PLANT MALFORMATIONS IN VICINITY OF STE. ANNE DE BELLEVUE, QUE.

AN INVESTIGATION

into the

Nature and Cause of Certain Plant Malformations Observed

In the Vicinity of Ste.Anne de Bellevue,Que.

Illustrated by Original Photographs specially taken,

enlarged, described and annotated by the writer,

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the whole constituting

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TYPES OF INSECT GALLS.

The attentive observer of vegetative growths must often have noticed on the trunks and branches of trees, on the stems of weeds and flowers, on leaves and their petioles, on roots, and even on the more lowly forms of plant life, such as our mosses and algae, certain curious deformities which he rightly suspects as being anomalous. (1)

These he finds to vary in size, from the simple hypertrophy of a single cell, e.g., Pilobolus kleinii with Pleotrachelus (2), which is a type of Mycocecidia or Fungus Gall, to the production of malformations measurable in feet (3), where whole tissues have become hypertrophied and modified to such an extent, in both form and function, as to be at first quite unrecognizable.

As to color, the observer remarks that they may follow the natural seasonal changes of their host, or immediately assume a grotesque hypertrophied and blackened condition, as to shape, that they are varying and fantastic, sometimes taking on the form of a pea, a cherry or other familiar natural object; and following the more singular shapes suggesting a pine cone, a toy trumpet or a cocks-comb.

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(1) "By an anomaly we mean any extraordinary modification in the formation or the development of organs, irrespective of any influence upon health", Moquin-Tandon 1841. Elements de teratologie vegetale. Paris, p.18.

(2) Tubeuf & Smith, 1897. "Diseases of Plants", p.25, par.2

(3) "By a monstrosity or malformation I presume is meant some considerable deviation of structure, generally injurious, or not useful to the species". Darwin Orig. of Species, ch.II, par.I.

EARLY WRITERS.

The insect origin of a vast number of galls appears to have been entirely unsuspected until comparatively recent times. Pliny, in his Natural History (Vol.XVI,9,10, XIX,5) remarks, that a kind of gnat is produced in certain excrescences on oak leaves, but he concluded that they arose spontaneously.

The first reference to galls in the English literature is found in "Trevisa", (Barth.De P.R.XVII) where, in reference to Mandregora the following appears "Apples groweth on the leus, as galles groweth on oaken leues" (Connold, 1908). To Malphigi, however, belongs the distinction of being the first systematic writer on this subject, and his valuable treatise "DeGallis" (Discorides I.146, Paris 1549), with his later works appearing in the Anat.Plantarum (part 2, De Gallis, pp.22-50, London, 1679), are recognised to-day as authority, containing as they do careful and accurate description of the malformations found by the writer at this early date in Italy and Southern Europe.

Although Malphigi realized that insects, which he observed to emerge from galls, were intimately associated with their development he seems to have been unable to account satisfactorily for the initial stimulus to hypertrophy, nor did he associate oval and larval activities with their development, for he concluded that galls were the direct result of the piercing of tender plant tissues by insects; a theory which is now discredited*.

In 1711 the first records of the investigations of Dr. Derham (Physico-Theology, III. c.6.) were published. They contain a careful comparative study of the galls of England and those described by Malphigi in Italy, together with observations that whereas many species of galls are common to both countries the more southern climate of Italy is vastly more prolific.

J. C. Fabricus and Linnaeus (1775, Systema Entomologie, Fleusburg), also collected, incubated and described many types of galls, the majority of which they placed in the Genus Cynips. Their work however, occasioned some confusion to succeeding investigators, owing to their including under this name Cynips not only the true Gall insects, but also the numerous Gall inquilines and parasites which are now recognized as belonging to greatly varying orders and families of insects and mites. The work of Malphigi appears to have been unknown to Linneaus and Fabricus.

At a somewhat later date, we have the names of A. G. Olivier, 1811, St. Hilaire and P. A. Latreille figuring prominently in the investigation of the malformation of continental Europe. Each of these men seem to have appreciated the objections to following the nomenclature of Linneaus and Fabricus, for we find them limiting the names Cynips to certain Chalcibibae and employing the generic name of Dipololepis for the original Gall makers. Most of the latter were collected from species of Quercus, which, even in this northern climate, harbours a very large number of galls.

Modern writers, following the precedent established by Theodor von Hartig, 1843, (Ueber die Familien der Gallwespen, 1840 - 43), have limited the application of the name Cynips to the Gall makers alone and placed the inquilines and parasites in their respective families, although the males of many species still retain the old nomenclature. This task of Hartig's, in endeavouring to revise the nomenclature of this family (the Cynipidae),was indeed an arduous one but was made the less difficult by the valuable contribution of Reaumer, 1738, (Memoirs pour servier a l'Histoire des Insectec), and those of Malphigi and Derham already referred to.

Other continental writers of note were Ratzeburg of Vienna, 1844, and a little later G.Mayer also of Vienna. Both these men added extensively to the already large list of described galls. Particularly is this true of Ratzeburg who, in the capacity of State Forester, was enabled to observe and record many phenomena relating to the true life relations of Gall makers and inquilines hitherto unsuspected.

In 1853 Lacaze-Duthier, an eminent French Zoologist, presented in an admirable series of monographs, a resumé of the investigations of continental writers (Récherches pour servir a l'Histoire des Galles), while in England, J. O. Westwood, 1855, E. A. Fitch, 1874, Halliday and Peter Cameron, 1885, added much to our knowledge of galls and Gall insects, particularly those of the British oaks. Professor Westwood, 1869 (Gardener's Chronicle) in addition to his investigation of oak galls, described for the first time a Gall upon the black currant which he found to be caused by "a peculiar species of Acarus". This, so far as I have been able to find, is the first reference in English books to the now famous "black currant Bud Gall", which to-day required the combined efforts of British horticulturists to control, and which we now recognize as due to the attacks of Eriophyes ribes, Nalepa*.

M. W. Beyerinck ("Beobachtungen uber die ersten Entwicklungsphasen einiger Cynipidengallen" Natuurk. Verh. der Kon.Akad.Deel XXII 1-198) in Holland has from his wide botanical knowledge made many

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*Classification and revision of the nomenclature of the family Eriophyida has been recently defined by Dr. Alfred Nalepa, 1898, Vienna -Das Tierreich, L.4-8.

Valuable suggestions as to the inter-relationship of plant and insect in bringing about these anomalous growths.

In America the student of plant malformations seems to have been quite as energetic as his European con-frères, and the names of C. R. von Osten-Sacken, H.F.Bassett, B.D.Walsh*,C.V.Riley, T.W.Hains and A.T. Bruce are intimately associated with the discovery and detailed description of many distinctly American species of Gall insects.

The work of Bassett (Can. Entom. v.V.,p.91-94 1873) on seasonal dimorphism is the result of particularly keen observation and study. During this same year, Bassett's work was corroborated by Prof.Riley who presented definite proof of the existence of an alternation of generations between Cynips operator and Cynips operatola.

Among other Canadian and American investigators of note may be mentioned:- W.H.Ashmead, J.M.Aldrich, Nathan Banks, Wm. Beutenmuller, W,B.Barrows, F.T. Biolleti, W.A.Cameron, G.H.Chadwick, T.D.Cockerell, J.H.Comstock, M.T.Cook, E.Porter Felt, Harrison Garman, C.P.Gillette, H.A.Hagen, T.D. Jarvis, etc.,

The greatest of modern works, however dealing with the various aspects of the question is undoubtedly Dr. Hermann Adler's "Alternation of Generations", translated from the German, with many valuable

suggestions relative to British species, by
Dr. Charles R. Stratton, 1894.

* Dimorphism in Cynips, Proc.Ent.Soc.Phil. II., 443.

HYPERTROPHY, The result of a snock to the plant's tonic equilibrium.

To all these extraordinary modifications in the formation and development of plant organs mentioned the term "gall" may be applied, they are striking examples of the very great reactionary possibilities of the healthy plant to any abnormal or unusual condition. Any factor that threatens to modify or destroy the conditions which have brought about a plant equilibrium or "tone" tends to induce an hypertrophied condition resulting in a malformation or monstrosity. Now these exciting factors may owe their stimulative character to various causes such as, for example, the occurrence (above or below the optimum for growth) of unusual conditions of

(1) Illumination, thereby destroying the phototone of the plant,

(2) Temperature, modifying the thermotonic equilibrium; or

(3) Water, causing some unbalance to the hydrotonic conditions of tonic tension of the cells.

Or again, the factors may owe their stimulative character to a combination of these conditions, brought about through the mechanical and chemical influences of parasitic plants, fungi, mites or insects.

The Appreciative Irritability of Plants.

This ability to receive and respond to external and internal stimulative influences is designated IRRITABILITY, and it is this appreciative sensitiveness of the plant to any modification of its tonic conditions that enables it to perform and maintain the many vital functions essential to health and growth.

A single instance of how this irritability induces hypertrophy is seen in the course of procedure adopted by a healthy tree in reacting against the mechanical stimulative influence of a knife wound.

When, for example, a branch is removed from a healthy growing tree, the equilibrium of the part is destroyed and its irritability greatly augmented. This is shown -

First, in the rapid turgescence and hypertrophy of the meristematic Phellogen, fascicular cambium and adjacent parenchymatous tissues exposed by the removal of so intimate a part of the plant's body;

Second, in the rapid subdivision of the cells of these tissues, and frequently, it would seem, by a resumption of the meristematic condition by adjacent woody cells.

The result is the familiar cortaceous ring, which, however, from a morphological point of view may be considered as an "extraordinary structure", resulting from the abnormal functioning of the part, and developed by the plant in its endeavour to re-establish the normal tonic conditions.

In this example the extreme intimacy which exists between the structure of an organ and the functions it performs is clearly shown. Moreover, it should imagnently aid our imagination in the analysis of the very intricate and abstruse relationships which arise through the action and counteraction of plant and parasite.

Herbert Spencer,(1) in discussing this relationship of structure and function says:- "Everywhere structure in a great measure determines functions, and everywhere functions are incessantly modifying structures. In nature the two are inseparable co-operators, and science can give no true interpretation of nature without keeping their co-operation constantly in view. An account of organic evolution in its more special aspects must be essentially an account of the interactions of structures and functions".

In the example of pruning which has been cited, the stimulus of primary importance, resulting in the rapid subdivision and modification of the structure, is undoubtedly that of reduced tension on the part, consequent upon the deprivation of its normal protective covering. Hence we find that the injured and dead cells

(1) Herbert Spencer. Principles of Biology, Vol.II, p.4.

are shoved outwards before the rapidly subdividing meristems - phellogen and fascicular cambium, as a result of the efforts of these to repair the mestome and stereome tissues. In this way the potentialities of the part are exhibited and soon result in the re-establishment of the normal processes. Similarly in the development of Galls, whatever the stimulii may be it is only the potentialities of the part to these influences that are evidenced in the resultant malformation, and these are always arranged advantageously to the developing gall insect.

This may be attributed to the processes of Natural Selection, for it is only these insects, mites or parasitic plants which, through their energetic feedings, secretions and excretions, have excited the host plant to prepare these abnormal tissue combinations or galls, that have been able to survive ; those less fortunate having been long ago exterminated by the birds, rodents and other natural enemies.

Similarly also is this force of Natural Selection shown in the maturing of the eggs of the gall insect, in the instinctive deposition of a number proportionate to the space occupied by mature galls, and in the food requirements.

The fact that the under surface of the leaf lamina is the more frequently attacked is explained by the conduplicate vernation of this organ in the bud and by the somewhat more delicate texture of the lower epidermis and spongy mesophyll.

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THE EXTENT TO WHICH MECHANICAL STIMULII ARE THOUGHT TO INFLUENCE GALL FORMATION.

By early writers such as Malphigi and his contemporaries this mechanical form of stimulus to hypertrophy was considered to be fundamental and primary to all galls. Modern investigators, on the other hand, are satisfied that mechanical irritation alone has comparatively no stimulative effect except wheh brought to bear on some exceedingly sensitive and rapidly developing part such as, for example, the dermatogenic tissue, the periblem or the plerome of the apices of a growing point. In these cases the slightest pin-prick if continued for any time would make its influence felt upon the subsequent uniformity of the part; (by inducing the development of primary permanent tissues) moreover, as I have already pointed out, in the severing of a limb from an actively growing tree, the Phellogen and fascicular cambium are exposed and required, in the general economy of nature, to act in an extraordinary manner in order that the re-establishment of the normal requisites to health and growth may be accomplished, thus furnishing another illustration of mechanical stimulation.

Goebel, 1900, (Organography p.201) in discussing the movement of substances in the vegetative cone remarks that if some molecules "of such substances as are required for the formation of anthers deviate only the 1-1000 mm. to the right or to the left from their normal path, or in their passage into the vegetative point of the flower are delayed or hastened, they may enter into and induce a partial anther character in a carpellary leaf or a petal."

Accordingly, when we consider the possible effects of insects, mites or other parasites, no matter how minute, upon so tender a plant-part as the vegetative cone, it is quite conceivable how a complete change in both the appearance and function of the subsequent growth is rendered possible. At the same time it does not necessarily follow that this alteration in the normal structure is due to the formation of a completely new organ, but rather, as Peyritsch* has shown to be the case in the formation of double flowers, the resultant monstrosity is merely a derangement or re-arrangement of the natural organs and not usually the formation of any distinctly new organs, notwithstanding that the result of the intermingling of these different characters may present results which may at first appear to be more than a readjustment of the former normal forms. The exact nature of the modified structure depends upon the time and nature of the parasitic attack. A common example of this modification one meets in herbaceous plants, ~~and~~ which may be induced mechanically is the very great reduction of the

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* J. Peyritsch, (1888), Uber Kiinstliche Erzengung von gefiillten Biitten, ~~und~~ in Situngsber, der Wiener Akad. der Wissensch, XCVII.

stem, owing to that organ having been injured while yet in its primordium. Frequently, also, leaves, pedicles and floral organs appear in a much reduced phyllotaxy, or show a decided enlargement of the vagina and at the same time a reduction of the lamina. All such changes may be accounted for by mechanical stimulii affecting organs while in their primordium.

It is also essential, if we wish to consider scientifically the effects of mechanical stimulii upon gall-formation,-although no doubt the excretions or salivary secretions also play an important rôle - to bear in mind that atavistic peculiarities of the individual frequently present themselves; such as the conversion of a primordium of a foliage leaf in a similar manner to what is observed in the normal metamorphosis of a catophyll or hypsophyll.

Goebel (Organography p.197) admirably sums up the situation, "What is new is only the combination of the possibilities of the plant, the peculiarities that are combined remain the same, like the pieces which furnish the changing pictures in the Kaleidoscope".

The extent to which CHEMICAL STIMULII are thought to influence Gall formation.

Lacaze-Duthier, 1853, together with Hoffmeister and Charles Darwin, seem to have agreed that the initial and main stimulants to Gall formation in plants was an irritating fluid or virus secreted by the female insect and deposited with her egg in the puncture made by her ovipositor in the foliaceous parts of a plant, causing, as a result, extraordinary combinations in the development of affected organs.

The weight of modern investigation, however, would seem, as it has already been partially shown, to prove this hypothesis of Lacaze-Duthiér's untenable as a General Theory of the main stimulus in Gall formation. For example, we have on the one hand types of insects such as the Midges (Cecidomyiidae), the beetles (Saperda sp.) and Moths (Gelechiidae, Tortricidae, Tineidae), which produce galls without possessing any possible means of inoculating the tissues in the manner stated. Again, there are those numerous animal forms, not, strictly speaking, insects, but which cause by their concerted effort in puncturing a few epidermal cells and partaking of the succulent juices within, and hypertrophy ranging from a simple trichomatous outgrowth, similar to what a plant develops under xerophytic conditions to avoid excess of transpiration or

or evaporation, to peculiar bladder-like outgrowths resembling the inverted finger of a glove.
I have here reference to species of Eriophyes, Phyllocoptes, Cecidobia and certain Aphids.

On the other hand, there are members of the family of Saw-flies (Tenthredinidae), which would seem to have this trait of piercing and depositing a poisonous secretion substantiated.* At the same time the exact extent to which this secretion or virus is instrumental in predisposing a plant to hypertrophy has not been conclusively proven.

A susceptibility of the plant tissues to the stimulus of insects must be acknowledged to exist, inasmuch as, in the majority of cases of Gall formation each species of Gall Insect or Mite, limits itself to some one vegetable structure whereon alone it is capable of inducing an anomalie**. This susceptibility is the same for any equal stimulus whether it be mechanical or chemical.

Adler (Adler and Straton, Alter.Gen.p,98,1894), in discussing the formative affects of the piercing and secretion of insects during ovi-position states, that "hitherto it has constantly been stated that the prick of the Gall Fly and the simultaneous introduction of a glandular secretion excited a specific cell growth which led to the formation of a Gall."

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*See writer's experiment with Pontania hyalania.
Pontania pomum produces typical reddish galls on the willow, but these never occur upon the leaves of maple or any other host save willow.

This supposition derived a certain amount of probability from the frequent occurrence in plants of increased cell formation around wounds, as seen in those swellings of the bark that follow a saw-cut. Judging from analagous phenomena occurring in animal tissues, it is thought the cells reacted to the stimulus of traumatic irritation, so that increased metabolism and the production of new cells took place.

This was made the foundation of a most misleading hypothesis. It is assumed that Gall flies, by means of a poisonous glandular secretion which they poured into the wound at the time of ovipositing instituted a specific form of cell activity, and in this way each species produced its own peculiarly formed and equipped Gall; hence it was only required to ascribe to each individual species the possession of a specific secretion". The present writer's investigations indicate that the differentiation of the Gall tissues commence only when the larva has emerged from the egg, although hypertrophy of existing tissues usually precedes this. Dr. Adler was also of this opinion, but limited application to oak galls, the majority of which belong to the family Cynipidae, and announced that in the family of Saw-flies (Tenthredinidae) he has observed leaves a few hours after having been pierced by a Saw Fly to gradually assume am hypertrophied condition, which he explains by saying that

"In this case the wound caused by the fly is the immediate exciting cause of cell activity. and leads to gall formation."

Beyerinck, 1888, as a result of his investigations of a European species of Saw Fly (Nematus capreae), which he found inducing galls upon Salix amydelina, concluded that in this particular case the Gall is evoked through the wounding of the plant tissues and the injection into them of a virus by the female Saw Fly even "though no egg be deposited" and further, that "the destruction of the egg" after deposition does not arrest the Gall formation but merely affects its size. Beyerincks' conclusions coincide with the hypothesis of Lacaze-Duthier, namely, that the VIRUS was the sole stimulus to hypertrophy. They may also be said to partially agree with the observations of Dr. Adler already alluded to.

With a view to substantiating these results, the writer undertook an experiment with a species of Saw Fly (~~Nematus~~ Pontania hyalina, Norton) producing galls abundantly on the leaves of species of Salix in the vicinity of Ste. Anne's, but was compelled to conclude that in this Gall also the hypertrophy and subsequent differentiation are governed by the activities of the egg and larva. So that as far as the writer's experience with Canadian galls is concerned, all are composed of relatively simple hypertrophied tissue until the larva emerges.

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An experiment with PONTANIA HYALINA, NORTON.

This species of Saw Fly evokes tender green fleshy swellings on the leaves of willow, occurring either in two parallel rows, one each side of the mid rib, or confined to a single row on one side of the leaf and again, though less frequently, occurring singly.

These anomalies are elongate-ovate in shape, project from both surfaces of the leaf and are slightly flattish on top. In colour, they are green when young and follow the normal seasonal colour changes of the leaf, although greatly precipitating these changes and assuming autumnal tints as early as the middle of June.

On June the third, 1908 a number of leaves, bearing these galls in a very immature state (not more than twelve hours old), were selected by the writer and covered with fine linen mesh bags, to prevent the invasion of any inquilines unobserved. Ten days later, June the thirteenth, twenty-five of the galls, which had increased rapidly in size, were punctured with a fine dissecting needle with a view to destroying the eggs and developing larva. The incision, in each case, was made parallel to the plane of the gall's greatest axis, which was also parallel to the plane of the lamina. The galls were then covered to await developments. On June the seventeenth disorganisation of the Gall tissue was quite noticeable, in the course of another week it resulted in the production and accumulation of a dark brown mass of disorganised cells. Further, this useless mass of cells was found to be distinctly separated from adjacent healthy tissue and vessels of the leaf by the formation of a sheath of collenchyma, which completely invested the former Gall. This partitioning sheath, which later became sclerenchymatized, was observed in greater or less degree of completeness in twenty-one of the twenty-five galls punctured. Dissection of the remaining four galls showed the eggs to have been uninjured in the puncturing operation and the larvae only very recently - a few hours - emerged. The reaction of the plant to the simple mechanical irritation of the needle was appreciable only by the slight thickening of the cell walls throughout its course.

The results of this experiment suggest two questions of importance -

<u>First</u>.- Whether the development of the Gall - the greater part of which occurs before the larva emerges - cannot be accounted for in other ways than by the stimulative influence of the virus injected by the female.

Second.- Whether this "virus" is not after all equal to the simple lubricatory secretions of other insects, and produced by the female imago to insure an easy working of her terebra in piercing and preparing a suitable place for the incubation of her eggs.

With regard to the first question it is interesting to observe that the eggs of Tenthredinids are particularly noted for the unusual manner in which they increase in bulk, even though they be deposited upon the exterior of the leaves. The exact cause of this enlargement is not understood. Comstock, 1904, (Manual p.612) remarks. "that in some strange way, perhaps by absorption of moisture, the eggs increase in size before they are hatched".

This increase in size causes and explains the increased pressure, tension and consequent hypertrophy of adjacent cells.

The hypertrophy at this stage is simply one of the leaf paranchyma accompanied by an increase in the number of cells. No differentiation of tissue occurs. Moreover, these newly formed cells in our experiment rapidly developed chloroplasts and became actively photosynthetic; a fact which I attributed to the respiratory exhalation and secretion of the developing larva. This occurred even while the larva was still enclosed within the chorion.

These products of the egg, whatever their exact chemical nature may be, prevent the normal translocation of nutrient substances produced in the Gall area; therefore, they cannot be said to have had any very great irritating propensities such as for example mechanical maraudings of the larva. For the latter stimulus invariably induced an energetic reaction of the host plant in investing tissues of thick wall cells in its effort to isolate the centre of the disturbance.

With regard to the second question, the experiment I have cited would seem to prove that in this species,(hyalina) at least, the "inoculated-virus" hypothesis cannot hold inasmuch as the destruction of the egg soon caused the disorganisation of a Gall, and therefore must be essential to its being.

The Sclerenchymatous investment which later arose, was developed by the plant so that the disorganised Gall - beyond repair - should in the economy of nature be set aside.

The suggestion of Beyerincks therefore, that the destruction of the egg had no affect on the Gall formation seems inaccurate, at least in so far as this species is concerned.

It also seems reasonable to suppose, that this virus can have under any conditions but a temporary affect upon the functions of the plant, especially when we consider the very diminutive quantity of such secretion a Tenthredinid might be expected to deposit, and also when we consider the movements and metabollic processes of protoplasm.

So potent are these agencies that any symptoms which this virus might induce would be expected to become generalized, and moreover, the galls are concentric to the egg and not to the plane taken by the female terebra*.

Although I made careful search for Pontania galls which had developed without an egg and by the stimulative virus alone, as Beyerinck believes to be the case in Nematus Capreae, none were found. All showed indications of having borne an egg. It is true, one occasionally finds, immature galls in mid-summer among their more highly coloured neighbours which appear, as though developed, without the stimulative influence of the egg, but further examination shows that the egg or larva has been destroyed by a spermophagous or phytophagous insect.

A curculio (Anthonomus sycophanta) was frequently found probing into these galls and destroying their occupants**.

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* I note that W. Magnus, 1908, was also unable to corroborate Beyerinck's results.

** C. L. Martlett, 1896, revision of Nematinae of N.A. states: "The eggs and larvae are subject to the attacks of certain mites and thrips, also a curculionid

(Anthonomus Sycophanta), and a Lepidopterous larva which eats out the entire interior of the Gall, Tenthredinid and all."

William G. Dietz, M.D., "revision of Gen. and sp. of Anthonomini of N.A.", Transact. of Am.En. Soc. XVIII,p.177, says "As is well known,all members of the present tribe as phytophagous, and the greater number no doubt Spermophagous. A few, like A.synchophanta, A.crataegi,Coccotorus, etc., are said to breed in galls. I regret that I have nothing new to offer in the life-history of the insects".

Transformation of Floral Organs into Foliage Leaves.

As an illustration of this let us consider for a moment the GOLDEN ROD BUNCH GALL, occurring on the apex of a stem of Solidago canadensis. The several hundred leaves which make up this malformation on Golden Rod are induced by a delicate midge-like fly or Gall Gnat - Cecidomyia solidago - this Gall Gnat arrests the growth of the stalk by depositing its egg upon the very apex of the terminal embryonic bud. In the course of a few days the egg hatches - the exact time depending upon Thermotropic and Hydrotropic conditions - into an extremely small maggot-like larva, having nine pairs of spiracles and a horny breast-plate, situated between the second and third segments of the ventral aspect of the abdomen.

The larva, although quite small, is a voracious feeder, and by eating into the primordial tissues of the vegetative cone, destroys many, and sometimes all the primordia of the flowers and also that of the stem; consequently, instead of the usual compound raceme or cormb of flowers so characteristic of Solidago influorescence, we have an extraordinary collection of imperfect flowers and foliage leaves arising almost sessile from a stunted stem. Such an anomaly is an excellent example of Phyllody or the metamorphosis of the floral organs into leaves. The leaves, in this case, which have replaced the floral leaves being identical to normal foliage leaves of the plant in every respect save that of size, being somewhat smaller as we might expect.

Transformation of Foliage Leaves into Scale-like Leaves.

Other members of the family Cecidomyiidae or Gall-gnats are known to cause curious transformations in organs. A very common example in the vicinity of Macdonald College, and one that is also quite general throughout the eastern provinces of Canada and the United States, is the Pine-cone Willow-gall.

This Gall which is induced by the attack of a Gall-gnat, Cecidomyia strobiloides, Osten Sacken, occurs on the terminal twigs of many kinds of low willow. As in the former case, the attack of the Gall-gnat is centered around the primordial tissue of the vegetative cone, the cells of which are excited to abnormal hypertrophy and subdivision as a result of the presence of the foreign body or egg. However, the influence exerted upon the plant by the egg must not be considered to be due entirely to mechanical irritation, for, as we shall see, there are other factors that must be accounted for. The effect of the egg resting on the cell-walls may be either mechanical or chemical, and enlargement of the host-cells is one of the most frequent phenomena accompanying such conditions, this enlargement, however, may be due to purely mechanical stimulation. Apart from this, we note the excretion of certain vapourous and gaseous products that must undoubtedly be given off by the egg during its period of incubation. It seems fair to suppose that these chemical products or their combinations with the contents of the host cells, exercise an influence over the subsequent behaviour of these cells adjacent to the egg, and also the contents of the cell which may become changed through these material influences - mechanical or chemical - of the insect during any stage of its metamorphosis, all such influences, however, being controlled by the peculiarities of the plant.

Sachs, 1887, in discussing the "flower-forming material" in certain malformations says: "what I understand is that extremely small quantities of one or of different substances - chemical combinations - arise in the leaves, and these them so influence the plastic materials which as we know flow into the vegetative points that they assume the form of flowers", and further, that "these flower-forming materials may act like ferments upon a large mass of plastic substance, whilst their own amount is extremely small". An equivalent relationship may be said to exist in this Pine-cone Willow-gall. Beyerinck's (1888) investigations of the nature of the stimulus causing malformation, resulted in his arriving at a somewhat similar conclusion to that expressed by Sachs, and to these excretory substances of the insect he has given the name "growth-enzymes"; both agreeing in a distinction being necessary between MATERIAL and FORM, and that all organic changes in form are governed by the changes in the processes of the nutritive materials.

I found that in this Pine-cone Willow-gall the primordium of the stem was completely destroyed and the foliage leaves transformed (Goebel, 1897) into relatively large scale-leaves; however, these still retain the normal spiral phyllotaxy, but are sessile and closely compact as a result of the destruction of the stem primordium.

The scale leaves continue their growth until the larva is surrounded by a concial, top-shaped growth bearing a singular resemblance to the unopened pistillate flower of Pinus sylvestris, hence the common name, Pine-cone Gall.

Many interesting and peculiar malformations have been observed in Valerianeae and Cruciferae as a result of the introduction of a parasite - a mite belonging to the genus Eriophyes and formerly known as the genus Phytoptus - which was the direct cause of the plant reacting in an anomalous manner. Abnormal types of leaves having fringe-like projections from the leaf-edge are recorded (Goebel, 1900), also such peculiar prolifications of the flower as the production of single stamens and carpels; the doubling and tripling of these organs, or an unaccountable multiplicity in the lobes of the corolla. The greatest divergences are in the parts which we might expect to be most sensitive; i.e., the vegetative parts of the plant where the movements of food material and cell division are so concise.

Further, and in conclusion, it will be observed that this study of a plant's behaviour to foreign stimulation - as a result of that fundamental property of protoplasm - irritability, resolves itself into a most exacting knowledge of the delicate inter-relationship of plant and environment. The plant's action is analogous to the rudimentary nervous system of lower animal forms, owing to the delicate protoplasmic strands that connect the living cells, and ~~this~~ which enable~~s~~ it to aympathetically react to affected areas.

As an example of the highest specialization of this characteristic we have the instantaneous reaction of the Sensitive plant (Acacia) to any sudden movement in the surrounding atmosphere.

The Problem of Initial Stimulus.

Summary of Mechanical and Chemical Affects on Gall Formation.

From the foregoing examples we might conclude that the question as to whether the initial and determining stimulus of galls is mechanical or chemical, or whether the subsequent and combined mechanical excitation of the larva are of greatest account in determining the nature of the Gall, can only be accorded specific importance. Whether it is the one or both of these influencing factors, we must expect - an have ample reason for supposing - that they vary greatly in degree of virulence, as the gall increases in size and the various metamorphic stages of its occupant are realized*.

In endeavouring to work out the cause and effect of the commoner species in the vicinity of Ste. Anne de Bellevue one observation seemed to be applicable to every case, viz., that whereas the relative variations in form and size are great they can all be traced back to the primordial meristem or to that investing layer of formative cells, the cambium ring, from which all secondary vegetable tissues develop, and which so closely invests the plant from root to leaf.

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* If the initial stimulus be chemical it must be derived from oval secretions and not from any inoculative substances deposited by the imago (See Pontania expt.).

These undifferentiated though highly meristematic cells always react in the same way against the same or equal stimulus, and it is this fact which has enabled students of plant malformation to give specific significance to insect galls even before the insect primarily responsible for their development is known*.

In general, therefore, it may be said that all organic changes in form, such as are observed in galls, are governed by changes in the process of nutrition, due to a single or composite processes which individually would establish normal tissues, but which when unbalanced by the introduction of a foreign factor, neglect the old relationship similarly to what is observed when the individual peculiarities of two species are combined in a hybrid.

The character of the malformation depends upon these latent powers of the plant to react against disturbances, whether the stimulus be the mechanical wound of a knife, the gnawing or piercing of embryonal parts by insects, or the chemical stimulation of what Beyerinck (1888 Botan.Zeitung) has termed"growth enzymes" and secreted by fungi, and also as he maintains by certain Tenthredinidae.

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*Some confusion has been caused by over zealous entomologists of the past, giving specific importance to Cynipid galls before their true habit was understood.

These present to the investigator morphological problems, so entangled with extraordinary structural modifications arising through the development of latent specific peculiarities, that attempts to solve them have been but partially successful.

MORPHOLOGICAL CHARACTERISTICS.

In degree of complexity of their internal structure galls differ considerably. Dissection reveals enlargement of the cells composing the paranchymatous tissue, together with an increase in their number. Moreover, in the majority of cases the protoplasts also appear greatly enlarged and their photosynthetic activities is evidenced by the presence of an abundance of starch and proteids.

Modifications such as these are decidedly favourable to developing larva and indicate that the normal translocatory enzymes have been wholly or partially destroyed. It is also found that accompanying this increase in the paranchymatous tissue there is usually a reduction of the thicker collenchymatous and sclerenchymatous tissues.

Some galls are monothalamous (single chambered) and contain but one larva of the Gall maker, while others are polythalamous (many chambered) and numerously inhabited. The largest class is composed of the unilocular or singly inhabited galls, although those which contain more than one larva are numerous and somewhat more complicated in structure. When the salivary enzymatic secretions or excretions of the egg and larva arise from a single point the resultant Gall is unilocular, but when there are several eggs, and consequently several points of equal stimulus the Gall results in a polythalamous excrescence.

Although the mchanical movements of the larva are important in accounting for the deposition of certain tissues, they cannot along explain all the tissues composing the Gall, for as has already been pointed out the hypertrophy of existing tissues usually commences while the larva is still enclosed within its egg.

Certain chemical substances possessing the nature of enzymes emananate from the egg and so affect the surrounding tissues as to result in the formation of a mass of cells containing starch and proteid substances relatively out of all proportion to that of any equal mass of normal tissue. The larva, upon hatching, ravenously attacks this nutritive tissue, but by this very act introduces an additional stimulative influence that materially controls subsequent growth, viz., mechanical mandibular irritation.

It is at this period of development that the greatest differentiation of tissues is recognised. The chemical and mechanical influences vie with each other for control, the result however always being the same for a given species of insect upon similar plants, which indicates that the relative influences upon growth of these two stimulative factors is quite definite.

It would appear as though much food during its course of translocation from neighbouring or more terminal photosynthetic parts was directed to and stored within the tissues of the Gall, as though in compliance with an intelligent appraisement on the part of the plant, ofthesubsequent requirements of the insect. The amylolytic and inversive ferments seem indefinitely impeded in their conversive and trans-locatory actions, if not indeed completely destroyed.

Later, in the united effects of mandibular secretion and action - the latter predominating - we have the appearance of an investment of sclerenchyma. This is an effort on the part of the plant to arrest the marauding escapades of the insect.

In some species the larva seems to obtain sufficient nourishment within this isolated chamber to enable it to pass on to the next stage of its metamorphosis. The subsequent stimulii result in many and fantastic means of protection, such as the deposition of tannin, gallic acid, cork, false cavities, trichomatous out-growths or unsavory glandular secretions - all these tending to protect the Gall-insect from the attacks of the outer animal world.

In other species (Cynipidae) the larva, by attacking and destroying part of this investment, induces the plant to deposit a secondary nutritive and thick-walled investment. Contrivances such as I have mentioned and their structural value have secured the evolution of so many various types of galls.

It is therefore obvious that the differentiation of the tissues and the formation of nutritive cells about the larva must depend on substances other than those which induce thick scleretic cells, and it is the writer's opinion that in the galls of the Cynipidae, and it would appear also in at least one species of Tenthredinidae (Pontania hyalina), the nutritive layer is induced by the respiratory and salivary secretions of the larva while yet enclosed within its chorion; and that the thick-walled sclerenchyma is developed by the plant in its endeavour to check the further mechanical irritation of the constant and increasingly active larva.

From observations such as these it seems impossible to suggest any categorical reply to the old question as to "what the stimulus to hypertrophy in galls may be". As I have endeavoured to point out the causes are many and variable and no hypothesis other than that it is the quality of the irritant and meristematic condition of the tissue at the time of its application, that controls the preliminary deposition by the plant can be seriously maintained.

MORPHOLOGY.

A singular characteristic of GALLS is the great diversity in formation and structure which is found in those formed by insects so closely related as to be included in the same genus and which might perhaps be expected to produce uniform types.

In illustration of this diversity we have those peculiar little red galls so common upon the leaves of the maple, and more rarely upon the elm, formed by extremely small and curiously shaped mites belonging to the genus Eriophyes. On the Hard Maple these galls assume a slender and somewhat cylindrical form, tapering to both extremtities. On the Soft Maple, however, they are rounder and have a short petiole, presenting a top-like appearance. Again, on the Manitoba Maple these galls are sessile, while on the Birch they form adventitious buds. On the Elm they are similar to to those of the Soft maple but smaller, while upon the Pear leaves they appear as reddish blisters which often coalesce, forming large blotches owing to the eggs having been laid close together on the leaf.*

It is therefore not only the insects of different orders or families that produce characteristically constructed galls, but even species belonging to a single genus have distinct variations that are traceable (Eriophyideae).

In the identification of galls in summer, perhaps one of the first characteristics which it is well to observe is, whether or not there is any natural opening into the gall. It is by means of this distinguishing feature

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* These galls were but a few years since erroneously considered by some botanists to be fungus growths and were so described in the genus Cephaleuros.

that galls formed by members of the families Eriophyidae, the Aphididae and Psyllidae (the plant lice and jumping lice) may be differentiated. All other galls, so far as it is at present known, which have no natural opening belong to the gall-making insects of the orders Hymenoptera or Diptera. Although this distinguishing point is quite reliable in summer it does not hold strictly true in the autumn, for many insects emerge at this time to pupate over winter in the ground.

The openings of the galls of the Psyllidae and Aphididae are usually quite large and occasionally aphids may be seen passing in or out on a fine summer's day. The openings of the mite galls (Eriophyidae) are generally to the under side of the leaves and are in proportion to their size much smaller than those of the aphids. They have also peculiar trichomatous growths through which the mites when emerging from their Gall must crawl, but which are sufficiently fine to keep out tramp insects. (Fig.).

A singular feature of these three families; viz., aphididae, psyllidae and Eriophyidae, is a reproduction of insects within the galls.

-: P A R T T W O. :-

GALLS COLLECTED BY THE WRITER.

Having thus indicated some of the geneaal aspects of my subject, I now propose to describe the galls which I have personally discovered during the past few years. I have representatives of the following orders.-

(1) Hymenoptera, (2)Diptera,
(3) Hemiptera, (4) Acaridae,
(5) Lepidoptera, (6) Coleoptera.

I have personally photographed the specimens obtained, emdeavouring as far as possible to bring out characteristic features and metamorphoses. I now submit the photographs, indicating in each case the order, family, genus,and where possible,species, together with descriptive notes.

ORDER HYMENOPTERA.

Superfamily Cynipoidae.

The Superfamily Cynipoidae is divided into the families Cynipidae and Figitidae. To the former belong the true Gall-flies and to the latter the Gall-fly guests and the majority of parasitic forms.

Cynipoid Galls are found upon the oak, the rose, the blackberry, the roots of raspberry, wild lettuce, cinquefoil and many other plants. The majority however, are found on the oak.

The adult gnat is four winged, dark in color and wasp-like. The venation of the forewings presents several closed cells, but no stigma. The abdomen is distinctly compressed and joined to the thorax by a short peduncle, considered by entomologists to be a modification of the first abdominal segment. Of the remaining seven segments, the last five are short and overlap one another.

The antennae are characterized by having thirteen to sixteen joints and are not elbowed. The Galls of the Cynipoids are the most complex of all insect galls and may be either single-chambered (monothalamous) and contain but one larva; or many celled (polythalamous) and numerously inhabited, e.g., Lettuce Tumor Gall Plate VII.

Kraemer, according to Howard*, while investigating the origin of tannin in galls found, that

* Howard, 1904, "The Insect Book" p. 55.

gallic acid is first formed at the expense of the starcn during the chrysalis stage of the insect, but that in the maturing of the winged insect, the gallic acid was changed to tannic acid and tannin resulted from condensation. According to the same authority, it is said that as each species of one generation always produces a gall of exactly the same character, generic and specific names were given the galls before the insects were described, the name subsequently being applied to the insect itself.

The galls of all cynipoids are closed and consequently a hole must be burrowed through the gall by the insect before emerging. See Plate I.

No reproduction occurs within the galls. Some species emerge from the gall in the larval form and pupate in the ground, but with the majority pupation occurs within the gall. The larvae are maggot-like and have no caudal opening to the alimentary canal. In many species there is an alternation of generations; in fact so entirely different do some succeeding generations appear that they have not only been described as distinct species, but have been placed in different genera.

There are some species where the parthenogenetic form exists alone. In those species where an alternation of generations occurs the eggs are deposited on plants which are often quite different from those upon which the parent gall grew. The new gall, and gall-fly that finally issues therefrom, are quite distinct from the first gall and gall-fly, but exactly resemble their grand parents.

Kellogg states*, that one of these generations appears exclusively in the female sex and that th the other generation is composed of both male and female and produced uniformly from unfertilized eggs. However, this dimorphic form occurs only in certain species where this alternation of generations is known and is not characteristic of all gall-flies, some appear habitually in but one form and produce but one kine of gall.

The guest gall-flies or inquilines resemble the true gall-flies, but lay their eggs in galls already formed by the true gall-flies. Their larvae live upon the hypertrppphy caused by the true gall-fly larvae. Several hundred gallmaking cynipoids and inquilines are known.

O R D E R H Y M E N O P T E R A.

Superfamily Cynipoidae.

Family Cynipidae.

PLATE I.

OAK BULLET GALL, Holcaspis globulus, Fitch
Callaspidia globulus, Fitch

On the twigs of White Oak (Quercus alba), and Burr Oak (Q. macrocarpa). A smooth, round, corky, monothalamous gall somewhat resembling shot. Interior is corky, with a small lighter coloured oval cavity in the centre which contains the larva.

Found singly or in clusters of two or three.

COL.-Collenchymatous tissue of the external investment
LC. -The larval chamber (sclerenchymatous), showing the opening through which the mature larva escaped.
P. -Passage to the outside burrowed by the larva.
EA. -External opening of larval passage.

Enlarged five times.

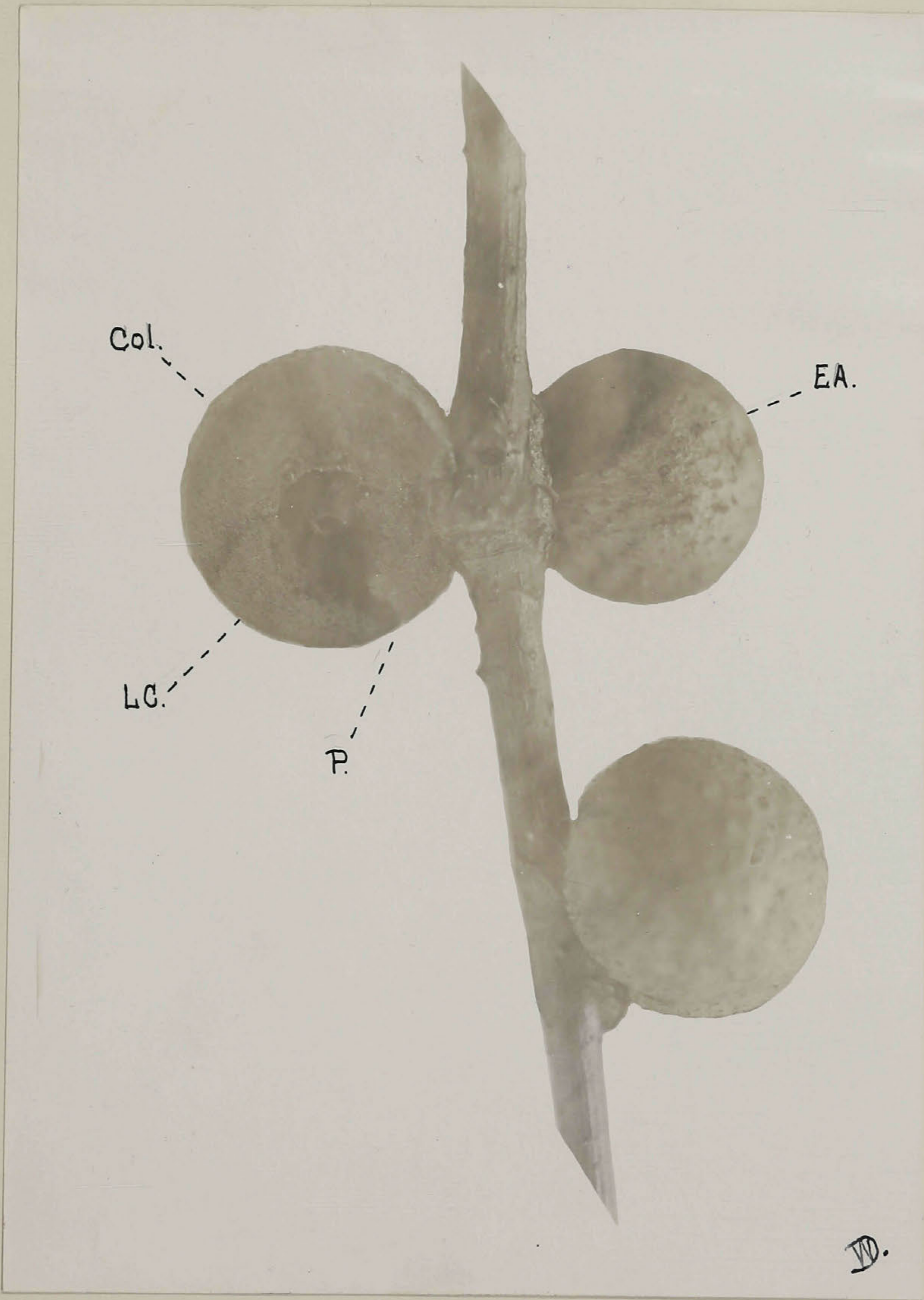

Plate I.

Oak Bullet Gall, Holcaspis globulus, Fitch.

PLATE II.

OAK PEA GALL, Cynips pisum, Fitch.

On the upper and sometimes lower surfaces of the leaves of White Oak (Q. alba), and Burr Oak (Q. macrocarpa). A spherical dithalamous gall, resembling a small pea with its surface fissured and netted with depressions between which are small elevations.

Follows the seasonal colour changes of the leaf, being greenish in summer and turning brownish in the autumn.

Enlarged twice.

PLATE III.

Oak Pea Gall, showing on the left, the immature Gall-fly and one of the two large interior chambers; on the right, three galls clustered together This photograph was taken on the 20th. of October 1907

Enlarged three times.

PLATE IV.

Oak Pea Gall, showing the same three galls as in the previous plate, but bringing out more clearly the peculiar fissured nature of the surface of these galls.

Enlarged eight times.

Plate II

Oak Pea Gall, (Cynips pisum, Fitch.)

Plate III.

Oak Pea Gall, (Cynips pisum, Fitch.)

Plate IV.

Oak Pea Gall, (Cynips pisum, Fitch.)

PLATE V.

OAK BUTTON GALL, Neureterus umbilicatus, Bass.?

On the upper and lower surfaces of the leaves of Burr Oak (Q. macrocarpa). Small round button-like galls.

Enlarged twice.

N.B., To the right of the plate, in the torn portion, may be seen a single specimen of the Oak Pea Gall (Cynips pisum, Fitch.

Plate V.

Oak Button Gall, (Neuroterus umbilicatus,Bass.)

PLATE VI.

LETTUCE TUMOR GALL, Aulax tumides, Bass.

On the stem of Wild Lettuce (Lactuca canadensis), Irregular, oval, knotty, polythalamous enlargements of the stem, varying greatly in size.

About natural size.

PLATE VII.

Lettuce Tumor Gall, showing the soft, pithy interior, with its numerous brown larval chambers. The larvae are straw coloured, taper at both cephalic and caudal extremities and have dark coloured mouth-parts. The average measurement of the larvae in this Gall was 4 x I½mm.

The pupae cases are transparent, brittle, chitinous chambers and are brownish in colour.

Enlarged seven times.

Plate VI.

Lettuce Tumor Gall, (Aulax tumides, Bass.)

Plate VII.

Lettuce Tumor Gall, (Aulax tumides, Bass.)

F A M I L Y T E N T H R E D I N I D A E.

It would be inaccurate to characterize the members of this family as gall producers for it is only certain species belonging to the genera Nematus, Pontania and Euura which induce malformations, usually upon the Willow,that are at all common. The remaining species and genera are ferocious plant feeders.

Sawfly larvae resemble somewhat the larvae of moths and butterflies, but the majority differ from these latter in having a characteristic habit, not noticed in Lepidopterous larvae, of curling or turning the caudal end of the abdomen. The Sawfly larvae also have from twelve to sixteen prolegs whereas, the true caterpillars have only ten.*

The adult Sawfly lays her eggs on the food plant, the aperture being made by her terebra set side by side in a groove on the under side of the abdomen. These terebra or saws are thrust back and forth out of a socket and a slit cut in the leaf. Into this slit the Sawfly slips an egg and then flies away and repeats the pperation two or three hundred times.

Before hatching, the eggs are seen to increase considerably in size,which according to Comstock** is

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* Except in the family Megalopygidae which have ten pairs of legs, three thoracic pairs and seven abdominal.

** See Comstock, Manuel, p. 612.

brought about by the gradual absorption of moisture from the surrounding foliaceous tissue.

The larvae of the Gall-producing species, so far as I have been able to observe, pupate over winter in the ground, which they reach by means of a fine silken thread or when the leaves fall in the autumn. The cocoons are usually dark-brown in colour and have a parchment-like texture.

PLATE VIII.

WILLOW CHERRY GALL, Pontania hyalina, Norton.

On the leaves of White Willow (Salix alba), appearing as tender green swellings in the spring. As summer advances, the Galls become larger, reddish in colour and protrude from both upper and lower surfaces of the leaf. The larvae are of a bluish colour. These Galls reach their maximum size towards the latter part of June, or earlier if the season is favourable, when they are said to resemble cherries.

Natural size.

Plate VIII.

Willow Cherry Gall, (Pontania hyalina, Norton)

PLATE IX.

Willow Cherry Gall Same as in previous plate.

Enlarged three times.

PLATE X.

Willow Cherry Gall,Showing Galls which have been attacked by a parasitic species of sawfly either before or very shortly after the original larva has emerged.

These Galls will be seen to be almost round, i.e., concentric to the egg from which the stimulus to hypertrophy comes; whereas, in plate IX. where the larval stimulii have been reacted against by the plant the conformation is quite different.

Slightly reduced.

Plate IX.

Willow Cherry Gall, (Pontania hyalina, Norton)

PLATE XI.

WILLOW APPLE GALL, Pontania pomum, Walsh.

On the leaves of Willow (Salix discolor). Round, fleshy galls of a yellowish-green colour, somewhat resembling a very small immature apple.

The eggs of this Sawfly are laid in April. In about a week, the larva hatches. It pupates over winter in the ground which it reaches by a fine silken thread. The cocoons are brownish in colour.

During September (1907), several of these Galls were found which contained small silken cocoons of a parasite along with the dead host larva; however, efforts to breed out the parasitic form have so far been unsuccessful.

Enlarged slightly.

Plate XI.

Willow Apple Gall, (Pontania pomum, Walsh)

Plate XII.

Willow Apple Gall, (Pontania pomum, Walsh)

Club Gall, (Cecidomyia rigidae, Osten Sacken)

PLATE XIII.

On the branches of Pinus sylvestris. The Gall is caused by a species of Sawfly belonging to the genus Lyda. The eggs are deposited on the terminal twigs of the branches in June. The larvae eat the needles and also use them, together with a dark, stick secretion to form the gall.

This Gall sometimes measures two or more feet in length. The larvae pupate within the gall, the adults emerging the following spring.

Somewhat reduced.

Plate XIII.

Unsightly Gall of Pine, (species of Lyda)

O R D E R   D I P T E R A.

Family Cecidomyiidae.

This family Cecidomyiidae or Gall-gnats, comprises many insects of great economic importance owing to the tremendous losses suffered by farmers as a result of the ravages of certain of its members upon wheatfields, cloverfields and the pines of our forests.

About a hundred species are known to attack our herbs, shrubs and trees. These minute flies are midge-like and also resemble somewhat the mosquitoe, but are not known to bite.

Their antennae are many jointed and have whorls of large hairs arising from them. Their wings are simply veined, sometimes having but a single cross-vein and the longitudinal veins few in number.

Th e larvae are brightly coloured, small and maggot-like and destitute of head and feet. They probably receive nourishment through the thin abdominal wall by osmosis. The colour varies according to the species; red, pink, yellow and orange being common examples. Some build cocoons within their galls, while others descend to the groundand still again, with others the pupae are naked.

In Canada and the Northern United States, during the month of May, "legions of these delicate minute flies fill the air at twilight, hovering over wheat-fields and shrubbery. A strong North-West wind, at such times, is of incalculable value to the farmer" *

Probably the most familiar Gall formed by a Gall-Gnat is the Pine-cone Willow-gall (Cecidomyia strobiloides, Osten-Sacken) Plate XVIII, although other familiar forms appear on the Goldenrod, Sunflower and Astor.

A particularly striking feature of the larvae of this family is the presence of a horny piece of chitin situated on the lower side of the abdomen, between the second and third segments. The homology and use of this breastbone have not as yet been determined, perhaps it helps in locomotion, or it may be for the lacerating of soft tissues to increase the flow of nutrient substances.

These Gall-gnats are among the smallest, most inconspicuous and frailest flies known, but owing to their great numbers and the vegetable feeding and Gall-making habits they may well be considered formidable enemies.

* A. S. Packard, 1873, Our Common Insects p.203.

PLATE XIV.

GOLDENROD BUNCH GALL, Cecidomyia solidaginis,Loew.

An apical gall on the main stalk of Goldenrod, consisting of the unnatural accumulation of several hundred leaves into a globular mass as a result of injury to the stem while in its primordium.

Many of the flowers and flower pedicles are also affected and appear as simple fpliage leaves, from the base of which arise the uninjured stalks.

Reduced.

Plate XIV.

Goldenrod Bunch Gall, (Cecidomyia solidaginis, Loew)

F A M I L Y T R Y P E T I D A E .

These Gall-making Dipterous flies often disfigure the seed-heads of plants. They are small flies with beautifully banded and marked wings. Their colour varies from yellowish to almost black and the body is often spotted.

The larvae are cylindrical, footless maggots which burrow in fruits and plant stems, often producing Galls.

The family is represented by Trypeta solidaginis, Fitch, which produces a hard globular Gall on the Goldenrod.

PLATW XV.

GOLDENROD SPINDLE GALL, Eucosma scudderiana,Clemens.

On the stems of Goldenrod (Solidago canadensis A large elongated monothalamous gall usually three-quarters way up the stem among the flower pedicles.

Reduced.

(Two specimens on right)

GOLDENROD BALL GALL, Trypeta solidaginis,Fitch.

On the main axis of Goldenrod. A solid globular, monothalamous gall measuring about three centimeters in diameter. Occuring singly or in twos or threes. Most conspicuous in the winter when the leaves have fallen. The larva hibernates over winter in the gall and emerges in the spring.

Plate XV.

Goldenrod Spindle Gall, (Eucosma Scudderiana, Clem.)

Goldenrod Ball Gall, (Trypeta solidaginis, Fitch)

Plate XVI.

Goldenrod Ball Gall, (Trypeta solidaginis, Fitch)

PLATE XVII.

GOLDENROD BALL GALL, *Trypeta solidaginis*, Fitch.

Showing the solid pithy structure of the interior and the fat maggot-like larva working its way towards the exterior.

Enlarged five times.

Plate XVII.

Goldenrod Ball Gall, (Trypeta solidaginis, Fitch)

PLATE XVIII.

PINE-CONE WILLOW-GALL, Cecidomyia strobiloides, O.S.

On the terminal buds of Willow shoots. It is a bud Gall formed of closely imbricated leaves, resembling a Pine cone; appears in May and is usually full grown by the latter part of June.

The larva remains in the Gall over winter and pupates in spring, the imago emerging soon after.

Several species of inquilines are usually found among the scaly leaves, the most common one being Cecidomyia albovittata.

Plate XIX, shows the gall in section.

Natural size.

Plate XVIII.

Pine_cone Willow_Gall,(Cecidomyia strobiloides,O_S.)

Plate XIX.

Pine-cone Willow-Gall, (Cecidomyia strobiloides, O-S.,)

PLATE XX.

WILLOW CLUB GALL, Cecidomyia rigidae, Osten-Sacken.

On the lateral shoots of Bush Willow, an enlargement of the whole stem, tapering from the centre to both ends. Occasionally galls are found having terminal shoots growing from them.

The longitudinal section of the Gall to the right shows the hypertrophy to be general, the deposition of the eggs by the Gall-gnat causing an adventitious growth of all the surrounding tissues. Larvae are white in summer, becoming brownish in autumn. 6 m.m.in length.

Reduced one-half.

PLATE XXI.

WILLOW EGG GALL, Euura ovum, Walsh.

On branches of Willow (Salix discolor). Hypertrophy is oval in shape and is an enlargement of only the superficial tissues.

Galls are soft and spongy in summer, but become harder in autumn. Larvae are recognized by a horny breastbone on the ventral surface between 2nd and 3rd segments.

Larvae pupate over winter in Gall, imago emerging in the spring.

L = Longitudinal radial section showing larva in its elongated cavity.

Natural size.

Plate XX.

Willow Egg Gall, (Euura ovum, Walsh)

Plate XXI.

Willow Egg Gall, (Euura ovum, Walsh)

ORDER HEMIPTERA

Family Aphididae.

Aphids or plant lice are found infesting all kinds of vegetation. Some are black, others green and still others are covered with a white woolly secretion. There are winged and wingless forms amongst our most common species. Their size is small, seldom being over a quarter of an inch in length. Their life history is rather surprising and they show a symbiotic relation to ants. Their rate of increase is so enormous that vegetation would be practically wiped out, were it not for their legions of natural enemies. The rapid increase is owing to

(1) Early age of reproduction.

(2) Parthenogeneric forms.

(3) Most species producing living young during the summer.

After several generations of aphids have been produced during the summer, asexually, there somes a sexual generation in the autumn. The males and females pair, eggs are laid and hatch out the following spring. During the summer the females are nearly all wingless, winged forms appearing only once or twice during the year, or where migration is necessary on account of scarcity of food.

The aphids secrete a honey-dew which is fed upon by ants, bees and wasps. Several species form fleshy galls on the leaves and soft tissues of plants.

Species of the genus Schizoneura and Lachnus, found commonly on the branches of trees, excrete large quantities of honeydew, upon which fungus growths develop, forming large spongy galls; e.g., Scorias spongiosum (Comstock p.161).

Schizoneura Canigera, Hansen attacks the apple, producing galls on the roots and sometimes markings on the branches, but has not been collected in this locality.

Grape Phylloxera, (Phylloxera vastatrix,Planchon) sometimes proves a serious pest. It has four well-defined stages:

(1) The sexual form, consisting of a single generation;

(2) The leaf gall stage, consisting of from one to five generations;

(3) The root gall form, consisting of several generations;

(4) The winged form, which is a single summer generation. *

* Mel. T. Cook. "Galls of Indiana".

PLATE XXII.

SPRUCE GALL LOUSE, Chermes abietis.

Showing the characteristic bending and swelling of the young spruce twigs.

Adult emerges from the galls about August 1st, and after a day's rest is capable of flying long distances. Female lays from 30 to 40 eggs, then dies while resting on the eggs. The eggs hatch in about two weeks and the larvae burrow into the immature buds and remain there overwinter. The following spring their presence in the bud causes the hypertrophy.

Found on Black Spruce (Picea nigra),
White Spruce (Picea canadensis),
Balsam (Abies balsamea),
and Hemlock (Tauga canadensis).

Natural size.

PLATE XXIII.

SPRUCE GALL LOUSE, enlarged three times

PLATE XXIV.

These peculiar galls are upon the trunk of an old Balsam Poplar (P. balsamifera).

Probably caused by one of the plant-lice - Schizoneura. Photograph was taken in the Green Mountains, Eastern Quebec, and this particular tree was practically covered with these galls; unfortunately, however, the tree was so located that specimens could not be collected. The photograph was taken through the trees with a tele-photo lens.

About natural size.

Plate XXII.

Spruce Gall louse,(Chermes abietis)

Plate XXIII.

Spruce Gall louse, (Chermes abietis)

Plate XXIV.

Large excrescences on Ppplar, (Schizoneura sp.)

O R D E R A C A R I N A.

Family Eriophyidae.

A family which until recently was known as the Phytoptidae, possessing members of curious cylindrical form and minute size.

They are strictly plant feeders and many species form galls. These galls or acarocecidia, are abnormal growths of the leaves and buds of plants, and consist of variously thickened portions which, in the case of leaves, are usually most hypertrophied on the upper surface. The lower or under part of the Gall is drawn up to the interior, whichis filled - as is also the opening - with tufts of hair or trichomatous outgrowths among which the minute insects live. Galls occur on the maple, elm, birch, basswood, pear, plum, ash, alder and many others.

These minute cylindrical Gall-mites rarely exceed 1/200 of an inch in length, and a quarter of this measure at the greatest width. The family includes the more familiar forms known popularly as Red Spiders, True Spiders, Scorpions, Cheese Mites and numerous parasitic forms.

Banks, (1907) states that there are at present four hundred and fifty species, grouped in one hundred and thirty-three genera, known in America, many of which play an important part in the economy of the country.

The very simplest and elementary type of Gall is found in the excrescences induced by members of this Gall-mite family Eriophyidae. This family has been the careful study and investigation of Dr. Nalepa, 1898, of Vienna, according to whose revision of the classification and nomenclature we have the family divided into two sub-families: Eriophyinae and Phyllocoptineae. Of the Eriophyineae we have two genera: Eriophyes and Monochetus, the former containing 146 species, 31 of which are known to occur in Great Britain (Collinge, 1904) and 40 Gall-forming species collected by the writer in Canada.

Description of Gall-mites:

Gall-mites are as a family of a hyaline or pinkish colour, cylindro-elongate in shape, tapering gradually towards the caudal extremity and more suddenly towards the cephalic direction, where there are two pairs of short stubby legs, distinctly five jointed and terminating in two tarsal-claws. The lower of these tarsal-claws usually bears hair-like spines, but the upper one is spineless, blunt and somewhat longer.

Between the two pairs of legs, and somewhat anterior to them, is the head which is drawn out into a snout. The mouthparts consist of a pair of needle-like mandibles and a three-jointed maxillary palpi. The head is united with the thorax, forming a cephalothorax, covered dorsally by a shield-like covering with longitudinal furrows. The abdomen is divided into many delicate segments, on each of which rows of small, stubby protuberances arise. Extending laterally from the abdomen are hair-like bristles or setae, usually five pairs; i.e., seta lateralis, seta ventralis I, seta ventralis II, seta ventralis III, and the seta caudalis.

At the posterior end of the body, immediately caudad to the seta caudalis, are two disk-like appendages which may be opened or closed at will, forming a sucker-like organ by means of which the mite can erect its body and by curious spring-like motions jump several millimeters.

Collinge, 1904, says in regard to the functionings of this caudal organ "they obtain a firm hold with the tail-disc and seem to wait three or four minutes in this position hoping to attach themselves to some insect or arachnid". This remarkable method adopted by the mites as a means to migration was verified by the writer, by causing specimens of Musca domestica, rendered more or less listless as a result of the attack of a fungus, Empusa muscae, to parade over a leaf of Tilia americana which was badly affected with Eriophyes abnormis. Microscopical examination of the legs and abdomen of the fly later, revealed many mites adhering.

Newstead, 1901, referring to this peculiarity of the mites standing erect says "I have seen an individual while in such a position support eleven of its companions, all of which had anchored themselves to its body by their anal claspers", indicating the enormous strength these mites have in being able to raise their bodies in this manner on so short a leverage. The epidermis of the mites is of a chitinous nature which makes staining and clarifying for microscopical examination difficult.

As to size, the mites vary according to the species. A single adult female of Eriophyes parvulus measuring 100 microns 1/250 of an inch, while the female of Eriophyes mentharius, one of the largest species known, measures 310 microns 1/80 of an inch.

THE FROST MITE GALLS.

These foliaceous excrescences or Erineum (Marshall Ward, 1901), are commonly met with in the vicinity of Macdonald College, upon the leaves of Acer Saccharum, Acer saccharinum, Acer spicatum, Ulmus americana, Betula alba, Betula papyrifera, Betula lenta, Fagus sylvatica, Fraxinus americana and Rhus radicans, and are the simplest form of Gall known, consisting merely in the simple hypertrophy of epidermal cells, attacked while still embryonal, into trichomatous outgrowths, as a result of the nibblings of the mites. The trichomes arise in clusters and are apparently a factor in the plant's endeavour to prevent the loss of cell sap which would otherwise be more pronounced and analogous to the reaction of many plants when grown under xerophytic conditions; i.e., the production of hair-like outgrowths from the epidermis to modify heat and evaporation.

These patches upon the leaves are whitish at first and resemble isolated areas of hoar-frost. Many, however, soon assume a reddish or brownish colouration possibly as a result of the secretion of oxidative enzymes by mites.

According to Marshall Ward, 1901, Persoon has described these Frost Mite-galls as being a result of fungus activities and given them the generic significance of ERINEUM.

Many species producing these Frost Mite-galls on our Canadian flora have not as yet been worked out. Specific differences in the size, number of abdominal striae and setae, etc., have been noted by the writer.

Fusiform and Pouch Mite-Galls.

Other Eriophyid Galls are found, varying from the Frost Mite-gall in having more pronounced hypertrophy, followed by the intussusception of the leaf tissues. This gives rise to galls popularly known as Dimple Galls Capsule Galls, Pocket or Pouch Galls, according to the extent and nature of the tissue inversion.

....

PLATE XXV.

MAPLE POCKET GALL, Phyllocoptes quadripes, Shimer.
Eriophyes quadripes, Shimer
Phytoptus " "

On the leaves of soft maple (acer dasycarpum). The galls are small and variable, usually somewhat convex on upper surface and connected to the leaf by a slender neck.

These galls appear on the maple, with the unfolding of the leaves, as slight swellings of the parenchyma, and usually expand into little galls as the leaf matures, rising from the upper side of the leaf. The Gall follows the seasonal changes of the leaf, greenish in summer turning reddish, finally brownish in autumn. The outer surface is smooth, but the walls are broadly and irregularly impressed, making an uneven outline.

Position of the Gall on the under side of the leaf is indicated by a depression with a tuft of white hairs or trichomes in the centre which covers the opening into the Gall and keeps out tramp insects. Slightly reduced.

Plate XXV.

Soft Maple Pocket Gall, (Phyllocoptes quadripes, Shimer)

PLATE XXVI.

Photograph of an adult mite taken from Gall on soft maple, showing the general contour of the mite and the four sucker-legs, all rising from the anterior end of the body.
Enlarged three hundred times.

PLATE XXVII.

MAPLE POUCH GALL, Phyllocoptes aceris-crumena, Riley.
Eriophyes acericola, Garman.
Phytoptus acericola, Garman.

This mite produced galls on the leaves of hard maple (Acer Saccharum).

The Gall is very slender and tapers to both extremities; about 1/10 to 1/5 of an inch in length and is attached to the upper surface of the leaf by one end.

Mites were found in large numbers in these galls during September and October (1905) and the striae on the body averaged about 28 in number.
Slightly reduced.

PLATE XXVIII.

ELM POCKET GALL, Eriophyes ulmi, Garman.
(Phytoptus ulmi)

A small more or less spherical Gall, with slightly constricted neck, occurring upon the surface of the white elm (Ulmus americana). In general form, this Gall resembles the P. quadripes; but is smaller, more slender and not constricted so abruptl at the neck. The walis are thick, with numerous folds projecting into the inner cavity. The young and adults were found in the galls in July and September.

The outer surface of the Gall has unicellular hairs or trichomes projecting from it.

Size of galls in plate 17 m.m.

Adult mite is very slender having from 67 to 70 striae.

Natural size.

PLATE XXIX.

MANITOBA MAPLE WART-LIKE DIMPLE GALL, Eriophyes sp.

Roughened, wart-like, sessile galls upon the upper surfaces of the leaves of Manitoba Maple (Acer negundo). The galls vary in size and sometimes grow together, forming irregular roughened areas.

The position of the Gall from the under surface of the leaf is recognized by a cavity or depression, filled by trichomes as in previous described species.

Natural size.

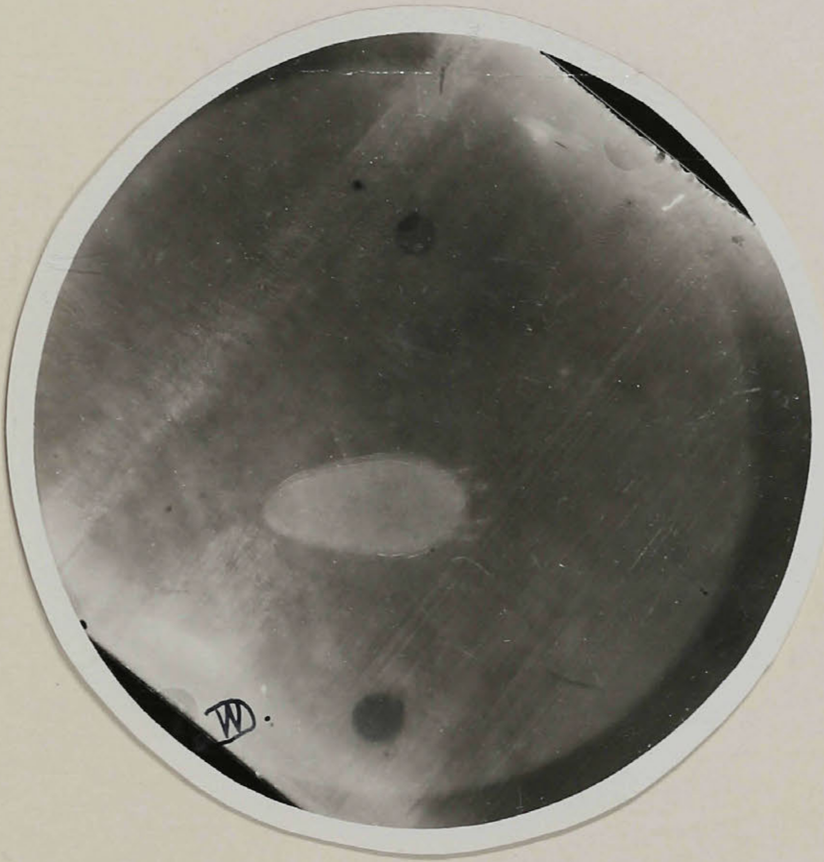

Plate XXVI.

Photo micrograph of Phyllocoptes quadripes.

Plate XXVII.

Sugar Maple Pouch Gall, (Phyllocoptes aceris-crumena, Riley)

Plate XXVIII.

Elm Pocket-Gall,(Eriophyes ulmi, Garman)

Plate XXIX.

Wart-like Dimple Gall, (Eriophyes sp.)

PLATE XXX.

ADVENTITIOUS BUD GALL, Eriophyes sp.

Causes an adventitious development of buds upon the small lateral branches of Birch (B.entea). The mites, which are extremely small not exceeding 1/200 of an inch, were found in large numbers in the interior of the buds last autumn (1909). Reproduction evidently occurs within these galls as in the species on the maples. New buds are added to the clusters each spring; but the most profuse development occurs on the younger branches. It is probable that the old mites attack the newly formed buds each spring and deposit their eggs in them.

PLATE XXXI.

ADVENTITIOUS BUD GALL OF BIRCH, enlarged twice.

Plate XXX.

Adventitious Bud-Gall, (Eriophyes sp.?)

Plate XXXI.

Adventitious Bud-Gall, (Eriophyes sp.?)

PLATE XXXII.

Showing the under surface of a leaf of Basswood (Tilia americana), with some interesting galls upon it. The white tufts of hairs are the trichomes which cover the entrance to mite galls (Eriophyes sp.).

The little tufts of hairs in the axils of the leaves are called Dermatia (Barnes Plant Life); they roof over the angles made by the viens and form a shelter for mites which are supposed to be beneficial to the plant; however, very little is at present known regarding the function of the Dermatia and their residents.

Another Gall that is shown is the BASSWOOD WART GALL (Cecidomyia verrucicola, Osten Sacken). These are small rounded wart-shaped galls and occur in large numbers on the leaves.
Common locally.

PLATE XXXIII.

COCKSCOMB ELM GALL, Colopha ulmicola, Fitch
Brysocrypta ulmicola, Fitch
Thelaxes ulmicola, Walsh
Colopha ulmicola, Monell
Glyphina ulmicola, Thomas
Colopha ulmicola, Riley.

On the upper side of the leaf of Elm (ulmus Americana). Gall is narrow, erect and irregularly toothed. Varies greatly in size, from an insignificant

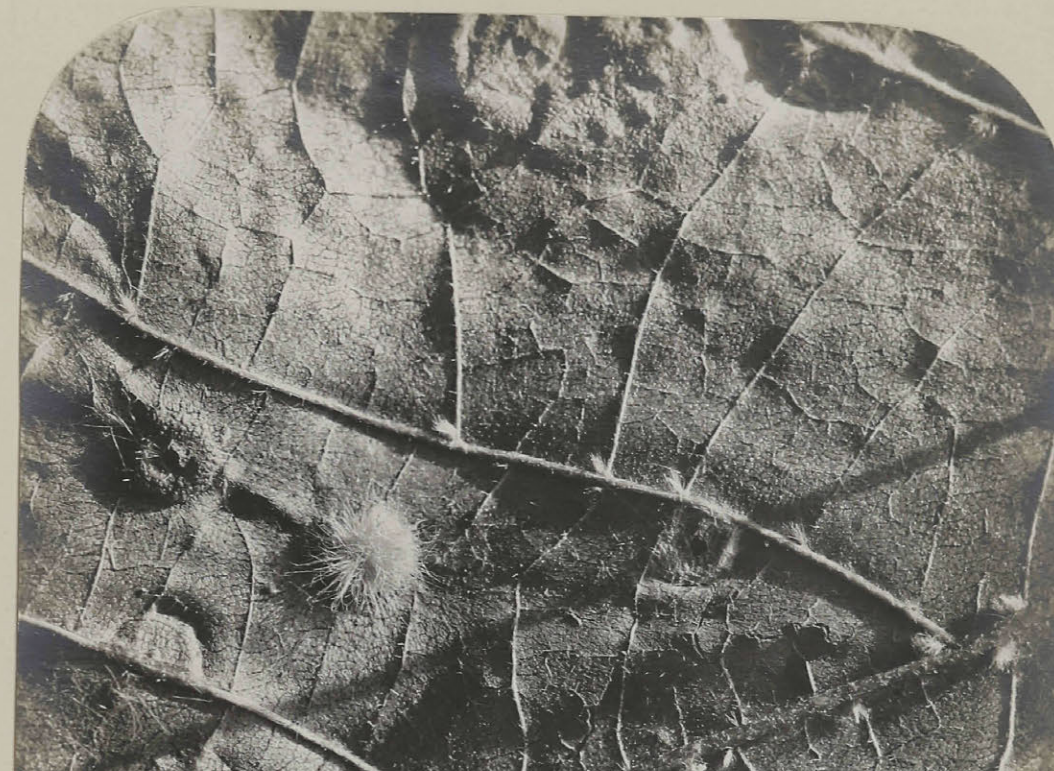

Plate XXXII.

Trichomatous gtowths in the openings of theSerrated

Pouch-Gall of Basswood.

Plate XXXIII.

Cock's comb Elm Gall, (Colopha ulmicola, Fitch)

Gall to one an inch or more in length and a quarter of this in height. Opening of Gall is on the under side of leaf.
Slightly enlarged.

PLATE XXXIV.

POPLAR STEM GALL, Pemphigus populicantis, Fitch.

At junction of petiole and leaf of Carolina Poplar (P. Monilifera). Irregular and Spherical Gall, having the petiole apparently tucked under an extension of the leaf, leaving a long narrow mouth-like opening which is clearly shown in the upper left-hand specimen.

Interior of the Gall is hollow, making a suitable home for the plant lice.

PLATE XXXV.

POISON IVY DIMPLE GALL, Eriophyes sp.

Galls are many, convex on upper surface of leaf, green to bright reddish in colour and usually converging into one another by midsummer, forming large granular masses.

Plate XXXIV.

Poplar Stem Gall, (Pemphigus populicaulis, Fitch)

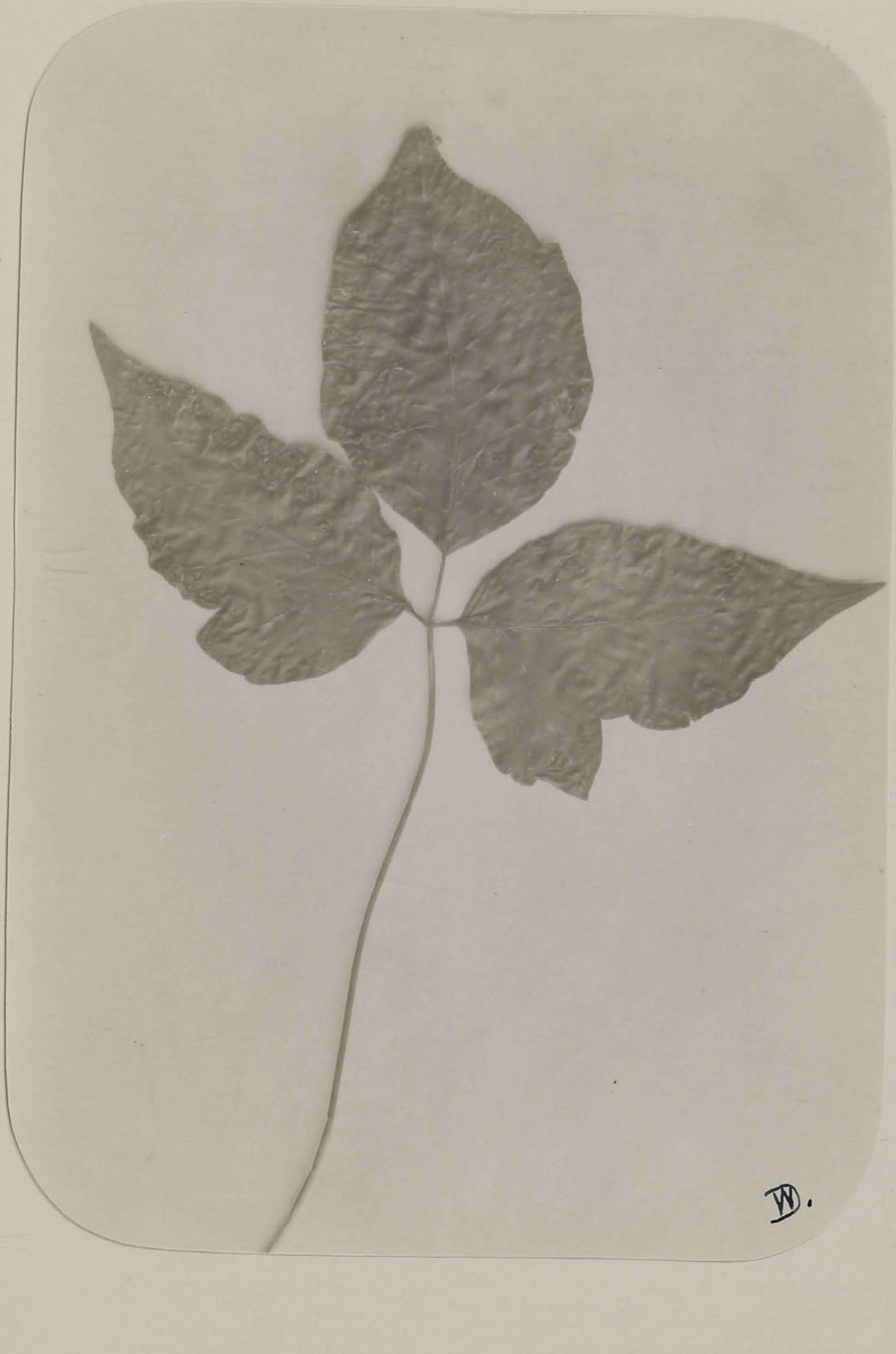

Plate XXXV.

Poison Ivy Dimple-Gall, Eriophyes sp.?)

PLATE XXXVI.

HAWTHORN LEAF-FOLD GALL, Acarus crataegi verniculus, Hagen.

An irregular folding of portions of the leaf between the veins on the upper surface of leaves.

PLATE XXXVII.

PLUM BUD GALL, Eriophyes phleocoptes, Nalepa.

A small knotty growth surrounding the buds and shoots of Prunus domestica.

Plate XXXVI.

Hawthorn Leaf-fold Gall, (Acarus crataegi vermiculus Hagen)

Plate XXXVII.

Plum Bud-Gall, (Eriophyes phloeocoptes, Nal)

ORDER COLEOPTERA.

Of other insects which have been recognized as Gall-makers there are certain curculionids (Gall-weevils) and a species of Cerambycidae (Saperda imbruata) which according to F. H. Butler* forms the pseudo-galls of salix longifolia and Populus angulata or cottonwood.

Melville T. Cook states in his report on the "Galls of Indiana" that a species of the family Buprestidae, Agrilus inficollis Fabr., (The Red-necked Agrilus) is very destructive to raspberries and blackberries in parts of the United States. The eggs are deposited in the canes in July or August and soon hatch; the larvae immediately bore into the sap wood and cause irregular elongated galls known as the raspberry gouty gall. The winter is passed in the gall and the adult emerges in June or July.

*Encyp. Brit. Vol.X., p.43.

PLATE XXXVIII.

WILLOW BRANCH GALL, Saperda concolour.

Found on the branches of Willow (Salix discolor). The eggs are deposited in the tender plant tissues; but whether the hypertrophy is due to the irritating fluid or virus secreted by the female insect and deposited with her egg, or to the simple oval or larval irritation of itself, is still an unsettled question.

Natural size.

Plate XXXVIII.

Willow Branch-Gall, (Saperda concolor)

ORDER LEPIDOPTERA.

Among the Lepidoptera are Gall-forming insects belonging to the following families:-

Ageriidae

Tortricidae,

Pterophoridae and the Tineina,

The Family Gelechiidae is represented by the Guerimoschema Gallaesolidaginis, Riley, (Gelechia Gallaesolidaginis) which produces an elongated Gall on the golden rod (Solidago canadensis).

The Tineids are the smallest Lepidoptera known, many of them live until full grown within the tissues of leaves forming various shaped mines and galls.

Plate XXXIX.

Elliptical Goldenrod Gall, (Gnotimoschema
gallaesolidaginis, R

PLATE XL.

ELLIPTICAL GOLDENROD GALL, Gnorimoschema gallaesolidaginis, Riley.
Gelechia Gallaesolidaginis.

On stems of golden rod (Solidago canadensis). In the left stem may be seen two larvae, each having its own apartment.

Photograph was taken in October when the larvae had ceased feeding and become comparatively inactive preparatory to pupation.

Stem on the right shows the moth in its pupa stage. It remains over winter in this condition and imag emerges the following spring.

Woolly material surrounding pupa consists of cotton used to bring out detail in the photograph.

PLATE XLI.

FUNGUS GALL, Gymnosporangium macropus.

Found on branches of Red Cedar (Juniperus virginiana) and sometimes mistaken for an insect Gall. It is the telentospore stage, and is probably the same species that attacks the apple - apple rust.-

Not common.

Natural size.

Plate XXXX.

Elliptical Goldenrod Gall,(Gnorimoschema gallae-olidag
solidaginis,Riley

Plate XXXXI.

Fungus Gall, (Gymnosporangium macropus).

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