On the Red Clover.

(Trifolium pratense)

Thesis for the Master's Degree,

By

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There is probably no natural order of plants more easily distinguishable than the Leguminosae or Pea or Pulse tribe; yet, for the most part, people, and even students, are satisfied with an acquaintance of the external features of the different plants of this order, leaving unstudied, as it were, the symmetry of form, the delicate mechanism displayed in their structure, and the beautiful contrasts in color only slightly hidden even in the most common representatives of the family.

With the purpose of thoroughly examining into the peculiarities in structure of a leading genus of the order, the better acquainting myself with the chemical elements entering into its composition, the commercial value and many other attributes, is the purpose of this paper; and, I have chosen as my subject one of the most easily attainable, most valuable and most common members of the family, - the Red Clover, Trifolium pratense.

It is this plant that greets the eye of the traveler, enlists the interest of the botanist and raises the spirits of the farmer and stockman throughout the greater portion of North America and Europe. And just here before I proceed further I deem it not out of place to note briefly a few of the external features of the order to which this interesting plant belongs.

The leading characteristics of the order, Leguminosae, are that it consists of plants bearing pods or legumes; and as the order is named from this circumstance it should be clearly understood. It is a superior, one-celled or many seeded fruit, opening above so as to form two valves. The seeds are arranged alternately along one side, supported by short pedicels as in the ~~pea~~, or destitute as in the clover. As a type of a legume the pea pod forms an excellent example, though varying in form and varities. It is twisted or screw-like in the Lucerne, snail-like in the Medicagos, worm-like in the Acacias, still it is a legume preserving its identity to the pea pod. It varies greatly in size, being very small in the clover, while in the Cassia it attains a length of several inches.

Then comes the singular arrangement of the petals resembling a butterfly with wings extended. To the subdivision, Papilionaceae, belongs our selected example, the clover. The calyx of the clover, likewise all leguminous plants, is apparently composed of one entire piece, evidently five sepals united into a tube, ending in five distinct points two of which, I observed, were longer than the others. It is light green with ten little markings or ribs on its surface, the whole covered with hairs. This contains the corolla with its curiously shaped parts. These parts by their natural engraftment present the anomaly of a monopetalous corolla. The corolla consists of five parts one of which is larger and broader than the rest, and stands up and back of them forming, as it were, sort of a mantle to them before the flower expands. Because of this office it is sometimes referred to as the standard, banner, or vexillum. Closely connected with and adherent to the standard are two wings folded over a projecting apparently boat-shaped petal or petals which bends forward and is called the keel. Examining this organ more closely, I find it is composed of two petals united along their lower edges. In this keel or cradle, as it were, lies hidden the provision which nature has made for the growth of future generations of this and all similar plants.

It is a thought worthy of remark, and I find upon inquiry that it is a failing common among casual observers, that but few persons who have looked at the clover flowers only as they are clustered in the head, have observed the resemblance between these and the flowers of the pea or bean; but a close inspection will show that the general configuration of the flowers is the same; and though the pod in most members of the clover family, is concealed in a deep calyx, yet a careful examination of this will show a perfect pea pod containing from two to six seeds when perfect. The pea-pod-shaped pistil is particularly noticable in the Trifolium repens and T. hybridum.

Bear with me while I briefly note the difference in the shape of the petals of the pea and bean as compared with the clover.

The flower of the pea differs from that of the clover in that its banner petal is broader, and the wing petals much longer in proportion to the size of the keeled petal. In the bean the petals are exceedingly irregular, the winged ones possessing quite a petiole with blade considerably developed. The keeled petal differs much from the corresponding one in the clover. In the bean, the petal terminates in a curl enclosing the hair-like stamens, while in the clover the petal consists of a mere hood, simple in structure enveloping the essential organs.

A peculiarity of the clover family

is that the flowers do not shed their bloom. It is a matter of general observation that the calyx or flower cup retains its green and fresh appearance till the seed has fully matured, and though the corolla leaves wither and die, becoming brown, yet they are not shed at any time.

Having now traced the five parts of the corolla which differ so much from each other and the calyx as scarcely to be recognized, I will now proceed to describe the essential organs, - the stamens and pistils.

The fruit, in its first stages, protected by the keel, is enveloped in a membrane formed by the filaments of the stamens which cohere one to another below and to the tube of the corolla ~~above~~, but distinct above, surround the germ of the legume. These ten filaments are united only ~~by~~ at their base, being separated thereafter into two sets, one and nine each. It is evident the solitary stamen has gradually separated itself from the others and in so doing has made it possible for the embryo to develop itself. The entire freedom and wide spread separation here manifested in a flower such a tendency to cohesion is singularly interesting; and possibly this is necessary in order to preserve a sufficient aperature to give access to the nectary.

On the top of each of these slender threads is the anther bearing the dust-like pollen which falls upon the stigma that terminates the style. The style is a thread like organ furnished with hairs below the stigma for the adhesion of an excess of pollen which falls upon the stigma; and whose only office is to convey the pollen to the unfertilized ovules and so ensuring the complete legume with its perfect seeds. The nine stamens, faithful to each other, having fulfilled their function, wither and die together leaving the tenth issolated and alone as their only representation. It was because of this peculiar division of the stamens that Linnaeus made this order to constitute his class Diadelphia, or two brotherhoods. Plates XVIII & XIX

We will now direct our thoughts to the consideration of the seed.

The Seed.

Not the least uninteresting feature of this family of plants is their seeds, the singularity of construction and methods of germination of which are worthy of study. If we take a seed to turn our fingers and scrutinize it closely we shall find that it contains a testa or covering enveloping two cotyledons, or a mass of pulp or meat, as it were, on which the young plant for a while subsists. This white substance encases the little embryo plant, and is composed largely of starch. When the seed is kept dry the process of development does not go on; but when moisture and heat are applied, chemical changes immediately take place by which the starch is decomposed and gradually converted into sugar and dextrine. If the seed be planted in the soil, or placed between dampened folds of paper, it absorbs water from it which causes the seed to swell and burst its external case. The cotyledons spread apart and draw able to distinctly trace the imperfect spiral fibres and woody tissue; and the little embyro plant became evident protruding first downward, with its tiny radicle or root, and then upwards with its little greenish white plumule or stem. The testa, in which the young plant was nourished, having performed its function, remains in the ground and soon withers and dies away.

The seed consists entirely of two cotyledons or seed-leaves which cover the embyro and which at the time of germination separate, allowing the radicle and plumule to come forth. The cotyledons now assume the form of leaves, and, as the tiny sprout bears upward, the cotyledons rise out of the ground with it, presenting that curious phenomenon so noticeable in sprouting peas and beans. What a grand sight is this! All nature seems to be but the preparation for a higher existance. If we follow the progress of the plant further, we shall see these seed-leaves withering away and giving place to the stem leaves; and these become perfected in the budding flower which in all its beauty is but the temporary abode of those organs which have for their object the perpetuation of the species. What a grand truth here unfolds itself to us! Nature has skillfully packed away within the tissue of the cotyledons "the precious germ of life"; and when bathed in sunlight and moisture - God's breath - this germ awakens from its slumber and comes forth to develop into the mature plant, shedding its fragrance and scattering its seed broadcast for man's welfare, a testimony of God's goodness to mankind.

Plates VI. and VII.

The Root.

We have seen that the first outward appearance of the presence of life the seed reveals is in the sending forth from its cotyledons a tiny shoot - the radicle - which turns downward and becomes the root to the growing plant. Continuing onward in its course it develops into a great root sending off rootlets from all sides, clothed with hairs innumerable which absorb plant food from the soil. The first years growth is small, the plant doing little more than establishing itself for the life that is soon to follow. The second year, as the warm days of Spring come and go, a tiny stem starts from the central axis and is soon provided with leaves, other latteral stems follow and these furnish the forage which later is cut and cured as hay or utilized for fertilizing purposes. The great root has, in the meantime, penetrated the soil to considerable depth, the tiny rootlets seeking every possible crevice, loosening the soil, making it more active and adding both to its size and value by pumping up, as it were, as food valuable ~~soil~~ constituents from the subsoil. The clover root is a remarkably deep feeder, cases being on record of roots measuring from four to seven feet in length. Of the benefit such an abundance of growth is to the soil, I will discuss under another head.

Clover roots are effected by the frosts of winter and the dashing rains of spring. Often times the roots are heaved from the soil several inches, only the tip of the root remaining in the ground. This injury of course, interferes with the growth of the growth of the crop; the lateral stems do not put forth their leaves, apparently all except the ~~centre~~ central root dies and the resulting loss is severe. To remedy the injury as far as possible apply a roller as soon as the ground will admit.

Stripping down the latteral stems we find a central axis composed entirely of woody fibre which extends to the smallest rootlets below and to the stems above.

Plate IX illustrates different sections of the root.

An experiment was made to ascertain whether or not the branches could be made to produce roots. Sand to the depth of eight inches was heaped about a stool of clover. At the expiration of three weeks roots one-quarter to one-half inch long have started from several stems two or three inches above the original surface. I have also attained the same result by turning the stems flat down upon the ground and placing a light weight upon them.

The Stems.

The stem of Red Clover is small, quite smooth, round, more or less hairy, with its diameter nearly equal throughout its whole length, and broken by nodes at regular intervals. The color is light green. It may be distinguished from the large medium red by its stem being much smaller and less woody, leaves more oval, shorter in stature and coming into bloom from two to four weeks earlier. In size the diameter of the stem varies much, the largest specimen I met with measured 7.5 C.M.; the smallest 1.5 C.M.; average of several 6.625 C.M. and 1.75 C.M. respectively. A cross section of the stem studied under the microscope reveals much that is interesting & instruction.

The epidermis is composed of cell tissue destitute of coloring matter. These cells were quite regular in form and apparently forming one tier. Next within are irregularly constructed cells with thickened walls containing parenchyma. Both classes of cells are shown in Plate XVIII, Fig. 1, a and b respectively. Next in order is a set of cells in crescent-shaped bundles forming one division of the Fibro vascular System - the Bast cells. These may be described as elongated, spindle-like shaped cells with sharp ends and either simple or branched. They seem to have uninterrupted lateral connection uniting into bundles. They also possess little central discs. See Plate XVI. Fig. 2.

Plate XVII shows dotted cells of single fibres after having been treated to KHO & HNO_3. The next tissue is made up of sieve tubes which form the medullary rays in timber. These are shown in Plate XVIII. Fig. 2. These tubes are greatly elongated and vary much in size and outline; walls composed of delicate, colorless, cellulose membrane.

The woody bundles, the other division of Fibro Vascular system, are next met with; the walls are heavy and bundles short. The pith cells follow in order and are illustrated in Plate XII. Figs 2 & 4. The canals connecting the cells are figured.

The Leaves.

A clover leaf consists of a petiole, furnished with stipules and three leaflets nearly sessile on the apex. The uniform appearance of the three leaflets on each food stalk gives to the genus its Latin name, Trifolium, Tri - three and folium a leaf. This has been converted into the English Trefoil which was origionally the generic name.

The stipules are broad, linear appendages with distinctly marked venation, ending in two acute points. These accessories serve to protect the young shoot as it pushes forth from the axis.

The petiole is irregular, round, linear and well covered with fine, white hairs.

The three leaflets are oval or obovate, often notched at the end; one-half to two inches long and marked with a white spot or lunate band finely toothed. Venation distinct, forked, under surface of leaves clothed with hairs; "heads terminal, sessile, globose at length ovoid, subtended by opposite leaves with much dilated stipules." The microscopical appearance of the upper epidermis is interesting. There are but few stomata on the upper surface and about twice as many below. The venation, stomata, a greatly magnified hair and surrounding tissue are shown in Plate I. Figs 1, 2, 3.

Sleep or Nyctitropic Movements of Clovers.

This is one of the most interesting phenomena connected with the study of these plants. Several bunches of clover representing the red, medium, white, and a variety of the latter having reddish colored leaves and branches, were marked for study. The plants were examined at 8 A.M., 2 P.M., and 9 P.M. for several successive days, and it was observed that the leaves of all species assumed widely different positions at night from what they held during the presence of sunlight. The leaves seemed to close up, go to sleep, as it were, one after another towards sundown and did not expose their upper surfaces directly to the sun's rays till long past day break, and, in some cases, till 9 A.M. In nearly every one at 9 P.M. the upper surface of the lower leaflets was turned away from the zenith at angles varying in the different species. By singularly & complicated movements, the latteral leaflets would gradually face each other while the terminal leaflet which first assumed a verticle position would a little later bend over and finally expose its entire under surface to the heavens, forming a cover or roof, as it were, to the latterals. This position was especially noticable in the white clover.

Why the clovers and thousands of others

plants assume these positions is not clearly understood. Mr. Darwin thinks it is to prevent the chilling of the leaves by radiation which any observing botanist or gardener knows is detrimental to the growth of the plant. At any rate it seems to be the way nature has provided for the plant to husband its powers.

I observed that when the sun shone intensely upon the leaflets at 2 P.M. they moved upwards. This peculiar phenomenon of the movement of the leaves, both diurnal and nocturnal, Mr. Darwin says is effected in two ways, first by means of pulvini which become turgescent on opposite sides; and second, by increased growth along one side of the petiole or midrib, and then on the opposite side.

To test the probable effects of radiation on a clover leaf, three leaflets were pinned to light pieces of cardboard, properly supported, about 7 P.M., so that their upper surfaces were exposed to the zenith during the night. At six o'clock the next morning the result was noted; the leaf was observed to be covered with dew, whereas those leaves growing from the same root which had not been disturbed were comparatively free from moisture, which would seem to indicate that the temperature of the leaves experimented with was lower than those undisturbed.

During the year and in connection with this experiment with the clover, my attention has been directed to other plants assuming nyctitropic movements. The Oxalis shuts up its flowers and leaves like umbrellas on the first approach of night and opens them at sunrise.-- The dandelion opens before six when exposed and closes about sundown. The little daisy that greets us by the wayside, retires to rest each evening and rises to meet the early beams in the morning.

The marsh marigold goes to bed at sun down and rises at sunrise.

Tulips begin to prepare for repose about tea time and are late risers.

Plate XIV.

Fertilization.

Fertilization is effected by the presence of the essential organs of the flower,- the stamens and pistils. In many families these organs are present in one and the same flower, as in the Rose and Grass families; it is then called a perfect flower. Sometimes these organs are borne on different parts of the plant, the pistils and stamens being produced upon different branchlets, as in the Corn and Oak families; the flower is then said to be monoecious.

In the fertilization of monoecious flowers, some means of transportation of the pollen to the pistil must be effected to accomplish fertilization; and I have observed that even in perfect flowers, as the clover, it is found to be not the rule for the pollen, wholly unaided, to fall on the stigma of the same flower. Hence it is evident that some assistance must be given such plants to effect complete fertilization. Such help may be found in the wind, bees and other insects.

It is evident there are two processes of fertilization, close or self fertilization, as when the pollen of one flower acts directly upon the stigma of the same flower, and second, cross fertilization when the pollen of one flower is applied to and acts upon the stigma of ~~th~~ another flower.

We would naturally suppose that in perfect flowers self fertilization would be the rule, and so it used to be taught, but now we know it is the exception. This is true of the clover. Clover plants protected from the approach of insects, particularly bumble bees, have borne seed, but only a small quantity as compared with those plants to which the bees had free access.

In connection with a classmate while I was an undergraduate, an experiment was undertaken to determine the necessary presence of bumble bees for the fertilization of clover, and how it was effected.

A small lot containing 50 heads were protected by course netting through which small insects could pass freely but not bees. When the clover matured the 50 heads were examined, 31 of which were not fertilized; in the others there would sometimes be 1, 2, and in a few instances 3 flowers fertilized. We then examined 50 heads from plants growing near the first lot, on which we had seen bees daily, but failed to witness the presence of other insects. Of the 50 heads examined 38 bore seed, the remainder were unfertilized; these 38 heads contained from 5 to 12 seeds each, proving quite conclusively, we thought, that the presence of bees in this instance was a necessity; also that self fertilization was again shown to be the exception.

Cases have been noted where other insects, particularly butterflies, have seemed to be the prevailing means to the fertilization of the clover. However it is my object to show that clover is not self fertilized, but that insects, bees, particularly bumble bees, are essential for the maturity of a full crop of seed.

Now that bumble bees or other insects are essential for the fertilization of Red Clover, the question follows: What is the position of the bee on the flower, and how is fertilization effected? See Plate XIX. Fig. 3.

The bee, I have observed, when searching for nectar, lights upon the wings and keel in the flower of the pea, and would do the same in the clover were a single flower large enough to sustain him, places his head against the banner petal and pushes his tongue downwards in search of nectar. In the act, the wings and keel are pressed downward, and the pistil which is furnished with little hairs below the stigma to which the pollen adheres, protrudes in consequence. The stigma strikes the abdomen of the bee, and the style also brushes against it. The visit to the next flower is similar. The stigma strikes the abdomen as before but having been dusted with pollen from the previous flower, a portion of it is retained by the stigma, thereby effecting cross fertilization. The bee usually visits all the flowers in the head before leaving for new fields; and it is customary to take the flowers in the order in which they occur, that is, beginning with the lowest circle and going around and round the head till the top of it is reached. Plate XIX.

Nectar Glands.

The nectar glands in the clover lie at the base of the corolla. They are granular and may be seen in Plate XX, as heaped up about the filaments of the stamens which extend to the base of the tube. These glands secrete nectar in abundance while the bloom is fresh, and they may be seen under the microscope by preparing a portion of the corolla of a young flower in the usual way.

General Points.

Red clover is a biennial plant, though with proper treatment it may be made a perennial, and seems to be especially adapted to nearly all kinds of soils. As a forage crop it has become an important factor in the crops of all well regulated farms. I think I may safely assert there is no grass, natural or artificial, more valuable to the stock grower or farmer than Red Clover. Widely diffusing itself over nearly every part of North America, Europe and the Russian Empire, it has completely revolutionized the systems of agriculture, wherever introduced. It has made it possible to adopt a system of crop rotation on every farm, and, by its rapid and luxurient growth of both root and stem, gathers in, as it were, an abundant supply of mineral matter for succeeding crops. Well may it be styled the "corner-stone of agriculture"!

Not only does it yield an immense amount of grazing, but furnishes an abundance of nutritious hay and valuable seed. Further it possesses the properties of a vigorous ameliorator of the soil, storing up a large amount of available nitrogen in its roots and stems, increasing the yield of succeeding crops, thereby bringing refinement, wealth and happiness to the homes of those farmers who sow it.

Red Clover has been found to contain 35% of lime in its inorganic constituents, hence we infer that a lime stone soil, or a tenacious loam will grow it luxuriently. Mr. Gould says: "The best soils for clover are the best wheat soils; where the one will grow luxuriantly there will the other grow luxuriantly also."

Professor Way has determined the chemical elements entering into its composition as follows:

Moisture - - - - - - - - - - - - - - -	16.60
Fatty Matters - - - - - - - - - - - - -	3.18
Albumen and other flesh forming matter - - -	15.81
Gum, sugar, musulage and Carbo hydrates - convertible into sugar - - - - - - - -	34.42
Cellulose tissue - - - - - - - - - -	22.47
Ash - - - - - - - - - - - - - -	7.52
Total - - - - - - - - - - - -	100.00

This is an analysis of Clover hay.

Dr. Collier of the Department of Agriculture gives this analysis of clover in full bloom and in seed.

Nitrogen, - - - - - - - - -	17.00	14.00
Water, - - - - - - - - - -	8.55	8.15
Ash, - - - - - - - - - - -	7.60	6.75
Fat, - - - - - - - - - - -	4.38	3.65
Carbo-hydrates - - - - -	47.42	49.90
Crude fibre - - - - - - -	14.55	17.55
Albuminoids - - - - - - -	17.50	14.00
Total - - - - - - -	117.50	114.00

There are so many methods of curing clover hay, it is hardly worth the while to enter into the discussion here. Each farmer has a way of his own and each thinks his is the best. I pass to the cultivation of the seed.

This has become quite a source of revenue to some farms. A farm near my birth place, a few years since, produced $1000 worth of seed in a single season; and my Father has not unfrequently raised $200 worth of seed per annum for several succession years. His method was to mow the first crop when about one-third of the heads were in bloom. It was observed that more and better seed could be raised per acre (often 2½ to 3 bushels) by this process than by pasturing the clover field closely about June 10, and then lean it to mature its seed.

The objection to pasturing closely was that the stock, particularly sheep, would bite so closely as to nip out the central stem, hence partially checking the stooling of the plants. Mowing obviated this objection, besides checking the growth and oftentimes destroying worthless weeds.

The seed should be cut with a self-rake reaper when about three-fourths of the heads are grown, the material being left in bunches or gavels upon the ground till cured, then pitched upon the wagon with a barley fork. This method which I always followed when on the farm prevented the waste of seed and the collection of foreign material in the stubble as is likely to be the case when the seed is garnered after the method of making hay.

Just when to sow clover seed to ensure a good "catch" varies with different soils and with the season. Most farmers agree that seed should not be sown in the fall as the tender root is almost certain to be winterkilled. Sow in spring on the soft snow, or later after the soil has become settled, when a light harrow may be applied. The seed should not be covered more than one-half inch deep, hence a roller is quite enough to passed over newly seeded lands. Of the spring crops, barley I believe to be the best to seed with, the early maturity of the crop ensuring ample room for the growth of the young plants.

The amount of seed to be sown per acre varies with the condition of the surface, coarsely divided or lumpy soils requiring more seed than finely pulverized lands.

From four to eight quts per acre are usually sufficient; when mixed with timothy or orchard grass a still less quantity is sufficient. The mature seed has a purplish tint, and weighs 64 pounds per bushel.

It must not be understood that seed finds demand only on the farm; it is largely used in the arts and manufactories for fixing colors, and in many other ways.

As a fertilizing crop clover has no equal on any soil on which it grows. Mr. Flint says of it: "Its long roots penetrate the soil, loosening it and admitting the air, while it also seems to fix certain important elements which enrich the soil. Being a rapid grower its foliage keeps in check weeds, thistles, &c, besides the shade afforded the soil, which improves its fertility not a little." Red Clover is one of the best crops that can be grown for green manuring. Being largely an atmospheric grower it is not exhaustive to the soil; in fact, it leaves two and one-half tons more of nitrogen in the soil than it consumes, the roots storing this amount in excess of the foliage; and if the crop be allowed to mature its seed the soil is still richer in nitrogen, a fact known to observing farmers in the yield of a wheat crop which grew on clover sod that had matured its seed.

And thus we might go on praising and extolling the many virtues of this valuable plant; but enough has been written concerning it by other pens to warrant me in bring this lengthy paper to a close.

And here I desire to thank my preceptor, Dr. W. J. Beal, for his kindness and attention during the prosecution of my studies in his department. I fully appreciate the interest he has shown in me and shall endeavor to merit the kindly assistance rendered throughout all my future labors.

Description of Plates.

The drawings are made from sections cut from fresh specimens of the Clover, by means of a razor. The section was placed upon a thin plate of glass, a drop of water was applied, and a very thin cover glass put over the whole. The section thus prepared was put under the compound microscope and the result is as shown in the plates. Sometimes they were drawn to no scale, but in most cases the number of diameters which the object was magnified is marked in figures near the drawing.

Plate I, Fig. 1.

Shows the arrangement of cells composing the upper epidermis of a leaflet of the Red Clover, with connective tissue.

Fig. 2.

Shows the veins, a, of the upper epidermis.

Fig. 3.

Is a hair greatly magnified, found on the upper epidermis.

Fig. 4.

Drawing of the mid rib of leaf of clover, showing mid-rib, woody cells, &c. near base of leaf.

Fig. 5.

Cross section of stem of clover at base of leaf blade, showing woody bundles, honey lobing, peculiar shape of stem and especially the hairs.

Fig. 6.

Horizontal section of stem of leaf taken one-half inch below the base of leaf. a indicates the lower or back portion of stem as opposed to the upper surface of blade. The different kind of cell tissue is clearly shown, as displayed in a cross section in Plate twelve.

Plate II, Fig. 1.

Surface of clover stem, outside peeling showing intercellular spaces, b, red coloring matter as a, and other smaller cells as c.

Fig. 2.

Is another drawing of same view differently focused, showing stoma, &c. as a.

Fig. 3. Drawing of cross section of petiole of leaflets at the base of the three leaflets, revealing the division of the main stem into three. The cellular tissue is prominent, also woody bundles.

Plate III. Fig. 1.

Is a drawing of cells and spiral vessels of petal of Clover, magnified 110 times.

Fig. 2.

Is an enlarged view of spiral vessel magnified two hundred diameters.

Figs. 3, 4, 5 & 6.

Exhibit drawings of pollen grains of clover viewed at different forms.

Fig. 7.

Drawing of portion of sepal of clover showing cells (a), bases of hairs (b), heavy mid veins as at c, and hairs as in d, swollen places at bases of hairs as at e. Magnified 110 diameters.

Plate IV. Fig. 1.

Drawing showing part of cross section of calyx of clover, two of the different forms of hairs. The spiral vessels are also numerous in this specimen and are beautiful in the extreme.

Fig. 2. Hairs of Solanum tuberosum exhibited in right hand drawing as a. a. a. and that of the night shade in (b). This drawing shows the hairs of different shape and partitioned not shown in the cylindrical hairs of clover.

Fig 3.

Section of outer epidermis of root of clover, vertical section.

Plate V. Drawing of section of rizome of clover root near the heart, showing intercellular tissue, air spaces, also some chlorophyll.

Fig 2.

Drawing of same root at the surface showing a little different arrangement of cells, with surface coating.

Fig. 3.

Vertical section of root showing protoplasm.

Plate XVIII

This plate is a drawing of the keeled portion of the corolla of red clover, exhibiting the two divisions of the stamens, - diadelphous as Linneas described them. The ten stamens are divided into two sets, one and nine respectively. The nine are united by their filaments and their anthers alternate in length each way from the central one which is the longest. The one solitary stamen at the right springs from near the base of the ovary and may be seen after the others have disappeared. This peculiar division of the stamens is probably due to the fact that the bees and other insects could not reach the nectary glands and gather the sweet were the tube closed.

a a a shows anthers which have not yet shed their pollen, it being too young a specimen. The keeled portion was taken from a corolla which had not yet tinted.

B - filaments, and c pollen grains.

d ovary or legume containing, in this particular specimen, three ovules

K - style, h stigma with hairs below.

Plate XIX.

Fig. 3. Drawing showing the relative position of the petals and sepals.
a represents the calyx, B, banner petal, c keel or petal which encloses the stamens. d. d. winged petals.
Fig. 2.
A side view of stamens, giving their position in the flower.
Fig. 1.
This represents the corolla split open along one side showing all parts.
a is the banner petal. B.B. winged petals, c keeled petal showing the attachment of the stamens e.
O, the pistil, f ovary or legume
d, the odd stamen.
7

Plate XX.

This represents a portion of a petal. The dark lines are the filaments of the stamens running down.
a. a. a. a. are nectary glands, these appear as granular bodies heaped up along the base of the filament.