MEMORANDA

ON

VEGETATION.

BY

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PREFACE.

The original Manuscript from which these Memoranda have been printed was a small quarto, bound in parchment, evidently intended as a Common-place or Note book; its contents were chiefly in the hand-writing of Mr. Hunter. It was entrusted to the Council of this College in 1833 by Captain Sir E. Home, Bart., R.N , through the instrumentality of Robert Keate, Esq., and was returned to him early in the following year, after a copy had been taken for the use of the College.

The majority of the Members of the Medical Profession may not be aware of the number and variety of the experiments made by Hunter on the growth and functions of Plants; for in addition to those "On the Heat of Vegetables," published in vol. lxv. of the 'Philosophical Transactions,' and those in the Croonian Lectures on Muscular Motion, in vol. iv. of Palmer's edition of Hunter's works, there is another series, alluded to as follows:—"I have made several experiments upon the seeds of vegetables similar to those on the eggs of animals; but as inserting them would draw out this paper to too great a length, I will reserve them for another *." These words form the concluding paragraph to the paper "On the Heat of Vegetables," before alluded to. None of the experiments, or notes of experiments, described in this volume, appear to have any connexion with the subjects treated of in either of the above-mentioned papers; but the contents would rather favour the idea that almost all have relation to

* Phil. Trans. vol. lxv. 1775.

the growth of plants, to the formation and decay of leaves, and to the effects produced by the partial or total removal of the bark. Many of the specimens upon which he operated are still preserved, and some of them are described in the first volume of the Pathological Series; others will be found in the volume devoted to the Plants and Invertebrate Animals in the dry state. A large number of plants, especially those exhibiting the organs of the sexes, are to be found in the Physiological Series, and not a few in the Pathological and Natural History divisions; but no distinct work on the subject, like that represented as lying on the table in the celebrated portrait of Mr. Hunter by Sir Joshua Reynolds. On this account the present Memoranda have been thought, to a certain extent, worthy of supplying the deficiency. Blanks occur in some of the pages of the original; these have been carefully filled up, and wherever the subject appeared to require it, notes in small type at the foot of the page have been added.

Royal College of Surgeons, September 1860.

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MEMORANDA ON VEGETATION.

THE greatest growth among all the different shoots of a plant is always in the top one; the next is in the branch immediately under the top shoot, and the growth of the top shoots of the branches decreases downwards, but the top shoot of each branch is always longer than the side shoots of the same branch. The top shoot is always perpendicular and highest, or most so of any; and this falling off from the perpendicular towards the horizontal, becomes gradually more and more so downwards to the lowest branch. The Weeping-willow is an exception to this, and there may be many more. Is it owing to this perpendicular position that the growth is greater, or owing to the greater height*?

A Scotch Fir had its top or middle shoot cut off; it had four principal second shoots or lateral branches immediately under the top shoot. On the 1st of July I tied up one of these four shoots; in three days the young growing shoot became perpendicular, and in the same line with the stock on which it grew, and had also grown an inch longer than any of the young shoots upon the other three branches, so that it got the impression of the leading shoot.

* This may be the case in the earlier stages of the growth of the plant, but not always at a later period, as the lower branches of many trees are much larger than those nearest to the top, and larger than the top shoot itself, as in the Oak and others. In many of the trailing plants, the laterals often grow much faster than the first shoot, at a very early stage.

From the above principle in growth, we should suppose that the greatest growth was at the top, and that it becomes weaker and weaker downwards, but we find this not to be the case; it is not strength of action, but it is a principle of action: we may as well say that the powers in a man's legs are greater than in any other part, because they grow longer; but we know that their powers from this cause are weaker than every other part, and we also know it is the weakest in the vegetable, owing to the same causes; for we may observe that when anything affects the general health of a vegetable, such as transplanting, severe winter, &c., it is always the top shoot that shows signs of weakness most; and upon the same principle that the extremities in animals are weaker in their living powers; and we may observe that although branches do not form such long shoots as the top, yet the top is first in action in the spring*.

Have any of the juices of a vegetable the power of converting either animal, vegetable, or even earth, to living vegetable matter, similar to that of an animal?

When trees begin to throw out their leaves in the spring, or rather form new shoots, it is always on their lower branches first, and in gradual and regular succession upwards; but still the upper will make the greatest progress, having more the principle of growth: also if a tree is newly planted, and does not take kindly to its new situation and is weak, we find that the most vigorous parts are its lower branches, decreasing upwards to the top shoot, which is the weakest of the whole: also if we cut off the stem of a bean above the fifth or

* The top of a plant suffers in transplanting, not from weakness of action, but from its succulence and the readiness with which it parts with its moisture, and, in severe frosts, from the rupture of the cells from the freezing of the fluids, which are more abundant in the unripened parts; but when the ends of the shoots are thoroughly ripened, they are as well able to bear transplanting and frost as the other parts of the plant.

The juices of the plant alone have no power to convert animal or vegetable substances into living vegetable matter.

sixth joint, new stalks will shoot out at the joints; but it will be at the first and second, not at the fourth, nor even at the third joint.

A bean grows by shoots; every shoot is almost the only addition to the plant; however, not entirely so, for it grows a little in all its former shoots; but that growth is proportional to the age of the shoot; viz. if there are three shoots, and a fourth beginning to grow, or growing, the third shoot grows (while the fourth is increasing) a little, and more than the second, and the second more than the first: the first shoots seem to lose their power of growth in proportion to the number of shoots beyond them, so that by the time there are five, six, or seven shoots, the first has hardly any perceptible growth; for every new shoot may be supposed to stop the growth of the first one degree, or a new shoot does not begin to grow till the last has grown almost to its full length. Cut off the top of a shoot before it has grown its full length, and it will continue to lengthen, but not so much as if the top had been left on.

The great growth of every shoot is an elongation of the top; but, besides this, the part of the shoot that is already formed grows in all its parts, but that is only in proportion to the age of the part of the shoot; for the last-formed part increases most in itself, and gradually less and less so to the setting on of the shoot, so that every part of the shoot loses the power of growth within itself in proportion to its age. This is the case with the Fir, Asparagus, and many other plants.

When a seed is put into the ground in common, the root grows downwards from that seed, although the point from which the root grows is placed upwards. *Vice versâ* with regard to the stem.

The first growth in a seed is the root, and then the plant.

Cut off the root, a new root sprouts out; but the growth of the plant is stationary till the new root is fit to carry nourishment to the plant.

Vegetables are much more in our power to manage than animals. Thus, a plant can be made a dwarf, it can be made to shoot strong, it can be made to vary, it can be made to bear.

The juices of vegetables, commonly called sap, can either ascend directly, pass laterally or obliquely. Thus if we bark a tree nearly all round, leaving only a little part, the juice of the plant, to supply the tree above, passes directly up through this part, and as it supplies the whole above, it must then diverge in all directions; this is best known in those trees which die to the heart whenever barked; but in others it might be supposed that the body of the tree carried up its juices beyond the barked part, as in the Apple, Pear, &c. From this property the juice can be made to take any direction: if a straight stem of a tree has a piece of bark removed in an oblique direction, which, when carried on, runs into the spiral, the sap will be conducted along the remaining bark, which, of course, is also spiral; and these spiral turns may go several times round; but this is as much as many trees can do, and more than most. In those trees in which the wood dies when barked, the spiral barking may go round several times; for we may suppose that the wood of the tree conducts the juice when barked in this way, as well as when barked all round: but in those trees in which the wood dies to the centre, the bark must carry the whole juices, and, excepting the little bit of wood that is covered, which may carry some of the juice, the whole or the best part must go along the spiral bark; and as this in such is not sufficient if the turns are many, it is necessary to go at first only once round the first year, then the second once more, and so on; from which it would appear that the parts acquired a facility in conducting the juice, or rather the last year's bark on this spiral part was so formed as to conduct the juice better than the bark at large*.

To produce seed is the ultimate power in vegetation. In vegetables

* The ascent of the sap is through the wood of the trunk and branches to the leaves,

there are several steps of perfection. First the flower, in which step the vegetables may proceed no further; the second is the fruit, which may be produced, but not the seed, perfect; and the third is where the whole is perfected.

Of Vegetable Life.

The life of a vegetable comes under the same definition with that of an animal. It is a power of action within the vegetable itself, independent of any mechanical power whatever; for although impulse, which can produce a mechanical effect, may be a cause of this power being brought into action, yet even the effect is not mechanical; that is, although the body impelled may lose some of its power by this impulse, yet the body that receives it has not acquired the same power, which would be mechanical; but it may exert a power much greater or less according to circumstances, which power was not received from the impelling body, nor was the power in the impelling body lessened in proportion to the action of the body receiving the impulse.

In speaking of vegetable life, and the actions arising from it, the same language that is used in speaking of the operation of an animal are equally applicable here; they are expressing actions whose causes and effects are very similar, although the mode of performing them may not be similar.

Most plants have their periods of growth and periods of rest, independent of variations of seasons, such as heat and cold; but in the same degree of heat a tree shall rest from growth, and then begin

where it is elaborated and fitted for the nutriment and growth of the plant; it descends by the bark, forming new wood, &c., in its course. *Vide* "On Barking Trees" in p. 18.

The vessels of the bark and the wood communicate laterally, so that if a spiral piece of bark is removed from the lower part of the trunk of a tree, even although it should make two or three complete turns, the tree continues to grow; but if a ring of bark is removed, the tree will die.

to grow again: perhaps this cessation from growth arises from the formation of seed going on in the plant, or endeavouring to go on, or the time it should go on in that plant; and when that period is over —the season favourable respecting to heat—it begins to grow again, producing what is called the second growth*.

This second growth of the branches of plants appears to be a continuation of the first; for we never find a new branch shoot out from the sides of the first growth, upon the renewal taking place.

Most plants, but not all (that have branches), form in each shoot the buds of its own branches, which either branch off the same year, or wait till the year following, and even both in the same plant, according to the earliness of the shoot, as the Privet, Cherry, &c.; others have all their buds developed into branches the same year, as the Holly.

Others, again, never form lateral buds for branches, but only the shoot terminates in a cluster of buds, the lateral intended for the branches, the middle for the stem; such as the Scotch Fir, Weymouth Pine, &c., which confine their branches to clusters.

Some vegetables would appear to have particular places for the formation of branches, or rather stems, when the original stem is destroyed by any accident; such as the common bean; and these places or spots may be considered as so many buds.

Cut off a stalk below the first joints or leaves, then a new stalk will grow out from the bean in the ground, which would not have grown if the first stalk had not been destroyed.

Cut off that new stalk below all the joints, and a new stalk or stalks will still shoot out from the same bean.

Cut off the stalk above the first shoot, joint, or leaf, then a new

* All plants have seasons of growth and rest; in some they are caused by alternations of cold and heat, but in others by rainy and dry seasons. In temperate climates, plants are principally influenced by temperature; in tropical climates by moisture.

stalk will not grow from the seed or bean, as in the former ones, but from the joint, shoot, or leaf below.

Cut off the stalk above the second joint, leaf, or shoot, and then two stalks will shoot out; one from the first joint, and one from the second.

Cut off the top of the stalk above the fifth or sixth shoot, and the new stalks will shoot from the first and second, &c. joints, but not from the last joints, or those nearest to the top.

Cut off the young shoot, and a third will grow out from the root of that, so that these joints are similar to roots or seeds.

The last shoot of a plant is always the weakest part of that plant, and the last part of that shoot is the weakest part of that, and of course the weakest of the whole. This fact is best known in severe winters, or a cold beyond the natural temperature of the plant; for when the cold has been too great, we find that the last shoot either dies, or if not so severe as to kill the whole of the last shoot, it shall kill the last-formed part, so that new shoots are obliged to rise from those branches that are two years old or more.

All plants are not capable of supporting themselves, and therefore are obliged to have recourse to some mode of support; they are such as grow in length beyond their proper or proportional thickness. It would appear that weakness in anything that has powers of action within itself, produces or stimulates the parts, so weak, to take all advantage of collateral support. Even a bean, which, when strong, seems to depend entirely upon its own powers, yet if it grows weakly, as when not in the sun, or any other cause acting to hinder strength when growing,—in such, if a stick is put into the ground close by it, it will twine round it in loose spiral turns. They may be called creepers, or those which pass horizontally; climbers, those which ascend; twiners, or those that twine round a body; and clingers, or those that lay hold of lateral support. The first is the weakest; the second and third next in strength, and I believe pretty equal; and the last the strongest. I believe most form lateral roots, although not all; the last probably the least; although they do, as the Vine. Those that go on horizontally, have gravitation for their principle; but those that ascend on trees, walls, &c., I believe have an attractive principle; probably it is touch, as in the climbers and clingers, which immediately bend or incline to some body; for instance, the Ivy.

The twiners seem to depend on another principle. There are some that partake of two principles, both climbers and clingers.

The creepers are a large class; the Strawberry may be given as an instance.

The climbers are, I believe, not so numerous; the Ivy is an instance; but both the twiners and the clingers are an extensive tribe.

The twiners are a large class, and what is very curious in them, besides their twisting round bodies, is the constant manner in which they do it; and, according to this regularity, they may be divided into two, viz. those that always go round as they ascend, from left to right, and the contrary of the others. The Hop, Honeysuckle, go from left to right, or with the sun; all of the pea kind, such as the Convolvulus, go the other course. This regularity must depend on some principle, and which I conceive to be the following:—The fibres of which they are composed grow spiral, and in the same manner they turn*.

The clingers are also a large class. The Vine may be given as an instance; its tendrils move in all directions in search of a hold, and when they get it, they cling round it, and in any direction. The Passion-flower is of this class.

The Virginia-creeper may be given as an instance of both climbing and clinging. It is curious to observe this plant attaching its tendrils

* It has been found in almost every case where the minute structure of the wood of left-handed climbers has been examined that the delicate fibre within the spiral vessels also takes the direction of the stem, viz. from left to right.

to the wall; they then become broad at this part, and stick by a kind of suction, or attraction of cohesion, or they will insinuate themselves into holes or crevices. It is curious to observe its tendrils always inclining to the wall, although arising from the opposite side.

"Dear Sir,—I received yours, and have considered your Qs., which, as general questions, are very easily answered; but when we come to particulars,—to tell how many have twining stalks, rooting stalks, and what number support themselves by cirrhi or tendrils; how many, by shutting up their leaves at night, have the appearance of sleep; those which are affected by touch, and how many have self-motion,—we shall find it very difficult to ascertain the exact number, even of the plants that are known, both for want of observation and recollection. However, the general answer is, that all the plants in which these different motions have been observed bear no proportion to the number of those in which we see nothing but the common mode of vegetating and growing. Supposing there are 13,000 vegetables known, I cannot recollect above 773 out of that number that have any particular motion. I have made a hasty calculation of these as follows, viz.:—

Somniferous plants	448
Caule volubili	195
Caule radicante	16
Foliis cirrhiferis	107
Affected by the touch	6
Having self-motion	1
	773

"This calculation can by no means be depended on as near the number that have the different motions mentioned above. There is no doubt that a great number of plants sleep at night that have not been noticed; and we shall in all probability by observation find many that have self-motion, &c. On the whole, the different modes of plants are very imperfectly known; we have little acquaintance with the plants of hot countries, and those of Europe have been more studied for their uses than for the advancement of natural knowledge.

"Daniel Charles Solander*."

Some plants do not grow equally at all times in the 24 hours; some growing only when dark—Beans, Peas, Lupins, &c.

* This letter, written to Mr. Hunter in answer to some inquiries, was introduced into the manuscript at this place.

Some plants grow equally at all times in the 24 hours—Asparagus, Fir, Duke of Argyll's Tea, &c.

In the Island of Feroe the vegetables do not grow when the sun is for some months above the horizon, but grow when he is under it, viz. when dark.

In trees, the first shoot or stalk is always better wood than the second, the second better than the third, and so on, even of the same age.

Thus, if we compare the first year's growth of a sucker, or that of a seed, with the second year's growth of another sucker, or of a seed, we shall find that the first year is much heavier and much tougher.

The stalk is always better wood than that of any of the branches, even of the same age; so that the branches upon the whole are worst of all.

Thus if we compare a branch of any given age with the stem of the same age, we shall find a still greater difference.

The branch from a branch is worse than the branch from a stem, and so on; so that every succeeding year's wood is always worse than the preceding, and of course growing worse the older a tree grows.

Every branch may be reckoned a stalk, or a principal to the shoot beyond; and in this view it is similar to the stalk with its second, third, &c. shoots, and it may be reckoned a principal to its own branches, and is always better wood.

The reason of this is evident, for the strength or goodness of the wood must be always in proportion to what it has to do, or support in future.

The stalk is always strongest wood where it gives off a natural successive branch, because, there, it has not only to support the tree equal to every other part of the stalk, but to support the weight, motion, &c., of that branch.

As wood grows by a new layer being formed every summer on the surface of the last, and as each layer is several months in forming, the first part formed of every layer has the whole summer to perfect itself in, and so on less and less, as the succeeding parts are later and later in forming, so the last part formed has but little time in the summer to become good wood; therefore each layer is made up of wood of different degrees of goodness. This is evident in the wood itself, and shows itself upon almost every occasion; for instance, cut a piece of wood across, and look upon the cut end, we shall find the inner part of each layer is the hardest and most solid to the eye, but the exterior part is porous, &c., and if it is Fir, we find it fuller of resin*. The same appearance takes place upon a longitudinal view of each layer. This is not only seen in sound wood, but much plainer in the decay of wood, for we find that the outer part of each circle or layer is soonest rotten, and becomes hollow while the other stands.

On the 1st of August I observed that the present summer's growth of Fir and Laburnum was become now the external layer of wood of the tree; and what now came off in form of bark, was a new layer of wood beginning to form, which was of a pale green, covered by two cuticles,—one, an outer, thin and brown, the other thicker and green. The outer surface of the last layer of wood was of a very pale green, which could be pushed off with one's nail. This new beginning layer of wood, I apprehend, is formed by a second growth, which trees commonly have, and by its being of much longer standing.

Trees, after a certain period of their growth, which is pretty early, but more so in some than in others, generally make shorter and shorter shoots every succeeding year of their growth; but as the number of branches increase, it is no more than probable that those of any one year's growth, taken as a whole, not only exceed in number,

* The vessels are chiefly found at the commencement of the year's growth, the woody fibre at its close; this is well seen in the Oak and Conifers, although by many the distinction in this latter is denied.

but also in the quantity of vegetable matter added to those of any former year; so that, although the shoots of this year, taken separately, are less than those of last year, yet the tree has gained not in an additional progression, viz. by adding the same quantity yearly; but perhaps in an arithmetical progression, viz. multiplied by the same multiplier, or perhaps in a geometrical progression, which is much more*.

Some vegetables close their leaves in the evening, as the Sensitive-plant; others have theirs open in the evening, while the majority of others are not in the least affected by either evening or day.

To ascertain what was the cause of the internal influence which produced these effects, I made several experiments. As the visible differences between day and night are heat and cold, light and darkness, I made the following experiments upon these principles.

For distinction, I shall call that action which appears to arise from the greatest quantity of vigour, *extension*; and that action which appears to arise from a loss of power, *flexion*; although many of the motions themselves with regard to the position of the parts are not always strictly so.

I took a Sensitive-plant, and in the evening, when in a state of flexion, put it into a room: at five o'clock in the morning, a little while after sunrise, it was beginning to expand its leaves and erect its stalks, and continued this position till about five o'clock in the evening, when it began to close again, but before the light was materially gone.

The second day I kept the room dark till five o'clock in the afternoon (the time that the others were beginning to close), and it ex-

* The life of a tree may be divided into three periods:—1st, the rise, in which the rate of growth is slow; 2nd, the period of vigour, in which the growth attains its greatest development; and, lastly, the decline, in which the growth becomes less and less each year until the signs of life are limited to a few branches, and at length the trunk decays and dies.

panded itself and kept expanded till dark, when all its extremities began to collapse.

Third day I kept it in the dark room all day, and it maintained the flexed state; about eight o'clock in the evening I threw a light upon one leaf from a concave mirror, by means of two candles put close together, which was continued for three hours, but it had no effect.

The fourth, fifth, and sixth, it was kept in the dark room, and still continued flexed, but was beginning to decay.

This process of expansion and collapsing does not arise from an increase and decrease of heat between day and night; for in the winter, in the hothouse, where there is very little difference in the degrees of internal and external heat, and less so in the house, where a pretty regular heat is kept up, we find this plant performing the same motion.

If the stem of the *Mimosa pudica* be touched with a hot wire, the leaves above collapse.

If the top of a branch or pinnula is touched with the hot wire, the whole leaf gradually collapses, then all the leaves above, while only one or two at most collapse below.

Stimulants, such as a strong solution of common salt, did not produce a collapse, excepting when put on the joint, and this uncertain.

Ether applied to the top of a pinnula will oblige the whole leaf to collapse, as also other leaves on the shoot, both above and below: a cut into a strong stem will not produce a collapse, but if into the tender part, it will produce a collapse of all above, and commonly on the same side; but a deep cut may affect the other side. Tie a ligature round the stem or stems of a branch, it may be cut below this without affecting the petioli or pinnula above; the branch may even be cut off without a collapse. If a collapse be produced, they do not expand so freely.

It is curious the not collapsing of the leaves upon being gradually heated, so as to be burnt. It would seem that the presence of the heat hindered collapsing.

The Sensitive-plant has evidently parts fitted for motion. At the setting on of the foot-stalk to the stem, and the joining of the foliola to the *rachis* of the compound leaf, there is evidently a part in both different from the other parts of the same stalk, &c. It is in these parts that the flexion and the extension are performed: but when the leaf performs a rotatory motion, which it will do when the plant is inverted, the whole of the foot-stalk appears to join in this motion, so that it is simply a twist upon the axis of the foot-stalk.

In the *Dionea muscipula*, or Tipitiwitchet, the whole of the leaf has an equal motion through its entire length, and it appears to be nearly equal on all sides, for in its various motions the lobes are bent towards that side where the plant bends; and, the bends taking place on every side, a kind of conoid motion is produced.

In the Vine, if the stem rise perpendicularly, the foot-stalk generally comes out, making an acute angle with the stem above; but if the stem hang, which it often does, then the petiole makes an obtuse angle with the same part of the stem. This action is performed at the setting on of the petioles; but in this last position of the stem the foot-stalk is obliged to make a twist of half a circle to bring the upper side again uppermost. This twist is principally performed at the root of the petiole, but it in some degree runs through the whole.

The flexion and extension, with the conoid motion, must be performed by longitudinal contracting powers, but the rotatory motion must be performed by oblique.

With the idea that it was possible that the contracting tissue of vegetables might be muscular, and therefore composed of the same species of matter with animals,—especially, too, as they yield the same elements when analysed, although not in the same proportions,—I made the following experiments:—

I cut off from several leaves of the Sensitive-plant the active part of the petioles, and also of the foliola, and put them into a phial of water, No. 1.

I took as much in quantity of the more inactive part of the petioles and put them into another phial with the same quantity of water, No. 2, and sunk them both into the tan in a hothouse. When they had stood thirty-six hours, I smelt them both, and found that the phial No. 1 had a strong sickish or faintish smell, but the odour of the other was hardly perceivable. When they had stood forty-eight hours, I found the smell of the first increased, but not that of the second. I took some of the water of the first and put it to the syrup of violets, and it turned it of a very fine green; but No. 2 had no effect upon the syrup. It did not produce the same effects again, and I continued them in it for more than three weeks, upon the very same parts, and at last they produced an acid.

Of the Influence of Light on Vegetables.

It would appear, from common observation, that light was the immediate cause of the green colour of vegetables; but upon a further investigation of this subject, it seems to be only the remote cause. That it is not an immediate cause in all cases is plain, from many vegetables of the same species not being green in all, nor in all parts of the same, as the Variegated Holly, Aloe, &c. Many vegetables are green through and through their whole substance, and a considerable number are green on their outside, viz. in their cutis and in their new layer of wood, especially if but newly formed; also many vegetables are green on the inner surface of the canal of the pith, for instance the young shoots of the Elder; from all which it would appear that light was not the immediate cause of the green colour, but a remote cause, viz. the cause of a certain degree of health or proper action, which produces the green colour. Those which are not green, even when exposed to the light, are not capable of taking on this necessary mode of action, although under the influence of light; from all which it would appear that light is capable of stimulating most plants into such action as produces a green colour in certain parts of that plant, no matter whether immediately, or not immediately under the influence of light.

The leaves of most plants are green, although not all. In those that are naturally green, we find that in proportion to the health of the plant, the green is darker; and when not healthy, it is more of the yellow cast.

Those that are naturally yellow do not change: yellow is the colour that green vegetables take on in the act of dying; therefore when plants are not of so dark a green as common, they have but few or little powers of life: a dark green in any plant shows great vigour of life, and their growth is luxuriant.

Of the Barking of Trees.

When a tree or a branch is barked in any one part half round or more, the remaining bark in the circle forms a much thicker layer than it would otherwise have done, thicker than it is anywhere else on the same trunk or branch of the tree; it is perhaps equal to a whole circle of the same trunk or branch. The stimulus of growth is increased by a real weakness being produced*.

* When a tree is barked nearly round, the remaining bark becomes much thicker than anywhere else, but it is not equal in sectional area to a whole circle of bark in the same trunk or branch; for instance, suppose the bark of a tree to be half an inch thick, and the circumference of the bark to be 10 inches, if 9 inches are removed, the remaining inch of bark will not become 5 inches thick.

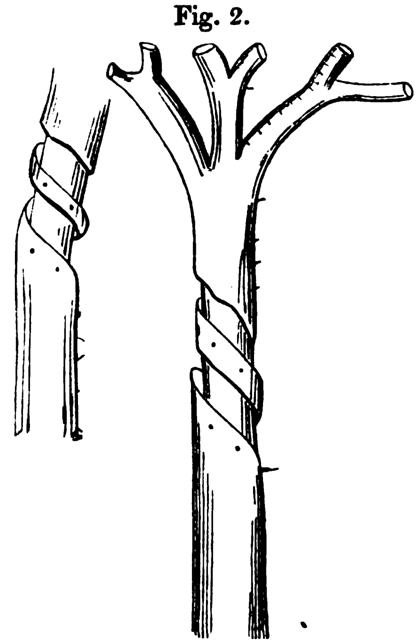
The whole of a barked branch grows more rapidly than a similar branch that is not barked, as the removal of a ring of bark prevents the elaborated sap from passing below the barked part, and the greater growth of the part of the branch nearest the barked part is caused by the accumulation of organizable substance there.

Upon the same principle it is, when a tree or branch is barked all round, that the cut-edge nearest to the extremity of the tree or branch, close to the barked part, grows faster or thicker than any other part of the same branch, as in fig. 1. But this increased growth close to the barked part I believe is only in those trees which live beyond the barked part; but in those which only live that season in which they are barked (as the Laburnum), the growth of the part beyond where the bark is taken off is less near to the barked part than it is further on.

An Apple-tree barked spirally about once and a half round, fig. 2, threw out many branches below the barked parts, but near it, as also in the spiral between the spiral turns of the barked parts. This is upon the same principle; for the unbarked part has no sensation of the part above, and therefore sends out shoots.

Fig. 1.

Fig. 2.



Pear-trees, when barked, often throw out a new bark from the wood in different parts of the barked part.

The same thing takes place in the Hazel, which shows that the surface of the barked part keeps alive.

We often find trees throwing out leaves about the beginning of October, and even blossoms; such I have observed have dropped their leaves very early in the autumn, so that they had gone through their suspension of action a sufficient length of time to take on a new action; but such are commonly, if not always, weaker than those in due season; the leaves are paler, commonly a mixture of yellow, which denotes weakness. I had a Lime-tree that threw off its leaves in August; I thought it was dead, but it threw out a second set of leaves in the latter end of September; but they were pale, therefore not healthy or vigorous. A Horse-chestnut tree at the King's Head door, Brompton, had one of its branches which lost its leaves very early in the season, and by the latter end of September it had shot out fresh leaves and a full-grown flower: the leaves were paler than those in due season.

Leaves have considerable motion when the wind blows. Is this in some degree to take off the force of the wind upon the whole tree?

Some trees have much smaller branches than others, the stem being the principal, such as the Birch, Poplar; such also have small leaves; of course those that have large branches having larger leaves.

The casting of the leaves of plants is most probably similar to sloughing or exfoliation in animals. It is at least an operation of the plant, producing a separation of the leaf; and the only thing that proves it is, that the leaf will not fall off if both the plant, and of course the leaf, is dead: but if the leaf dies, although long before its destined time, it withers, it is separated, and it falls off; but if both the plant and leaves die at the same time, viz. before the separation has taken place, then the leaf will not fall off, even when dried.

These facts show gardeners whether a new transplanted plant is dead or alive. If the leaves fall off by passing the hand over them, then they are sure the plant is alive; but if they do not fall off of themselves, nor will they be separated by passing the hand over them, then it is most probable that the plant is dead, for then both continue one piece, as before drying.

All trees and shrubs grow in thickness by a new layer of wood being laid every year on the outside of the last year's, immediately on the inside of the bark, which is at first but slightly attached to the last year's layer, but every year becomes firmer and firmer in its attachment.

I find that when the branches are cut off in the autumn, after this outer layer is completely formed, but not yet firmly attached to the last year's layer, it will not now attach itself till the following year; and even then it will not be attached strongly, because this year's shoots are not such as give great influence to the action of the stem.

Many vegetables form their flower on their extreme shoot; such can never have a leading shoot, but must always be obliged to grow from a lateral shoot or branch; such can never grow tall and straight, but must grow bushy; they may grow more or less into large bushes. I believe all the annuals, without exception, form their flower on their extreme shoot. In them, the flower forming one very shoot cannot hinder a repetition of the growth, as the whole dies away in the same year.

The same observations are applicable to those whose stalk dies away every year, but which form a new stalk from the root; therefore may be said to live by suckers, and should have a time expressive of this, as it is their great characteristic. Then there are those included as shrubs and trees, which may be said to have no fixed termination, and live for years. These appear to me to be of two kinds, with the immediate one like the former, having its flower on its extreme branch; so that it never can grow to any great height, but must become thick and bushy. The large Sumach is of this kind, every branch terminates in a flower; but it is reasonable to suppose that it is a plant of a warm climate, for its later shoots or branches do not come to perfection; and as the winters here are too cold for the extreme end on which the bud is to form to allow it to live, it dies, and the flower is prevented from forming the summer following. The Elder is also of this kind; but as it is a more hardy plant, more of its branches flower, and some live through the winter to flower next summer, but they still terminate in a flower. The other continues to shoot or elongate in both trunk and branch; all of the Fir kind are probably the best instances of this. Is the first the character of the shrub, and the second of the tree? The mixed is that in which in some branches the growth shall go on in the leading shoot for one or two years, but shall be interrupted in the second or third by its terminating in a blossom. The Horse-chestnut is of this kind, as also the Mountain Ash; but it is not till they have arrived at a certain age they flower, therefore have arrived at the size of a tree, not having now the true properties of a tree.

I know a Scotch Fir transplanted in July 1772, which after it had made that year's shoot, in the spring following had not the least sign of active life, and was supposed to be beyond recovery, although on removing the bark at any part it was found fresh. In the month of July, 1773, it began to shoot, and continued to grow.

The same thing happened to a White Thorn. A Spanish Broom was under the same circumstances, and was attended with the same effects.

On the other hand, we shall find that the actions of life shall be very weak for a season or two, and die at last; this is a very common thing with new planted trees, and probably with everything that is newly planted; but in many things they do not remain long in this inactive state, and either recover or die, as many annual plants, or those that live two or three years, as Cabbages.

Of the Suspension of the Actions of Vegetables.

The actions of a vegetable depend on the living principle; we see these actions often suspended, although the living power is still existing; and probably this power can lay much longer inactive in the vegetable than in the animal, its own existence not depending so immediately upon action in the vegetable as in the animal; but this varies very considerably in the different classes of vegetables, as also in the different classes of animals; however, it is probable that the vegetable, which can the least bear a suspension of its actions, is more than the animal, which can bear it longest. I am here not alluding to those natural suspensions of actions which appear to be a necessary part of their economy, and probably could not act two seasons without an interruption to their vigorous actions, but to those suspensions arising from some violence, such as transplanting, or probably disease; we find also many trees may have their actions suspended for one, two, or three seasons, but still living, and shall die at last.

I planted some Scotch Firs in the month of July, 1772, when the shoot was full-grown. The spring following one of them did not send out fresh shoots, although the buds were fresh and the whole green; it remained in this state all the summer; the winter following it appeared just the same as the preceding winter, viz. the last shoot, which was a year and a half old, appeared like those of the last spring's growth in the others; the spring following, 1774, viz. two years, it was stationary, and kept fresh as in the preceding spring, but it died in the summer. Here was life sustained for two years; but as it had not powers to act, it lost its powers of life, not being able to live under a long suspension of its action.

On the other hand, we find that many vegetables, although their powers are weak, do not suspend their actions when the proper season is calling them forth; but often these necessary actions are more than the powers are capable either of perfecting or continuing. If the necessity to act is not more than the power, then they go on very well; but if the necessity to act is more than the power, then they become weak, and perhaps cannot even support life, and die. This is seen in very hot weather in summer, when trees, &c. are dying every day with heat, although well watered. It is more remarkable in newly-planted trees, where the living powers are rendered much weaker than at another time; for if the weather becomes hot, and continues long so, they certainly die. We shall see them send forth their young shoots and leaves, but those shall die upon the approach of the too hot weather, and if mild or cold weather comes on, they shall begin to shoot out stalks afresh, as also leaves. Such trees (if of value) should be sheltered from the sun for the first summer, especially if the heat be considerable.

In every vegetable there is a certain power of action. In some it is much more than in others, as in the Blackberry-bush.

Many plants, such as trees, when they have become very much weakened by a long hard frost or winter, shall in the spring begin to shoot out their buds, but when the weather becomes warm they are then not able to act equal to the heat, and they die. This sometimes takes place in the whole plant, in others only in part, often in one or more branches; but as the last shoots of plants are the weakest, we find this effect mostly in those. In many hard winters the last shoots shall die, and we shall see the living part next to the dead, shoot out its leaves; but as the heat of the weather advances those leaves shall fade and wither away, and those lower on the vigorous stalk or branch below shall live.

Of Monsters in Vegetables.

In vegetables we have monsters, that is, a deviation from the common principles in some of its productions, either in form, flower, seed or colour, and this is what has produced the variety in every species; and this arises more from cultivation than any other immediate cause; and the cause of the variety, viz. cultivation, becomes also the cause of their being preserved and propagated: but their propagation is, in many, perfectly artificial, viz. by budding or engrafting; but when left to the natural mode of continuance, they go back to the original again, or at least it is not certain what will be the produce; a new monster may arise. All our finer fruits are instances of this kind; therefore in some vegetables, whenever a monster arises, it never dwindles gradually into the original stock, but keeps the same, excepting another monster arises, which may be that of the original from whence it came, or any other; Beans, Peas, &c. are changing every day.

The male parts in vegetables for the most part far exceed in number those of the female. I am not now considering the seeds as a female part, they being only a production of the female.

The stamina of the male, which are the spermatic vessel and testis or true male parts, are in much greater number than the styles of the female; and the number of particles of the pollen, which are the production of the male parts, far exceeds the number of seeds in the female.

The produce or effects of the female parts are pretty well determined with respect to number, viz. the number of seeds, because they form a part of the vegetable creation: but although the produce of the male be well determined, yet its effects are not; for they do not make a part, but only are to affect the female part, and that affection is in a good measure a matter of chance. It is like shooting at a bird with a great many shot, while one would kill if with certainty it could be properly applied.

As vegetables are every year, or are constantly supplied with an addition of vegetable matter everywhere on the outside, they must have their parts respecting external influence renewed every year, such as the parts of generation; therefore they may be said to be always young, because these new-formed parts are young, and it is these young parts that perform the natural actions of the plant.

Either the stem or the branches of trees grow in thickness in proportion to the quantity and size of the branches beyond, viz. in proportion to the support wanted; therefore, if the branches are cut off from the trunk, or the smaller branches from the larger, the trunk or branches so deprived of their dependents will still only grow in proportion to the decreased dependents*.

The effects Barking all round has upon different Trees.

The bark of trees appears to be one of the most essential parts of the tree—it appears to be the life of the tree; for, first, without it it cannot live; and, secondly, it is the immediate cause of growth, not only in the part covered by its bark, or in other words, each part receiving its increase from that part of the bark which covers it, but the bark has a sympathizing communication through the whole tree, so that the tree shall be variously affected, just as the bark of any particular part shall be affected.

The effect that the removal of the bark has upon trees is of two kinds: one producing death in that part, as deep as the centre or pith; the other is only death a little way beyond the surface, like an exposed surface of a bone; and I believe in many life is retained on the very surface, at least on many parts, as is often seen in the Pear-tree.

If the barking be only partial, in either case little or no effect upon the tree in general is produced; for if this partial part be killed to the centre, the remaining bark on the same plane with this is sufficient to

* As the sap is elaborated by the leaves, the growth of the trunk and branches is in direct proportion to the number and size of the leaves.

carry on the communication between the two parts of the tree, viz. between the root and part barked, and beyond the part barked: but if barked all round, then two very different and material effects take place; for the tree that dies from the surface to the centre, now dies all round to the centre, and we find that every part of the tree beyond the barked part dies, although not immediately; and the other only dies a small depth from the surface all round, and the parts beyond the barked part do not die, but produce a number of new parts.

In the tree which dies to the centre when barked all round, the parts beyond do not lose their life immediately; but this appears to occur sooner or later, according to circumstances, at least so far as my experiments have yet gone. If the bark be taken off in the autumn, they appear to die sooner than when it is taken off in the spring experiment. In the month of September 1779 I took off a circular piece of bark of two branches of a Laburnum, with the view to see if the parts beyond lived the first year. April 1780 they began to shoot forth, but they both died. From the circumstance of their beginning to throw out leaves, &c., we must allow that they had lived through the winter, and probably this was because they had at this time little or no action to perform. Experiment second, April 1780: on the same Laburnum I took off a circular piece of bark, and it shot forth its leaves, flowers, &c. as strong as any of the other branches. March 1781 it began to shoot forth its leaves and flowers a second time, but they were both very small; and in the autumn it visibly died.

Experiment third.—The same experiment was made upon another Laburnum, and was attended with nearly the same circumstances; the only difference was that this was rather more lively in all its actions, but they were nearly the same proportioned.

Experiment fourth.—At the same time, viz. March, the same experiment was made upon a branch of a Walnut-tree, which threw out leaves, &c., but lost the leaves by the latter end of August, which was much sooner than the other branches did, and it became dead that winter; so it did not live so long as the Laburnums. So much for the effects of barking all round upon the Laburnum and Walnut.

In those trees which live at the barked part, and therefore live beyond the part barked, nothing particular happens respecting the mode of throwing out their leaves, branches, or flowers, but other circumstances take place. The Scotch Fir, Plum, Pear, Apple, are not killed by being barked all round; but a very curious circumstance respecting the vegetable economy takes place, the facts relative to which I shall now describe.

In those trees which do not die upon being barked, we shall constantly see the three following facts taking place. First, I find that, if barked all round, the part beyond grows in general as fast as if it had not been barked, while the part between the root and barked part grows but very little; so that we shall often see a thick part above, and it shall become small all at once. Second, all that part of the tree above the circular barked part, not only grows as if nothing had been done, but it grows faster in thickness near to the barked part than in any other part, and much faster than if it had not been barked. And thirdly, the increase of the new layers over the barked surface to cover it, is much thicker, and makes a much quicker progress on that side next to the root; indeed, it hardly makes any progress at this part at all.

These three facts explain much more of the vegetable economy than any other circumstance attending vegetables. We may first observe, that from the circumstance of the tree dying beyond the barked part, in consequence of its dying at the barked part, that the nourishment of the tree is carried through the wood and not by the bark (at least) alone; but the three facts just mentioned respecting the growth of the part beyond the barked part in those which do not die at the barked part, are still more curious, for the disproportion in the growth of the two parts is a curious fact; it shows that by barking a tree all round, the intelligence between the two parts is cut off, although in the part beyond the nourishment is still carried on, and that portion near to the mischief is so sensible of injury, as to set to work and repair it. That it should be sensible of injury is evident, because from this and the consequences of it, viz. the second and third observations, the loss is repaired, and the intention of this repair is to support all above. Therefore we may assert that the part of the tree beyond the barked part is conscious of the injury, conscious of a part rendered weak, and the stimulus of the necessity of growth takes place here; or it may be put in this light: the part near or close to the barked part is conscious of the injury done on one side, and conscious of what is to be supported on the other, therefore sets to work accordingly, that it may be able to repair it.

The part between the root and the barked part growing but very little, is also easily explained; for by admitting that the communication between the two parts is cut off, then it is only reversing the above theory, viz. that its not being conscious of any part beyond it, is similar to its having been cut quite through.

The branches of trees on that side where there is something obnoxious to the growth, such as high wind, too much sun, sea air, &c., do not grow so strong as they do on the other side of the same trees. I suspect that this failure does not arise entirely from the branch itself, but that side of the tree has not powers equal to the opposite side, so as to give sufficient nourishment to the branch.

April 1775 I made the following experiment:—I slit the bark of a branch of a Scotch Fir for about two inches in length, and separated the bark from the wood all round, and put a piece of card round between the bark and the wood to keep them separate, the slits allowing me to pass the card all round. This branch shot out as long shoots as any of the others in the same circle, but it died in the winter.

The same with a Laburnum; one of the slits of the bark formed wood on its inner surface, and the branch lived.

The same with a Lilac. The flowers of this branch did not blow so soon as those on the other branches, nor did they come to perfection. The leaves were of a paler green than those of the other branches.

The leaves of trees increase the necessity of the growth of the stem or trunk, without the necessity of increasing the number and size of the branches for this purpose; so that the stem and branches do not bear a due proportion to one another, but the leaves and branches taken together do.

Of the Bark of Trees.

The bark of trees is that external covering which may be said to have no sap in it, and hardly has any particular arrangement of its parts or substance.

This part of a tree may be divided into two kinds respecting permanency; the first is where it is never changed, and the other where it is. As this part of the tree does not grow in the same proportion that the tree which it covers does, there must be some provision in nature for this; we find in such that the bark cracks, and those cracks at their bottom are filled up with new bark, probably from the sides of the cracks.

The circumstance of many vegetables shooting out branches when the trunk is cut off, would appear to arise from a certain quantity of action necessarily taking place in the plant, and if destroyed, or obstructed in one part, it takes place in another.

This is somewhat like St. Vitus's dance in the human subject.

When trees shoot out many suckers, or many and strong lateral branches from the stem, we may be sure there is a deficiency in the growth of the top, the growth of the top not being in proportion to the growing power of the tree*.

When a tree sends forth its new shoots, and the leading one is allowed to grow, then the harmony of growth is preserved; but if the leading shoot is broken off, then there is an endeavour in all the lateral shoots to become leading shoots; but some one gets the start, and then the whole affair becomes settled.

Of the Change of the Colour of Leaves and Stalks of Vegetables from the Green to the Yellow when dying.

This change is an operation of the living powers of the plant, and not simply death taking place. It is extremely gradual when the part is as it were allowed to die a natural death; but either a great drought or a few frosty evenings will hasten on the decline, and they die sooner or faster. That this is an operation of the plant, arising from debility or stimulus of death, is, I think, evident; for if a plant in full vigour, in which it is at the greenest, be killed immediately, by putting it into boiling water or by electricity, it retains its green colour, and will die green, and even dry that colour, from whence we may suppose that the strongest plants, or those with the greatest powers of action of any one species, will be of the deepest green; and I believe that this is shown every day by experience.

They not only retain their colour after death when killed suddenly, but they retain other properties; for if dried in that state and wetted again, they come back again much nearer the fresh plant than those which die gradually or naturally.

* When trees throw out suckers, it shows that the roots collect more sap than the leaves can elaborate. This is seen in many grafted plants, such as weak Roses and fruit-trees upon *vigorous* stocks; these especially, when severely pruned, throw out an abundance of suckers; but if the head of the plant be encouraged, the suckers become less numerous, and frequently altogether cease to be formed.

Of the Casting of the Leaves of Vegetables.

Every vegetable is deciduous, but differs in times, and probably may be divided into the following:—First is what may be called annual, being similar to those plants which die the same year or the same season, or rather when finished growing, as in all the plants commonly called deciduous; but to keep to the true analogy, they should be called perennial, as it is similar to those whose stalks only live the same summer, but the roots live, and shoot out new stalks: however, it is never the last or former year's shoots that throw out leaves, it is a new shoot.

The second is what may be called biennial, or the second season of its age, or when finished the second growth. This would be similar to the Raspberry; for the Raspberry does not die the same season of growth, as many vegetables, but the second, as the leaves of the Scotch and Weymouth Pine, Laurel, &c.

The third may be called perennial, or the third season of its age, or when finished its third shoot.

There may be a fourth, a fifth, a sixth, &c., the last of which seems to be the case with the Spruce. Every winter exposes the first class, and in all of the Pine kind this fact is easily known, but in most others of the second, third, &c., can only be known by a succession of observations.

Whenever a tree, or probably any plant, throws out strong suckers, or throws out new strong and healthy branches from the stem, be assured that the top is not so strong as the bottom; there is not an equal quantity of life or powers of growth in both. It is on this principle that those plants which are continued by suckers, produce the suckers or new stem; for if the old one was continued in full force, no suckers would arise. This appears to be the case in trees nearly full-grown. A tree beyond a certain period begins to make shorter shoots, and this goes on in a kind of inverse ratio to its age; but if a lateral branch shoots out from the stem, it grows luxuriantly like a young shoot. Thus, when we see trees lopped up to near the top, the side-shoots are strong, while the continued shoots of the top branches are weak,—just the reverse of a young tree.

The lower a new branch rises the stronger it is, and in the same proportion larger, from which principle a sucker is the strongest wood, longest and thickest.

Of the Effect of different Winters on Vegetables.

It appears from observation that a long hard winter does more harm to vegetation than a much severer season of a shorter duration.

The January of 1775, when the thermometer was about 10°, 15°, or 20°, did less harm than the spring of 1780, which was late, although the thermometer was seldom lower than 20°; however, it may be remarked that in the winter of 1775 there was a good deal of snow, while in the winter of 1780 there was none.

Of the Natural Decay of Parts of Vegetables.

In vegetables, many of the first-formed parts die while new parts are being formed. Thus many trees prune themselves, as probably all of the Fir tribe; but this is more or less according to circumstances. If a tree stands alone, so as to have a thorough air and light surrounding its lower branches, there will not be that disproportion between branches and the leading shoot, as if the branches were otherwise circumstanced, and in proportion as the branches are allowed to grow, the leading shoot is more stinted in its growth; and this is the reason why in woods, where the trees are growing thick, that they run up tall and straight, and have few or no branches below; for the lower they are they become sooner under the influence of shade and confined air, while the upper branches not yet being so long as to meet each other, so as to exclude air and light in a considerable degree.

Buds.

A plant that continues to shoot for two or more years, has always terminated the preceding year in a bud.

Buds are always the *ovum* or the *embryo* of a shoot or flower.

In the bud is contained the whole of the following year's shoot, and when the shoot is fully blown or extended, then it forms another bud or buds; often it is a continued bud; often a continued bud with lateral buds surrounding it, as in the Fir or Pine; often it is not the continued bud that is formed, but a lateral one, as in the Lilac.

When a bud contains a flower, it also contains everything relative to it.

A bud and a leaf generally, if not always, form together; whether on the side or termination.

Buds in most trees, the Scotch Fir and Weymouth Pine excepted, grow on the sides of the growing stalk, forming as the stalk forms, each bud having a leaf annexed to it; a bud never forms on the side of a grown stalk, or on any part of a stalk after it is formed; but as the external surface of a tree is growing every year, or rather as there is a new layer formed every year, there are places developed in the bark which answer the purpose of a bud, which, when stimulated to action by cutting off its intelligence from the parts above, oblige it to supply what appears to be wanting; but all trees have not this.

It is not clear to me but that these were originally buds, which did not branch, and by that means became flatter and flatter, but still retained the disposition of a bud when called upon. All buds are not intended for branches only, but also for leading stalks, in case the stalk is broken, as in the Bean.

The lateral buds in many trees appear to be so much a termination of the shoot, that the leading bud is obliged to strike off obliquely, and which is more or less the case when the buds form alternately; but it is remarkably so in the Lime-tree, making the whole shoot after it is formed take a zigzag course when the buds arise, or are formed in pairs or in clusters; then the leading shoot goes on straight, being equally influenced on each side or all round. Most shoots go on in a straight line with the stem, whether of a branch or main trunk; but the Virginian Creeper would seem to be always growing backwards, having its last-grown part bent backwards on itself for two inches, and as it grows, it is in the same proportion unbending itself.

Probably every tree has in its nature an annual cessation in growth. This is perhaps better illustrated in the Lilac than most others. This plant terminates its summer growth in two buds, exactly similar to those on the sides, at the attachment of the leaves; and this bud has no disposition to grow till it has lain dormant some time.

Query: What is the reason of all this? Is it because the last year's bud has fully expended itself, therefore can shoot no further, and must form a fresh bud to go on with next year?

Of Trees and Shrubs.

It is impossible to form a just idea of the distinction between a tree and a shrub without taking the two extremes; for the moment you begin to proceed in the graduation between the two, you are immediately connected with properties belonging to both. Probably no true definition can be given of either the one or the other; yet by giving a few properties of the one as also of the other, we shall see why one may be called a tree and the other a shrub.

The true character of a tree, I should say, is a plant which grows by a continuation of its shoot not being interrupted by any natural cause, whose branches bear no proportion to the stem, and have no suckers. All of the Pine kind come nearer to this definition than any other plants I am acquainted with. A Fir has so far this principle in it, that if it loses its top shoot, the only branch that will rise to take the lead will be from the top, not from the sides; so that the natural bent of the tree is to ascend with a leading shoot, and the higher the shoot the more it is disposed, and the lower the shoot the less is it disposed, from two causes, one the reverse of the above; and the second, the top having taken the lead, the lower became less disposed than what they naturally would have been from their situation alone. The Birch seems to be endowed with these properties, and the Poplar I believe has nearly the same.

THE END.

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