Observations on the nature, longevity and size of trees / by Alexander Harvey.

OBSERVATIONS

ON THE

NATURE, LONGEVITY, AND SIZE

OF

TREES.

BY

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OBSERVATIONS

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NATURE, LONGEVITY, AND SIZE OF TREES.

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It is often asked, both in regard to trees generally, and also in respect of particular kinds of trees, *e. g.* the oak, the elm, the fir, &c., How long do they naturally live? And what is the size to which they naturally grow?

These questions manifestly involve the assumption, that every tree is a single or an individual object, in a sense precisely analogous to that in which an ox or a horse is so regarded; and they proceed on the principle that, however the appointed term of life and size of organism may vary in different kinds and species, all living beings, without exception, are subject to the laws of a limited duration of life, and of a definite size of organism.

This principle is unquestionably a sound one. No law of nature is more absolute or universal in its operation than the law of mortality. Every thing that lives, be it animal or vegetable, exists as such only for a certain time, on the expiry of which it passes into the state or condition of death. Nor is this left to be brought about by accidental causes. By these, indeed, it is often induced; but, independently of any

such, the cessation of its vital actions, and the loss of its vital properties, is a fundamental law of the constitution of every living being. The provisions to which it owes its existence, and by which its vital actions are for a time performed, necessarily involve the extinction of its vital powers. Such changes are gradually wrought in it by the very agency of its vitality as are ultimately incompatible with the longer continuance of life, and death follows as a matter of course. And those changes are attended by, if they do not essentially consist in, a gradually increasing languor or sluggishness in the activity of the vital processes, and by a corresponding density and rigidity of the textures composing the organism—constituting a state to which the name of old age is given, which obtains uniformly when life is not prematurely cut short, and is indicative of the approach of death. Again, all organized beings have a definite size or bulk of organism. Of lifeless inorganic bodies, it cannot be affirmed that they possess any such quality, being smaller or larger to any conceivable extent, according as circumstances may determine. It is otherwise, however, with animal and vegetable organisms, which have naturally a fixed or standard size to which they grow, and from which they never greatly deviate. This fact in their history may not perhaps be so obviously true as that of a limited duration of life; nevertheless it can be shewn to be an equally general one, and the exceptions to it to be only apparent, not real.

But, acquiescing in the truth and universality of the principle now referred to, it may be confidently asserted in regard to trees, that, on the assumption stated as to their nature—to wit, that every individual tree is an individual plant—there are many facts in their history which it is difficult to reconcile with that principle; and, generally, that nothing definite or satisfactory has yet been ascertained respecting either the natural longevity or the natural size of any one species of tree,—a circumstance which contrasts remarkably with the precision of our knowledge, so far as it goes, as to these particulars in the case of animals, and the more, from the facilities that exist for making observations upon trees.

The assumption, however, is, I apprehend, a false one. It may be shewn, I think, in opposition to it, and it is the design of the following observations to prove, that a tree is actually a collection of distinct individual plants of the same species, the production of a series of successive years, and that of these plants each lives only one year, attains its full size within the year, and makes provision, in the form of buds, for the evolution of similar plants the following season :—the plants of each year shooting up in spring from buds formed by the plants of the previous year, and growing *parasitically* on the *persistent dead remains* of these ; acquiring their maturity in summer, and reaching to the height of a few inches only—seldom at least exceeding one or two feet ; passing into the state of old age and eventually dying in autumn—save only the buds which survive the winter ; and speedily after their death undergoing decomposition and disappearing, the dead stems and roots, however, remaining, to serve the purposes of a *temporary* soil, and of a *permanent mechanical support* to the plants of next year.

According to this view, a tree is nothing more than a congeries of annual and comparatively small-sized and slender plants, the propagation of which, from year to year in all time coming, is effectually provided for by buds; and the accumulation of which *en masse*, by the living growing as parasites on the residue of the dead, necessarily keeps pace with the annual succession of plants. And if this be the true account of the nature of trees, and of the mode of their formation, it will of course follow, that a tree is an individual precisely in the same sense as a body-corporate, or as a genealogical tree, and that,—contrary to the common opinion, but consistently with the principle before adverted to,—*there will be no limit*, except from purely accidental causes, *to the size it may attain, or the number of years it may live.*

The views thus briefly set forth appear to me to possess considerable interest in relation to the questions stated at the outset, inasmuch as, if well founded, they supply us with principles for the satisfactory solution of them, and thus serve at once to give precision to our ideas, and to relieve our cu-

riosity in regard to the natural longevity and size of this class of objects. Moreover, they seem to me peculiarly interesting, as evincing the essential *unity* of the plans in this department of His works of the Author of Nature, and as affording unequivocal indications of *design*. For, if we can perceive the same general principle to pervade alike the economy of *tree-plants*, which *appear* to live for ages and to grow to an enormous size, and that of confessedly annual and obviously very small plants, which completely disappear at the close of every season, it cannot but enhance our conviction, that the whole vegetable kingdom, the extremes of it thus meeting, proceeds from one and the same Creator. And such a principle we may perceive ; for both the one and the other are strictly annual and moderately sized plants, and are constructed exactly on the same general plan. Certain peculiarities there are, indeed, in the economy of tree-plants, viz., the property of growing as parasites on their fellows, and the persistency of their dead stems and roots,—peculiarities leading, in the course of years, when the species is greatly multiplied, to the formation of the masses known as trees. These peculiarities, however, in a physiological point of view, or in reference to merely physical causes, are entirely unessential. They are important only in relation to final causes, or as furnishing conclusions in Natural Theology. And with reference to these they are most important. For they clearly bespeak a design or purpose in the mind of the Creator: provisions they are of His, whereby, out of short and slender annuals, He forms *timber* for the use of man,—a substance which, if not indispensable to the existence, ministers at least in a thousand different ways to the comfort and wellbeing, of our race ; but the production of which would be impossible, did not the economy of the plants in question thus differ from that of all other annuals.

The principles now advanced in regard to the nature of trees have no pretensions to originality. Though not suggested by any knowledge or recollection of the circumstance, they are, in fact, the principles long ago put forth by M. Du Petit Thouars, respecting the nature of buds. The applica-

tion of them, however, here made to the questions already specified, does not appear to have entered into the view of that ingenious physiologist. So far, at least, as I can gather from the writings of Richard, Lindley, and others, M. Thouars seems to have applied them only in explanation of the nature and the mode of formation of the woody layer annually produced in exogenous trees. At all events, both the principles themselves, and the application I have made of them, manifestly differ from the views commonly entertained as to the nature and the natural longevity and size of trees. Nor can I find anything amounting to a distinct recognition or detailed exposition of them in any of our systematic works on Botany. If they are correct, however, their scientific interest and importance clearly demand this, even in the merest outline that can be given of vegetable physiology. And as the evidence in support of them appears to me conclusive, I am inclined to hope that the present attempt to bring them prominently forward may not be deemed undeserving of attention.*

In proceeding to vindicate, and more fully to illustrate, those principles, it is desirable, in the first instance, to inquire what is known in regard to the natural longevity, and the natural size of trees, according to the view usually taken of the nature of this class of objects. The inquiry, by shewing how imperfect that knowledge is, and how difficult it is to impart to it any character of precision, will naturally pave the way to the consideration of the principles in question, and probably dispose to a more cordial reception of them.

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* Since these observations were put together, I have seen a foot-note in Roget's Bridgewater Treatise (vol. ii., pp. 555–6, 3d Ed.), wherein the views promulgated in the text are briefly hinted at, on the high authority of De Candole. More recently, I have had the satisfaction of finding a clear and distinct statement of them in Dr Carpenter's *Manual* of Physiology. "A forest tree may go on extending itself to an almost indefinite extent;" "but the increase is produced, not so much by the continued development of the individual, as by the continued production of new individuals which remain in connection with the original. Thus, each bud of a tree may be regarded as a distinct individual; because, if placed under favourable circumstances, it can maintain its life by itself, and can perform all the actions proper to the species."—Pp. 2, 3.

I. Viewing, then, every individual tree as an individual plant, the popular notion seems to be nearly limited to this, that, as compared with any known animals, the generality at least of trees are very long-lived, and capable of attaining to a gigantic size. It is believed, indeed, that, equally with all other living beings, they are subject to the law of mortality, and reach only a certain size, and, perhaps, that the appointed term of life and size of organism vary in each species of tree ; but, beyond the general fact just stated, little appears to be known, and there seems to be a general persuasion, that nothing definite has yet been ascertained on the subject. Even in works on Botany and Vegetable Physiology, little information is to be had, and none that is satisfactory. For the most part the subject is passed over in silence, or, if treated of, the observations made are of the most meagre description. M. Richard, for example, in his *Nouveaux Elemens de Botanique*, has sections respectively entitled, " De la durée des Arbres ;" " De la hauteur des Arbres ;" " De la grosseur des Arbres ;" from the first of which we learn merely, that trees growing in a suitable soil may live for ages—the olive for about 300 years—the oak for about 600—the boabab, according to the (erroneous) calculations of Adanson, for about 6000 years ; and that the cedars of Lebanon appear to be in a manner indestructible ; from the second, that certain trees acquire, after many years, a considerable height and thickness, and, in general, that the greatest increase in height which the forest trees of France arrive at, is from 120 to 130 feet, those of America, however, often exceeding 150 feet; and, from the third, that the trunks of individual boababs have a girth of 90 feet, of a dragon-tree in the Canaries, a girth of 45 feet, of a sycamore, in South Carolina, a circumference of 62 feet ; and, generally, that in France certain trees which he specifies have trunks with a girth of from 25 to 30 feet.*

That trees, as such, are naturally very long-lived, and grow to a vast size, is indeed most certain. In Britain there are still extant, and growing, oaks, and probably elms, which were

* Richard, Op. cit., 5th Ed., pp. 150–1, 2.

planted before the Conquest, *i. e.*, more than 800 years ago. And there are yew trees much older still; *e. g.*, some at Fountain's Abbey, near Ripon, in Yorkshire, are believed to be more than 1200 years old; two in the churchyard of Crowhurst in Surrey, 1450 years; one at Fortingall in Perthshire, from 2500 to 2600 years; one in Brabourn churchyard in Kent, is said to have attained the age of 3000 years; and another at Hedsor in Bucks, which is still in full vigour, and measures above 27 feet in diameter, appears to be upwards of 3200 years old.* But, perhaps, the most remarkable species of tree, in respect of size and longevity, is the Banian of the East,—the *Ficus indica*. Every branch from the main or primary trunk throws out its own roots at first in small tender fibres, and several yards from the ground, but which, growing thicker, and reaching the surface, strike at length into the soil. These gradually increase till they form large and distinct trunks, and in their turn send out new branches from the top, which, in time, suspend their roots, and become trunks also. The tree thus continues to progress and extend itself indefinitely. An individual of this species, growing in an island in the river Nerbudda, is believed to be identical with one that existed in the time of Alexander the Great, and which, according to Nearchus, was even then capable of overshadowing 10,000 men. It is not now, indeed, so large as formerly, parts of it having been carried away by floods. What remains of it, however, affords ample room for 7000 persons to repose under its shade, and has a circumference of 2000 feet, measuring only round the principal stems. The overhanging branches cover a much larger space. The chief trunks of this *single* tree greatly exceed our English oaks and elms in thickness, and are above 350 in number; while the smaller stems are more than 3000, and every one of them is becoming thicker, and sending out new branches and hanging roots.

Such statements, however, as these, in regard to the Banian, the yew, &c., or those given by Richard, convey to us

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* Dr Dickie, in Quarterly Journal of Agriculture for March 1843; Church of England Magazine, vol. xxi., p. 192.

no idea whatever of the natural or allotted duration and size of trees. They do not even inform us as to the extreme limits to which their lives may be protracted, or the extreme height and thickness to which they may grow. For it may be confidently asserted, that, in different parts of the world, there are individuals of almost all kinds of trees which have already stood as many years, and grown to as great a size as any of the species have ever been known to do, and many of which are still vigorous and growing, and, what is remarkable, exhibit as yet no signs of what can properly be regarded as old age. Much of their trunk may be hollowed out from decay of the heart-wood, and many of their larger branches may have been destroyed in the lapse of time; but the great body, or a large part of many of them, remains, and evinces as great activity in the vital processes as ever, *i. e.*, is the seat of as vigorous a circulation of sap, and forms and puts forth leaves and flowers, and fruit, as large and perfect as in its earliest years, and is every year having additional bulk given to it.

The considerations now stated, and especially the facts relative to the Banian, may very naturally suggest a doubt, whether, with respect to their longevity, there is not some peculiarity in trees beyond a merely very prolonged existence; nay, though (according to the common opinion as to their nature) it seems absurd seriously to entertain the idea, whether there is not in their case, so far as yet appears, an actual exemption from the law of mortality. Some such idea, at least, may not unreasonably be supposed to have been in the mind of Richard, when he remarked of the cedars of Lebanon, that they appear to be indestructible,—a remark which is still more applicable perhaps to the Banian, but which, if it has any meaning, is equivalent to saying, that they appear to live for ever, and obviously involves the assumption that the law of mortality is not universally operative.

Such is the present unsatisfactory state of our knowledge with respect to the longevity and the size of trees, regard being had to the popular notion as to their nature. In the case of each species of animal, the natural term of life, and the appointed size of organism, are either known to us, or may,

without difficulty, be ascertained by us. With regard to trees, however, of whatever species, these points in their history may be said to be absolutely unknown to us, and that, too, as before observed, notwithstanding the facilities which exist for making observations upon them. Every such object is looked upon as a single individual, in the same sense that a man or a dog is so regarded; and while it is believed to be subject to the law of mortality, and to the law of a definite size of organism, it is believed also to be, as compared with any known animal, very long-lived, and capable of attaining to a gigantic bulk. But no more precise idea than this is entertained as to its longevity or its size, and even this view of the matter is beset with considerations of perplexity.

II. But if the principles formerly advanced in regard to the nature of trees are well founded, that perplexity will be obviated, and an accurate idea may be formed as to the longevity and the size of this class of objects.

Agreeably to those principles, a tree is not what it is usually regarded, nor what it appears to be, a single or an individual *plant*, capable as such of living for many years or ages, and of attaining to an enormous size. On the contrary, it is a collection, congeries, or congregation of individual plants of the same species, the production of a series of successive years, and consists, at mid-summer, partly of living and entire plants, the produce of the existing year, and partly and chiefly of the persistent dead remains of the plants of bygone years. And of the individuals composing it, each lives only one year, reaches its full size within the year, and on dying at the close of it completely disappears, save only the buds which survive the winter, and the dead stems and roots which are to serve the purposes both of a temporary soil, and of a permanent mechanical support to the plants of next year. And, accordingly, the production of the aggregate of dead and living plants is referable to the living plants of each year growing parasitically at the extremities of, and also either around (as in Exogens) or within (as in Endogens) the dead stems and roots of the plants of the previous year.

Those principles, however, it may be remarked, are only a

part of a proposition in vegetable physiology of a still more general character; and it may conduce to a clearer apprehension of them, to bring that proposition formally into view. It may be thus stated:—That all plants, without exception, even those called perennial, are strictly *annual* productions, live therefore only one year, and reach their full dimensions within the year; that is to say, that all plants spring up anew each year, either from seeds or buds, and attain their maturity within the year,—forming in the course of it either seeds or buds (or both) for the development of similar plants the following year; that as the season advances, their vital actions languish, and a change in the matter of their organism takes place, both constituting their old age; that at the close of the season they die; that then the structures composing them speedily undergo either an entire or a partial disintegration; in the one case, wholly disappearing, in the other, some portion remaining to serve ulterior purposes in the vegetable economy of nature, but still remaining only as dead vegetable matter. And, in connection with, and as forming part of this general proposition, that the only difference between the plants called annual, and those called perennial is, that while the former produce seeds only for the propagation of the species, and are reared annually from seeds alone, the latter produce both seeds and buds, and *qua* perennial, spring up each year from buds; and, therefore, that seeds and buds are potentially of the same nature; the only difference between them, and that not a uniform one, being, that seeds are free and detached, buds fixed and adherent.*

If, now, the question be formally proposed in regard to any

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* M. Du Petit Thouars; see Richard, Op. cit., p. 103.—"Les bourgeons donnent naissance à des *scions* ou jeunes branches chargées de feuilles, et le plus souvent de fleurs. Chaque bourgeon a une existence en quelque sorte independante de celle des autres. M. Du Petit Thouars les regarde comme analogues, dans leur developpement et leur structure, aux embryons renfermés dans l'interieur des graines, qui, par l'acte de germination, developpent une jeune tige que l'on peut comparer, avec juste raison, au scion produit par l'evolution d'un bourgeon. Aussi donne-t-il à ces derniers le nom d'*embryons fixés* ou adherens, par opposition à celui d'*embryons libres*, conservé pour ceux renfermés dans l'interieur de la graine."

given tree, How long does it naturally live? the answer must be—contrary, however, to the common opinion—that there is no limit to the age it may attain, or the number of years it may live, except what is imposed by purely *accidental* causes; because, according to the principles insisted on as to the nature of trees, there is no natural limit to the annual propagation from buds of the individual plants of which every such object is truly composed. According to this view, the observation of Richard formerly quoted, to wit, that the cedars of Lebanon appear to be indestructible, is perfectly intelligible, involves no violation of the principle that all living beings are subject to the law and the dominion of death, and is applicable besides to all trees. And if it be asked in respect of any given tree, what is the size to which it naturally grows? the proper answer is—contrary, again, to the popular belief—that there is no natural limit thereto, and no actual limit, except from such accidental causes as prevent the formation of buds, or the evolution of new plants therefrom.

If, however, the like questions be put in respect, not of individual *trees*, but of individual *tree-plants*—of the oak, the elm, the fir, for example, viewed simply as plants, and independently of their parasitic relations to others of their respective species, very different answers must be returned. The answer to the former question will be, that they live, one and all of them, only for a single year, and are, as regards their longevity, on the same footing with confessedly annual plants. And in answer to the latter, it may suffice to state, that, as they all attain their maturity within the year, so the size of any of them may be accurately judged of by observation of the seedling plants of its kind growing in the forester's nursery, or of the yearly shoots issuing from the buds on a tree of that particular species; and that while subject to some variety, it does not, in general, in any species, exceed a few inches, or, at the utmost, a very few feet.

But if the representation which has been made of their nature is well founded, how comes it, it may be asked, that we nowhere find, what we might expect to see, trees evincing by their appearance that they are probably coeval with the creation of the world—coeval at least with the deluge, or the

age immediately succeeding that catastrophe? Assuming that none such exist, it is, I apprehend, a sufficient answer to that question, to say, that no tree then existing has been able to withstand the "manifold changes and chances" of time. All dead organic matter is subject to, and sooner or later undergoes, chemical change and disintegration; and by reason thereof the heart-wood of every tree disappears after a time, leaving the trunk hollow within, often reducing it to a mere shell, and thus necessarily weakening the mechanical support given by it to the superincumbent mass. Again, after a tree has stood for many years, the vast height and breadth of surface presented to the wind will enable this to act on it to its destruction at an advantage infinitely greater than in its earlier years. And it is obvious to remark, that the older a tree becomes, its liability to be uprooted by any passing storm of wind increases in a double ratio; on the one hand, from its greater size, and on the other, from the more extensive decay and removal of the heart-wood. Add to these, the exhaustion of nourishment in the soil, which may, and often does occur, and the inevitable occurrence, in the course of ages, of a thousand other destructive influences—of frost, fire, lightning, hurricanes, the necessities and the caprices of man himself,—and a calculation of chances puts it beyond all doubt, that every tree, or almost every tree, then existing, must long ere now have disappeared from off the face of the earth.

It remains to substantiate the allegations that have been made in regard to the *nature* of trees. If these can be established, the inferences as to their natural longevity, and their natural size, must necessarily be true.

Now, the evidence to be adduced will consist in shewing, *first*, That the annual growths proceeding from the buds constitute, severally, perfect and independent plants; and that a succession of such plants may be kept up from year to year, for an indefinite period, from buds alone; and, *secondly*, That at the end of the year, the annual plants or growths in question, with the exception, of course, of the newly formed buds,

cease to be, and never afterwards become, the seat of any vital action.

I. First, then, the annual growths emanating from the buds constitute, severally, perfect and independent plants; and a succession of such plants may be kept up from year to year, for ever, from buds alone.

On the return of spring, "when the earth, by an annual miracle, rises again, as from her grave, into life and beauty," we see the buds on each of the stems of the previous year, first swelling, and afterwards sending out an entirely new stem, new leaves, flowers, and buds, all of which are pervaded and connected together by a new set of circulating vessels or cells. And in the course of the season seed forms and is matured. Now, in this annual formation, we have issuing from the buds on the stems of last year all the parts essential to the constitution of a perfect plant; and on the new stem of this year we have buds provided for the evolution of such a plant next year.

With the view of shewing more distinctly, at once the individuality and the independency of the growths thus formed, and their claim to be regarded as perfect plants, and the ability of each of them to reproduce its kind annually in endless perpetuity from buds, reference may, in the first instance, be made to what obtains in the potato-plant—a plant which, though not a tree, contains all the elements of one, and is equally perennial in its duration as any tree. The tuber familiarly known as the potato bears an exact resemblance to, and is essentially of the same nature with, the yearly shoot or stem of a tree. It is, in fact, an underground stem, consisting of a layer of bark, and a layer of woody tissue, enclosing a mass of pith, and furnished with buds. This underground stem, when planted in spring, sends out from each of its buds a growth which has a stem (underground), and leaves and flowers, and forms buds and seed, structures which are exact counterparts of those composing the growths issuing from the buds of trees. Does any one doubt that the annual potato-growths constitute perfect and

independent plants? Does any one doubt that from the buds alone, without ever having recourse to seed, a succession of such potato-plants may be kept up from year to year for ever? I apprehend not. If so, we are warranted in ascribing the same character to the annual growths of tree-plants emanating from their buds, and in inferring that the succession of them from year to year, as congregated together and constituting a tree, may equally go on for ever.

The only difference, in fact, between a tree-plant and the potato-plant, lies in the situation of their respective stems, in the changes which these and their roots respectively undergo after losing their vitality, and in the habitudes of their respective offspring; the stems of the one being above, those of the other under ground; the dead stems and roots of the one continuing undecomposed and persistent for years or ages, those of the other decaying early the following year, when planted or left in the ground, and passing away; the offspring of the one growing together, and as parasites, on the persistent dead remains of their parent, those of the other striking down singly and separately into the soil, and having no connection with any portion of their parents, the residue of which has, in fact, ere now wholly disappeared, and nothing remaining around which, as a common centre, and a mechanical support, they could grow as parasites. Had it suited the purposes, immediate and remote, which the Author of Nature had in view in giving them existence, we might have had the respective peculiarities in the economy of the plants completely reversed,—the potato-plant and its progeny growing together and parasitically, and forming by their aggregation a true potato-tree, fantastic, doubtless, in its aspect, but possessing, as a whole, the same individuality which common opinion ascribes to an ordinary tree, and the separate plants being regarded and spoken of merely as annual growths; the tree-plants, on the contrary, growing and extending themselves year by year as distinct and separate individuals, and the so-called annual growths being looked upon as perfect and independent plants.

Reverting, now, to what takes place in trees, the processes of grafting, of budding, and of slipping, seem to me to furnish

sufficient evidence that the allegations made as to the annual growths are well-founded, and indeed to be explicable only by a reference to the principles involved in them. From the yearly bud taken from one kind of tree and duly grafted on another, of the same natural family, though of a different species, we obtain the following year a growth, and in the course of years a tree, exactly similar to the tree, and to the other growths of the tree, whence it was derived; the tree thus formed, though growing on another, preserving, nevertheless, its own distinctive character, having its own peculiar leaves and blossom, producing its own peculiar fruit, and being in every way as perfect a tree as if it had been raised from a seed, and had grown up independently from the ground. And it is not unimportant to observe, as instanced in our various "fruit" trees, that any particular variety may be, in this way, not only multiplied indefinitely, but preserved *in perpetuity*, although the original, or any single tree of that variety, will not (from accidental causes, however) continue to last for ever. Similar observations apply to the indefinite multiplication and endless perpetuation of such trees (*e.g.* the willow) as admit of being artificially propagated by slips or layers. And it is thus that the Banian tree extends itself naturally, dropping branches provided with buds, fixing themselves in the soil, and becoming vast trunks, and these readily convertible (I presume) into separate and perfectly independent trees, by artificially severing their connections above. And the trees thus produced admit of a similar extension, and the trunks proceeding from them of a similar conversion.

The evidence adduced under this general head seems to me complete and decisive. It may be asked, however, where are the *roots* of the annual growths (and alleged perfect plants) in trees? And, again, what is there in avowedly annual and perfect plants, or even in such perennial plants as the potato, analogous to the *woody layer* in exogenous trees, which extends downwards from the base of the shoots into the soil?

These questions may easily be answered. With reference to the former, it may be remarked, that the circumstance of the growths in question being destitute of true roots, sup-

posing this to be the case, would by no means take from them the character of entire and perfect plants, if it could be shewn that the office of roots is otherwise adequately provided for. And, with reference to the latter, it may be observed, that the fact of a structure entering into their constitution, not existing in other plants, would not at all affect their claim to be so regarded, particularly if it could be shewn that that structure is required to meet some condition of their existence peculiar to themselves, or to serve some ulterior purpose in the economy of nature. And the woody layer, it is to be remembered, is strictly an annual formation, and so far accords with the view taken of the growths in question as being annual plants.

Now, the structure referred to—the woody layer—clearly subserves, immediately, the purpose of a mechanical support to the growths or plants of the same year's formation with itself, and remotely that of producing timber. Without it trees could scarcely grow at all, or, if they could, would be of little use to man. But it serves also the office of roots to those growths or plants, being the channel by which the nutritive matters in the soil are conveyed upwards to the growing stems, and leaves, and flowers. And if it thus serves these various purposes, the questions stated must be regarded as satisfactorily disposed of. The only question will be, whether the woody layer, in its origin and mode of formation, be actually of the nature of, or rather identical with, roots, and only secondarily intended for a mechanical support, and for the production of timber; or whether it is truly a special formation for the accomplishment of these latter objects, and only virtually of the nature of roots?

After what has been stated, however, this other question is of no real practical importance in relation to our present inquiry. The woody layer may be formed in the manner that M. Du Petit Thouars supposes, or in that insisted on by M. Mirbel and others. If in the former, it constitutes true roots, and is nothing more than "a mass of roots;"* if in the latter, it is only virtually roots. The mode of its forma-

* Dr Lindley, *Introduction to Botany*, First Edition, p. 245.

tion, however, and its precise character, is unimportant. Still, if it is genuine roots, as M. Thouars maintains, and as Dr Lindley and Dr Carpenter agree with him in believing,* it will at once follow that the growths in question have roots, and that having these, they have no extraneous element entering into their composition. And a positive and very valuable fact will be added to the general body of evidence already adduced in support of the view, that those growths possess the character ascribed to them.

II. Secondly, at the close of every year, the annual growths or plants, with the exception, of course, of the newly-formed buds, cease to be, and never afterwards become, the seat of any vital action, *i. e.*, they die, and never afterwards live.

This is sufficiently obvious as regards the leaves and flowers, which wither, fall off, and completely disappear. It is equally true, however, of what remains of the other parts of the plants, *i. e.*, of the roots and the woody stems or shoots.

But on what grounds are we entitled to say that these parts then die, and never again live?

1. In the first place, because after the fall of the leaves, and during subsequent years, no growth or increase of the organic matter composing them takes place, as should be exhibited in an increase of their length and thickness, and produced in the way that the leaflet of spring is gradually developed into the full grown leaf of summer. They appear, indeed, to elongate and become thicker, *i. e.*, to grow in length and breadth. This growth, however, is not a real extension of the parts in question, as it is in the leaflet; it is a new and independent formation at their extremities, and either around or within them, and may, by examination, be seen to be quite distinct from them,† being, in fact, the roots and

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* "The most consistent account of its development is that given by Du Petit Thouars, who, followed by Lindley, regards the fibrous [woody] tissue as formed in the leaves, and growing downwards into the cambium, just as roots are prolonged into the soil. This view would liken the woody fibres to the roots of the buds; and such a comparison, though at first sight improbable, is fully borne out by facts."—Carpenter, *Principles of General and Comparative Physiology*, 1st Ed., p. 278.

† Lindley, Op. cit., p. 228 and p. 241, *et seq.*

stems of the new plants attached to and growing upon them.

2. In the second place, no removal, by interstitial absorption, of their substance, and replacement of this by new vegetable tissue, ever takes place. The tissue composing them undergoes no subsequent change of this kind. Once formed, it is never afterwards the seat of any change corresponding to the renewal of substance, which is continually going on in the living tissues of animals.*

And, with reference to this, it may be remarked, that the absence of any such change goes far to shew that, on their growth being completed, the parts in question are really dead. Judging from what obtains in animals, many of which truly live for years, it is not unreasonable to infer that a continual or frequent change of substance is essential to the maintenance of the vitality of any structure which really continues for any length of time to be the seat of vital action. The brain, for example, of an animal is possessed of vitality, and performs important vital actions during the whole time that the animal lives ; but the maintenance of its vitality, and the performance of its vital actions, appear to be dependent on, and to involve, a continual change in the substance of the organ. Moreover, the rapidity of that change seems to be exactly proportioned to, and to afford a measure of, the frequency and energy wherewith the vital actions of the organ are carried on,—to be more rapid when these are often and actively performed, and less rapid when they are seldom and feebly exerted. Is it, then, an unfair inference, that the absence of that change, and the inability to undergo it in any tissue, are tantamount to this tissue being the seat of no vital

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* "The economy of vegetables is fitted for their office of constantly converting inorganic into organized matter, by this peculiarity, that their nutrition is maintained without any such function as the interstitial absorption of animals ; and necessarily involves, during the whole time that any living actions are going on, continual additions to their substance."—Alison, *Outlines of Physiology*, 3d Ed., p. 12.

"In vegetables there is none of that absorption of the different parts which takes place in animals. The matter of which they are composed, being once deposited, is never taken up again ; whilst in animals there is a constant process going on, by which the old matter is taken away and the new deposited, and the organs thus renewed."—Dr Ware, in Smellie's *Phil. of Nat. Hist.*, Introduction, chap. ii.

action, or destitute of vitality, after its formation is completed?

3. In the third place, we know, that after a time the heart-wood decays and disappears, and that this change may go to such an extent as to destroy a large part of the entire thickness of the trunk, without, however, in the least impairing the vegetation going on at the extremities, and on the exterior of the tree. This it is easy to understand, according to the view here taken of the nature and duration of life in trees; but very difficult on the supposition of an entire tree constituting a single or an individual plant, and being endowed with vitality in its every part. On this supposition, such a change occurring in the heart-wood should spread to the adjoining living tissues, and sooner or later, but before long, destroy the vitality of the whole fabric. This, however, does not happen; nor is the complete and premature decay of an entire tree ever to be ascribed to the agency of such a cause.

It may be supposed, however, that although the old stems and roots, after the year of their formation, are the seat of no nutritive organic change, and actually decay and disappear in the course of years, the circulation of the sap moving through them the following and during several subsequent years, is a clear proof that they retain their vitality for a much longer period than is here allowed.

It does not therefore follow, however, that the parts in question are alive. To warrant such an inference, it must be shewn that they contribute *actually* and *actively* towards the movement, and that, too, in a way not referable merely to their porosity, or to any other simply physical property which they may possess. The experiment is well known of strewing cress or mustard seeds on a vessel covered with flannel, placing that in a saucer filled and regularly supplied with water, and of finding the seeds vegetating and covering the vessel with living plants—the flannel, by reason of its porosity, conveying the water upwards from the saucer to the living seeds and plants. No one, however, would say that the flannel is alive. No more are we entitled to affirm, that the old stems and roots of a tree are alive, because of the sap moving through them to the growing parts above. They may be merely the medium or channel of its transmission

and aid in effecting this in the same way that the flannel does.

Unquestionably, the movement of the sap is a vital action, and due to vital agency. This agency, however, has its seat in the living buds, and in the living structures proceeding from them, and actually growing. It is directly connected with, and dependent on, the vital processes going on there during the spring and summer.* The first movement of the sap in spring is in the immediate vicinity of the buds. The fluid there, previously at rest, is the first to be set in motion, and its movement is determined by the act of vegetation beginning in the buds under the influence of heat and light. The subsequent increase in the activity of that process demanding additional and greater supplies of sap, an agency is exerted which operates downwards in the direction of the soil, and causes the nourishing fluid to ascend. And it is farther important to remark, that the movement of sap from the soil upwards through the trunk to the parts where vital actions are undoubtedly going on is, the whole season through, regulated by the activity of these actions. Of all this we have several decisive proofs. If a branch of a tree, standing in the open air, be introduced into a hot-house at a time when no vegetation, and no circulation of sap is going on in the tree, the buds of that branch will vegetate, and sap will circulate through it, while as yet nothing of the sort is in progress in any of the other branches of the tree.† It is quite inconceivable that the roots and stems should exert so exclusive an agency, or have any share in producing so partial a change. Again, if the buds be cut off from a branch prior to the commencement of the annual process of vegetation, no sap will pass into the branch during the entire spring and summer, although the other branches, not thus mutilated, will be filled with it. Once more, if, at a later period in the

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* "It is evident, then, that the force, whatever be its nature, by which the continued movement is kept up, must be developed by the processes to which that movement is subservient; in other words, that the changes involved in the acts of nutrition and secretion, are the real source of the motor power."—Carpenter, *Manual of Physiology*, p. 315.

† Alison, *Outlines of Physiology*, p. 70; Carpenter, *Manual of Physiology*, p. 313.

season, the leaves be stripped from off a branch, the flow of sap through it will speedily, if not immediately, cease.

What may be the nature of the agency thus exerted in the growing buds and leaves which causes the sap to circulate, and regulates the quantity of it passing through the old stems and roots, it is not easy to say, and for our present purpose unnecessary to inquire. But the old stems and roots may be no farther concerned in it, than as being the channels through which the nourishing fluid passes upwards from the soil. And no facts yet known to physiologists demonstrate that they have any other share in it.

But, in the course of the season, there is a *descending*, as well as an upward, movement of the sap. And the former must be regarded as being equally of a vital nature as the latter, and equally due to vital agency. Does not that movement, at least, argue vitality and vital action in the old stems and roots? I apprehend not; and for this reason, that while the ascending current seems referable to the processes going on in the buds and leaves, the movement in question appears to be connected with the formation of the woody layer all over the exterior of the tree, and referable to the process by which that structure is evolved. Whether the woody layer be of the nature supposed by M. Thouars, or of that insisted by other physiologists, is immaterial. It is distinct from the woody layer of previous years, and is of the same year's formation with the existing leaves and flowers. And it requires for its organization equally as these do for theirs, a supply of prepared or elaborated sap. But the sap is elaborated only in the leaves; and as the woody layer extends from the base of these *downwards* to the extremities of, and even beyond, the roots of last year, so that sap can only be supplied from *above*, and must *descend*, in order to the formation of the tissue in question. This descent, however, may be solely connected with that formation, and there is no proof that it has any thing to do, directly, at least, with changes going on in any of the other structures of the tree.

It has thus, it is hoped, been satisfactorily made out, *first*, that the growths emanating from the buds of trees constitute perfect and independent plants; and, *secondly*, that what remains of them, after the fall of the leaves and flowers, and fruit in autumn, with the single exception of the new buds,

ceases to be, and never afterwards becomes, the seat of any vital action.

And if this be conceded, it will probably be allowed also, that the view which has here been taken of the nature and of the natural longevity and size of trees is well-founded; that is to say, that a tree is simply a collection of annual plants of the same species, the production of a series of successive years,—the individual plants of each year shooting up in spring from buds adherent to the persistent dead remains of the plants of the previous year, growing as *parasites* on these remains, putting on the characters of *old age* in autumn, and speedily thereafter dying, having made provision, however, in summer, in the form of buds, for the reproduction of similar plants the following year. And that being thus evolved, and thus growing from year to year, and having no *natural* limit to their increase and aggregation, there is no natural limit to the age or to the size to which the tree collectively formed by them may reach.

The statement repeatedly made, that the persistent dead remains of the plants of the previous year serve as a *mechanical support* to the plants of the following year, does not appear to require any explanation. With regard to the other statement, that they serve as a *temporary soil* to these plants, it may be observed, that the buds are always placed in intimate connection with the *pith* or *medulla* of the shoots to which they are adherent, and that the pith is soft and juicy in spring, but in the course of the season becomes dry and shrivelled. According to M. Thouars, the buds vegetate in the first instance at the expense of the pith, deriving from it the materials of their development in spring. When this supply of nourishment is exhausted, or at least when the buds send out their own proper roots, *i. e.*, the fibres formerly mentioned, which, by their interlacement form the woody layer, another supply is provided in the succulent *cambium* into which those fibres pass, and along which they descend to the soil. From this, of course, is ultimately derived the materials, or a part of the materials, necessary for the growth of the young plants emanating from the buds.