eliminate the influence of humidity, which has a much greater influence on the secretion.

I first took *Prunus Laurocerasus* and put it into saturated air at 22° C. The secretion was at this temperature very active. Then I lowered the temperature to 8°–6° C., and after ten hours I could see that the secretion had decreased. Repeating the same process several times, I got always the same results.

With *Prunus yedoensis, Excoecaria japonica, Vicia sativa, Polygonum cuspidatum, P. sachalinense* and *Ligustrum lucidum*, the secretion stopped entirely at a temperature of 8°–6° C.

With young or scarcely active nectaries, the effect of cold was still evident. At a temperature above 33° C., the nectaries of *Prunus Laurocerasus, P. yedoensis* and *Viburnum japonicum* ceased to secrete, and at 40° C., the leaf itself lost its activity.

c. Influence of light.

On putting *Ligustrum lucidum, Viburnum japonicum, V. opulus, Prunus yedoensis*, and *P. Laurocerasus* in a dark moist chamber, I found that their young nectaries produced no nectar at all, but their fully developed nectaries secreted in the dark equally well as in the sunlight.

Prunus Laurocerasus secreted in a dark place for three weeks, the washing being repeated daily. The secretion was always ample in quantity. *Prunus yedoensis* in the dark produced nectar thrice. The influence of light on the secretions of the nectaries is, in short, of an indirect nature, except in the case of *Vicia* and some *Euphorbia*.[1]

A specimen of *Vicia faba*, 20 cm. high, cultivated in diffused light, produced two blossoms, but their nectaries did not secrete. Another specimen of *Vicia faba*, cultivated in the open air exposed to direct sunlight, had secreted nectar before the flower buds appeared.

In *Vicia*, the secretion takes place from the lower stipules

1) Conf. Haupt. l. c. p. 28.

and as the plant grows proceeds to the upper ones. Sunlight seems to be of the greatest importance to the growth of the nectaries, but not, in most cases, to the secretion of the nectar.

d. Phenomena of secretion.

Out of a large number of extranuptial nectaries, I found only a few that were actually secreting nectar. Some of these nectaries were of a very small size, especially in the cases of *Diospyros Kaki*, *Callicarpa japonica* and *Paulownia tomentosa*. In these plants, it is difficult to discern any nectar drops on the nectaries. I could infer the actual occurrence of secretion only from the presence of ants on these nectaries. In *Ligustrum ciliatum*, *L. medium* and *L. japonicum*, the nectaries decay, after the secretion is finished, and are covered with a corky layer which is developed from the basal cells of the nectaries. At the next season, there are formed sometimes on the same leaf new nectaries, which then secrete the nectar. The nectaries of *Prunus Laurocerasus* retain vigorous activity, producing under favourable conditions fresh nectar repeatedly.

When a stem or a branch with extranuptial nectaries on it is cut off and its end is put in water, the nectaries soon begin to secrete. In a quarter of an hour, small drops of nectar may be observed gathering on the surface of the nectaries. The secretion is a transparent colourless liquid, which has a very sweet taste. It reduces Fehling's solution, but it gives no reaction of fat or albumen.

IV. Conclusion.

1. There are two forms of extranuptial nectaries. One is represented by *Polygonum sachalinense* and the other by *Prunus yedoensis*.
2. The first type of extranuptial nectaries develops from

epidermal cells, while the second from a group of cells both epidermal and hypodermal.

3. Foliar nectaries are situated on the underside of the leaf, while petiolar nectaries are situated on the upper surface of the petiole.
4. Extranuptial nectaries consist of two parts: secretory cells, which directly secrete the nectar on the surface of the nectary; and subglandular cells, which have only an indirect relation to the secretion.
5. External circumstances are of little importance to the secretion as compared with the inner conditions of the nectary itself.
6. Among different external circumstances, moisture seems to be of the greatest importance.
7. The secretion in the case of the nectaries of the second type is more active than in those of the first type.
8. Ants are attracted by extranuptial nectaries.

V. List of Japanese, native or cultivated plants which have extranuptial nectaries.

The names of cultivated plants are put in parentheses, and those studied by myself are marked with an asterisk.

Polypodiaceae.

* *Pteris aquilina* L.

Dioscoreaceae.

* *Dioscorea japonica* Thunb.

* *Dioscorea Tokoro* Makino.

Salicaceae.

Populus balsamifera L. var. *suaveolens* Lond.

* *Populus tremula* L. var. *villosa* Wesm.

Polygonaceae.

Polygonum cuspidatum S. et Z.

* *Polygonum cuspidatum* S. et Z. forma *Meigetsuso.*

Polygonum cuspidatum S. et Z. forma *Himeitadori.*

* *Polygonum multiflorum* Thunb.

* *Polygonum sachalinense* Fr. Schm.

Rosaceae.

Prunus Buergeriana Miq.

* (*Prunus cerasus* L.)

Prunus communis Huds.

Prunus Grayana Maxim.

Prunus incisa Thunb.

Prunus japonica Thunb.

* (*Prunus Laurocerasus* L.)

* *Prunus macrophylla* S. et Z.

Prunus Maximowiczii Rupr.

Prunus Miqueliana Maxim.

(*Prunus mume* S. et Z.)

Prunus pendula (Sieb.) Maxim.

Prunus persica S. et Z. var. *vulgaris* Maxim.

Prunus tomentosa Thunb.

* *Prunus yedoensis* Matsum.

Leguminosae.

(*Cassia laevigata* Willd.)

Cassia mimosoides L.

* (*Cassia occidentalis* L.)

* (*Cassia sulfurea* DC.)

(*Phaseolus multiflorus* L.)

* (*Vicia Faba* L.)

* (*Vicia sativa* L.)

Simarubaceae.

* (*Ailanthus glandulosa* Desf.)

Euphorbiaceae.

* *Aleurites cordata* Muell. Arg.

* *Excoecaria japonica* Muell. Arg.

* *Mallotus japonicus* Muell. Arg.

* *Merculiaris leiocarpa* S. et Z.

* (*Ricinus communis* L.)

* *Sapium sebiferum* Roxb.

Balsaminaceae.

* (*Impatiens balsamina* L.)

Malvaceae.

* *Hibiscus rosa-chinensis* L.

(*Hibiscus syriacus* L.)

* *Hibiscus tiliaceus* L.

* *Urena sinuata* L.

Sterculiaceae.

* (*Sterculia platanifolia* L.)

Flacourtiaceae.

* *Idesia polycarpa* Maxim.

Ericaceae.

* *Vaccinium bracteatum* Thunb.

* *Vaccinium hirtum* Thunb.

Ebenaceae.

* *Diospyros Kaki* L. *f.*

* *Diospyros Lotus* L.

* *Diospyros Morissiana* Hance.

Oleaceae.

* *Ligustrum Ibota* Sieb.

* *Ligustrum japonicum* Thunb.

* (*Ligustrum lucidum* Ait.)
* *Ligustrum medium* Fr. et Sav.
* *Osmanthus aquifolium* B. et H.
* *Osmanthus fragrans* Lour.
Osmanthus japonicus Sieb.
* *Syringa amurensis* Rupr. var. *japonica* Maxim.
* (*Syringa vulgaris* L.)

Asclepiadaceae.

* *Cynanchum caudatum* Maxim.

Convolvulaceae.

* *Ipomoea Batatas* Lam.

Verbenaceae.

* *Clerodendron trichotomum* Thunb.
* *Callicarpa japonica* Thunb.
Callicarpa mollis S. et Z.

Scrophulariaceae.

* *Paulownia tomentosa* Baill.

Bignoniaceae.

* (*Tecoma grandiflora* Loisel.)
* *Catalpa Kaempferi* S. et Z.

Caprifoliaceae.

* *Diervilla floribunda* S. et Z.
* *Diervilla grandiflora* S. et Z.
Diervilla japonica DC.
Sambucus javanica Bl.
* *Sambucus racemosa* L.
(*Sambucus nigra* L.)
* *Viburnum dilatatum* Thunb.
* *Viburnum Opulus* L.
Viburnum Wrightii Miq.

Cucurbitaceae.

* (*Luffa cylindrica* Roem.)
(*Lagenaria vulgaris* Ser.)

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PLATE I.

Explanation of the Plates.

n, extranuptial nectary; *e*, epidermal cell; *c*, crown cell; *st*, style cell; *b*, basal cell; *p*, parenchymatous cell; *cr*, crystal cell; *sc*, secretory cell; *subg*, subglandular cell; *fb*, fibro-vascular system; *is*, intercellular space; *ch*, chlorophyll grains;

D. II, D. III, F. II, &c., Lenses of Zeiss microscope.

Plate I.

Fig. I. *Polygonum sachalinense*. *a*, stem; *b*, longitudinal section of the nectary; *c*, the same as *b*.

Fig. II. *Ipomoea Batatas*. *a*, young leaf; *b*, glandular papilla of the nectary; *c*, origin of veins on the leaf.

Fig. III. *Polygonum multiflorum*. *a*, stem; *b*, glandular papilla.

Fig. IV. *Polygonum cuspidatum* forma *Meigetsuso*.

Fig. V. *Syringa amurensis* var. *villosum*. *a*, lower surface of the leaf; *b*, longitudinal section of the nectary.

Fig. VI. *Osmanthus aquifolium*. *a*, lower surface of the leaf; *b* and *c*, longitudinal section of the nectary.

Fig. VII. *Urena sinuata*. Lower surface of the leaf; *b*, longitudinal section of the nectary; *c*, glandular hairs.

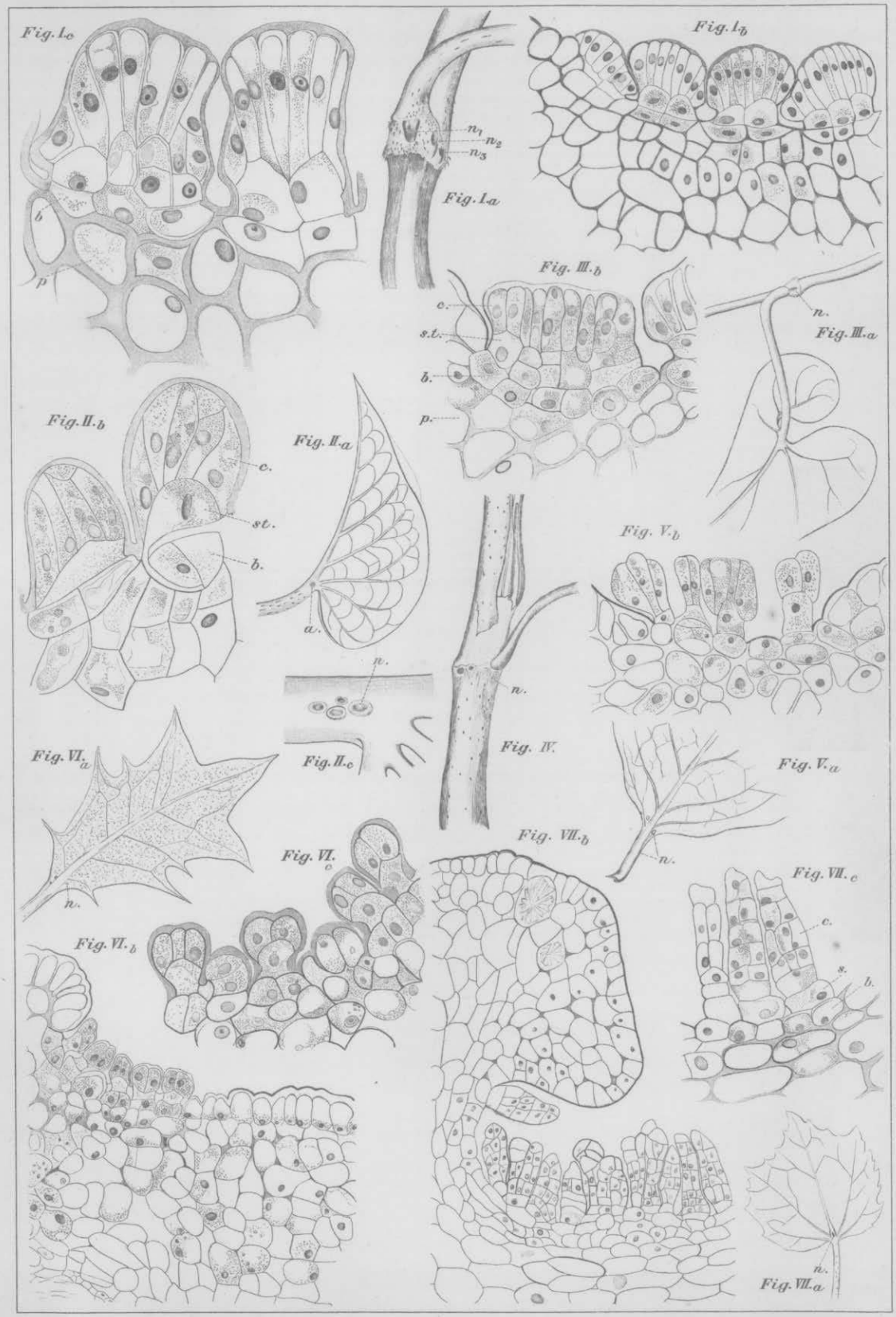


Fig. I.c
b
p
Fig. I.a
n_1
n_2
n_3
Fig. I.b
Fig. III.b
c.
s.t.
b.
p.
n.
Fig. III.a
Fig. II.b
c.
st.
b.
Fig. II.a
a.
n.
Fig. II.c
Fig. IV.
n.
Fig. V.b
Fig. V.a
n.
Fig. VI.a
n.
Fig. VI.c
Fig. VI.b
Fig. VII.b
Fig. VII.c
c.
s.
b.
n.
Fig. VII.a

PLATE II.

Plate II.

Fig. I. *Clerodendron trichotomum.* *a*, lower surface of the leaf; *b*, longitudinal section of the nectary.

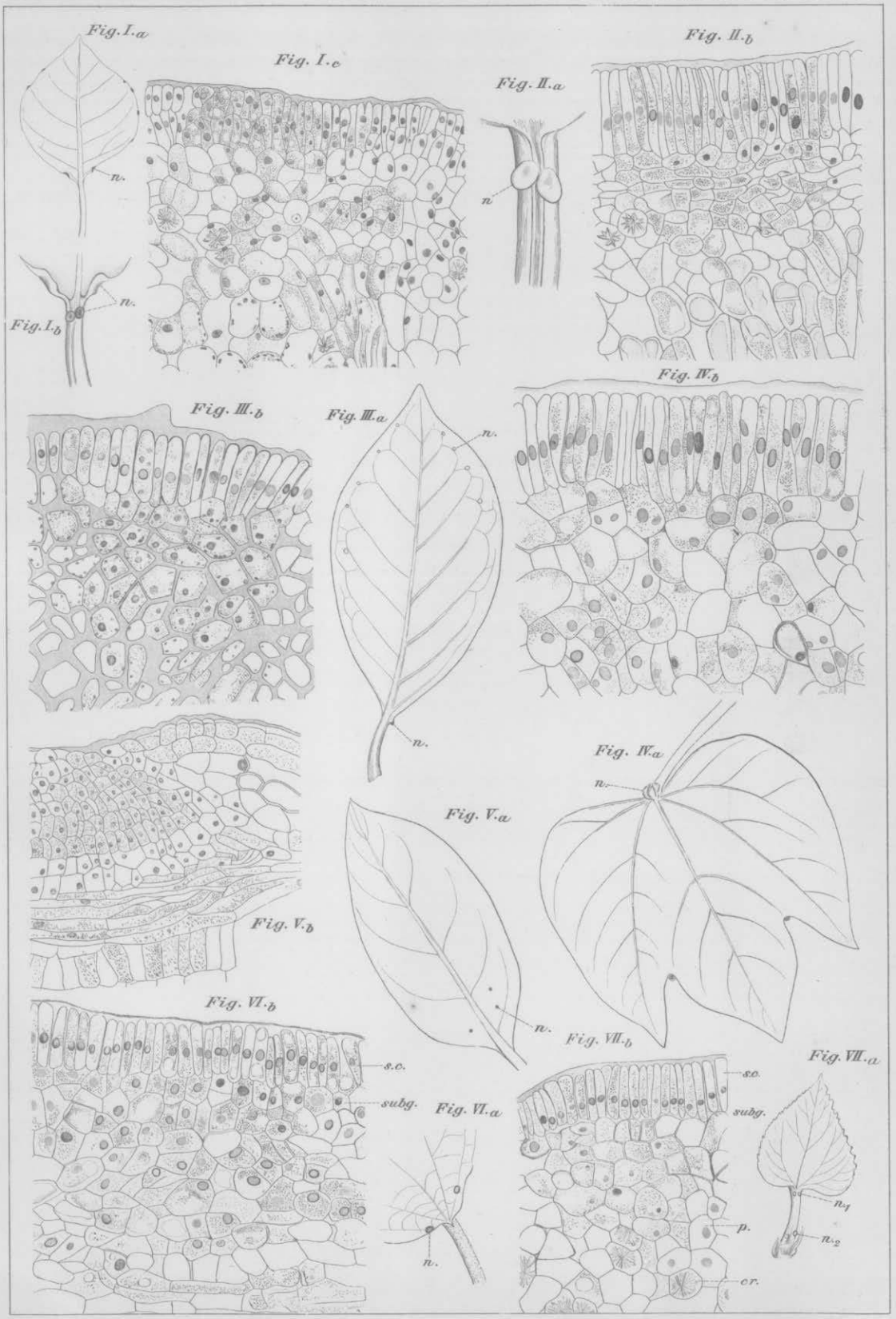
Fig. II. *Callicarpa japonica.* *a*, upper surface of the leaf; *b*, longitudinal section of the nectary.

Fig. III. *Catalpa Kaempferi.* *a*, lower surface of the leaf; *b*, several nectaries between the veins; *c*, section of the nectary.

Fig. IV. *Paulownia tomentosa.* *a*, upper surface of the leaf; *b*, longitudinal section of the nectary.

Fig. V. *Tecoma grandiflora.* *a*, stem with leaves; *b*, section of the nectary.

Fig. VI. *Diervilla grandiflora.* *a*, lower surface of the leaf; *b*, section of the nectary.



Ono del. *Extranuptial nectaries.* Lith. & Imp. Tokyo Printing Co., Ltd.

PLATE III.

Plate III.

Fig. I. *Sapium sebiferum.* *a*, lower surface of the leaf; *b*, upper surface, showing petiolar nectaries; *c*, longitudinal section of the petiolar nectary.

Fig. II. *Prunus yedoensis*, *a*, petiole; *b*, longitudinal section of the petiolar nectary.

Fig. III. *Excoecaria japonica.* *a*, lower surface of the leaf; *b*, longitudinal section of the nectary.

Fig. IV. *Aleurites cordata.* *a*, upper surface of the leaf; *b*, longitudinal section of the nectary.

Fig. V. *Diospyros morissiana.* *a*, lower surface of the leaf; *b*, longitudinal section of the nectary.

Fig. VI. *Mallotus japonicus.* *a*, upper surface of the leaf; *b*, longitudinal section of the nectary.

Fig. VII. *Idesia polycarpa.* *a*, upper surface of the leaf; *b*, longitudinal section of the petiolar nectary.

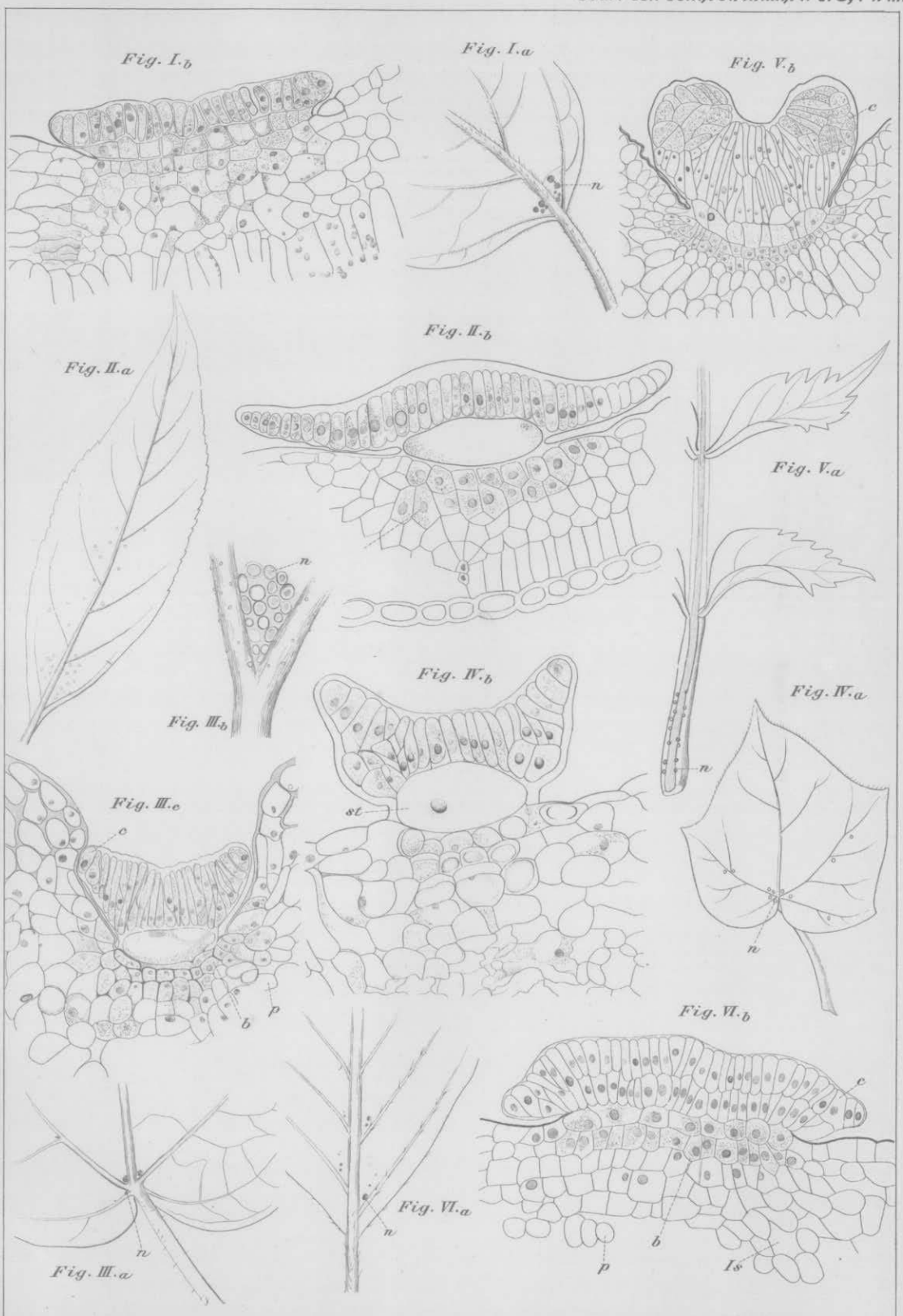


Fig. I.b
Fig. I.a
n
Fig. V.b
c
Fig. II.b
Fig. II.a
Fig. V.a
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Fig. III.b
Fig. IV.b
Fig. IV.a
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Fig. III.c
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Fig. VI.b
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