in a sealed tube, disinfecting this completely by immersing it in alcohol and carrying on the further manipulations in another laboratory, the needles melting at 29° could be isolated. Afterwards, when the form (44°) had not been used for some weeks, the infection seemed to have practically vanished, and, with the usual precautions, the needles melting at 29° were stable in the air.

The conversion of the two forms into each other is readily accomplished; the fused mass yields, on cooling, the form melting at 29° which by inoculation or in an infected region passes spontaneously into the stable form 44° with generation of heat.

From this it is quite evident that we are dealing with a case of dimorphism and more in particular with a case of monotropism where the one form is always labile towards the other.

This research will be communicated in detail in the "Recueil des travaux chimiques".

Botany. — *"Contribution to the knowledge of watersecretion in plants."* By Dr. W. Burck.

(Communicated in the meeting of September 25, 1909.)

In a previous paper *"On the biological significance of the secretion of nectar in the flower"* [1]) I pointed out the correspondence between the secretion of nectar in the flowering period and of water or mucilaginous fluid in the closed flower-bud. On continuing the investigation there arose a doubt in my mind as to the truth of prevailing views on water-secretion at the surface of the plant.

This induced me to make some observations, the results of which will be communicated here, which give a different view of what is to be understood by water-secretion.

I propose to show later that these modified views on water-secretion are not without significance for our conception of floral and extrafloral nectar-secretion.

The phenomenon that in many herbaceous plants and shrubs drops of water are secreted during the night and the early morning hours at the tips and margins of the leaves (guttation) is ascribed to the power of the roots for forcing up considerable quantities of water under favourable conditions; when the air cools down and approaches the dew-point this water is forced out in the form of

1) These Proceedings, Nov. 28, 1908.

drops. At the place where the drops appear there are generally found peculiar pores; these water-stomata were first distinguished by DE BARY from ordinary stomata.

It is assumed that the secretion of water is of importance to the plant in order to prevent the danger, that water, forced up by root-pressure, should become subject to increased pressure in the vascular bundles in consequence of impaired transpiration, and should thus be injected into the intercellular spaces.

Of late years doubt has occasionally arisen whether in all plants and under all circumstances this guttation is only to be ascribed to the forcing up of the water taken up from the soil by the roots, and whether it is to be regarded as filtration pure and simple.

In 1895 HABERLANDT [1]) expressed the view that in some plants the anatomical structure of the leaf-tooth and especially of the tissue between the terminal tracheids of the vascular bundle and the water-pores — the so called epithema (DE BARY) — suggested a glandular function. He also showed experimentally that in *Conocephalus ovatus*, for instance, this tissue really plays a part in the secretion of water. In *Fuchsia*, however, where the structure of the epithema also very strongly suggests a gland, the process was nevertheless found to depend in filtration, but here the tissue was supposed to keep the system of intercellular spaces between vascular bundles and water-cavities filled with water in order to ensure the separation of the tracheal system.

In any case HABERLANDT considered the glandular action to be dependent on root-pressure; the gland was only supposed to act when it was stimulated by the increased pressure of bleeding.

An investigation by NESTLER [2]) in 1896 clearly showed, however, that the phenomenon does not always depend on root-pressure.

NESTLER found that cut leafy shoots of *Tropaeolum majus* which were kept under a moist bell-jar with their cut surface in water, showed after three days drops of water on the younger leaves, at the termination of the vascular bundles; i. e. in the same place where under ordinary circumstances the phenomenon of guttation occurs; on the fourth day the formation of drops was also observable on some older leaves.

NESTLER remarks in this connexion, that here the epithema cannot be concerned in the secretion; in the first place this tissue is not

[1]) G. HABERLANDT, Ueber wassersecernirende und absorbirende Organe. Sitzungsberichte der Kais. Akad der Wissensch. in Wien. Abth. II Vol. 104, 1895.

[2]) NESTLER, Sitzungsberichte der Kais. Akad. der Wissensch. Wien. Vol. 105. 1896. p. 524; Vol. 106. 1897. p. 401. Vol. 108. 1899. p. 690.

well defined in *Tropaeolum* and secondly drops of water also appear on the stem, where there can be no question whatsoever of epithema. The secretion there takes place through water-pores which in position and shape differ more or less from the ordinary stomata. He believes that the explanation of the phenomenon must be sought in osmotic forces, which are called into play under the circumstances mentioned, and cause the secretion.

Properly speaking this was not the first time that this phenomenon was mentioned.

As early as 1881 WILSON [1]) believed he had observed formation of drops on the cut branches of *Impatiensglandulifera*, *I. parviflora* and *Fuchsia*, but an investigation of GARDINER [2]) soon showed that, as regards *Impatiens*, there could be no question in WILSON's experiments of the secretion of water, but of nectar, whereas in *Fuchsia* the fluid observed by WILSON was not derived from the water-pores of the teeth, but was secreted by water-glands in the neighbourhood of these pores.

It is very remarkable that the phenomenon here in question has not been observed much earlier, for, as I have found, there are undoubtedly numerous plants which, under the above-mentioned external conditions, quite independently of root-pressure or artificial pressure, show the formation of drops in the clearest manner. I have observed this formation for instance in *Kerria japonica*, *Philadelphus coronarius*, *Weigelia rosea variegata*, various species of *Spiraea*, *Hydrangea pubescens*, *Hydrangea campanulata*, *Deutzia crenata*, *Cornus sibirica* and in other species of *Cornus* and I am convinced that afterwards, in a more detailed treatment of this subject, I shall have no difficulty in showing it is the case with many other plants.

In all these plants clear drops appear after some hours on cut branches under the bell-jar at the tip and margin of young leaves; on removal the drops are renewed.

It will be shown that these drops are formed in definite leaves, and that they owe their origin in some cases to mucilage-glands which later only secrete water, and in other cases to glands which secreted water from the beginning.

We may safely assume that in the case of many plants in which

[1]) W. P. WILSON, On the cause of the excretion of water on the surface of nectaries. p. 11. Leipzig 1881.

[2]) W. GARDINER, On the physiological significance of waterglands and nectaries. Proceedings of the Cambridge Philosoph. Society. Vol. V, p. 34—50.

one sees in their natural condition at night or in the morning the formation of a certain number of drops of water on the leaves, a part of these drops have passed out independently of the direct influence of root-pressure.

The phenomenon of guttation may be regarded as the formation, under certain external conditions, of drops of water at the tip and the margin of the leaf, whether from the water-pores as a direct consequence of root-pressure, or as a result of the activity of internally situated glands. Further investigation of water-secretion has shown me, however, that this phenomenon of guttation only gives a very incomplete idea of what water-secretion in the plant may be considered to be.

There are numerous plants which do not show proper drop-formation, but which nevertheless continually secrete at their surface fairly considerable quantities of water or watery mucilage — especially in their younger parts.

It may be remembered that TREUB [1]) showed more than 20 years ago, that there is another kind of water-secretion in plants, by epidermal trichomes.

TREUB found that the flower-buds of a tropical Bignoniacea, *Spathodea campanulata* always contain water which is most probably secreted from the cushion-shaped trichomes, which cover the inside of the calyx in large numbers.

Afterwards, as is well known, the same phenomenon i. e. secretion of water in a closed flowerbud, was observed in other tropical plants; in these cases similar trichomes were always observed, whether only on the inner surface of the calyx or also on the outer surface of the corolla, and there was every reason to assume that the fluid was secreted by these epidermal trichomes.

For a long time this phenomenon was considered a thing apart. There was no inducement to connect this secretion of water inside the flower with that outside on the leaves. It was regarded as a special contrivance, a useful adaptation, brought about by natural selection in order to protect the young floral parts inside the calyx against too strong transpiration.

A few years after TREUB's paper, HABERLANDT, however, discovered that such a water-secretion, resulting from the secretory action of externally situated glands, can also be observed outside the flower.

During his stay at Buitenzorg he found on the surface of the leaves

[1]) TREUB M. Annales du Jardin botanique de Buitenzorg. Vol. VIII. 1890.

of *Spathodea campanulata* the same trichomes which secrete the calyx-water inside the flower and he could show experimentally that under favourable conditions these latter are also able to secrete water.

In addition HABERLANDT described in other plants metamorphosed epidermal cells and multicellular trichomes on the surface of the leaves, which under certain conditions functioned as water-glands.

HABERLANDT's observation regarding the occurrence of water-glands on the leaves was soon followed by others.

NESTLER gave a detailed account of the water-secretion from epidermal glands in *Phaseolus multiflorus* and in Malvaceae and VON MINDEN [1]) in *Nicotiana* and *Glaux maritima*.

With regard to one very important point, viz. the conditions under which water-secretion from the glands takes place, HABERLANDT, however, reached a conclusion which is not in agreement with the results of earlier observers, particularly with those of GARDINER on the water-secretion from the multicellular epidermal glands on the leaf surface of *Limoniastrum (Statice) monopetalum* and from the water-glands of Polypodiaceae, nor has HABERLANDT's conclusion been confirmed by the above-mentioned later investigations.

Starting from the view that the secretion of water would serve to prevent an overloading of the leaf with water and an injection of the intercellular spaces, HABERLANDT regarded the glands on the surface of leaves and also those of ferns and similar glands as *regulators of the water-content* which only begin to act when the hydrostatic pressure in the vascular-system, i.e. the so-called bleeding-pressure, has reached a certain height through interrupted transpiration.

NESTLER [2]), to whose investigations on water-secretion in leaves of *Phaseolus multiflorus* we owe the certain knowledge, that the water is really excreted by the glands (he succeeded in directly observing under the microscope the excretion of drops of water from the cells of the glandular hairs), was unable to confirm this view [3]). He found that the secretion of water is independent of root-pressure, as GARDINER had also found for *Limoniastrum* and for ferns. The drops of water appeared on the surface of cut leaves which were kept in a space saturated with aqueous vapour.

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1) M. VON MINDEN, Beiträge zur anatomischen und physiologischen Kenntnis wassersecernirender Organe. Bibliotheca botanica Heft 46. 1899.

2) l. c. Bd. CVIII. 1899 und Berichte der deutsch. bot. Gesellsch. Bd. XVII 1899, S. 332.

3) That we cannot always deduce from the presence of glands that any water which may occur has been secreted by those glands was shown by NESTLER's investigation of water-secretion in *Boehmeria* (Sitzungsber. Wien Vol. CVIII, p. 690).

Von Minden obtained the same result from his experiments. He found that the secretion of water from the glands on the leaves of *Nicotiana* and of *Glaux maritima* took place equally well with cut branches placed under a bell-jar, with the cut surface in water, as with root-bearing plants. He suggested that many of Haberlandt's plants might have behaved in the same way, in as much as the glands of *Phaseolus multiflorus* correspond closely to these of *Nicotiana*, and those of *Bignonia brasiliensis*, *Spathodea campanulata*, species of *Piperomia*, *Artocarpus integrifolia* correspond to the glands of *Glaux maritima*.

It will be shown below that this suggestion was perfectly legitimate. In my own investigations I have found so many plants which have epidermal glands which are independent of root-pressure that I do not hesitate to express the conviction that this is the general rule.

Invesrigation has also shown me, however, that such water-glands which secrete a more or less mucilaginous fluid, are much more common in plants than has hitherto been supposed — especially in the younger parts — and that in arriving at a conception of the process of water-secretion we must in the first place take into account these ever-functioning epidermal glands.

Thus I have observed a secretion of water on the leaves of: *Philadelphus coronarius*, *Hydrangea pubescens*, *Hydrangea campanulata*, *Weigelia rosea*, *Deutzia crenata*, *Corylus Avellana*, *Ulmus campestris*, *Sambucus nigra*, *Syringa vulgaris*, *Forsythia viridissima*, *Fuchsia* spec., *Calystegia sepium*, *Datura Stramonium*, *Nicandra physaloides*, *Cosmos hybridus*, *Dahlia variabilis*, *Melandrium album*, *Thymus Serpyllum*, *Malva silvestris*, *Sidalcea candida*, *Abutilon Daruinii*, *Abutilon Avicennae*, most of which will be further considered below.

First, however, it may be as well to point out that we may deduce from Reinke's paper in Pringsheim's Jahrbücher of 1876 [1]) on the histological structure of so-called secretion-organs, occurring on leaves, that Reinke had already observed that the exudation of drops of water at the apex or the teeth of the margin of leaves may be a result of glandular activity.

Reinke's paper is a continuation of Hanstein's investigation of resin- and mucilage-secreting structures in buds, which was published

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1) Reinke, J., Beiträge zur Anatomie der an Laubblättern, besonders an den Zähnen derselben vorkommenden Secretionsorgane. Pringsheim's Jahrb. Vol. X. 1876 p. 119.

in the Botanische Zeitung of 1868[1]). In this paper HANSTEIN had pointed out the fact, then almost unknown, that in the first stages of the development of buds in many dicotyledonous plants, trichomes of the most different forms occur on the very young leaves but especially on the stipules and leaf-sheaths; sometimes these trichomes consist of bristles or woolly hairs, often also of colleters, which possess the power of secreting a mixture of resin (or balsam) with mucilage, the so-called Blastocolla; by this sticky substance the youngest leaves are surrounded.

REINKE now showed that this secretion in the bud of mucilagenous and resinous substances, which HANSTEIN had brought to light, is much more general in plants than HANSTEIN had led one to expect, and that these glands especially occur at the teeth of the leaf-margin. In his paper he gives a description of the structure of the glandular teeth in no less than 83 species, belonging to widely different orders, and here and there he also indicates how the secretion-product is extruded.

REINKE summarized his results as follows:

"Die auf vorstehenden Blättern gegebenen Mittheilungen zeigen, "dass die Sägezähne am Rande der Dicolylen-Blätter in den meisten "Fällen Träger eigenthümlicher Organe sind, von denen sich in der "Regel eine secernirende Thätigkeit nachweisen lässt, die entweder "in der Zeit des Knospenzustandes oder in spätere Altersstufen der "Blätter fällt . . . ."

"Was das gelieferte Secret anlangt, so ist dasselbe in der Knospe "ein zäher flüssiger Schleim oder Harz, am ausgebildeten Blatte nur "eine wässerige oder etwas schleimige Flüssigkeit; im Einzelnen sind "darüber besondere Untersuchungen anzustellen."

"Was die verschiedene Form der Drüsenorgane der Blattzähne "anlangt, so gruppiren sich dieselben naturgemäss in äussere hervor-"tretende und eingesenkte Drüsen; die ersteren bilden eine stufen-"weise sich ändernde Reihe, die folgende Typen umfasst: *Kerria*, "*Prunus*, *Betula*, *Corylus*, wo das secernirende Organ im ersten Fall "aus einem ganzen Blatt-Abschnitt, im letzten Falle nur aus einem "aufgesetzten Trichom besteht. Die zweite Hauptform, ... ist besonders "zahlreich und tritt erst am entwickelten Blatte deutlich hervor, um "hier unter günstigen Umständen klare Tropfen auszuscheiden. Wenn "die hierher gehörigen Zähne auch bereits in der Knospe Schleim "secerniren, so verhalten sie sich mit *Kerria* übereinstimmend."

[1]) HANSTEIN, Prof. J., Über die Organe der Harz- und Schleim-Absonderung in den Laubknospen. Bot. Zeit. 1868. p. 697, 721, 745, 756.

"Combinirt treten beide Formen z. B. bei *Viola* auf," u. s. w.

In order to make this quotation more clear I add that REINKE found in *Kerria japonica* that the portion of the leaf-margin situated above the termination of the vascular bundle — therefore that portion where in many plants a so-called epithema is found — consists of a mucilage-secreting gland. In *Prunus*, as long as the leaf is young, each tooth of the leaf bears a dark red conical projection, which secretes balsam abundantly during the bud-stage. In *Betula* a large number of peltate glands (Trichomzotten), are found on the surface of the young leaves and internodes, while the leaf-teeth terminate in an egg-shaped mucilage gland. The latter only secretes in the young bud, whereas the peltate glands seem to function principally in the fully-developed leaf. In *Corylus* the young leaves are also covered over the whole of their surface with glands (Trichomzotten) which have the form of pedunculated buds. In addition every leaf-tooth also terminates in such a gland. The latter secretes in the young bud; the others are only developed afterwards.

It may be deduced from this quotation that according to REINKE a phenomenon, comparable to guttation, may arise in various ways, independently of root- or bleeding-pressure, as a result of the activity of glands. This activity may be due to internally situated glands of the leaf-margin, or to secretion of water by externally situated trichomes which at an earlier stage secreted mucilage (resin, balsam) or finally it may be the result of both internal and external glands.

Except for the fact that the secretion of water is not always preceded by that of mucilage and that conversely the secretion of mucilage is often not followed by that of water, I have confirmed REINKE's results.

To the circumstance that in discussing his results REINKE made only a passing reference to secretion of water and did not refer to it at all in the body of his paper, nor mentioned experiments relating thereto, must be attributed the fact that this reference did not receive much attention, although his paper became widely known.

I will now mention some observations which show that secretion of water in the plant can indeed be brought about by various ways.

As will be seen, the problem demands a more detailed and systematic treatment; I therefore intend to revert to it at a later time.

In the first part of this communication I will limit myself to the secretion of water in leaves, and return afterwards to that in flowers.

I. *Secretion of water in leaves.*

Kerria japonica.

The leaf-apex and the teeth of the leaf-margin are acuminate and lanceolate. The vein running into the tooth ends at some distance from the apex; above this there are a number of water-pores resembling stomata.

The portion of the leaf-tooth above the termination of the vascular bundle, where in other plants there is a so-called epithemal tissue of peculiar structure which has more or less the properties of spongy parenchyma, consists in *Kerria japonica* of a mucilage-gland of which both the epidermal and the interior cells are rounded and filled with highly refractive substances. The secretion of mucilage occurs in young-leaves in the bud; it takes place with elevation of the cuticle.

Similar glands but somewhat larger and more rounded are also found at the apex and margin of the young stipules and especially also at the edge of the calyx-segments; they differ from the glands of the leaf-margin in shape and in size, but the cells of which they are composed have the same highly refractive contents.

If a cut branch of this plant is placed in a moist space a formation of drops soon takes place at the apex and the teeth of the young leaves, as was mentioned above. The drops secreted from the same cells which formerly, in the bud, secreted mucilage, contain no mucilage or at most very little. If these drops are removed with a strip of blotting-paper, new drops soon make their appearance.

The same phenomenon occurs in the young flowerbud. The water is secreted in the form of droplets which flow together to a few large drops. There can be no question of a secretion of water by means of an epithema. It must undoubtedly depend on the endosmotic activity of the gland-cells which with great force draw water from the surrounding tissues and from the vascular bundle and press it out.

Philadelphus coronarius.

In the second half of April when the buds began to open, a cut branch was placed in a glass of water under a glass bell-jar which was kept moist.

The outermost leaves of the bud, which before had their margins adjoining, began to separate. The next pair of leaves, placed alternately, thus became visible; of this pair the margins still adhered. The remaining leaf-pairs were still enclosed.

Already on the evening of the same day, clear droplets could be seen at the apex and the teeth of the outermost leaves, and at the apices of the next pair of leaves, while the space between each pair of young leaves was filled with water.

The apex and the teeth of the budleaflets differ especially in anatomical structure from the rest of the leaf in having larger epidermal and subepidermal cells, which have a denser contents and contain stomata at an early age.

REINKE is of the opinion that these cells secrete mucilage in the younger stages of the bud, but I have not been able to observe this. I consider that in this case the secretion of water is not preceded by that of mucilage, but that the glandcells secrete water from the outset.

The surface of the leaf is further covered with numerous unicellular long, pointed hairs, which are laid down very early; their rounded base is afterwards surrounded by prolonged epidermal cells.

From these pointed hairs with rounded base the water is doubtless derived which under the bell-jar fills the space between each pair of leaves; they are therefore true waterglands, not glands which formerly secreted mucilage (balsam or resin).

A month later when the 4 or 5 outermost pairs of budleaves were fully grown, the experiment was repeated. The adult leaves had now lost their power of secreting water and there now only appeared waterdrops on the two pairs of small immature leaves and on a pair of leaves of the bud.

Hydrangea pubescens.

On the 1st of May a cut branch was submitted to the experiment in a glass of water under a moist glass bell-jar. The outermost pair of leaves of the buds was not yet fully grown, but nevertheless the leaves had already taken up a horizontal position. The following pair of leaves was still erect, but the leaf-margins which at an earlier stage were closely applied, began already to separate; the other leaves still formed a completely closed bud.

The leaf of *Hydrangea pubescens* terminates in a long apex and bears on its margin a large number of long narrow teeth, which point outwards in the upper half of the young leaf and which in the lower half are more or less directed backwards.

In each tooth a vein terminates and above this there are one or more waterpores. The young leaves are further covered above and below with long unicellular hairs; those of the upper surface are broad, rounded above and have very thin walls, those of the lower surface are more pointed, have thicker walls and are marked with protuberances.

Next morning there were numerous clear drops, both at the apex and on many of the teeth, but only on those leaves which had not bent over and become free of the bud; the apices of the following third pair of leaves also showed the formation of drops.

In addition to the secretion at the teeth and at the apex, which is to be ascribed to the same cause as in *Philadelphus coronarius*, namely to the secretory action of the epidermal and sub-epidermal cells, we observe, in addition, that the hairs with which the leaf is covered, behave as glands and secrete the water with which the young leaves are covered.

In *Hydrangea campanulata* the mode of watersecretion is not very different from that in *H. pubescens*.

Weigelia rosea variegata.

In this *Weigelia* the young leaves have both halves rolled up to the middle vein. Secretion of large, clear drops of water takes place at the apex of the young leaves and at the apices of the teeth, which anatomically agree with those of *Hydrangea*. The leaf surface, especially the upper one, is thickly covered with trichomes of various sizes, shaped like a pedunculate cushion (Köpfchendrusen), which is so often found in watercalyces; they occur especially on the basal half of the leaf They secrete abundantly so that the space enclosed by the rolled-up leaves is filled with water.

They do not occur in the very youngest leaves. The youngest leaves, of which the teeth are not yet formed, only have a covering of long unicellular hairs, of which the rounded base takes part in the secretion of water.

In an experiment made in the end of May, when the leaves of the bud were fully grown, no formation of drops took place under the circumstances mentioned.

Corylus Avellana L.

In *Corylus Avellana* every leaftooth bears at its apex a large, compound, almost cylindrical gland, by way of appendix. The teeth are placed in two rows, one of which consists of much smaller teeth which are pointed inwards; these smaller teeth also have the character of mucilage-glands.

In the branch, on which the experiment was made, the buds were just beginning to unfold. The outermost leaf had already liberated itself from the bud and was bent outwards; the glands at the apices of the teeth and the smaller leafteeth, which are turned inwards, had at this stage already lost most of their contents and had become brown. In the younger leaves they produced much mucilage and the youngest leaflets of the bud were completely enveloped in it. In addition to these large glands every leaf bears, especially on its upper surface, a large number of smaller mucilage-glands, which too, are stalked and are compound and more or less spherical; furthermore the leaf is also covered with long thick-walled bristles. Not only the leaves, but also the stipules bear in the bud numerous mucilage-glands of both kinds: larger ones at the margin in a pretty close row between the hairs and smaller ones on the leaf surface, especially on the lower portion of the stipule. In the very youngest stipules and leaves these small spherical glands cannot yet be observed; they only appear when the large glands at the margin and at the apex have already lost their contents; as in *Kerria japonica* the apex and the margin of the leaves of *Corylus* show a growth in advance of that of the rest of the leaf.

In the moist atmosphere under the glass bell-jar the outermost leaflets, which are most advanced in development, become covered on their upper surface with numerous clear drops of fluid. Often the hairs at the edge of the leaflets are covered with clear droplets. This fluid is secreted by the glands of the leaf surface, which originally secreted mucilage, but now secrete water containing but little mucilage. On the first day there is seldom any real dripping, but the secretion of water may nevertheless be relatively important.

Ulmus campestris [1]).

In *Ulmus campestris* the leaves are folded up in the bud round the middle vein and are placed to the left and right of the central axis.

When, on the 2nd of May, a cut branch was placed under the glass bell-jar, the lowest leaf of most of the buds had unfolded itself and was beginning to turn itself outwards; the next leaf was still erect but the halves of the leaf had begun to separate a little; the higher leaves were still all folded up and enclosed by the stipules.

The young leaves bear long, pointed, unicellular hairs with rounded base, which are bent parallel to the leaf-surface; in addition these leaves are covered especially on the upper surface, with mucilage glands (Trichomzotten) which consist of 4 cells, viz. of a short basal cell, a cylindrical stalk-cell and two gland-cells placed one above the other, of which the upper one is hemi-spherical; the glands

1) Verg. REINKE l.c. p. 156.

produce much mucilage. The leaf teeth have two shapes; between the larger egg-shaped ones, rounded in front, there are smaller teeth turned more inwards.

As REINKE already observed a lateral vein of the leaf terminates in every leaftooth, just below its apex; above this there are some stomata. The secretion of mucilage takes place from the epidermis, the cells of which contain mucilage; the epidermis contains in addition larger cells, completely filled with mucilage. These mucilage-cells are also found in the sub-epidermal layer of the tissue. Often their number is so large, that as a result the leaftooth shows numerous transparent spots.

But besides the secretion of mucilage by the numerous teeth and glands of the leaf surface, there is also a secretion by the stipules and especially by those which are placed higher on the axis. These are covered on their inner sides with very numerous glands of the same shape as those which occur on the leaves, and they too bear numerous large mucilage-cells in their epidermis.

The youngest leaves and stipules are covered with a thick layer of mucilage.

In the moist space under the bell-jar the outermost leaves were already completely covered with fluid next morning. This fluid consisted of water or very watery mucilage and had evidently been secreted from the glands of the leaf surface, which, although originally mucilage-glands, afterwards behave as water-glands.

At that time there was no proper formation of drops, but some hours later it could be observed at the apex and the teeth.

Sambucus nigra.

The young leafteeth are completely hidden, because the leaves are rolled up very closely in the bud; they lie against the leaf surface and curve upwards. The secretion by the leafteeth is limited to the extreme apex, which resembles that of *Kerria japonica.* In the youngest bud-stages there is here a secretion of mucilage.

In addition the leaf surface is closely covered on its inside and outside with strongly secreting club-shaped trichomes, the shape, development and mucilage-secretion of which have already been described in detail by HANSTEIN (l. c. p. 731).

In the experiment with a cut branch under a bell-jar a fine formation of drops is soon observed at the apices of the young leaves, Further it becomes evident on unrolling the leaves, that the inner space is filled with water, while numerous drops of water are also found on the outside. The latter fluid is certainly derived from the glands described by HANSTEIN, and the droplets which occur at the apices of the leaves, have here again the same origin as in *Kerria japonica*.

Syringa vulgaris.

During the bud-stage the leafapex of *Syringa vulgaris* exactly resembles that of *Kerria japonica*; the epidermal and sub-epidermal cells are in this case unusually large and they are filled with highly refractive contents. They secrete mucilage but soon degenerate. In consequence there is later no secretion of waterdrops. There are no leafteeth.

The upper and lower surface of the young leaf, especially the upper surface and the margin, are covered with numerous mucilage secreting trichomes, which have been described and figured by HANSTEIN (l.c. p. 733) and which during the bud stage secrete considerable quantities of mucilage.

If a cut branch is placed in a moist space the leaflets are soon covered by a layer of moisture. In the bud the young leaves are rolled up over one another; the intervening spaces are filled with water. The mucilage-glands (Keulenzotten of HANSTEIN) which therefore behave as water-glands, can be easily observed on the young leaves with a lense; they no longer occur on the adult leaflets.

Forsythia viridissima.

Forsythia viridissima in the main resembles *Syringa vulgaris*. The mucilage-glands have here a different form and do not mutually resemble each other.

They are generally made up of a stalk, which some times consists of one and some times of two rows of three cells, and of an almost spherical head of gland-cells proper.

Their number is if possible even larger than in *Syringa* and when there is secretion of water in a moist space there is not unfrequently formation of actual drops.

In conclusion I wish to append a note on *Fuchsia*, the plant which has first been mentioned in the literature on this subject, but which nevertheless cannot be reckoned among those plants which clearly show the phenomenon.

Fuchsia.

It has already been stated, that WILSON's observation on the water-secretion of cut branches of *Fuchsia* in a very moist space has been

22*

confirmed to the extent that HABERLANDT noticed a formation of drops on the leaf-teeth.

I myself have, no more than NESTLER, been able to distinguish with certainty the formation of droplets on the leaf-teeth.

The latter bear at their apex a single pore with a large opening, which leads to a relatively small cavity filled with fluid, below which the epithema is situated. Of this tissue HABERLANDT has given a very detailed description and some figures.

As regards the structure of the bud, REINKE already pointed out that at the base of each leaf there are two small acicular stipules, which broaden out at the base, and secrete much mucilage with which the youngest parts of the bud are completely surrounded. Speaking generally, these are again completely simular to the tops of the leaf-teeth of *Kerria* and the cells of which they are composed, are distinguished by their highly refractive contents. In addition the lower surface of the young leaves in the bud is thickly covered with thin walled trichomes which have a broad club-shaped end and are already formed when the leaves are still extremely minute.

Here and there the same hairs occur also on the upper surface of young leaves, especially on the basal portions and they are further found in large numbers on the young flowerbuds and stalks.

For the rest the upper surface of the leaf bears somewhat longer pointed hairs with thicker walls and a cuticle with markings.

If a cut plant is placed under the moist bell-jar, the phenomenon to which GARDINER drew attention, is soon observed i. e. the upper and especially the under surfaces of the young leaves appear bedewed with numerous fine droplets.

This phenomenon is brought about by the vigorous secretion of the numerous club-shaped hairs referred to above; each of these bears at its end a droplet of water, thus showing itself to be a water-gland. This secretion may be so copious, that the lower surface of the leaf is soon (on the 2nd or 3rd day) covered with a layer of water.

The same may be observed on the young flowerbuds; these are soon surrounded by as many hundreds of small clear waterdrops as there are glands which have found a place on the surface.

It follows from the above, that in considering the secretion of water on the surface of the plant, we must not only take into account the formation of drops which result directly from root-pressure, but also that which is brought about the apex and the margin of the leaf and on the leaf-surface as a result of the action of glands.

In many cases the glands are originally mucilage-glands (Colleteren, Keulenzotten, Trichomzotten) which secrete resin or balsam in the bud, as proved to be the case in *Kerria, Sambucus, Corylus, Ulmus, Syringa, Forsythia,* but in other plants they are from the beginning real water-glands: *Philadelphus, Deutzia, Hydrangea, Weigelia,* etc.

Physics. — "*On the theory of the* ZEEMAN-*effect in a direction inclined to the lines of force.*" By Prof. H. A. LORENTZ.

(Communicated in the meeting of June 26, 1909)

§ 1. Certain phenomena observed by HALE in sun-spot spectra have induced me to work out the theory of the ZEEMAN-effect on the assumption that the direction of observation is oblique to the lines of force, a problem that has already been treated by VOIGT [1]), but in which some details remained to be examined.

Our subject will be the "inverse" effect, to which the direct one is intimately related, and we shall start from the fundamental equations in the form I have given them in a recent article in the "Mathematische Encyklopädie" [2]), supposing the magnetic field to be homogeneous and parallel to the axis of z.

We shall assume that the particles of the body through which the light is propagated, unless they be magnetically isotropic (i. e. of such a structure that a rotation of a particle in the field has no influence on the frequency of its free vibrations) are turned by the magnetic force in such a manner that a certain "axis" proper to each particle takes the direction of the field. We shall further imagine that each particle contains a certain number of electrons forming by their arrangement some definite and regular configuration, and capable of vibrating about their positions of equilibrium under the joint influence of "quasi-elastic" forces, of resistances and of the action exerted by the external field. Though, on account of the complexity of its structure, the mode of motion of a particle may be far from simple, we can easily treat it mathematically in a general way. This is due to the circumstance that, under certain simplifying restrictions,

1) W. VOIGT, Weiteres zur Theorie der magneto-optischen Wirkungen, Ann. Phys. I (1900), p. 389.

2) H. A. LORENTZ, Theorie der magneto-optischen Phänomene, Encyklopädie d. math. Wiss. V 22, p. 199.