# HAMPSHIRE LITERARY AND PHILOSOPHICAL SOCIETY.

# A PAPER

ON THE

# PAPILIONACEOUS LEGUMINOSÆ,

COMMONLY CULTIVATED IN GREAT BRITAIN,

BY


## W. FRANK PERKINS,

(BY EXAM. :—MEMBER ROYAL AGRICULTURAL COLLEGE; LIFE MEMBER AND PRIZEMAN, ROYAL AGRICULTURAL SOCIETY OF ENGLAND; LIFE FELLOW, HIGHLAND AND AGRICULTURAL SOCIETY OF SCOTLAND; DIPLOMA, SPECIAL CERTIFICATE, AND SILVER MEDALLIST, ROYAL AGRICULTURAL SOCIETY OF IRELAND; SPECIAL PRIZEMAN AND PROFESSIONAL ASSOCIATE SURVEYORS' INSTITUTION.)


MARCH 17TH, 1890.


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## "*The Papilionaceous Leguminosæ, commonly cultivated in Great Britain.*"

Perhaps the best excuse which can be offered for the choice of snch a subject as this, which forms the title of my paper, is that botany in its gentler and more familiar aspects, and shorn of the terrible terminology of modern specialism, appeals to the interest of almost everyone who delights in the works of nature, and more particularly to the gentler sex, which forms so large a proportion of this Society. It seems to me that ladies are instinctively botanists. Plants require gentle, kindly treatment and constant attention, if they are to be brought to perfection in our gardens and our greenhonses. There are many operations of a delicate character that may be performed on them, which the deft fingers of ladies are pre-eminently fitted to carry through. Anyone who has had experience of grafting, or of cross fertilizing, will understand the extreme tenderness necessary to make these operations successful, and will wonder that the work of man's clumsy fingers has in the past been attended with the very considerable success which has been attained. Perhaps the explanation may be that nature's complaisant compliance with man's rudely enforced desires more than counteracts his clumsy methods of execution. The practice of horticulture and the study of botany are, therefore, essentially suited to the capacity of ladies, and I have often wondered that among all the wild schemes for finding employment for gentlewomen, no one has hazarded the suggestion that they should take up the higher branches of horticnlture as a profession.

I have, therefore, chosen Botany as my subject, and with the desire to make my paper as generally interesting as such a

Society as this has a right to demand, I have chosen one big group of plants with most of whose members you will be perfectly familiar, and in discussing them I hope to generalize sufficiently to enable you to understand their relations and affinities, and the reasons which underlie their classification. I may as well say at once that I am a wretched botanist, and that you will listen in vain for any deeply scientific disquisition. My only interest in these leguminosæ this evening is in their practical relation to the business of agriculture, and so I have limited my range still further by selecting only the cultivated leguminous plants and only those commonly cultivated in Great Britain. You will see that this is a very different thing, indeed, from the plants of common occurrence, for it is noticeable that a great many cultivated leguminosæ are not native (although they are now perfectly acclimatised), but at various times and from various places they have been introduced into Great Britain.

Anyone possessing an elementary acquaintance with systematic botany will know that the huge natural order leguminosæ, said to contain 4,800 species, is divided into three main groups :—

I.—The Papilionaceæ.
II.—The Caesalpinieæ.
III.—The Mimoseæ.

As a matter of fact, however, the two latter are entirely extra European, and therefore will not concern us this evening. Suffice it to say that among the caesalpinieæ are plants which furnish us with tamarinds, cassia, balsam of copaiba, carob beans, Tonka beans, and Brazil wood dye, and that members of the mimoseæ include the very interesting sensitive plant, and furnish us with gum arabic and catechu, and you will understand their importance.

The papilionaceæ, however, are largely of European occurrence, and flourish in the temperate zone. They are for the most part, herbs or soft-stemmed plants, the laburnum being a good example of the exceptions. It may be as well that we should be quite clear at starting as to what the term *Leguminous* means, or, as our practical acquaintance with them is confined to the papilionaceous group, to understand the term *Papilionaceous.* Latin and French scholars will at once guess that the group in question has been so named from some resemblance to or connection with the butterfly, and if you will look at the diagram on the wall of a papilionaceous flower, you will at once admit that it is not a bad name to apply. Without undue poetic license, one may trace the suggestion of a resting or hovering butterfly on every papilionaceous flower, and with especial force in such a flower as the cultivated sweet pea. If you will take the trouble to dissect a few papilionaceous flowers, you will become familiarized with the floral structures which are common to all of them. Every flower of this sub-order can be easily divided into five petals, always arranged in the same relative positions, which are respectively known as (i.) the vexillum or standard, which forms the uppermost portion, (ii.) the two aliae or wings, and (iii.) the carina or keel, formed of a second pair of petals more or less united. These pretty fancy names are suggestive of the poetical manner in which the ancient botanists looked at flowers. They had not then learned to look at vegetation merely as so much *matter*, but they had time to trace and to name any resemblance or suggestion, however fanciful. The standard suggests the white flag flowing in graceful undulation with the breeze, and when we remember that in olden times flags were carried more frequently on a horizontal than on a vertical support, as are now our Sunday School banners, the force of the suggestion is at once felt. The two wings, one on each side, are names almost self-explanatory, and the keel, shaped somewhat like the keel of a ship, is an equally forcible name. Like to a butterfly as is a papilionaceous flower, I have often thought that the comparison of it to a nautilus would be even happier, especially as the ancients, ever since the time of Aristotle, believed that the Argonaut hoisted a sail in fine weather and put out natural oars, so suggesting to mankind the possibilities of navigation. The standard, the wings, or sails, and the keel, are names more suggestive of the nautilus than of the butterfly. But whether you prefer to consider them as nautilus-like or butterfly-like, either term will enable you to remember that a five-petalled corolla, arranged in a particular form, is a certain indication that the plant on which it grows is papilionaceous. It is fortunate for some of us amateur botanists, that in more orders than one the arrangement of the petals is characteristic. For instance, the huge natural order of cruciferæ all bear flowers of four equal sized petals arranged crossways.

Another characteristic of all leguminosæ, and consequently of all papilionaceæ, is found in the fruit they bear. Perhaps the non-botanical members of my audience will be astonished to learn that such humble plants as clover, vetches, and lady's slipper produce any fruit at all. But the popular acceptation of the term fruit is not the botanical one. The fruit is really the matured ovary, and contains the seeds; it is not necessarily succulent, or even good to eat, and, for sufficiently good botanical reasons, the edible parts of neither the strawberry, nor the apple, nor the fig are true fruits, being accurately described as pseudocarps or sham fruits.

The fruit of a leguminous plant is what is known popularly as a pod. All members of this order produce their seed in a podded fruit called a legume, which pod bursts open to emit the seed both along both its lower and its upper edges. Further than this, the seed is contained in one cavity only, there being no central partition. This latter distinction must be borne in mind in attempting to judge by the fruit whether a plant is leguminous or not. For it happens that the fruit of the cruciferæ is also a pod, only in this case the pod has *two* cavities, arranged with a central division or placenta, to which the seeds are attached. The pod of the pea is a good example of a legume; the pod of the mustard a good example of a cruciferous seed. I may be subjected to criticism if I neglect to notice that although in *nearly* every case the legume consists of one cavity only, there is a peculiar exception seen in the fruit of *hedysarum*, a species of sainfoin, wherein each seed is apparently contained in a separate cell of the fruit, and the pod bursts open, not in the direction of its length, but into a series of cross sections; in this case it is not called a legume but a lomentum.

A very peculiar case of the legume occurs in the earth nut or underground kidney bean—*arachis hypogea.* These legumes are forced into the ground after flowering. Another very well known foreign legume is that called the locust bean or St. John's bread (carob bean), whose seeds are said to have provided the original carat weight of the goldsmiths.

We have now considered the two most salient distinctions of a leguminous plant, viz., its flower and its fruit. Another point of distinction which is characteristic of all papilionaceæ is the presence of asparagin as a form of transport for the albuminous substances which are so abundant in them. The form of albumin found in the seeds of leguminous plants is called vegetable casein, a substance which corresponds with animal casein or cheese. Hence the favour in which vegetarians hold pease pudding. I may mention that many, and in fact most, of the native papilionaceous plants are not cultivated at all, although they are very well known in the wild state. Of the seventeen genera classified by Hooker as native to this country, only seven have representative cultivated species, and, of these seven, only four can be said to be commonly cultivated. As a fact, many of the papilionaceæ which are in common cultivation are not native at all, but have been introduced as cultivated plants from various parts of Europe. Neither the bean nor the pea are native, although they may be considered to be acclimatised. It is extremely curious to notice how very few of our agricultural plants are native: wheat, barley, oats, rye, potatoes, beans, and peas, are all foreigners, and, supposing that England were an inaccessible island, its inhabitants would have to depend on wild berries and roots for their vegetable nutriment. It is, indeed, fortunate that four such prolific starch-bearing fruits, and such a starchy tuber as the potato have been possessed of such complaisant constitutions that, although exotics, they have not succumbed to the rigors of the English climate. In Dr. Lindley's *Vegetable Kingdom* he remarks of the leguminosæ that the tendency to irritability which all possess, and the extreme sensibility of certain of them—as, for instance, the sensitive plant mimosa—have led naturalists to classify them as in contact with the limits of the animal kingdom. It is scarcely necessary for me to expose the fallacy involved in this exploded idea. Plants and animals may be compared to two equally strong, diverging main spires of a tree, whose common root is protoplasm. It is only among the lowest plants and the lowest animals, the thallophytes and the protozoa, that the distinction between the animal and the vegetable kingdoms becomes lost or difficult to trace ; whereas the highly-organised leguminosæ stand very high up among the aristocrats of the vegetable kingdom.

Having now paved the way for something a little more systematic in the way of classification, I will venture to direct your attention very shortly to the species of papilionaceæ in common cultivation, premising that I am regarding them rather from an utilitarian or agricnltural than from a botanical aspect. A distinction which, although in itself interesting, is not of any particular importance, has been drawn by Dr. Lindley between two classes of papilonaceæ. In that excellent old work, the *Synopsis of the British Flora*, he remarks that the papilionaceæ are naturally divided into two classes :—

i. Genera whose cotyledons in germination rise *above* the ground and become green leaves, such as Ulex, Genista, Anthyllis, Trifolium, Lotus, Trigonella, and Medicago. These plants, it may further be remarked, have no tendrils.

ii. Genera whose cotyledons in germination remain under ground, such as Ervum, Pisum, Vicia, Lathyrus, and Onobrychis. These have tendrils.

Dr. Lindley elsewhere points out that the former division are generally acrid, poisonous, or medicinal plants, the latter only affording seed fit for man.

*Genista tinctoria* the Dyer's Greenweed is a very well known little plant, but whether it can be said to be cultivated at all I am very doubtful. I cannot, however, find any recorded case of its cultivation except in the herbarium. It furnishes a yellow dye which formally was in far greater request than at the present time.

*Ulex Europœus.*—It will surprise a good many people to learn that the common Furze or Gorse, whose abundant yellow blossoms so beautifully adorn the Common, is ever cnltivated. And yet a little reflection will convince you that there is good reason why it should be turned to account. For if you will go on to the Common in early spring, before the grass has begun to grow in our fields, you will find that on the southern side of every furze bush are a multitude of light green shoots, still soft and not spiny, which horses, donkeys, cattle, and sheep devour with great eagerness. Now gorse will grow where the soil is too poor to support anything else, consequently, it is sown in rough places to provide a winter and spring feed for live stock. It should be cut down twice a year, or oftener, and the young shoots are sometimes two feet long before cutting. The shoots are chaffed, or preferably passed through a special machine, called a furze masticator, before use. It is said that young cattle, and especially horses, thrive amazingly on it.

Furze is also used for hedgerows, for game cover, for littering and thatching. A French variety is recommended as being better for all purposes than the native sort. You will see the seeds on the table. The ancient saying that "When the gorse is not in bloom, kissing is out of fashion," is almost on a par with our local saying that "When the lions at the Bargate hear the clock strike twelve, they will walk three times round the West Marlands!"

*Cytisus scoparius*, the common Broom, is another plant which is very occasionally sown to provide cover for game. Perhaps someone learned in archeology may be able to explain the popular error which attributes to the name Plantagenet the derivation "Planta genista—a piece of Broom." Genista is not broom, but cytisus is. I see that Hooker has a note that the seeds of broom are a substitute for coffee. In my ignorance, I imagined that chicory was the only adulterant that we had to fear. Darwin observes that "the flowers of the broom are almost sterile if they are not disturbed, and if insects are excluded. The pollen from a distinct plant is more effective than that from the same flower in prodncing seeds."

*Trigonella* is the characteristically leguminous plant whose seeds furnish the fenugreek or fenugrek of commerœ. Anyone who has smelt the sweet scent of fenugrek will be able to recognise it in an instant. Fenugrek meal is beloved of horses and cattle, and forms the basis of most condimental cattle foods. It is, I believe, occasionally grown in the Eastern Counties for its seed, althongh it is a very risky crop. It is grown both for fodder and for seed to a considerable extent in Southern Germany. The name Trigonella is probably earned by the shape of the seed, which is roughly triangular in section, as you will see by examination of the specimens before you. You will please not to forget the characteristic and spicy odour of the seed.

*Medicago Sativa*, the common lucerne of the farm, and *M.*

*lupulina*, the black medick, are cultivated, as well as wild plants in Great Britain. According to Hooker, however, lucerne, though found wild, is not indigenous. Lucerne is nsually cultivated in rows, and the green fodder is specially prized by horsekeepers and cow keepers. Pigs prefer it to clover. It is noticeable that the roots of all the papilionaceæ in common cultivation penetrate very deeply into the soil, their root range being probably considcrably greater than that of any other farm crop. Lucerne, in particular, has a tremendously long, stout root, which goes down iuto the subsoil, and keeps the plant flourishing cven in seasons of the greatest drought. There is recorded an instance of a tap root of lucerne being found 66ft. long. Sir John Lawes for this reason recommends this plant to everyone who wants green food continuously through the snmmer, and whose land is liable to drought. Lucerne is perennial ; three or four cuttings of it may be taken during the summer, and, practically, it requires renewing about every seventh year—not so much because it is exhausted, but because it has become so choked with grasses and weeds that it ceases to be a remunerative crop. The Greeks and the Romans valued lucerne very highly indeed as a forage crop, and ancient agricultural writers are constant in their praises of it. The purple flowers, pale green leaves, and curious twisted legume of lucerne, are all very characteristic. It is curious to notice that although Hooker describes *M. sativa*, he gives it the common name medick, and leaves out the far better known name lucernc—which, according to Stebler, is not derived from the Swiss town of the same way of spelling : its derivation is nnsettled. But the botanical name *medicago* is founded on the Latin name Medica, it being a plant introduced from Media as early as 470 B.C.

*M. lupulina*, black medick, or more commonly hop trefoil, is used as an apology for a crop on such light sandy or chalky soils as are unable to grow clover, and it obtains in most seed mixtures for temporary pasture. It is often included in seed prescriptions—for seedsmen as well as doctors have prescriptions—for permanent pasture, but trefoil is a biennial, and so is of no *permanent* value. M. lupulina seeds very abundantly, and consequently its seed is very cheap. Mixed with Italian rye grass and clover, it forms an excellent green fodder. It is an unfortunate thing that the name hop trefoil is applied indiscriminately to M. lupulina and to T. procumbeus, though neither plant much resembles the hop. The term Yellow Clover is also applied to M. lupulina, and to T. procumbens, T. filiforme, and T. minus.

We next come to a group of papilionaceæ, which furnishes us with some cight or nine cultivated plants, and which is, perhaps, thc most interesting of the several groups to which I am drawing yonr attention. The clovers, of which some 150 species are known, are commonly found all over England, both in the wild and in the cultivated state. The generic name trifolium, or *three-leaved*, is, perhaps, a scarcely fortunate one, for, although all the clovers are tri-foliate, this distinction is not confined to them, such plants as the trne shamrock (oxalis acetosella, wood sorrel,) M. lupulina, and sativa being perfectly tri-foliate. I may say here that the so-called shamrock, which is cultivated in English gardens, is usnally a dwarf form of Dutch clover, much as the statement may grate against the convictions of Irishmen. I have been repeatedly told by Irishmen that the true shamrock does not grow outside Ireland, and I was once asked to believe that no English botanist had ever sncceeded in classifying it. Clovers have been known as cultivated plants from the very earliest times. The derivation of the word clover is a little obscure, there being two equally acceptable theories regarding the word. Mr. Hulme in "Familiar Wild Flowers" says, "the plant was by the Anglo Saxons called clœfer wort on account of its deeply cleft leaves, and as the Anglo Saxon words, though they vary to clœfer and clœfra, still keep closely in sound and sense to the one we have first quoted, we may be well content to see in these the origin of our modern word. Prior, on the other hand, in his excellent work on the popular names of British plants, finds a significance in the Latin word, clava, a cudgel or club, though in what respect the plant resembles a club he does not mention. Granting, however, this foundation, which he supports by a reference to the *clava trinodis*, or three-knotted club of Hercules, he indicates the curious fact that onr clubs in playing cards are trefoils in form." The amateur botanist is as a rule very much puzzled to find sufficient reason why clovers shonld be classified as legnminous plants. He has probably never seen the seed pods, but finding that each flower is sitnated on a common receptacle or capitulum he may jump to the conclusion that the clovers must belong to the compositæ. But careful dissection of a few flowers will show him that the essential characters of a papilionaceous flower are all present, although perhaps modified almost beyond recognition. The sketches of a dissected flower of red clover before you, indicate very clearly the standard, wings, and keel of the corolla, as also they show the stamens and pistil, and the toothed and hairy calyx snrrounding the base of the corolla.

*T. Pratense*, the common red broad-leafed clover or marl grass, is the species in most general cultivation. It may be considered an annual, in contra-distinction to *T. pratense perenne*. The two varieties are quite recognised in agriculture, although botanically they are scarcely differentiated enough to require distinctive names. The perennial clover, also called cow grass, may be considered to represent the original wild red clover, of which the annual red is a cnltivated variety.

T. pratense may be distinguished by the following characteristics :—As compared with perenne it is a larger, taller, coarser plant with usually a hollow stem, broad leaves, and a large spherical light pink flower head. The wild clover on the other hand is perennial, is smaller, with a hairy and solid stem, narrow woolly leaves, and smaller dark pink and egg shaped flower head. Red clover is one of the most widely cnltivated of British crops, the returns for last year for Great Britain being more tban twenty million acres. It is sown nnder a good many different conditions, being equally servicable to the farmer wbether grown by itself or with rye grass, or with a mixture of clover and grass seeds, or, as is most customary, sown in among the young corn, nsually barley, but sometimes wheat. This last mode of cnltivation must seem very strange to the non-agricultnral mind. To sow two such dissimilar crops as barley and clover almost at the same time, the barley being harvested in the ordinary course, and the clover, which onght to be snfficiently lowly at the time, being left unscathed by the knife, is certainly a peculiar way of making the best of the ground. Clover forms a most valuable food for cattle, whether eaten green or made into hay. Haymakers have some difficulty in drying it sufficiently, becanse the stems are very tough and succnlent, while the leaves dry very rapidly, and when dry, prove so brittle that the least agitation of the hay crumbles them. For this reason clover hay never undergoes the operation technically known as "tedding," whether by the haymakers or the machine : it is turned over and back again as it lies in the swathe. As with the grasses, so it is with clover; the crop is at its best when coming into flower. One might think that the more matured the plant, the more nutriment would it contain ; this, however, is not the case. The nutritive value of a plant depends of course to some extent on the absolute quantity of food elements which it contains, bnt to a much greater extent is it governed by the state in which those elements occur. For example, tho albnminoid matter of flowering clover amonnts to abont three per cent. Bnt the absolnte nutritive value of this amount of proteids depends of course on its digestibility. In the same way the carbohydrates of the clover plant are eight per cent., but if during and after flowering some part of these carbohydrates becomes converted into cellulose, which is practically indigestible, it is obvious that the nutritive value of the carbohydrates is thereby diminished, although at the same time it may be that the total amount of substance described in an analysis as carbohydrates has increased. As a matter of fact, however, *Ritthausen* has shewn that the percentage of albnminoid matter actually decreases as the clover gets older, while the woody fibre increases most enormously. Here are his figures as quoted by Stehler :—

Clover hay containing 16·7°/° water.

| | Cut Quite Young. | 13 June. | 23 June. | 20 July. |
|---|---|---|---|---|
| Albuminoids ... | 21·9°/° | 13·8°/° | 11·2°/° | 9·5°/° |
| Wood fibre ... | 24·7°/° | 32·8°/° | 32·9°/° | 48·7°/° |

and not alone the nutritive matters contained in the plant diminish, but they become less digestible during its progress from adolescence to maturity.

Kühne has found that there were digested of the following constituents :—

| | Cut 20 May. Before Flowering. | 7 June. Flowering beginning. | 20 June. Flowering almost past. |
|---|---|---|---|
| Albuminoids ... | 70·9°/° | 65°/° | 58·8°/° |
| Fibre ... ... | 50·6°/° | 46·6°/° | 39·8°/° |
| Non-nitrogenous extractives | 70·2°/° | 68·4°/° | 66.3°/° |

Although clover is in itself so valuable a crop to the farmer, its usefulness does not cease with its death, for its remains—in the form of stems, roots, shed leaves, and heads—afford a particularly nitrogenous dressing to the soil. The late Dr. Vœlcker shewed that a crop of clover left behind it in the roots an enormous amount of nitrogen per acre as organic nitrogen. When it is borne in mind that clover is very commonly taken as the crop antecedent to wheat in the ordinary four-course rotation, the value of this nitrogenous residue can be appreciated. As the means whereby this enormous accumulation of nitrogen is effected will be discussed at the end of my paper, I will not enlarge on the matter here. In reference to the fertilization of T. pratense, Darwin has made some conclusive experiments to prove that without cross fertilization by bees it is practically infertile. He has also shewn that humble bees, and not hive bees, are the fertilizers of clover. All the cultivated clovers except T. procumbens and minus may be said to require cross fertilization, and it therefore is a most mistakon policy to destroy the useful humble bee.

No description of clover as an agricultural crop would be complete without reference to two parasites which, in some districts, play such sad havoc with the plant, the clover dodder, and the broomrape.

Clover dodder, *cuscuta*, is a parasitic plant, propagated from seed sown unintentionally with the clover, which lives and feeds on the juices of its host. I see that one authority describes it as of epiphitic habit, but upon what grounds, I am unable to judge. Dodder seems to me to be a typical parasitic plant. An epiphite is a plant which lives on another, or with another, bnt without doing it injury. Mosses on the bark of a tree or ferns among its branches are epiphites, for they only claim lodging of their host, being always in a position to provide their own board. Epiphites in the vegetable kingdom correspond to the *commensores* or messmates in the animal kingdom. But parasites, whether vegetable or animal, live, feed upon, and are dependent upon their hosts. In the case of dodder, it is true that the seed germinates in the ground like clover seed, and that the young dodder does shoot from the ground; but so soon as the nourishment contained in the seed is exhausted, or very soon after, the dodder, unless it can fasten on to some host or other close at hand, will most certainly cease to live. It is equally certain, also, that the nntrition of the dodder is obtained at the expense of the host upon which it has fastened itself, as anyone who has seen clover and dodder growing together can testify. The word dodder is apparently derived from the Dntch *dot*, meaning a ravelled thread. Perhaps the best description of the plant is the picture drawn by Dr. Lindley, and qnoted by the Messrs. Raynbird in their prize essay on clover, which was published in the R.A.S.E. Journal in 1861. Dodder is there described as a genus of leafless vegetable parasites maintaining their existence by twining round other plants, into whose stems the dodder inserts its sncker-like roots, destroying them by appropriating to itself the sap, which was intended for the plant's own use. In appearance dodder is like a number of fleshy threads twisted round a branch, or it may be compared to long worms, or even to small animal intestines, whence has come one of its vulgar names, "devil's guts." Here and there on the plant will be found minute scales, and eventually clusters of delicate, globular, white or pink flowers, which appear in balls on the stems, speedily forming fruit, and end in producing each fonr seeds, within each of which is coiled up an embryo plant, looking like a small snake. After making a few turns round a branch, and securing itself firmly in its new position, it again lengthens, and catches hold of some other branch, when more suckers are protruded, and thus it goes on branching and twining and sucking and branching again till it has that appearance which Prof. Henslow so well described as resembling "fine closely tangled wet catgut."

Fortunately for ourselves the dodder is not nearly so pestiferons in England as in some less favoured regions.

Not only clover, but flax, hops, beans, vetches, furze, nettles, and thistles are all snbject to the attacks of the several species of cnscuta.

Broomrape is a plant which is by no means well known among English people, although abroad it effects most serious damage to clover and other crops. The variety which is parasitic on clover is Orobanche minor ; but the plant is also found on broom, and this circumstance is supposed to be the origin of its name. The common broomrape is a strong growing, fleshy, leafless stem, standing a foot or eighteen inches high, with abundant red brown flowers. I was much surprised to find a very fine plant growing as a parasite on a potted geranium in a conservatory. The seeds of broom rape occur occasionally among dirty clover seeds, and the difficulty in the past was to separate the one from the other. An interesting suggestion on this point will be found in the R.A.S.E. Journal, vol. i. Nowadays, however, there is little excuse for the presence of broom rape seeds among seed clovers, because seed-cleaning machinery has been brought to the utmost perfection.

The remarks which I have made upon T. pratense and perenne will in great measure apply to the other cultivated clovers, to which, therefore, I need only briefly allude.

*T. Incarnatum*, the crimson-headed clover, is the crop which you will see in such perfection in the early summer all around Southampton. A field of crimson clover in full bloom is one of the most magnificent colour-pictures that can be conceived ; and especially when a breeze stirs the heads of the plants, the field looks like a veritable sea of crimson. It is a curious thing that T. incarnatum is almost invariably known by farmers in this neighbourhood as *trifolium*, while other clovers are always known as " trefoil," or clover. Crimson clover is always, or almost always, sown as soon as the straw crop is cleared in the late summer, being encouraged to grow through the winter and early spring for green fodder in April and May. When the time comes, I hope that you will take notice that crimson clover has oblong flower heads in contra-distinction to the almost spherical heads of the other cultivated clovers.

*T. Medium* is called by Hooker meadow clover, but zig-zag clover is its more usual name, and old writers call it marl grass. I believe, however, that T. medium is the true and original cow grass, and that perennial red has adopted the name from it. The use of the terms trefoil, cow grass, and marl grass was at one time not confined to one species, but to the common clovers of the meadow, which, I imagine, were all regarded as of one species. Zig-zag clover is so called because it has a zig-zag growth of the stem. The flower heads are situated at the end of a stalk about two inches long, and this will serve as an additional distinction between it and red clover. It propagates itself almost entirely by its roots, and very seldom does it seed ; consequently the plant is not recognised by seedsmen, although we must look upon the clover as a cultivated agricultural plant of perennial habit. Through the kindness of Messrs. Sutton and

Sons, the great Reading seedsmen, I am enabled to shew specimens of the seed, a small quantity of which they have at last been successful in saving. To the great liberality of the same firm, I am also indebted for the very complete collection of leguminous seeds which illustrates my paper. The plants of T. medium growing in the pot before you have been raised from these seeds, which I found to be more fertile than one would anticipate. The irregular shrivelled seed of the almost wild T. medium may advantageously be compared with the beautifully plump and even seeds of other clovers whose seed has for a long time past undergone selection.

*T. hybridum.*—Alsike clover is a species of more recent introduction into this country than the other clovers. It is perennial in habit; its flowers are a sort of dirty white colour, wherein red often appears. It is the great plant to grow on clover sick lands.

*T. repens* is the common white Dutch clover of perennial habit and small white flowers. As a practical distinction between alsike and Dutch it may be stated that the flower heads of the Dutch clover are always on the ends of long peduncles or simple leafless stalks, which spring direct from the creeping stem. Apparently the seed of Dutch clover has the power of resisting decay for almost an indefinite period: for it is a common observation that after a meadow has been dressed with lime or chalk, the Dutch clover will come up in the greatest abundance in spots where no Dutch clover was noticed before. And the position of old lime or chalk, or marl heaps, or heaps of brick rubbish can often be indicated by the abundant growth of the white clover on their sites. It is essentially a lime loving plant, and hence is unsuited to dense clay soils. There is too little lime in the alluvial soils of the Itchen Valley for Dutch clover to be seen in great abundance; but further inland, when one reaches the chalk formation, it will be found in any quantity in pastures and along the roadside.

Between *T. procumbens*, *T. minus*, and *T. filiforme*, distinction is almost impossible to the unskilled botanist. All three clovers have small yellow flower heads. But the flower heads of T minus are much smaller than those of T. procumbens, and the heads of T. filiforme are smaller still, and with very few flowers. These little clovers are to a certain small extent useful in a pasture, giving bulk and variety to it, and being perennial, they of course help to supply the clover element when in the course of years T. pratense has died out. T. procumbens seed is very seldom saved, T. minus, the suckling clover, being usually sown for it. They are also useful for lawns.

The clovers, and more particularly T. pratense perenne, are subject to a peculiar disorder or condition termed clover sickness.

Clover sickness is manifested by the leaves withering, and the plants dying back in patches all over the field. A great many causes have been assigned to this phenomenon, but I do not know that any one cause affords a satisfactory explanation of it under all circumstances. The exhaustion of the sources of nitrogen available by leguminosæ was at one time a favourite theory, but it was never proved. In the early days of agricultural chemistry some most extraordinary ideas were propounded. For example Liebig suggested that either the mineral constituents of the soil were exhausted, or else that the plants excreted actively noxious substances which made the soil in which they grew poisonous to themselves and to their successors. In 1860, in the 21st volume of the R.A.S.E. Journal, Messrs. Lawes and Gilbert had a most elaborate paper on the matter, but their conclusions were confessedly negative. The most recent theory is that of Miss Ormerod, the entomologist to the R.A.S.E., who ascribes the sickness to the presence in the roots of the clover of numerous eel worms *tylenchus devastratrix.* Miss Ormerod's theory is certainly tenable in the face of the observed phenomena of the disorder. For clover sickness is remedied by deep cultivation and liming, by the substitution of alsike for cow grass, and principally by taking crops of clover on the same land with a longer interval than four years between them. Tylenchus devastatrix may reasonably be assumed to object strongly to deep cultivation and exposure to frost; to being dressed with quicklime; to the less savoury roots of alsike, and to being deprived of his natural food for a longer interval than four years.

*Kidney vetch.*—Anthyllis vulneraria, also called sand clover, is a plant which is as yet very little grown in this country, although it is a native. According to Stebler, only within the last thirty years has it been cultivated. The introduction of this plant into the English cultivation was by the late Mr. Robert Raynbird, who also was the means of introducing alsike clover and giant sainfoin. The admirably descriptive picture of anthyllis—which is given in Stebler's work, and which I hope you will examine—renders any further description unnecessary. But you will please to remember that the pinnate leaves, with the long odd leaflet from which the lateral leaflets have aborted, the creeping rooted stem or rhizome, and the yellow flowers each in its white downy calyx, are very characteristic of the plant.

Kidney vetch is a certain crop to sow on the poorest blowing sands where nothing else will flourish; and it has been occasionally used in mixtures for permanent pasture, but with what success I am unable to say. It thrives best during a very hot dry summer.

The bird's foot trefoil or lady's slipper, *Lotus corniculatus,* is probably well known to everyone in this room, as its bright yellow flowers adorn every meadow. It is a hardy perennial, and useful only in seed mixtures for the lightest sandy soil, its long tap root rendering it drought proof. The legume, with each valve twisted on itself on dehiscence, is remarkable. The reason why the plant is so abundant in all our pastures is, I imagine, because the flowers are bitter, and hence the stock avoid them. They, therefore, seed very abundantly. It is a maxim among observant graziers that the least abundant plants in a grazed pasture are usually the most desirable, the fact being that they have never been allowed the chance to perpetuate their species. The superficial observer would probably think that the way to make a good pasture would be to apportion the seed in the order of abundance in which the plants of a good pasture occur. I may add that there is another bird's foot trefoil of larger habit—L. major, of Hooker—which I believe to be the same as the marsh-bird's-foot trefoil, L. uliginosus, of other authors; it is, however, only suited to very wet marshy land.

*Onobrychis sativa.*—Sainfoin is an agricultural plant of the greatest importance. The name is of course Norman-French, literally meaning holy hay. The plant delights in lime, and therefore grows to perfection on all chalk formations, and on the limestones and oolites. It is the great sheep fodder of the Cotswold Hill farmers. But it will grow very well on any soil which is sufficiently porous—the reason why it is pre-eminently a calcarious plant, being that it contrives to flourish on land where few other crops could exist.

Although sainfoin is very largely grown, it may not be known to some members of this audience, and so a word or two of description may not be unnecessary. The plant has a long tap root, an upright strong and hairy stem, small pinnate leaves, and abundant rose-coloured flowers, situate on a spike, with a long flower stem or peduncle. The seed is contained in a particularly tough pericarp, and in the seed trade it is sold in the natural state, or "milled;" "milling" is a process whereby the tough shell is removed, and the seed is set free. Farmers sow both the milled and the unmilled sainfoin, but there is every reason in favour of the milled seed, which germinates considerably better.

Sainfoin is a perennial of most persistent growth, and often it is laid down for ten years at a stretch, only being abandoned by the farmers when it has become smothered in grasses and weeds. Sainfoin hay cut before the plant has come into flower is very much prized by horse owners, as it is a fodder calculated to bring a horse into condition when all other food has failed. It is curious to notice that land becomes sainfoin sick in the same way as it may become clover sick. But in the case of sainfoin sickness the period of recovery is infinitely longer, and the crop cannot be relied on except after an interval of at least twenty years.

The vetch, *vicia sativa*, is such a well-known cropping plant that I only need mention it here that it may not be forgotten that it is leguminous. The vetch is an annual, and only one cutting is taken of it as a rule. There are two varieties, the spring and the winter vetch, but no botanical difference exists between them. Perhaps it may be worth noticing that the vetch is one of the few agricultural plants requiring provision for support during its growth, the vine and the hop being the others most generally known. The crop is sown with either oats, or rye, or beans, in order that the stiffer stems of these plants will hold it up from off the ground. Vicia sativa is one of the few leguminous plants not requiring cross fertilization.

I shall probably surprise you when I state that I have now mentioned all the *native* leguminous plants which are in cultivation in England, although I have not yet said a word about either of the two most important plants—the bean and the pea, and yet it is true that although perfectly acclimatized, neither bean nor pea is native of this country, which is much the same thing as saying that neither plant is found growing wild.

The bean which is generally grown in our fields is *faba vulgaris*, but it may be well to mention that in various parts of the world beans are grown belonging to the species *phaseolus*, *dolichos*, *cajanus*, and *soja*. For instance, the French bean is phaseolus vulgaris, the scarlet runner of our gardens is phaseolus multiflorus, the soy bean of China is soja hispida.

The cultivated bean is a plant of very respectable antiquity. According to de Candolle the Egyptians were acquainted with it, but considered it unclean, whilst the Hebrews knew of at least 1000 years B.C. The Romans had many curious superstitions regarding the bean, but they were all based on the idea that, if properly used, the bean brought them luck. Black and white beans were used in balloting. Beans are very occasionally cut green before the pods are matured for use as a fodder, but they are almost entirely grown for seed. Peas also are almost always sown for seed ; these two plants, therefore, are the only ones of all the leguminous plants grown in England whose seeds are used for food. Lindley has remarked, "That upon the whole the natural order must be considered poisonous, and that those species which are used for food by man and animals are exceptions to the general rule, the deleterious juices of the order not being in such instances sufficiently concentrated to prove injurious, and being, in fact, replaced to a considerable extent by either sugar or starch." Bean bread is, I believe, not unknown, and, of course, boiled beans are a valuable dietetic article. But nearly all the beans grown in this country are ground into meal, to afford a concentrated food for horses, dairy cows, and pigs. There are several very distinct varieties of beans grown in England, as you will see by the specimens before you.

The horse bean, or Scotch bean, has large, flat, dirty white seeds. The tick is of smaller growth, and produces smaller and smooth seeds. The mazagan is a modern variety, which is exceedingly popular among some farmers. Beans are essentially a clay-land crop, and if lime abound with the clay, they like it all the better. As with vetches so it is with beans; there are two classes of them, the winter beans and the spring beans. Darwin has shewn that Vicia faba is four times more productive when cross-fertilized by insects than when self-fertilized.

The peculiar convolutions of a papilionaceous flower must present considerable difficulty to the honey-loving insects, and yet as many of the previously mentioned papilionaceæ require fertilization from another flower (the pea and the vetch being exceptions), the insects must get into them somehow or other, for it is inconceivable how the pollen can be transported by any other agency. In reference to the structure of a papilionaceous flower, Sir John Lubbock has remarked that the bases of the stamens coalesce into a hollow tube, the inner walls of which at their base secrete honey in some species, although not in all. In the former, one or more of the stamens is detached, as in lotus, or atrophied, so as to leave a space through which bees can introduce their proboscis into the tube. In those species which do not secrete honey this is unnecessary, and the stamens are all fully developed and united. Muller, who gave the matter his closest attention, has described the marvellous adaptability to this end of some of the floral appendages. For instance, take the case of red clover, whose flower is especially adapted for fertilization. I will quote Stebler :—" The nectar, which the insects seek, is secreted at the base of the tube formed by the united corolla and stamens. It collects round the base of the ovary. There is an open passage to the honey beneath the standard, and between the wings. The insect takes up its position on the flower, inserts its proboscis, and extends it in order to reach the base of the tube, and sip the honey. To reach the honey the proboscis must be nine or ten mm. long, the same length as the tube of the flower. When the insect is sipping the nectar it is standing on the wings and keel. The weight of its body presses down these organs, and the stigma and stamens come in contact with the under surface of the insect's head. The stigma is now fertilized by pollen from the insect, and at the same time pollen is removed from the flower and attached to the hairs on the insect's body. When the weight is removed by the flight of the insect, the elasticity of the keel brings the parts back to their original position, and the sexual organs are again enclosed in the keel. The processes which lock the wings to the keel aid in bringing the parts back."

Some bees bore a hole in the corolla immediately above the calyx, and in this way, even though their proboscis be short, they can readily reach the honey without effecting any fertilization. The hole made by such robbers may again be used by other insects visiting the flowers later on.

This short cut to the honey is very often seen in the bean flower, the humble bee being credited with the ingenuity to make it. Darwin has a most interesting notice of this trick of boring holes. He says that the hole is sometimes bored through calyx and corolla. The bees show much skill in their manner of working, for they always make their holes from the outside close to where the nectar lies hidden within the corolla. A most remarkable instance is afforded by the case of lathyrus sylvestris. The nectar in this plant is enclosed within a tube, formed by the united stamens, which surround the pistil so closely that a bee is forced to insert its proboscis outside the tube ; but two natural rounded passages, or orifices, are left on the tube, near the base, in order that the nectar may be reached by the bees. Now, the left passage is generally larger than the right one ; and here comes the remarkable point. The humble bees bite holes through the standard petal, and they always operate on the left side over the passage which is generally the larger of the two.

Another remarkable fact in this connection is, that as soon as the hive bees have noticed that the humble bees get at the nectar of the flowers by way of this burglarious entry, they imitate them, and, although they very seldom bore the holes themselves, they freely make use of the holes made by their bigger brethren. But it is a very curious thing that in the case of the plant *Ononis*, whose flowers do not secrete honey, fertilization is entirely carried on by bees. How is it that the remarkable intelligence which teaches them where to bore holes for honey in one plant has not shewn them the fallacy of looking for it in plants which are honey-less ?

*Pisum sativum arvense* is the field, or agricultural pea, of which a great many varieties are known. The grey, the dun, the maple, and the partridge, are the varieties in most frequent cultivation. Peas delight in a warm, light soil, containing lime. Unlike garden peas, the field varieties are allowed to grow all over the ground without extraneous support. Although the pea is not a native of this country, it has a very near relative here in lathyrus, the everlasting pea. Indeed, so close is the relationship, that the *L. maritimus* of some writers is the *pisum* *maritimum* of Linnæus. The sweet pea of our gardens is lathyrus odoratus.

While on this subject, I may profitably draw attention to the fact that among the members of the pea tribe the standard of the flowers is usually brighter and differently coloured than the wings and keel. I can only hazard the suggestion, in explanation of this fact, that it is the manifestation of a greater effort on the part of nature to attract fertilizing insects to the plant. Darwin has pointed out (Cross and Self fertilization of plants) that " the flowers of pisum sativum are seldom visited by insects, and, consequently, the many varieties very seldom intercross, and this seems due to the rarity in this country of the visits of bees sufficiently powerful to effect cross-fertilization." In fact, the insects are not heavy enough to depress the keel sufficiently to allow the anthers and stigma to come in contact with their bodies.

There are a few remaining plants which, for the sake of completeness, may be mentioned, although they are considerably more talked about than grown. Lupines *(lupinus albus, hirsutus, angustifolius,* and *luteus*) are very occasionally grown on sandy soils in the eastern counties, and often merely as a means of reclaiming them.

*Lentils* enjoy an extremely restricted cultivation, a few being grown, I believe, in the southern counties under the name of " Dill." They are too delicate a crop for ordinary British husbandry.

*Liquorice* was reported to be grown as a field crop at Mitcham, in Surrey, in 1837, but I have found no reference to its growth elsewhere or subsequently. The wild liquorice is *Ononis arvensis*, more commonly called the Rest Harrow. *Vicia villosa*, the sand pea, and *lathyrus hisutus*, the meadow vetchling, are also known to seedsmen, but they are of little agricultural importance.

The most interesting, and at the same time the most difficult part of my subject may now receive attention, although the notice which I can and dare devote to it will be of a most cursory character. The nutrition of the cultivated leguminosæ, and more particularly the source or sources of their nitrogenous constituents, is a very complex, a very vast, and, as Lawes and Gilbert have said, a very *delicate* matter. Experiments have been devoted to this unsolved question in almost every laboratory in the world, till the literature, ancient and modern, bearing on the subject has become appalling in its immensity. Mere recapitulation of the authorities to be cited would scare away all but the most determined students, so that the admirable summary by Lawes and Gilbert of the main lines of inquiry, and their results up to October, 1888, which will be found in the philosophical transactions of the Royal Society, will be hailed with delight by everyone who has insufficient time to attack the whole literature of the subject for himself. I am also indebted in very great measure to a lecture by Dr. Gilbert, on the "Results of Experiments at Rothamsted on the growth of Leguminous Crops," which is published in the *Agricultural Students' Gazette* for December last; to a paper by Professor Marshall Ward "On some recent publications bearing on the question of the sources of nitrogen in plants," which will be found in the *Annals of Botany*, vol. 1; to a paper "On the Tubercular Swellings on the Roots of Vicia Faba," Phil. trans., 1887; and to a paper in the Transactions of the British Association, 1887, by Professor Vines, on the nitrogenous nutrition of the bean. I have given these references fully, so that anyone who takes sufficient interest in the subject will be able to study it for himself.

I cannot venture into any reference to the ancient history of this investigation, although the road is a tempting one; nor will time permit more than the merest outline of the recent researches and their results.

This problem, which has vexed agricultural chemists for so many years, and whose solution has eluded them so persistently, may be very shortly put in this form :—*Whence, and how, do leguminous plants obtain their nitrogen ?*

I must ask you to accept from me as proven, without any citation from experiments, that :—

i. A leguminous crop contains very much more nitrogen in a given area, and in its dry substance, than any other crop known to agriculture.

ii. A leguminous crop is only slightly benefitted by the application to it of nitrogenous manures.

iii. After a leguminous crop has grown on one spot for a number of years, the soil and subsoil are much richer in nitrogen than they were before it began to grow, or than they would be if left fallow, or if cropped with any other plant. In fact, leguminosæ acts as nitrogen accumulators.

iv. No leguminous crop can assimilate the nitrogen of the air *directly*. I must lay great stress on this word *directly*.

Bearing these four axioms in mind, we can realise how difficult is the explanation of the source of this nitrogen accumulated by leguminous plants. The amount supplied to the soil indirectly from the air in the form of nitric acid and ammonia has been proved to be very trifling. The plants cannot get their nitrogen entirely from the soil or subsoil, because both soil and subsoil are left actually richer in nitrogen ; and Boussingault and Lawes have shewn that they cannot make direct nse of the nitrogen of the air.

At various times it has been suggested that the leguminosæ had special means of obtaining nitrogen from inert nitrogenous bodies in the soil of a humus character ; that their roots secreted an acrid sap, which made these generally unavailable sources of nitrogen give it up for the use of the plants; that the greater root range of the plants enabled them to bring up nitrogen from the subsoil. But Lawes and Gilbert went down 108 inches into the subsoil, and shewed that it was rendered richer rather than poorer by a leguminous plant.

These sources of revenue, however, even if all of them are admitted, would be insufficient to account for the enormous amount of nitrogen which is found in and after a leguminous crop.

To follow up the course of discovery I must ask you to leave the question for a moment in this unsatisfactory state while I direct your attention to some researches of an entirely different nature, which really had nothing whatever to do with this nitrogen question.

Some years ago a Berlin scientist named Frank was investigating the growth of truffles. Truffles, as you are aware, are edible fungi (tuberaceæ) which occur under ground in woods. And you may also know that a race of intelligent pigs is exclusively employed in sniffing out their whereabouts. While working out the life history of the truffle, Frank ascertained that the younger roots of oak, beech, hornbeam, hazel, and chestnut consisted of a double structure, the true root, as a sort of core, covered with a close web of mycelium as an envelope, such association of root and fungus being named a mycorhyza. This mycelium develops free hyphae (or threadlike cells) which radiate into the surrounding soil and bear many morphological points of resemblance to true root hairs, whose function Frank insists they perform. Professor Marshall Ward, however, does not think that Frank has reason to assume that the hairs of mycorhyza can perform the true root hair function, which is absorption.

It is remarked of Frank's discovery that it is a new case of symbiosis, the fungus being a parasite, but the sole organ for the absorption of water, and materials from the soil. The fungus not only conveys water and food to the tree but also organic matters taken direct from humous and decomposing vegetable remains : only by the mediation of the fungus is the tree enabled to employ directly such organic matter.

Upon the publication of the researches of Frank, it was suggested that although the leguminosæ were unable to make direct use of nitrogen of the atmosphere, they were enabled by some fungoid growth upon their roots indirectly to make use of it. In fact a fungus might be the means of converting the nitrogen of the air into such nitrogenous substance as could be assimilated by the plant, nitrates and nitric acid in particular. For the compounds of nitrogen are for the most part available sources of plant food, cyanogen, and alkaloids, however, being exceptions to this rule. The fungus also might be the means of utilizing the inert humous compounds which exist in such abundance in the soil, but which are only very gradually rendered available for nutrition.

I do not know whether it was in consequence of this suggestion of Frank, or not, but soon afterwards Hellriegel undertook an entirely new line of enquiry, which has resulted in a series of very remarkable discoveries. In the first place he tried to grow plants of all kinds other than leguminous in a soil which he had rendered free from nitrogen. The plants, as one would expect, did not grow satisfactorily, and the total amount of nitrogen with which they started (in their seed) did not increase. He then added varying quantities of Nitrates, and found, as Lawes and Gilbert had found long before, that the development of non-leguminous plants was in direct ratio to the amount of nitrogen added to the soil, or present in it. He repeated the same experiment with leguminosæ, and found exactly contrary results. The leguminosæ grew and flourished in soils devoid of nitrogen and greatly increased the amount of nitrogen on which they started life. The increase was altogether beyond the possible supplies of ammonia and nitric acid from the air, and therefore the only assumption that remains is that the leguminosæ have the power of making use in some indirect way of the nitrogen of the air. Thus far, however, the ground had been covered by previous researches, and the question with which I started, how do leguminosæ obtain their nitrogen, supposing it to have been obtained somehow or other from the air, remained unanswered.

It has long been known that the roots of the commonly cultivated papilionaceæ are always more or less covered with various sized warts, or tubercles, whose function has never been understood. These tubercles appear on the plant at an early age, and they have generally been considered to be of no physiological importance, or else to be some fungus form affecting the plant below ground, as fungus forms of various kinds attack plants above ground.

Hellriegel had noticed "that when peas are grown on a nitrogen free soil, the growth is quite normal and the colour of the leaves quite healthy, until the reserve material of the seed is used up. Growth is then arrested, and the leaves become pale or yellow, but after a shorter or longer time they regain their green colour, a second period of growth begins, and it continues to the end. Examination showed that the plants which did not develop beyond the first period, had either no nodules on their roots, or only weak indications of them; whilst the roots of the plants which developed favourably had the nodules, and the more, or the older and stronger the nodules, the better was the development of the plants." Here you see was a relation established between the presence of the nodules and the growth of the plant. Further enquiry into the function of these nodules shewed that if a chemically clean soil of sand, which had been ignited in order to remove all life and all organic matter, was sown with peas, the peas, although supplied with everything they wanted except nitrogen, would not grow, and their roots had no tubercles. Even when nitrogen was supplied, they would not grow. But when to such a soil a very small quantity of the washings of a garden soil was added, other food constituents being supplied as before, the tubercles appeared on the plants, and the plants flourished. Further it has been shewn that the development of tubercles is directly related to the absence of assimilable nitrogen in the surrounding medium, the development of tubercles being much less when nitrogen is present in the soil than when it is absent, and as the nitrogen diminishes, the tubercles increase.

By growing peas and beans in glass vessels and supplying all the food elements to them in the form of solutions, it is easy to watch their behaviour and the development of tubercles on their roots. I may say that in the hope that the experiments might be of interest to you, I started a series of water cultures of the bean, with and without nitrogen, during the winter, but I had to abandon them because the season was so unpropitious. But I may explain that the idea of these cultures was to shew, as Professor Vines has proved, that beans grown in a nutritive solution containing nitrogen exhibit no tubercles, whereas in a non-nitrogenous water culture, they exhibit abundant tubercles. I suppose that it may be inferred from these experiments of Dr. Vines, that plants grown in nitrogenous solutions assimilate nitrates direct, and therefore the tubercles, whose function appears to be the indirect assimilation of nitrogen from the air, are not required. Take away the nitrates, however, and the plant gets its nitrogen from the air by means of these tubercles. But I do not yet understand how this nitrogen of the air gets down to the tubercles immersed in water. Can the small surface of water exposed to the air absorb sufficient nitrogen to provide for all the requirements of the plant? Or does it happen that there are tubercles developed above the water line? Further than this, experiments are required :—

i. To ascertain whether leguminous plants can be grown in *sterilized* non-nitrogenous nutritive solutions and in the absence of the tubercles.

ii. To ascertain whether leguminous plants grown in non-nitrogenous solutions and furnished with root tubercles can produce flowers and seed.

Professor Marshall Ward has recorded the results of experiments on these same root tubercles. He grew beans in sand and soil not previously heated: tubercles were regularly developed. He grew them in sand and soil which had been sterilized, and no tubercles appeared.

He germinated beans in sterilized soil, washed them after they had grown for a week and then floated them in a nutritive solntion. No tubercles appeared.

But what one wants to know, in order to render this last experiment complete, is whether, after growing beans for a week in sterilized soil and then floating them in a *non-nitrogenous* nutritive solution, they will produce tubercles. If they do not, and certainly all the other evidence points to the fact that they will not, prodnce tubercles, they cannot grow in this medium. But the mere fact that no tubercles appear when the beans are removed from a sterilized soil to a nitrogenous nutritive solution, proves nothing, because, as I have already recorded, the tubercles are not necessary for growth in a nitrogenous solution.

These experiments of Marshall Ward and of Vines appear to have been directed to ascertain the nature and occnrrence of the tnbercle rather than its bearing on the assimilation of nitrogen from the air.

With regard to its nature, Professor Marshall Ward says in the Phil. Transac. R. S., that the "Fungus is one of the ustilaginæ, which has become so closely adapted to its life as a parasite in the roots of leguminosæ that it has come to stimulate and tax its host in an exquisitively well balanced manner."

With regard to its occurrence, one may gathor from these experiments that the fungus exists in the soil of cultivated ground and in soil washings, and that as soon as a leguminous plant germinates, its radicle is fastened on by the fungus.

But, if a suggestion may be hazarded upon the method of investigation pursned by such eminent men as Professors Vines and Marshall Ward, there are two questions which must be settled before we can be said to know the whole truth about these tubercles. The first question which arises is whether beans or other leguminosæ, grown in a non-nitrogenous soil or solution, do accumulate nitrogen either in the plant or in the medium in which they grow. This of course is merely a question of a series of careful analyses.

The second question relates to the infection, if I may so term it, of the growing plant by this tubercle fungus. Does the tubercle ever occur in either nitrogenous or non-nitrogenous solutions when every care has been taken to free the seed and the solutions from its presence. I do not consider that experiments have been precise enough on this point, and in my own experiments I eliminated one possible source of error by germinating the beans between layers of damp flannel, rather than allow them to have any contact with the soil.

To sum up the whole question, I think we may safely say, that :—

i. Leguminous crops are accumulators of nitrogen.
ii. They accumulate it indirectly from the atmosphere.
iii. The means whereby the nitrogen of the atmosphere is utilized are provided by the so-called root tubercles.

With this brief and sadly incomplete summary of the recent researches into the sources of the nitrogen of the leguminosæ, I must conclude my paper. Although the nitrogen question is of course by far the most interesting, the stories of discovery made in investigations upon other food constituents of leguminous crops, remain untold. These are in their way equally remarkable, and afford even higher examples of the patience, the acumen, and the devotion to science, which are the life characteristics of our agricultural chemists.

I am only too sensible of the magnitude of the task which I have endeavoured to discharge, and of the errors of commission and omission with which the result is pregnant. If I have interested you I am more than repaid for my pleasant labour.

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NOTE.—Since the above paper was read, Sir J. B. Lawes has published a further communication on the question, which will be found in the current number of the *R.A.S.E. Journal*. Reference may also be made to Dr. Gilbert's paper in the April number of the *Agricultural Students' Gazette*.

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