vegetables consists of nothing more than a mere spongy cellular substance, forming, indeed, an admirable reservoir for moisture; and hence of the utmost importance to young plants, which, in consequence of their want of leaves and branches, whose surfaces are covered with the bibulous mouths of innumerable lymphatics, would otherwise be frequently in danger of perishing through absolute drought; but gradually of less use as the plant advances in age, and becomes possessed of these ornamental appendages; and hence, except in a few instances, annually encroached upon, and at length totally obliterated by the surrounding lignum.

All these lie in concentric circles; and the trunk enlarges, by the formation of a new liber or inner bark every year; the whole of the liber of one year, excepting indeed its outermost layer, which is transformed into cortex, becoming the alburnum of the next, and the alburnum becoming the lignum. Such, at least, is the common theory, and which seems to be well supported by the experiments of Malpighi and Grew: but it has lately been controverted by Mr. Knight, who contends, that the liber has no concern in the formation of new wood, which proceeds from the alburnum alone, a new layer of alburnum being formed for this purpose annually. I cannot discuss the argument at present: nor is it of any great importance; since, under either system, it is obvious that a mark of any kind, which has penetrated through the outer into the inner bark, must in a long process of years be comparatively transferred to the central parts of the trunk. On which account we often find, in felling trees of great longevity, as an oak, for example, the date of very remote national eras, and the initials of monarchs, who flourished in very early periods of our national history, stamped in the very heart of the timber on its being subdivided.

Some of these memorials are very curious, and M. Klein, the well-known Secretary of Dantzic, has given various examples in his letter to Sir Hans Sloane, bart., the President of the Royal Society.* One of these consists of a long series of letters discovered, in 1727, in the trunk of a full-grown beech, near Dantzic, in land belonging to the family of Daniel Berckholtz. The letters D. B. were chiefly conspicuous in the solid wood; the wood towards the bark, and that towards the heart, that is, in each extremity, "bearing not the least trace of letters." M. Klein relates another example from the Ephemerides of Natural Curiosities,† recorded by Joannes Myerus. It consists of a thief hanging from a gibbet, apparently drawn by nature's own pencil in the timber of a beech-tree: as also the figure of a crucified man, found in a tree of the same kind; and that of a chalice with a sword, perpendicularly erect, sustaining a crown on its point; which was preserved at the Hague, and had been seen by himself.

Such marks were formerly attributed to miraculous intervention, or regarded as marvellous sports of nature: but the hints now offered will easily explain their origin.

Foreign substances have often been found imbedded in the same way, having at one time been sunk into the inner bark, or penetrated it by a wound or other excavation, and afterward covered over with new annual growths of liber and alburnum. Thus Sir John Clerk gives an account of a horn of a large deer which was found in the heart of an oak in Winfield Park, Cumberland, fixed in the timber with large iron cramps, with which, of course, it had been fastened on.‡ And we are hence able to account for the occasional detection of a capricorn beetle,§ or other insect which has been found in the centre of a trunk, the animal having crept into an accidental cleft, and either died there naturally, or been arrested and imprisoned by the secretion of the matter of new inner bark while in the torpitude of its aurelian state. And hence, indeed, the cause of the very wonderful phenomena of toads or frogs being at times found in a like situation; having in the same way been impacted in the hole or crack into which they had crept, by the glutinous fluid of the inner bark, during sickness or a protracted winter sleep. Some

* Phil. Trans. for 1739, vol. xli. p. 231.
† Phil. Trans. for 1740, vol. xli. p. 448.
† Ephem. Nat. Cur. decad. iii. an. v. obs. 29.
§ Ib. 1741, vol. xli. p. 861.

of these are found alive when the tree is cut down, deriving both air and nutriment enough from the surrounding vessels of the tree during their imprisonment. In the Memoirs of the Paris Academy there is an example of a toad found in a tree that was proved to be a century old.*

As the series of concentric circles, produced in the trunk of a tree by the growth of every year, are still visible after the conversion of every other part into lignum, or hard wood, we can trace its age with a considerable degree of certainty, by allowing a year for every outer circle, and about two or three years for the complete lignification of the innermost.†

Independently of these more solid parts of the trunk or stem, we generally meet with some portion of parenchyma and cellular substance, and always with the different systems of vegetable vessels disposed in one common and uniform arrangement. The lower orders of plants, indeed, such as the annuals and biennials, consist almost exclusively of parenchyma or cellular substance, with an inner and outer bark, and the respective vessels of the vegetable system.

These vessels are adducent and reducent, or arteries and veins, lacteal or sap-vessels, and lymphatics. Many of these may be seen by the naked eye, and especially the sap-vessels: and the vascular structure of the whole has been sufficiently proved by Gessner, by means of the air-pump. The reducent or returning vessels are stated, by Sir E. Smith, to bring back the elaborated sap from the leaves to the liber for the new layer of the existing year.‡

The lymphatics lie immediately under the cuticle and in the cuticle. They anastomose in different ways through their minute intermediate branches, and, by surrounding the apertures of the cuticle, perform the alternating economy of inhalation and exhalation. Their direction varies in different species of plants, but is always uniform in the same species.

Immediately below these lie the adducent vessels or arteries; they are the largest of all the vegetable vessels, rise immediately from the root, and communicate nutriment in a perpendicular direction: and, when the stem of a plant is cut horizontally, they instantly appear in circles. Interior to these lie the reducent vessels or veins: which are softer, more numerous, and more minute than the arteries; and in young shoots run down through the cellular texture and the pith. Between the arteries and veins are situated the *air-vessels*, as they were formerly called; but which Dr. Darwin and Mr. Knight have sufficiently succeeded in proving to contain, not air in their natural state, but sap.§ They seem to be the true genuine lacteals issuing from the root, as, in animals, they issue from the villous coating of the intestinal canal. They are delicate membranous tubes, stretching in a spiral direction, the folds being sometimes close to each other, and sometimes more distant, but generally growing thicker towards the root, and especially in ligneous plants. These vessels also are very minute, and, according to numerous observations of Hedwig made with the microscope, seldom exceed a 290th part of a line, or a 3000th part of an inch in diameter.

The lymphatics of a plant may be often seen with great ease by merely stripping off the cuticle with a delicate hand, and then subjecting it to a microscope; and in the course of the examination we are also frequently able to trace the existence of a great multitude of valves, by the action of which the apertures of the lymphatics are commonly found closed.‖ Whether the other systems of vegetable vessels possess the same mechanism, we have not been able to determine decisively; the following experiment, however, should induce us to conclude that they do. If we take the stem of a com-

* Mém. de l'Acad. Par. 1731, p. 24.
† The palms form an exception to this general rule, possessing neither proper bark, nor fascicles of vessels displayed in any circular form: the bark being produced by a remnant of the leaves, and the vessels running in a straight line without regular order, and surrounded by cellular substance.
‡ Introd. to Botany, p. 56. See also Willdenow's Introd. p. 236.
§ See Smith's Introd. p. 47.
‖ This seems to acquire additional probability from Mr. Knight's experiments. See Phil. Trans. 1804; and Thomson's Chemistry, v. 385. See Willd. p. 236.

mon balsamine,* or of various other plants, and cut it horizontally at its lower end, and plunge it, so cut, into a decoction of Brazil wood, or any other coloured fluid, we shall perceive that the arteries or adducent vessels, as also the lacteals, will become filled or injected by an absorption of the coloured liquor; but that the veins, or reducent vessels, will not become filled; of course evincing an obstacle, in this direction, to the ascent of the coloured fluid. But if we invert the stem, and in like manner cut horizontally the extremity which till now was uppermost, and plunge it so cut into the same fluid, we shall then perceive that the veins will become injected, or suffer the fluid to ascend, but that the arteries will not: proving clearly the same kind of obstacle in the course of the arteries in this direction, which was proved to exist in the veins in the opposite direction; and which reverse obstacles we can scarcely ascribe to any other cause than the existence of valves.†

By this double set of vessels, moreover, possessed of an opposite power, and acting in an opposite direction, the one to convey the sap or vegetable blood forwards, and the other to bring it backwards, we are able very sufficiently to establish the phenomenon of a circulatory system; and, according to several of the experiments of M. Willdenow, it seems probable that this circulatory system is maintained by the projectile force of a regular and alternate contraction and dilatation of the vegetable vessels. Yet the great minuteness of these vessels must ever render it extremely difficult to obtain any thing like absolute certainty upon this subject. Even in the most perfectly established circulatory systems of animals, in man himself, it is not once in five hundred instances that we are able to acquire any manifest proof of such a fact: we are positive of the existence of an alternating systole and diastole in the heart, from the pulsation given to the larger arteries when pressed upon; but no degree of pressure produces any such pulsation in the minuter arteries, at least, in a healthy state; yet we have full reason to believe that the same action of the heart extends to the minutest as to the largest arteries. How much less, then, ought we to expect any full demonstration of this point in the vessels of vegetables, in every instance so much more minute than those of the more perfect animals, and seldom exceeding, as I have already observed, a three-thousandth part of an inch in diameter!

It becomes me, however, to confess, that no experiments which have hitherto been made have detected the existence of either motific or sensific fibres themselves in vegetables, although very high degrees of galvanic electricity have for this purpose been applied to the most irritable of them, as the dionæa *muscipula*, or Venus fly-trap; oxalis *sensitiva*; different species of drosera, or sun-dew; acacias of various kinds, and other mimosas; and especially the mimosa *pudica*, and *sensitiva*, the common sensitive plants of our green-houses. Humboldt has uniformly failed; Rafn appears to have succeeded in one or two instances; but his general want of success prevents us from being able to lay any weight on the single case or two in which he seems to have been more fortunate.

It should be observed, that the matter of fibrine, or the principle of the muscular fibre, formerly supposed to exist exclusively in animal substances, has lately been detected by M. Vauquelin in vegetables also. Dr. Hales cut off the stems of vines in the spring, and by fixing tubes on the stumps, found that the sap rose in many instances to the height of thirty-five feet. Tubes have been fixed to the large arteries of animals, as near as possible to the heart, in which the blood did not rise higher than nine feet.

It has long been admitted by botanists in general, that the thorns of plants are abortive branches; the scales of buds have, in like manner, been regarded as transformed leaves; and it has lately been conjectured by M. de Candolle,

* Impatiens *balsamina*:—This is the plant recommended by M. Willdenow for this purpose, as affording the clearest results.

† Yet Hales and Duhamel seem to have shown, that in the sap-vessels no valves exist, and that branches imbibe moisture nearly equally at either end. See Thomson's Chemistry, v. 385; an assertion, however, opposed by various facts. See also Smith's Introd. p. 57. 60.

that their petals are not special organs, but stamens in an abortive or transformed state.*

Plants are also possessed of cutaneous secernents or perspiratory vessels; and in many plants the quantity of fluid thrown off by this emunctory is very considerable. Keil, by a very accurate set of experiments, ascertained that in his own person he perspired 31 ounces in twenty-four hours. Hales, by experiments equally accurate, determined that a sun-flower, of the weight of three pounds only, throws off 22 ounces in the same period of time, or nearly half its own weight. To support this enormous expenditure it is necessary that plants should be supplied with a much larger proportion of nutriment than animals; and such is actually the fact. Keil ate and drank 4lb. 10oz. in the twenty-four hours. Seventeen times more nourishment was taken in from the roots of the sun-flower than was taken in by the man.

Plants, nevertheless, do not appear to have the smallest basis for sensation, admitting that sensation is the result of a nervous system; and we are not acquainted with any other source from which it can proceed: notwithstanding that Percival and Darwin, as already observed, have not only endowed them with sensation, but with consciousness also; and the latter, indeed, with a brain, and the various passions and some of the senses to which this organ gives birth.†

Yet, though the vessels of plants do not appear to possess any muscular fibres, we have evident proofs of the existence of a contractile and irritable power from some other principle; and a variety of facts concur in making it highly probable that it is by the exercise of such a principle that the different fluids are propelled through their respective vessels: nor is there any other method by which such propulsion can be reasonably accounted for. Grew ascribed the ascent of the sap to its levity, as though acting with the force of a vapour: Malpighi, to an alternate contraction and dilatation of the air contained in what he erroneously conceived to be air-vessels: Perrault to fermentation: Hales and Tournefort, to capillary attraction: not one of which theories, however, will better explain the fact than another, as Dr. Thomson has ably established; as he has also the probability of a contractile power in the different sets of vessels distributed so wonderfully over the vegetable frame.‡

That a contractile power may exist independently of muscular fibres, we have abundant proofs even in the animal system itself. We see it in the human cutis or skin, which, though totally destitute of such fibres, is almost for ever contracting or relaxing upon the application of a variety of other powers; powers external and internal, and totally different in their mode of operation. Thus, austere preparations and severe degrees of cold contract it very sensibly: heat, on the contrary, and oleaginous preparations, as sensibly relax it. The passions of the mind exercise a still more powerful effect over it: for while it becomes corrugated by fear and horror, it is smoothed and lubricated by pleasure, and violently agitated and convulsed by rage or anger.

Yet, could it even be proved that the vessels of plants are incapable of being made to contract by any power whatever, still should we have no great difficulty in conceiving a circulatory system in animals or vegetables without any such cause, while we reflect that one-half of the circulation of the blood in man himself is accomplished without such a contrivance; and this too, the more difficult half, since the veins, through the greater extent of their course, have to oppose the attraction of gravitation instead of being able to take advantage of it. It is in the present day, however, a well-known fact, and has been sufficiently ascertained by the late Dr. Parry of Bath, and on the Continent by Professor Dollinger, that the contractile power of the muscular fibres is not called into action even by the arteries in the course of the ordinary circulation of the blood, since, as we shall have occasion to observe, no increase of size or change of bulk of any kind takes place in arteries either in the contraction or dilatation of the heart's ventricles in a state of

* Mém. de la Société d'Arcueil, tom. iii.

† Willdenow, Princip. of Botany, § 226.

‡ Syst. of Chem. vol. v. p. 388. 1807.

health, unless where they are pressed upon by the finger or some other cause of resistance.

In what part of a plant the vital principle chiefly exists, or to what quarter it retires during the winter, we know not; but we are just as ignorant in respect to animal life. In both it operates towards every point; it consists in the whole, and resides in the whole; and its proof of existence is drawn from its exercising almost every one of its functions and effecting its combinations in direct opposition to the laws of chemical affinity, which would otherwise as much control it as they control the mineral world, and which constantly assume an authority as soon as ever the vegetable is dead. Hence the plant thrives and increases in its bulk; puts forth annually a new progeny of buds, and becomes clothed with a beautiful foliage of lungs (every leaf being a distinct lung in itself*) for the respiration of the rising brood; and with an harmonious circle of action, that can never be too much admired, furnishes a perpetual supply of nutriment, in every diversified form, for the growth and perfection of animal life; while it receives in rich abundance, from the waste and diminution, and even decomposition of the same, the means of new births, new buds, and new harvests.

In fine, every thing is formed for every thing; and subsists by the kind intercourse of giving and receiving benefits. The electric fire that so alarms us by its thunder, and by the awful effects of its flash, purifies the stagnant atmosphere above us; and fuses, when it rushes beneath us, a thousand mineral veins into metals of incalculable utility. New islands are perpetually rising from the unfathomable gulfs of the ocean, and enlarging the boundaries of organized life; sometimes thrown up, all of a sudden, by the dread agency of volcanoes, and sometimes reared imperceptibly by the busy efforts of corals and madrepores. Liverworts and mosses first cover the bare and rugged surface, when not a vegetable of any other kind is capable of subsisting there. They flourish, bear fruit, and decay, and the mould they produce forms an appropriate bed for higher orders of plant-seeds, which are floating on the wings of the breeze, or swimming on the billows of the deep. Birds next alight on the new-formed rock, and sow, with interest, the seeds of the berries, or the eggs of the worms and insects on which they have fed, and which pass through them without injury; and an occasional swell of the sea floats into the rising island a mixed mass of sand, shells, drifted sea-weed, skins of the casuarina, and shells of the cocoa-nut. Thus the vegetable mould becomes enriched with animal materials; and the whole surface is progressively covered with herbage, shaded by forests of cocoa and other trees, and rendered a proper habitation for man and the domestic animals that attend upon him.

The tide that makes a desolating inroad on one side of a coast, throws up vast masses of sand on the opposite: the lygeum, or sea-mat-weed, that will grow on no other soil, thrives here and fixes it, and prevents it from being washed back or blown away; to which the lime-grass,† couch-grass,‡ sand-reed,§ and various species of willow lend their aid. Thus fresh lands are formed, fresh banks upraised, and the boisterous sea repelled by its own agency.

Frosts and suns, water and air, equally promote fructification in their respective ways; and the termes, or white ant, the mole, the hampster, and the earth-worm, break up the ground or delve into it, that it may enjoy their salubrious influences. In like manner, they are equally the ministers of putrefaction and decomposition; and liverworts and funguses, the ant and the beetle, the dew-worm, the ship-worm, and the wood-pecker, contribute to the general effect, and soon reduce the trunks of the stoutest oaks, if lying waste and unemployed, to their elementary principles, so as to form a productive mould for successive progenies of animal or vegetable existence. Such is the simple but beautiful circle of nature. Every thing lives, flourishes, and

* On the leafing of trees, there is a curious and valuable paper in the Swedish Amœnitates Academicæ vol. iii. art. 46, by H. Barck, 1753, entitled Vernatio Arborum.

† Elymus *arenarius* ‡ Triticum *repens.* § Arundo *arenaria.*

decays: every thing dies, but nothing is lost: for the great principle of life only changes its form, and the destruction of one generation is the vivification of the next.* Hence, the Hindoo mythologists, with a force and elegance peculiarly striking, and which are nowhere to be paralleled in the theogonies of Greece and Rome, describe the Supreme Being, whom they denominate Brahm, as forming and regulating the universe through the agency of a triad of inferior gods, each of whom contributes equally to the general result, under the names of Brahma, Visnu, and Iswara; or the generating power, the preserving or consummating power, and the decomposing power. And hence the Christian philosopher, with a simplicity as much more sublime than the Hindoo's, as it is more veracious, exclaims, on contemplating the regular confusion, the intricate harmony, of the scenes that rise before him—

> These, as they change, Almighty Father! these
> Are but the varied God. The rolling year
> Is full of Thee.

LECTURE IX.

ON THE GENERAL ANALOGY OF VEGETABLE AND ANIMAL LIFE.

(The subject continued.)

The perfection of an art consists in the employment of a comprehensive system of laws, commensurate to every purpose within its scope, but concealed from the eye of the spectator; and in the production of effects that seem to flow forth spontaneously, as though uncontrolled by their influence, and which are equally excellent, whether regarded individually, or in reference to the proposed result.

Such is the great art of nature: and he who would study it with success must, as far as he is able, trace out its various laws, and reduce them to general principles, and collect its separate phenomena, and digest them into general classes. This, in many instances, we are able to do; and in such cases we obtain a tolerable insight into the nature of things. But so vast, so unbounded is the theatre before us, so complicated is its machinery, and so closely does one fact follow up and press upon another, that we are often bewildered and lost in the mighty maze, and are incapable of determining the laws by which it is regulated, or of arranging the phenomena of which it is composed.

The zoologist, in order to assist his inquiries, divides the whole animal creation into six general heads or classes: as those of mammals, birds, amphibials, fishes, insects, and worms. Each of these classes he subdivides into orders; of each of his orders he makes a distinct section for a multitude of kinds or genera; and each of his kinds becomes a still more subordinate section for the species or individuals of which the separate kinds consist. But he is perpetually finding, not only that many cases in each of his inferior divisions are so equally allied to other divisions that he knows not how to arrange them, but that even his classes or first divisions themselves labour under the same difficulty; since he occasionally meets with animals that by the peculiarity of their construction seem equally to defy all artificial method and all natural order. Thus the myxine *glutinosa*, which by Linnæus was regarded and ranked as a worm, has been introduced by Bloch into the class of fishes, and is now known by the name of gastrobranchus *cæcus*, or hag-fish. The siren *lacertina*, which was at first contemplated by Linnæus as an amphibious animal of a peculiar genus, was afterward declared by

* See upon this subject the Swedish Amœnitates Academicæ, vol. v. art. 80, by J. H. Hagen, 1757, entitled Natura Pelagi.