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ROBERTSON, William

Henry

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TWO LECTURES
ON THE
CIRCULATION, RESPIRATION, AND MODE OF NUTRITION
IN
ANIMALS AND PLANTS;
WITH A SHORT ACCOUNT OF THE
Mode of Growth in Monocotyledinous and Dicotyledinous Stems,
AND AN INVESTIGATION INTO
THE MUTUAL RELATION
WHICH SUBSISTS BETWEEN THESE CLASSES OF
ANIMATED NATURE.

DELIVERED BEFORE
The Chesterfield Literary and Philosophical Society,
BY W. H. ROBERTSON, M.D.

LONDON:
PUBLISHED BY BALDWIN AND CRADOCK;
BY MACLACHLAN AND STEWART, EDINBURGH; AND BY
J. ROBERTS, CHESTERFIELD.

1832.

TWO LECTURES

ON THE NATURE AND MODE OF ACTION

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ANIMALS AND PLANTS:

WITH A SHORT ACCOUNT OF THE

MODE OF ACTION OF THE VARIOUS CLASSES OF

AND A SHORT ACCOUNT OF THE

THE MEDICAL BELATION

OF THE SEVERAL CLASSES OF

ANIMALS AND PLANTS



BY W. H. ROBERTSON, M.D.

LONDON

PRINTED BY RICHARD AND JOHN CLAY, BUNGAY, SUFFOLK.

TO
THE PRESIDENT,
VICE-PRESIDENT, AND COUNCIL
OF

The Chesterfield Literary and Philosophical Society ;

With feelings of gratitude for many acts of kindness ; with the highest respect for their individual excellence ;—and with the warmest wishes for the success and prosperity of the common cause, to the support of which they have, both by their talents and their money, so ably contributed ;

This Publication is dedicated,

By their most obedient

Humble Servant,

THE AUTHOR.

TO
THE PRESIDENT,
THE PRESIDENT AND COUNCIL
OF
THE CHRISTIAN LITERARY AND THEOLOGICAL SOCIETY
With feelings of the highest respect and affection, and
with the warmest wishes for the success and prosperity of
the common cause, to the support of which they have, both
by their talents and their money, so ably contributed,
This Publication is dedicated,
By their most obedient
Humble Servants,
THE AUTHOR

PREFACE.

IN compliance with a long established and almost universally followed custom, the Author of the subjoined little work,—a work which is indeed little in two senses of the term, will not expose it to the searching eye of that most intelligent of critics and best patron of authors, the public, without a few preliminary remarks: it seems to him but fair that, ere he commits his bantling to so severe a scrutiny, he should at once state its pretensions, and at once give his reasons for thus disposing of it.

With regard to its pretensions he must in justice say, that he has not advanced any new doctrines, that he has not broached any new theories, that he has not in any degree enlarged the lamentably confined range either of vegetable or animal physiology.

All that he has *attempted* is to deck out the subject in a somewhat different garb, and all that he aims at is to give a popular view of these interesting topics; a view stripped of those technicalities which would make it unintelligible to any but the initiated, and thus to render it capable of inducing some, perchance many, to enter on the study of these departments, who had previously been almost ignorant that such subjects possessed sufficient captivation either to gratify or interest them.

If these, his reasons, and these, his motives for publication seem sufficiently good, the Author has only to trust that the reader will peruse his pages with candour, and to beg of him to bestow what censure he may conceive to be the Author's due with a lenient hand, as this is his first appearance among the much-abused class of caterers for the instruction of the public.

The Author must further observe, that for many of the physiological observations contained in the First Lecture, he is indebted to some manuscript notes which he took when attending the Lectures of Professor Alison, at the University of Edinburgh; and that many of the facts which he has mentioned in the Second Lecture, have been derived from the celebrated works of the distinguished Richard of Paris: nor have few of the ideas, which he has embodied in these Lectures, been derived from the valuable instructions of Professor Graham, of Edinburgh.

It seems unnecessary to add, that the great mass of facts adduced

have been obtained from a variety of sources. In a treatise on any department of science this must necessarily be the case: it is only by the accumulated labours of ages, by the united exertions of innumerable, and, alas! in many cases, unknown individuals, that truth has been stripped of the garments in which ignorance or superstition had invested her, and exposed to the admiring gaze of the eager and enquiring throng who attend to offer homage at her shrine. Facts, at first rarely noticed and but little attended to, which have been considered perhaps useless or unnecessary, have thus been gradually added to the stores of science; and have laid therein, a confused and disordered heap, until some master-mind has reduced them to order, has drawn from them deductions, demonstrated their important practical application, and thereby shown himself the benefactor of his species, the glory of his age, and the pride of the land which gave him birth.

While, then, the Author knew how absurd would be the attempt to give an authority for every individual fact which he has mentioned, and has consequently left unattempted a task which appears to him so impracticable; he has not failed, as far as his memory has enabled him, to state his authority for any important practical deductions which have been drawn from, for every important observation which has been reared upon, a collection of such facts. If, however, he has, in some cases, neglected to do so, when it may seem to his readers that such authority might have been given, he can only answer thereto that the error has been unintentional, and that anything resembling plagiarism has been the very last of his thoughts.

It will be apparent to all that the First Lecture, and the first part of the Second, are but preliminary to the consideration of the mutual relation which subsists between animals and plants.

Chesterfield, 14th April, 1832.

LECTURE THE FIRST.

THE contemplation of animated nature is replete with so many points of interest, it embraces so many topics by the investigation of which, useful knowledge is acquired, our intellectual man improved, and much real pleasure tasted and enjoyed, that it is difficult to give a preference to any single department; that it is difficult to say which is most calculated to satisfy the curious, to gratify the philosopher, or to repay for the outlay of time and study the mere utilitarian.

But whatever be the department which may seem most calculated to effect so much and to interest so many, however high the pre-eminence which it may have attained, either with reference to the interesting or the useful nature of the facts which it develops, still such subject is capable of further improvement. Without altering in any important degree the body of the picture, its colouring may be improved: we may likewise with reference to any department of science, by conjoining with it another but analogous investigation, add to such research the lovely and beautiful shadings of variety and contrast.

It is by thus connecting and coupling different departments of science, it is by thus uniting departments which are too often treated of separately, and as if they had no connection with each other, that we are at length enabled to view, by a single gigantic effort of mental vision, the whole of animated nature as one beautiful and harmonious picture; it is thus we are enabled to see that all natural objects, whether mineral, vegetable, or animal, are mutually and unavoidably dependant on each other; it is thus that we are enabled to view nature as a whole, each part of which must have been created with an evident design, and having once admitted the existence of design, we must likewise admit the pre-existence of a designer, who from the overwhelming magnitude of the task must be Omnipotent, who from the harmony and mutual dependence of the whole must be Omniscient, and from the union of Omnipotence and Omniscience must be God.

“ Still may I note how all the agreeing parts
Of this consummate system join to frame
One fair, one finished, one harmonious whole;
Trace the close links which form the perfect chain
In beautiful connection; mark the scale
Whose nice gradations with progression true,
For ever rising, end in Deity.”

But to go still further; when we reflect on the wondrous and beautiful harmony, the awful sublimity, the majestic grandeur, which is displayed in every part of creation; how much must our ideas of the powers of that hand, of the faculties of that mind which formed all these, be increased: how heartfelt and unassumed a sense of humility, a virtue which may justly be considered the most distinguished ornament of man, must take the place of those presumptuous ideas and opinions, which are too often to be found in the minds of those, who are ignorant of the great truths which are to be found only in the book of nature, and which it is the business of science to lay open to your view.

Organized matter differs so much from the objects of inanimate nature ; it is endowed with such remarkable properties and powers, and is capable of resisting so many of those laws which keep in perpetual and constant subjection the other great department of nature, that a few preliminary general remarks may not only be of service to you all, but to some of my audience may be absolutely indispensable.

Some of these properties are common to both the vegetable and the animal kingdom : both whilst life exists are capable of resisting putrefaction and decay, or at all events of resisting a general, a total decay, an entire resolution of their component parts : both are endowed with certain extraordinary powers, by means of which they assimilate or take into their own composition the objects around them, and by which they discharge from their systems that which has become useless to them, and which if suffered to remain would in most examples prove injurious to the individuals, and might perhaps deprive them of life : they all possess the power, wondrous as it must ever be incomprehensible to man, in his present finite state, of producing other beings similar to themselves : they all ultimately, in a longer or shorter time, cease to exist, their texture is destroyed, and they are totally changed : these various properties are either at variance with, or are totally independent of, either mechanical or chemical actions.

But in the animal kingdom we find these properties and powers to extend much further. To pass over as foreign to our present purpose all the mental faculties, we find that animals are endowed with certain senses, by which through the medium of prolongations of the great centres of the nervous system, to which prolongations the term nerves is applied, they hear, see, smell, touch, and taste. They are moreover capable of performing certain movements, often exerting thereby the most extraordinary power, and some of which are performed with unceasing regularity. Some of these movements are under the immediate dominion of the will, and have hence been called voluntary ; whilst others, and it is with these that we have at present to do, are not so ; but are accomplished by the peculiar kind of irritation to which each organ is specifically adapted : thus, the heart is called into action by the stimulus of the blood ; the stomach by the stimulus of food ; the bowels by the stimulus of bile. But there is a still further peculiarity with which you must likewise be made acquainted ; certain parts are accustomed to certain supplies, and if these be not afforded the stimulus is *then* called into action ; and to such a degree that if at first unattended to, it rapidly augments in power, and quickly makes the individual *feel* that of some of the actions performed in his own frame and for his own advantage, he has, by a beneficent Creator, been made the slave rather than the master. Thus it is that so long as we respire regularly, if the lungs and their membranes be in a healthy state, we experience no *sensation* in the chest ; but if we by a violent effort stop the respiration, even for a very short period, we shall rapidly find this sensation to augment, and that to a degree so insupportable, as no longer to leave it as a matter of choice whether we again expand the chest, but one of pure and irresistible compulsion.

CIRCULATION OF THE BLOOD.—We shall find that we are to this function indebted for the conveyance of nutriment to the various parts and organs of the body ; by this are all the secretions formed, which are so necessary, so essential to life ; and to its instrumentality is it that the warm blooded animals are indebted for their elevated temperature. In all warm blooded animals there is a double heart ; the one of these hearts being intended to drive the blood through the system, the other to propel it through the lungs. These two hearts are of course intimately connected together, and each contains two cavities : the one (the auricle) to receive the blood from the system, or from the lungs ; the other (the ventricle) to transmit this important fluid through the lungs, or through the system. The right auricle receives the blood collected by the veins from every part of the body, and transmits it to the right ventricle ; by this it is driven through the pulmonary artery and its minute ramifications in the lungs. In these

ramifications, which are commonly called capillaries, immediately before they terminate in the pulmonary veins, an exposure to the influences of the atmosphere takes place. The blood, thus aërated, returns, through the four pulmonary veins, to the auricle of the left heart, to be by it sent into the corresponding ventricle, by the powers of which it is to be propelled through the system; in its passage through which, becoming again impure, it is returned by the veins to the right side of the heart, to be by it again sent to the lungs to be re-purified.

Lest the blood retrograde in this its course, valves are provided at the entrance to, and egress from each ventricle, which, whilst they afford a ready passage to the blood when it is proceeding in the course in which the Omnipotent has destined it to flow, permit not a single particle to return, or thus obstruct the progress of the circulating fluid.

That this is the course of the circulation of the blood was proved by the great, the immortal Harvey; first, by the examination of those animals whose hearts are transparent, and in whom the course of the sanguineous current could consequently be distinctly seen: secondly, by putting ligatures on the great vessels which convey the blood from the heart, and perceiving the distension on the side near that organ, the flaxid state of that which was furthest from it; and, lastly, by the structure of the valves of the heart.

We have now then briefly described this wondrous and most extraordinary function; and have next to examine the great propelling agent, the great forcing pump by which so vast a power is exerted, by which so important a function is performed.

The heart contains, in warm blooded animals, four cavities, the walls of which are composed of contractile fibres, strongly laced together, and arranged with extraordinary regularity: many animals however have but a single heart; as frogs, fishes, &c.: in these, the blood is driven by the single ventricle through the lungs or gills and through the system, and is thence returned into a single auricle.

Some animals have three hearts, two for carrying on the pulmonary, and one for accomplishing the systematic circulation: I would adduce as examples of this organization many of the moluscæ; among the rest, the cuttle fish.

In man, the heart is said at every contraction to expel about two ounces of blood, and calculating that there are eighty such contractions in a minute, there must be one hundred and sixty ounces sent forth by it in that space of time; and in the course of about three minutes the whole blood in the circulation, on an average about thirty pounds, must pass through the heart; and in the space of one hour this must by consequence take place twenty times. What must be the feelings of that man who can think of these things without wonder? I envy not his feelings, I covet not his mind, who, reflecting on the tissues to be permeated, the functions to be discharged, the secretions to be formed from, and the nutritious substances to be taken into the circulating fluid; and reflecting upon how soon each particle, each atom of blood, after having been deteriorated in its constitution, and rendered unfit for the discharge of its important duties, is again driven through the lungs and again aërated; who, I repeat, reflecting on all these things, can retire from the investigation of the course of the blood in our frames without feelings ennobled, a mind improved, and the whole man rendered better by his researches. But, to carry this interesting investigation still further, let us suppose that two ounces of blood will occupy a cylinder eight inches in length; then it will pass through six hundred and forty inches in a minute, and thirty-eight thousand four hundred inches, or three thousand two hundred feet in an hour.

How is the heart's action excited? The fibres of the heart are endowed with an extraordinary irritability, and their internal surfaces are more irritable than their external. Haller proved that this is the case by observing that the auricles and ventricles only contract when they are filled with blood; proving thereby that such contraction is excited by the irritation which the blood produces in the

fibres of the heart. But you may ask; how is it then that the heart, even when removed from the body, still continues to contract? This we may readily explain by supposing that the blood stimulates the heart not merely to a single, but to a succession of contractions. We have found then that nature has provided for the constant and uninterrupted continuance of the heart's action, both by the irritability implanted in its muscular fibres, and by a constant renewal of the stimulus. How do the dilatations take place: how is it that the fibres elongate, and the cavities again dilate, in order to receive a fresh influx of blood? This action appears to be simply the consequence of the previous contraction: the fibres, which during their contraction had exerted a force almost incredible, have no sooner discharged their functions and thus relieved themselves from the stimulus which had induced that contraction, than they immediately elongate, and the cavities are consequently dilated; and they do this with such considerable power, that they exert to some extent a sort of suction influence, and thus, through the medium of the atmospheric pressure, draw the blood into them.

Is the heart then the sole agent of the circulation; does it unassisted prove sufficient to circulate the blood through such an infinite number of vessels; is it of itself capable of overcoming so much resistance, as the friction between the blood and these vessels must necessarily give rise to? No! even these vessels likewise assist in the important work, and, by a constant tendency to contract their diameters with which they are endowed; they assist in the propulsion of the blood through them: and so great is this tendency, that if emptied of blood they are found to contract to a degree which renders them almost impervious cords; nor do they again assume their original form until the animal has been for some time dead, and they, as the other parts of the body, have at length lost a power ultimately vital.—It appears unnecessary to dip more deeply into the circulating powers: the blood, impelled with considerable impetus from the heart, with that impetus rather augmented than diminished by the vessels through which it passes, is driven at length into the minute vessels technically called capillaries. In these, part of the blood is exuded, altered in its constitution, and deposited in the form of bone, muscle, ligament, membrane; or becomes bile, saliva, mucous, serum, &c. But this is not all; a portion of each old texture is absorbed for every portion of new which is deposited: thus, even in our constitutions, even in our frames do we change; and compensation is made for the wear and tear which our bodies are each moment undergoing, in the discharge of every function, in the performance of every movement, in even the momentary exercise of every sense, and in the various mental duties which we are called upon to perform. But neither is this all; the blood in these vessels becomes altered in its constitution and in its properties, it loses its vermilion hue and acquires a blackish colour; it is in fact no longer fitted for the purposes of life.

The blood passes from the capillaries to the veins: these vessels are much more delicate in their structure than are the arteries; the blood is doubtless driven through these to the heart, principally by the *vis a tergo*, or by the power previously exerted by the heart and arteries forcing it outwards. But we have likewise other causes which no doubt co-operate: amongst these we may mention one, which has long been a matter of dispute, but upon which many physiologists have at length agreed; viz., some slight degree of contractile power exerted by the veins themselves; secondly, the veins, particularly those of the extremities, are supplied with valves; these afford a ready passage to the blood as it passes from the capillaries to the heart, but absolutely prevent any retrogression; consequently, when the muscles of the limbs are called into action, when we perform any movement, these muscles swell out in their diameters, they press upon the veins, and as the blood cannot by reason of the valves recede, this pressure forces it onwards and accelerates its progress: hence, we may remark, arises the acceleration of circulation during exercise, the consequently accelerated respiration, and arising from that the obvious increase of temperature. We have other causes of less moment, such as, the expansion of the chest in

inspiration and the dilatation of the auricles; but upon these it seems quite unnecessary to dwell.

The blood, having passed through the veins, having entered the right auricle, and from thence having been drawn into the right ventricle, is, by its contraction, driven through the pulmonary arteries, and thence into the capillaries of the lungs, and there undergoes that important change called arterialization—it becomes purified, re-vivified, and again adapted to discharge its duties in the animal economy.

This important function is performed in some way by all animals, and if the blood be in any of them totally excluded from contact with air, they will infallibly be destroyed. But there are very great differences observable in the different classes of animals with regard to the mode of accomplishing this indispensable object, and with reference to the quantity of air consumed; and what may perhaps appear remarkable to some of you is, the well established fact, that in each class, with but few exceptions, the individuals are, “*cœteris paribus*,” more active, more lively, and, in proportion to their size and powers, capable of greater exertion, according to the quantity of air which they consume: thus, whilst birds which consume a vast, and indeed according to the accounts of some naturalists, an almost inconceivable quantity of air, are and ever have been the emblems of joy, hilarity, activity, and content; which have so often been the objects of the poet’s dreams, the lover’s fancies, and have occupied equally the thoughts of the enthusiast, the philosopher, and even the statesman; reptiles, which consume comparatively but little air, are remarkable for the sluggishness of their movements, the torpor of their natures, their loathsome characters, and inactive minds. But, to proceed; in some animals this exposure of the blood to the influences of the atmosphere takes place in the integuments; many of the zoophytes are examples of this, as for instance the Echinodermata. Other classes of animals, although endowed with a heart, and even in some hearts, do not send all but only a portion of the blood to the lungs or gills, by far the greater part returning to the system without being again aerated: these animals, as it will at once be apparent to you, consume but little air: some, as fishes, have an apparatus different from lungs. I allude of course to gills, which are the respiratory organs of fishes, &c. These animals take in water by the gills in a way analogous to the mode in which we swallow, and the vessels of the gills absorb the air which water, in its natural state, always contains mixed with it, and then, discharging the water deprived of the air, take in a fresh portion of the aerated fluid. Some animals have large cells in the lungs, in which air is contained as a *corps de réserve*; and, when the animal from circumstances is placed in a deteriorated atmosphere, he is capable of living for a considerable time upon the stock with which a kind Providence has supplied him: lastly, for it appears needless further to extend the list of these certainly interesting varieties, some have tubes to convey the air to almost all parts of the body, and it is in the vessels which circulate the blood around these tubes that the exposure to the atmospheric agency takes place. The class of birds furnishes a partial exemplification of this variety; but many of the insect tribe, as larvæ, &c., afford much more complete and satisfactory examples.

Let us now proceed to consider the respiration of man: we have traced the blood to the lungs; in them, the venous blood seems to excite a certain sensation, which rapidly augments, if unattended to, and causes us to expand our chests, and hence to draw a fresh supply of oxygen from the circumambient atmosphere; but some of you may say, “is it necessary to attend to the respiration? We have breathed from birth upwards, and have never breathed *less* regularly, or experienced more inconvenience in our respiratory organs, than others who have paid more attention to the process:” but allow me to ask, is there one of my audience, and upon this point I would particularly appeal to my fair auditors; is there one of you who has never sighed? I may anticipate the answer; it must from all be that they have; well, let me ask what is sighing? It is

simply the consequence of an intense occupation of the mind upon some object ; or of a complete abstraction of it from every thought : whether it be intensely occupied, or lost in complete inaction, the respiratory process is unattended to, until the sensation which is occasioned by the want of air becomes intolerable, and a deep inspiration is taken, as a natural and most effectual means of making up for lost time. How grateful ought we to be that it has seemed good to an all wise and all merciful Creator, thus, in apparent trifles, in matters totally everlooked by the great mass of mankind, to provide for the continuance of our beings ! Deprived of this, our first sleep would be the sleep of death, but with this we sleep in security ; and whilst our several functions are in a healthy state, and our sensoria unimpaired by disease, this sensation keeps up the action of respiration, when every other function is relaxing from its fatigues, resting from its labours, and preparing itself for the duties of another day. In respiration, the ribs are elevated, the diaphragm flattened, and the air, from the force of atmospheric pressure, rushes in to fill the empty space, which the enlargement of the cavity of the chest had necessarily occasioned : or, to speak more scientifically, on the elevation of the ribs and flattening of the diaphragm, which is, as the most of you know, the muscular partition between the chest and the abdomen ; the air, which even after the most powerful and complete expiration of which we are capable, remains still in the lungs, relieved from the pressure, expands ; but, as it is then not of the same density as the atmosphere around us, that atmosphere from its pressure forces itself through the mouth or nostrils into the branches of the air tube, to equalize that density ; and it appears, from the most approved authorities, that about forty cubic inches of air are drawn or forced into the chest at each inspiration, and that after each ordinary expiration, about a hundred and eighty cubic inches of air remain in the lungs ; but after a forced expiration, about one hundred and thirty cubic inches of air, in addition to the former, having been expelled, only about fifty cubic inches remain in the lungs.

The air inspired consists principally of two substances, oxygen and nitrogen ; in the proportion of twenty-one parts of the former to seventy-nine of the latter : now, the air expired contains four substances, one water ; which may readily be shown, as every child knows, by breathing on a cold plate ; the second oxygen, the third nitrogen, and the fourth carbonic acid : we find that of the hundred parts of air which have been inspired, the quantity of nitrogen remains unaltered, there are still seventy-nine parts ; but there are only thirteen parts of oxygen ; and the hundred parts of air are made up by eight parts of carbonic acid : this is the statement of Allan and Pepys : according to this there is no less than eight per cent. of oxygen lost, and in its place is found carbonic acid. The blood returning from the system being loaded with the carbonaceous matters which it has acquired in its course, reaches the lungs, and being there exposed to oxygen, the carbon unites with it and forms carbonic acid ; this being a species of combustion, heat is generated, and as the arterial blood is capable of receiving more blood into its composition, without a corresponding elevation of temperature, than is venous blood, this heat is not manifested in the lungs ; but when the blood has passed through the arteries and reached the capillaries, when it is being again converted into venous blood, this increased quantity of caloric or heat is evolved, and hence the elevated temperature of the higher classes of animals, a temperature which as a matter of course differs but little in different parts, whether nearer to or more remote from the lungs, for capillaries abound in every organ and every situation of the body, and as in these alone is the heat evolved, so in every situation will nearly the same amount of heat be disengaged, and thereby the same genial glow be experienced in all parts of the system.

I trust you will not be confused if upon this subject I give you a perhaps simpler and certainly more correct hypothesis : according to this, a portion of the oxygen inspired is absorbed into the circulation and mixed with the arterial blood ; being propelled into the capillaries, it there unites with the carbon, and

the heat is there evolved, and the carbonic acid mixing with the venous blood returns to the heart and, disengaged in the capillaries, is expired.

We have now examined, although it has been cursorily, the circulation and respiration of animals; we have found the blood running an endless circuit, removing old tissues, depositing new; we have found it to be the means by which all those secretions, so necessary, so essential to our existence, are accomplished; we have found that to this we are indebted for that elevated temperature, without which, according to our present constitutions, we must cease to live. It is the indispensable appendage of life. Animals, even human beings, have lived for days without brain; many animals seem to be almost, if not entirely destitute of any nervous mass; as for instance, many worms and some of the zoophytes, for example the echinus; indeed no *distinct* nervous system has yet, to my knowledge, been discovered in any of the zoophytes; many animals are destitute of hearts, and even human beings have been born without one; yet no animal, be its place in the scale of animated nature ever so degrading, has yet been found, which has not exhibited some kind of a circulation, be that circulation ever so imperfect: this important function may indeed be called the "sine qua non" of vitality, the most distinguishing feature of organized matter.

But there is still another important function which must be treated of, ere we can be considered to have fully investigated our subject. We have found that a great quantity of the vital fluid is expended in the various secretory organs, &c., and consequently this waste must be made up, this expenditure must be accompanied with a corresponding income: we have found that when new textures are formed the old ones are taken up by the circulation, to be subsequently excreted; and hence there is a constant amount of waste in the vital fluid which must be atoned for; and our next object is to investigate the means which an Almighty hand has made use of to fulfil this intention: we have consequently in the next place to examine briefly the phenomena of digestion.

Every individual of the animal kingdom requires, for his aliment matter, already organized, and can only digest such substances as have been previously endowed with vitality; and even in plants we find that a certain degree of previous assimilation is necessary, ere unorganized matter can become part and parcel of the composition of their frames: hence we may, perhaps without erring greatly, make the broad assertion, that life is the only nutriment of life, that matter previously organized is alone capable of supplying the deficiencies necessarily caused by the performance of the several functions in organized beings.

We may premise that numerous have been the discussions, multifarious the theories which have been broached upon the subject of hunger; upon its site, upon the peculiar condition of parts requisite for its development: suffice it to say that, although it be sometimes intimately connected with the sense of smell, its chief site seems to be the stomach and fances. To enter further into the subject would but lead us into a maze of doubt and uncertainty, would but involve us in a labyrinth from which when we had at length freed ourselves, we should find that we had but returned to the point from which we started, without advancing even a single step in the path of science.

The act of taking food is evidently instinctive; the little infant cannot, by any rational being, be supposed to know what purposes are to be answered, what intentions are to be fulfilled, by taking food: and further, as far as regards the movements themselves, he accomplishes at once, without any previous practice, one of the most complicated muscular actions of which the human frame is capable.

The first step in the digestion of aliment, which is in most animals requisite, is a comminution of the ingesta, previous to its reception into the stomach: for this purpose many of them are provided with a mouth and teeth; but upon this, for obvious reasons, I shall not dwell. What will, however, I doubt not, be to

many of you an interesting fact is, that many animals, as fowls, &c., which are not provided with teeth, have a strongly muscular stomach, by which the food may be comminuted, and its nutrient particles be with more facility taken to the system.

But to revert to the human species, the food has now to perform its journey to the stomach. For this purpose the tongue is raised up to the roof of the mouth, gradually from the tip to the back part; here, the morsel has to pass two cavities, to be guarded against diverging from its course in no less than two directions; lest it pass by the pressure of the root of the tongue upwards into the posterior part of the nostrils, a curtain is hung from the back part of the palate, and by the pressure of the morsel to be swallowed this is made to cover the aperture: but another and more important object is yet to be attained ere the morsel can, with safety to the individual, pass down into the stomach: there are two tubes in the throat, one for the passage of air to the lungs, the other for conveying the food to the stomach; of these, the former or windpipe is placed anterior to the latter or œsophagus: consequently the bolus must pass over the upper extremity of the windpipe, before it can reach the tube intended for its conveyance; and if a single atom of that bolus were to get into the windpipe it might cause the instant death of the individual: a beneficent Creator has provided a most beautiful apparatus for conquering this difficulty; a draw-bridge has been constructed, which is lowered by the, in general, welcome guest for its safe transit over the dangerous abyss; a body, resembling a tongue but of much smaller size, is placed perpendicularly on the anterior margin of the upper end of the windpipe: this affords no obstruction to the ingress or egress of air in respiration; but in swallowing the bolus presses against it, and laying it in a horizontal position, thereby making it cover the entrance of the windpipe, the morsel passes over it and reaches the œsophagus or food tube in safety. How is it conveyed thence to the stomach? "Oh!" it may be said, "the morsel has but to fall through the œsophagus, to descend by its gravity, and thus reach the stomach." In answer to this, however, we have only to say, that men can swallow standing on their heads, when of course had gravity any power the food would remain in the mouth: in fact the whole œsophagus consists of rings of muscles, which surround its walls, and these by acting one after the other force the food onwards until at length so far from *dropping* it is actually *driven* into the stomach.

The majority of animals have but one stomach; many however have two, three, or even four. In these, the aliment is in general of a most indigestible nature, it is in fact with difficulty assimilated, with difficulty brought to that condition, which it *must* have attained, ere it can, with safety, be mixed with the blood.

In the stomach the food remains for some time: this organ becomes rounded and distended, it prepares to perform its part in the assimilation of the crude and often heterogeneous mass exposed to its influences. I believe we must, with the celebrated Bichât, conceive that the lower orifice of the stomach, commonly called the pylorus, is endowed with the power of refusing passage to undigested substances; it seems in fact to be the stomach's janitor, refusing a passage through its portals to any thing, which has not been sufficiently prepared to enter the precincts of the upper bowels.—In the stomach the food is triturated and mixed with an acid, and as each portion has undergone the process, it is pushed forward by the muscular coat of this organ to the pylorus, and passes through it to the bowels; thus making room for a fresh portion of food to come into contact with the inner surface of the stomach, and consequently to undergo the same change.

The mass, soon after it has entered the intestines, is mixed with the bile; and soon thereafter a separation of the alimentary mass takes place; what is nutritious is absorbed into the system by a set of vessels called lacteals; these terminate in a duct or vessel, which, passing up the back part of the chest,

enters a vein commonly called the subclavian, situated behind the collar bone: and the nutritious matter, mixing with the blood, is conveyed to the right auricle of the heart; in that and the right ventricle being well agitated, it of course immediately passes into the lungs to be oxygenated and become perfect blood, adapted to the purposes of life; and to be conveyed by the circulation to supply the desiderated amount of nutriment to every part of the system. The contents of the bowels, the nutritious matters having been thus removed from them, pass downwards to be eventually discharged from the system.

I have now completed the first part of my task; we have waded through the circulation, respiration, and mode of nutrition in animals; and I have taken for my example in all these departments *Man*, as being the most perfect animal, and because he performs all these functions with an apparatus more complex than is to be found in the other classes: and occasionally, where such a course seemed calculated to give additional interest to the subject, I have dipped into comparative anatomy, into the mode in which other animals execute these offices: we have next to investigate the similar functions which are performed by plants, and the mutual relation which subsists between them and animals.

LECTURE THE SECOND.

Part the First.

SCIENCE, the term being used with reference to an acquaintance with natural objects, merits deep attention, close investigation, unwearied research, and the most assiduous culture; for reasons not a few. To pass over the additional beauty, the confirmatory evidence which it affords to our religion; to pass over the enlargement of intellect, the elevated feelings which its investigations must necessarily be attended with; and to omit the important effect which it necessarily has on all our domestic relations, our social comforts, our individual happiness, and our national prosperity: arguing for its cultivation on the score of amusement alone, it occupies a place unattainable by any other pursuit, far above all other occupations. But if this can be said of every subject within the almost unbounded sphere of natural philosophy, with what additional force will it not apply to every investigation connected with the vegetable kingdom? Where shall we find a man, even although his mind be destitute of all culture, and his only ruling impulse those dread and awful passions, which he has in common with all the brutes around him, whose mind will not, at some time or other, have been raised from its ordinary occupations by the voice of nature appealing to his every sense through the medium of vegetation? Plants by their beauty captivate all, by their majestic character the votary of ambition, by their structure and organization the philosopher, by the associations to which they give rise the scholar, by the combination of all these the man.

To reach the summit of all human happiness, to partake of the highest mental luxury which this earth affords, we must study nature in her own pure and unadulterated loveliness; and we shall indeed find that

“It is but in her summer sun to bask,
To mingle with the quiet of her sky,
To see her gentle face without a mask,
And never gaze on it with apathy.”

We turn over the pages of the “book of nature,” we examine the wondrous structure of the earth on which we tread, and unaffected astonishment fills our minds and engrosses our every thought during the investigation: we examine the planetary system, and on the very threshold of the research, in perusing the first line of that page of nature’s wondrous volume, we feel ourselves transported from the comparative spot occupied by this earth; and if we extend our investigations to the myriads of stars which spangle the gorgeous firmament above us, each of which is, in all probability, a sun, attended by its peopled planets pursuing one undeviating course in the boundless regions of space, we must pursue such research with increasing but never ceasing wonder, reverence, and awe. We descend again to the globe which we inhabit, we examine the structure, habits, &c., of the animals which people its surface, and we do so with unmixed and

unalloyed feelings of astonishment ; but when we enter on the investigation of the vegetation around us, we find our gentlest, best, and most hallowed feelings, our very virtues called into powerful action ; and even those, whose minds are either from birth or education the most callous, unfeeling, savage, and almost inhuman in their every thought, and word, and deed, seem thereby humanized, and more nearly approximated to, what, I would call, the higher order of their species.

Here is food for every mental appetite, be that appetite ever so capricious ; here is nourishment for every mind, whatever its nature, however diversified its tendency, or original bias. If the beauteous individuals of the vegetable kingdom charm not all, whole groups of these, resembling each other not only in appearance but in qualities, may effect that object ; and if these fail, the wide field of vegetable physiology, a large extent of which is still untrodden, must interest all, and afford an ample harvest of fame to every talented investigator.

But, to detain you no longer from the subject before us, I will merely add to these introductory observations, that, as there have been no strictly botanical lectures delivered before this Society, I shall conceive it not irrelevant, and in some cases even necessary, to deviate somewhat from my subject, and glance at the other departments of the vegetable kingdom.

Thus, it will be obvious to the initiated, that a preliminary view of the parts composing the *root* and *stem* will be indispensable, ere we can proceed intelligibly to describe the course of the sap.

These, together with the leaves, are called by botanists the "*organs of nutrition*;" they are in fact those, to whose care the life or preservation of the plant is intrusted.

The *root*, as of course you all know, is that part of a plant which is buried in the earth : it grows in a direction opposite to that of the stem ; for whilst the latter rises towards the heavens, the former, by each successive addition to its length, sinks deeper in the earth. By their roots, in most plants, nutrition is taken up, which is speedily converted into the sap or vegetable blood. Roots are, of course, of various shapes, forms, and appearances : they may consist of thin slender long fibres, or of thick fleshy masses ; they may be conical, as in the carrot ; top shaped, as in the turnip ; have bulbous swellings upon them, as in the potatoe ; they may be capillary, as in the grasses ; in fact, they present an infinite variety of forms, which it would be more tedious than amusing to enumerate. But besides the absorption of nutriment, an office which, in most plants is, more or less, intrusted to the roots, they serve another, which is to attach them to the soil, and they are thus, generally, of a strength and size proportioned to the plants which they have to support : this, however, is far from being universally the case ; for palms and pines, the height of whose stem is sometimes not less than a hundred feet, have short roots, whilst many plants whose weak and slender stems perish annually, as, for example, the liquorice, have roots of considerable length, and comparatively amazing magnitude. Roots only absorb by their extremities, which are supposed by most to be covered by a thin membrane or vesicle. I cannot help deviating somewhat to notice that roots appear to have a remarkable tendency to grow in the direction of a good soil, and, to effect that object, they frequently baffle all our endeavours to check their progress, and will triumphantly surmount obstacles which we may have vainly considered to be insuperable. The stem is that part of a plant which grows in a direction opposite to the root. I shall content myself with describing the two principal varieties, namely, those of dicotyledinous and monocotyledinous plants.

The stem of dicotyledinous plants is composed of concentric layers, which are placed within each other ; if we make a transverse section of it, we find in the centre the medullary canal, at the circumference the bark, between the two are placed the woody fibres, consisting, externally, of alburnum or false wood, internally of lignum, or wood properly so called.

The bark consists of four layers, the external is the epidermis, the middle

larger is the herbaceous integument, the innermost is the liber, and between the two latter are the cortical layers. The epidermis, or membrane analogous to the cuticle of animals is transparent, owing its apparent colour to the membrane placed beneath it. Immediately under this is observed the herbaceous integument: it may be readily exposed in young stems by detaching with care the epidermis; in the quercus suber it forms the well known substance, *cork*: we shall find hereafter that this remarkable membrane serves the same office in plants, that the lungs do in animals. Of the cortical layers, which are found between this and the liber, it seems unnecessary to say much: in most plants they are so slightly developed as to be not unfrequently invisible, even to a practised eye; but in one remarkable plant, to wit, the lagetto, or lace wood. they consist of layers which lap over each other, and, when extended, present the appearance of regular lace work. Immediately beneath these is the liber: this is indispensable to the growth, and even to the life of the vegetable; if a circular band of liber be removed, the plant will, at no distant period, perish: when it has been steeped for a considerable time in water, it separates into layers, which, from resembling somewhat the leaves of a book, have procured for it the name of liber.

The alburnum is placed between the liber and the true wood: the alburnum is in fact wood, but it is young, its fibres are tender, more distant from each other, and of a lighter colour than those of true wood; but, every successive year, the innermost layer of alburnum is converted into wood, and a new layer of alburnum is deposited externally.

The medullary tube lines the innermost layer of wood it is destined to contain the pith: this is the light spongy body which occupies the centre of the plant; it communicates with the herbaceous integument, formerly noticed, by certain prolongations which cross the woody fibres: these, of course, serve to keep up a direct communication between the pith and the herbaceous integument, between the internal and external parts of the vegetable.

The stems of monocotyledinous plants are widely different from those which we have hitherto been examining: on making a transverse section of these stems, we see no symmetrical concentric layers, all the parts seem to be mixed and confounded the one with the other; the pith, instead of being enclosed in a central medullary canal, is dispersed through the whole thickness of the stem; the wood, arranged in longitudinal bundles, is scattered without order in the medullary substance; the bark is not always present, and even when it is, the appearance of it is most indistinct, and the wood seems to be scarcely covered by it. In dicotyledinous plants the hardest layers are those nearest to the medulla; but in these the contrary takes place, and the external part of the stem is by far the hardest.

The anatomical organization of the roots is, in every important particular, the same as that of the stem.

But we shall enlarge no further upon this part of our subject; indeed, I fear that I have trespassed too far already upon the memories of the uninitiated; but, as necessity has compelled me to do so, I trust you will not blame me much on this account, more especially as we may now consider ourselves to have passed the "*pons asinorum*;" and I trust that the rest of our journey will be comparatively easy, and the path cleared of either thorns, briars, or impediments.

Many were the ideas formed by the ancients concerning the part of the vegetable through which the sap ascends from the roots; some contending that it passes through the pith, others as strenuously urging that the bark is the part permeated in its ascent; but when recourse was had to that only test experiment, it was satisfactorily proved that both these ideas were fallacious, and that through *wood* the sap ascends to perform its various and wondrous functions; but what may seem, to some, remarkable is, that it is not the softer wood, or alburnum, that it chiefly if at all permeates. No! it chooses what, to man's erring reason, would seem the more arduous and difficult path, and chiefly passes through the

hardest of the woody fibres, namely those nearest to the medullary canal.—The vessels of the wood communicate freely with the lateral parts of the stem, and with the branches; and there the sap deposits the nutritious matters, with which it had ascended surcharged and loaded; and these nutritious matters assume that form which the part, in which they have been deposited renders necessary, for the sustenance, the health, and the preservation of the individual. The sap, having arrived at the herbaceous integument, which covers, as you doubtless know, the stem and the leaves, and having been conveyed to the minute vessels ramified on it; undergoes remarkable, but necessary changes: not only does it part with air, superfluous water, and other substances unnecessary, useless, and which, if retained, might be positively injurious to the individual; but it acquires new properties, another element is added to its composition, an element, as necessary to the sustenance of the vegetable, as its excess would be noxious and even fatal to animals.

The quantity of water which the sap gives off, during its passage through the leaves, is greater than any previous idea could, by possibility, have led us to conceive. It however varies much, according to the dryness or moisture of the atmosphere; the transpiration being much more considerable in hot and dry, than in cold and moist weather. Hales found that the common sun-flower exhaled no less, on an average, than about twenty ounces during the twelve hours of day. You must all have seen, when you have risen early in the morning from the sleep-inviting couch; when you have early left the hot and confined bed room, charged with the air which your own lungs had deteriorated; and gone to greet the glorious orb of day mounting the eastern horizon: yes! on such an occasion you must all have noticed the glittering drops, shining with a brilliancy which the eye could scarcely look at, and refracting the sun's rays into all the colours of the rainbow, and hanging like gems on the leaves of the plants around you; and you may have thoughtlessly fancied them to be dew drops: these, however, are the effects of the transpiration from the leaves. But the water transpired must bear a certain proportion in quantity to that which is absorbed by the roots; or the plant loses its freshness and its vigour, it languishes and fades. Generally speaking, about a third is retained by the plant, to be decomposed, resolved into its elements, and to assist in nourishing, providing for the necessary waste, and contributing to the growth of the individual; whilst two thirds must be exhaled. Hence is it, that if plants be exposed to the almost uninterrupted heat of a summer sun, they fade, sicken, and not unoften die: not because they are deficient in moisture; but because the quantity of fluids transpired is not in due proportion to that which is absorbed by the roots.

But plants transpire not water only, but a portion of air, or other elastic fluids likewise; which have either been mixed with the sap, and consequently passed through the several tissues of the plant; or which have been received directly from the circumambient atmosphere: and these, having answered their purpose in the vegetable œconomy, are discharged from it, and form the *expiration* of plants. The nature of the gases expired differs much, not only in different parts of the same plant, but in the same part under different circumstances; if the plant be exposed to the sun's rays, oxygen is expired, in conjunction, of course, with undecomposed atmospheric air; but if the plant be placed in a dark situation, in a place inaccessible to the sun's rays, instead of oxygen, carbonic acid is expired. Further; to expire oxygen, the expiring organ must be green; or if it be not so, it invariably expires carbonic acid. Some plants, however, afford remarkable and inexplicable exceptions to the above rules: they invariably expire nitrogen; such are, the sensitive plant, the holly, &c.

The plant, having expired the airs which are no longer necessary for, and which, if retained, might be injurious to the individual, inspires atmospheric air; the carbonic acid of which, if assisted by the sun's rays, it is capable of decomposing: the carbon is taken up by the sap to be conveyed to different parts of the plant, and give to them the necessary amount of that substance; whilst the

oxygen is set at liberty, again to mix with the air around us, and give it an additional proportion of that all-powerful agent.

The sap, thus altered in constitution and properties, descends through the cortical layers and through the liber, and depositing various substances in its course, its elements being resolved into new and wonderful combinations, it forms the new annual liber, which, in another year, is to become a new layer of alburnum, and in future years to undergo still another conversion, namely, into wood.

We have now then described the course of the circulation of the sap: were we, however, to cease here, we might indeed be accused, and that with no small degree of justice, of having most inadequately treated our subject; we have still to investigate what proofs we have, that this is the course of the vegetable circulation; and, secondly, the powers by which this extraordinary function is carried on.

Proofs.—First; if the lower extremity of a branch, or young stem, whose structure is tender, and the parietes of whose vessels are delicate, be immersed in a coloured fluid it will rapidly be absorbed; and traces of it will be visible, not in the pith or bark, but little, if at all, in the alburnum; but slightly will traces be visible in the external layers of wood; but they will be found to be very abundant in those layers which are nearest to the medullary tube. Secondly; if a tree be bored, but little sap will be found to exude until the instrument begins to penetrate the innermost layers of wood, and then it will often run out in considerable abundance. Thirdly; a secondary sort of proof may be mentioned, which is of no mean importance in the consideration of this subject: we know that many trees become hollow, losing a great portion of their woody fibres, and of course the pith and medullary canal; and these plants still flourish in all the luxuriance and beauty of their youth: proving, thereby, that the sap does not necessarily ascend by the vessels of the medullary canal, as was the opinion of some naturalists. But when the remaining cylinder of woody fibres decays, then the plant fades and languishes, and rapidly losing its leaves, becomes a lifeless and sapless log; proving, thereby, that the sap does not ascend through the liber, or any other membrane belonging to the bark.

We have now to ask, what are the powers by which the ascent of the sap is accomplished? We know that many of our forest trees attain the height of one hundred and twenty or one hundred and thirty feet; and, in America, the palm often surpasses one hundred and fifty feet in height: now, it may be asked, by what power or powers is the sap raised from the surface of the earth to an altitude so amazing as the summit of these trees?

I know not any subject, within the vast range of philosophical enquiry, which has been so prolific of dispute, so productive of controversy; or in which have originated so many speculations as this: yet, out of a mass of heterogeneous and not unfrequently absurd ideas, I shall glean what seem most rational, and what have met with the most cordial approbation of the first naturalists of our times. We know from experiments that the force with which the sap rises is greater than even the pressure of the atmosphere; for whilst the ordinary atmospheric pressure is balanced by a column of mercury twenty-eight inches in height, Hales found the force with which the sap is raised, in the vine, capable of raising a column of mercury thirty-two inches. Capillary attraction was once the favourite theory, nor has it even now fallen into disrepute with some; but when I say that the circulation goes not on in a plant deprived of life, when this agent could act, to the full, as efficiently as it could during the fullest activity of its vital powers, it appears needless to add that this cannot be the cause of this wonderful phenomenon. Hence, then, we must admit the existence of a *vital* principle of contraction to be resident in the vessels themselves, or in the parts surrounding them; by which this function appears to be chiefly performed. But the experiments of Dutrochet have induced him, and most other naturalists of eminence, to admit the existence of another important agent of extraordinary and, as yet, de-

spite many I might almost say innumerable ingenious conjectures, inexplicable powers. This highly celebrated philosopher, who, on this account alone, would be entitled to an immortal and never-dying fame, discovered that if he attached to the end of a tube a portion of bladder, or other organized membrane; then poured some thick liquid into the tube, and immersed the covered end of it in a thinner fluid; an action immediately commenced: the thin fluid from without penetrated the membrane, and, entering the tube, caused the fluid to rise in it. Now, argued Dutrochet, we know that roots only absorb by their extremities, we know that these extremities are covered by a membrane or vesicle, we know that the sap within, is thicker than the water without this membrane, may not this very same power, whatever its nature be, which I found to cause the thin fluid to permeate the bladder in my experiment, and thus cause the ascent of the fluid in the tube; be the principal if not the sole cause of the ascent of the sap in the vessels of plants. It is easy, says he, to conceive the existence of vital contraction in the vessels of young herbaceous stems; but in hard indurated trunks, as the *Ficus Carica*, the wood of which is so hard at the end of October as to break with noise and cut with difficulty; how is it possible to conceive that such contraction takes place? You will observe, from this digest of Dutrochet's opinions, that he conceives the vital contractions of the vessels themselves to act, at all times, as an imperfect cause of the ascent of the sap, and in some cases to be altogether inert.

After stating briefly the opinions of a man so eminent, it might perhaps be better to leave the subject to the consideration of my audience, and to let each decide upon it according to the best of his or her judgment. This, as a partial cause, of the ascent of the sap has ever been a most favourite theory of mine; but I would, ere I leave this subject, beg leave with considerable diffidence to offer one remark for your future consideration; for you must all be satisfied that these lectures are rather intended to suggest matter for your future studies and meditations, than to communicate any amount of actual, *bonâ fide*, information. We know that the action which we have been examining will take place if a dried bladder be used, as well as it would with a fresh animal membrane: how is it, may I ask, if the vital contractility of the parietes of the vessels have no influence in the propulsion of the sap upwards; that, after a vegetable has lost its vitality, all the parts and, amongst the rest, the roots and the vesicles at their extremities remaining entire, the sap does not still continue to ascend? I would only further observe that it seems most probable that both these powers are agents in the performance of this necessary function, that, in all probability, they both are in some degree instrumental in its accomplishment. That the leaves exert some influence upon the ascent of the sap cannot, for a moment, be doubted: upon the nature of that influence I have not, at present, space to enter: suffice it simply to observe that if the leaves be artificially removed during summer, or naturally during autumn, the ascent of the sap is for the time necessarily arrested.

I shall take this opportunity of making a few observations upon that most interesting natural phenomenon, the fall of the leaves. You all know that to this winter owes its principle dreary features, that from this our wintry landscapes derive their naked, barren, and almost death-like appearances. We have found that, at the close of the season, the part through which the sap has principally, during the summer, descended, to wit, the *liber*, becomes altered materially in character, that its fibres become indurated, and it is converted into *alburnum*, or false wood. The descent of the sap is consequently at first retarded, and ultimately altogether stopped: it consequently becomes stagnant in the vessels of the leaves, and the ascending sap vessels are filled and over distended with fluids; the leaves are by consequence, necessarily deprived of the constant influx of nutritions, of life-supporting fluids, and by degrees they, from positive starvation, wither, and ultimately perish and fall off. Nor is it until the ensuing spring, when the genial influences of a vernal sky, an elevated temperature, and warmth breathing zephyrs, begin to operate upon the dormant powers of vegetation; that

the plant awakens from its lethargic slumbers, that it is aroused into renewed activity and fresh vital actions: but then the sap being attenuated by the heat, and the powers of the plant thereby stimulated into action; the ascent of the sap again commences, and it sets about forming a new set of vessels, a new herbaceous integument, and a new liber, by which it may again communicate with the atmosphere, by which it may get rid of its superfluities, and be thereby rendered capable of performing its various, diversified, and important duties in the vegetable œconomy.

To repeat then somewhat: we have found the sap to ascend, propelled with extraordinary power, through the vessels of the wood; we have found it, in its course, depositing various substances for the nourishment of the vegetable; we have found it to reach ultimately the herbaceous integument; we have found it, whilst passing through the minute vessels ramified on that integument, to part with a large quantity of superfluous water; thereby becoming thicker and better adapted to nourish the plant: whilst, at the same time, the vegetable inspires atmospheric air; which you know is a mixture of oxygen, nitrogen, and carbonic acid; and that, decomposing the carbonic acid, it deprives it of its carbon, and sets at liberty the oxygen, which, together with the oxygen and nitrogen of the air, is for the most part expired. Lastly, we have found the sap, thus altered in its consistence and changed in its constitution, to pass through the liber; there to deposit the substances necessary for the nourishment, growth, life, and well-being of the individual.

What are the uses, what the objects to be gained by the circulation of the sap in plants? To enter fully into this subject would render a complete circuit of vegetation necessary; we must condense then considerably, and, expunging whatever may seem less generally interesting, introduce what appears most likely to instruct or amuse the majority of my audience. By the circulation of the sap are all those secretions, so necessary to the vegetable, accomplished; by its instrumentality are the substances which might prove noxious to it excreted; by it, as we have seen, is the respiratory process rendered of service to every part of the plant, by conveying to it a new elementary substance which is necessary to its composition; by it are the additional tissues formed, the old ones removed, and new structures reared in their place; by it are the nutritious matters taken in from the circumambient atmosphere or the soil, rendered serviceable to every fibre which contributes to the formation of the individual; and by it, lastly, are the organs of reproduction produced, without which, on the death of the present race of plants, not a trace of vegetation would remain on the surface of this globe.

The uses of wood in the various departments of the architect and the mechanist, in the construction of those bulwarks of our nation's freedom, and the greatest source of its wealth, to wit, "the wooden walls of old England," are too well known to require any observations from me. But the circulation of the sap answers other wise and necessary purposes: it secretes certain substances of the highest service to us, and many, which, although perhaps not necessary to man, contribute to his comforts, minister to his appetites, and which, in civilized society, appear to be almost indispensable.

You all know the value of sugar, which is principally procured from the stem of the *Saccharum Officinarum*; although it may be obtained, by processes more or less complex, from many other vegetable substances.

You all know the value of the gum which is exuded from several plants; more especially several species of the genus *Acacia*: the most important being the plant which furnishes gum-arabic; a substance which is so nutritious that the Moors, during the gum harvest, actually live upon it; and one which is of so much importance in commerce that, even in the year 1787 no less than twelve hundred thousand pounds were purchased by the French and English merchants.

You must all be aware of the extent of obligation which we owe to the species of the genus *Pinus*; the sap of which secretes turpentine. This valuable substance, I may remark, "en passant," is obtained by cutting out longitudinal strips

of the bark; the turpentine gradually exuding from the wound, and being collected in cavities formed in the earth below these incisions: when these have become dried up others are made at another part of the tree: it is said that by this treatment these trees may be made to furnish turpentine for almost a century. You all perhaps know that this product is placed in a still: the oil of turpentine is distilled over into the refrigeratory, and the resin is the residuum. To the different species of this important class we are indebted likewise for pitch, tar, balm of Gilead, gum-thus or common frankincense, &c.

I need not remind you of the value of log-wood and Brazil-wood in dying, of the oak bark in tanning, or of a hundred other important uses which several other woods are put to, in the arts and manufactures of this mercantile country.

Every one must know the value of fruits and seeds in contributing to our well being, our support, and our happiness.

The natural family of the grasses is, without doubt, the greatest benefactor to man of all the families of plants: to this family, and to the assiduity of our forefathers for bringing the individuals to their present state of high cultivation, are we indebted for the wheat, the barley, the oat, and our various other grains. Whilst in these the seed itself is the part so important to man and animals, in others the parts covering the seeds are those most useful to us, either as the apparently necessary appendages of existence, or as the highly prized luxuries of civilized life. Who knows not, from dearly cherished remembrance, and long tried experience, the peach, the apple, the melon, the strawberry, &c.? Who knows not the importance of the coverings of the olive seed, from their yielding an oil of the greatest purity and value? Who knows not the grape; who is there with so little of the epicure in his or her character, as not to have partaken of this queen of nature's precious gifts to man, with almost more than rapture; and, alas! who knows not, from perhaps dearly purchased and severely punished experience, the innumerable variety of intoxicating, stimulating, and exhilarating fluids which are obtained from this fruit? Yes! blind, self-willed, obstinate man, by yielding to his gross, I had almost said bestial, appetites, has converted that, which by restoring vigour to his exhausted frame, and bringing back the roseate hue of health to his face, rendered pallid by disease, might have been a real blessing, into a temporal curse, into a certain means of inducing disease, poverty, vice, licentiousness, and premature old age.

Who is not acquainted with rice; on which it is supposed that one hundred millions of the earth's inhabitants subsist, and which, although chiefly confined to warmer climes, is perhaps more extensively cultivated than even wheat?

We must not omit the beautiful family of palms; the individuals of which, by the elegance of their forms, and the beauty of their symmetry, form the chief characteristic of the magnificent scenery of our Indian possessions; and which are no less remarkable in their uses than their appearance. The fruit of many of these, as the cocoa and date, and the terminal bud of the cabbage palm, form a food for the inhabitants of those tropical climes. The pith of some of these is converted, by certain manipulations, into the highly nutritious substance, sago, which in many parts of the East Indies is used as a substitute for rice; whilst some yield an oil of no small value to the natives of those countries, as well as an apparently necessary wash for their skins to protect them from the overpowering influences of a vertical sun; as likewise as an article of profitable commerce, to wit, palm oil.

We must not pass over too cursorily the Musacæ: a family which contains the plaintain and the banana tree; plants which furnish wholesome and highly nutritious aliment to the inhabitants of the tropical regions of both the old and new world; plants whose value and importance can hardly be estimated by the inhabitants of these colder latitudes. It is said that three dozen plaintains will serve a man for a week, and support him better than would bread.

The Bromeliacæ must not be omitted in this view of the uses of the circulation of the sap in plants, from its containing Bromelia Ananas; which has for its

fruit the pine apple, a native of South America : which, from its unequalled flavour has found its way into every civilized country, and which, despite the very great amount of loss which it is said to sustain in point of palatability, by a removal to these regions of mists and fogs and clouded skies, is an especial favourite with almost every Briton.

We must likewise notice the Laurinæ, as containing the laurel, that emblem of triumph and of victory, the camphor, the highly valued cinnamon, and a long catalogue of other plants scarcely less conducive to the necessities, as I suppose we must call them, of civilized society.

The tea consuming sex, as a young friend of mine was wont, I must say most impertinently, to denominate the fair daughters of Eve, might perhaps never forgive me, did I omit in this enumeration the Theacæ; two species of which, the green tea (*Thea Viridis*) and the bohea tea (*Thea Bohea*), yield, we are told, all the varieties of tea consumed in this country. This great money making article of China trade is perhaps too well liked by the most of you, either to require any eulogia, or to be the worse for any censures of mine.

The family of the Aurantiacæ likewise merits notice from its containing the orange, the lemon, and the bergamot: the rind of the fruit of the two latter of which yields, by expression or distillation, the cheap but grateful volatile oils of lemon and bergamot. This family likewise contains the *Citrus Decumana*, which has for its fruit the shaddock, a fruit which is said sometimes to weigh no less than fourteen pounds, and to be no less than eight inches in diameter.

The Saponiacæ must not be passed over, if it were only to show with what liberality the great Creator and Benefactor of mankind has, in certain regions, provided for man's every want, by placing him in the midst of a vegetation the most luxuriant; a vegetation which not only supplies him with every necessary, but furnishes him with many of even the comforts and luxuries of life: this family then yields the soap berry, with which the Americans wash their linen.

Aye more: in those fervid regions where even water is, at times, a luxury, scarce to be procured by the toil worn and parching traveller; a munificent Providence has provided a fruit, the cactus, whose juices have but little more taste than that most indispensable of fluids, to quench the thirst which had threatened him with destruction. Who has not heard of the water melon: a fruit so much prized by the Egyptians that they affirm it to be to them meat, drink, and physic? Who has not heard of the bread fruit tree, (the *Artocarpus Incisa*,) whose fruit is sometimes as large as a child's head, and is so nutritious and necessary to the natives of the countries in which it flourishes, as to have obtained for it the name of what is, even by us, justly called the staff of life?

We might prolong the list almost ad infinitum; we might enumerate the valuable spices, the fragrant perfumes, and the useful medicaments, for which we are indebted to the secretory powers of the sap in plants. There are, however, two remarks, whose interesting nature will I trust excuse their introduction here. In warmer climes, where the unobstructed rays of a vertical sun contribute so much, independent of any excess in diet, or defect of regimen, to the production of disease; medicinal substances, most powerful and efficient in their actions, abound: whilst in colder latitudes, where the diseases of mankind are brought on, for the most part, by the excesses of themselves or of their forefathers, for in this respect the sins of the father do indeed descend to his children's children, an all wise Providence has supplied but few medicaments of value; and what may seem strange to those, who are unacquainted with the myriads of instances in which the philosopher sees the hand of his Maker, in all that Maker's works; these medicinal substances are chiefly such as are useful in the treatment of what, to distinguish them from the acquired, I would call the native diseases of these climes.—Many seeds are surrounded with what, in botanical language, we would call a "fleshy pericarp;" the meaning of which you will at once understand when I say that the majority of our fruits are examples of it. Let us not presume so far as to suppose that this was added merely with the view of being subser-

vient to the appetites, or the luxuries of man? the botanist takes a less presumptuous, and yet more ennobling view of the subject: he looks upon this pericarp as intended to tempt birds, &c., to eat the fruit; and then, winging their aerial flight to far distant lands, carry the blessings of vegetation to the most remote quarters of the habitable globe.*

We have now to investigate the mode of nutrition in plants; we have now to trace the sources of those primary elements which we find to enter into the composition of vegetables: and, in the first place, whence is the carbon derived, which you know to be one of the principal constituents of plants? Soil does not *necessarily* contain it, and if it do, we must consider it as the remains of decayed animal or vegetable substances; and, further, when placed in a soil well known to be destitute of carbon, plants will grow, and the quantity of that substance in their composition, will considerably and sensibly increase. The carbon is *then* necessarily derived from the atmosphere; by the decomposition of the carbonic acid, which the air always contains, the plant taking the carbon into its own composition, and evolving the whole, or a part of the oxygen; but I am far from asserting that the whole of the carbon is invariably thus derived; we know too well by experience the value of a manure which contains a considerable quantity of carbon, not to be sensible that, when placed in such circumstances, a plant will derive its carbon from both sources, and thus, as a matter of necessity, supposing the other elements to be furnished in an equal ratio, become more vigorous.

Whence are derived the oxygen and hydrogen, which you know to be the other two elements necessary to the production, the formation of a plant? Of these, water is the principal source: this fluid, as the majority of you must be aware, consists of oxygen and hydrogen; and these two elements, resolved and combined with carbon in various, but definite proportions, are the only necessary constituents of the innumerable vegetable products by which we are surrounded. This view will explain at once the seeming paradox, a paradox, however, only to the unphilosophical, that plants will grow in distilled water, and some of them become every day sensibly heavier. You will now see at once, that, although water and air be the only elements supplied, and although the plant may be found to contain but little of either; yet these may be so united and combined together, as to form bark, wood, pith, and leaves, leaving not a trace of their original appearance, of their former sensible characters.

The most of you know that cane is surrounded with a shining coat of no inconsiderable hardness: you may not all be equally well aware that this coat is silica, the very same material as is rock crystal. Silica you all know to be insoluble in oil of vitriol, in aquafortis, or, in fact, in any of our acids except one, namely, Fluoric acid. Whence is the silica derived, and how is a substance so insoluble thus deposited? I regret that even modern philosophy does not enable me to give a satisfactory answer to either of these queries: all we can say is that, most probably, the silica is taken up from the soil, is mixed with the sap, and, being in a state of most minute mechanical division, is conveyed through the minute capillaries to the bark, and deposited on its exterior.

These remarks will likewise apply to lime, and the other earths, some of which are almost always, and others but rarely found in plants.†

* I should feel more regret at the very limited list of the necessary, or luxurious productions of nature which has here been given, were it not that, since the above was written, two most interesting volumes upon this very subject have emanated from the "Society for the Diffusion of Useful Knowledge;" whose indefatigable labours in the glorious cause of science have already been followed by so vast an amount of positive good; of whose works we may well doubt whether their purpose and intention, or the mode in which they are executed deserve most praise. It appears superfluous to recommend them to the attention of my readers: should, however, this publication fall into the hands of any who have not seen those volumes, I can most sincerely recommend them to his or her perusal.

† It may not be unknown to the reader that much has been said on the probability of

You all know that potash enters largely into the composition of most land plants, and that in fact it is by their combustion and then pouring water upon their ashes, in order to dissolve the potash, that this highly valuable substance is procured. That it is derived from the soil seems even more than probable from experiments which you would perhaps think me tedious were I to enumerate; but in what state it exists in the soil we know not, although, most probably, a considerable proportion of it, at least in cultivated lands, is derived from the remains of vegetable substances. I need scarcely say that, whilst potash is the alkali peculiar to land plants, soda is equally so to marine vegetables; the source of soda is of course obvious enough: the common salt, which you know that sea water contains in great abundance, is a muriate of soda, and the plant by its vital powers separates the soda from the muriatic acid, and, setting the latter at liberty, seizes upon the soda and drags it into its own composition.

We have now to proceed to the mode of growth in plants; and, as a portion of this subject has been already discussed, repetition shall be as much as possible avoided.

The seed consists, as the most of you are doubtlessly aware, of the embryo or future plant, and one or two cotyledous: hence the names, monocotyledinous, and dicotyledinous; these cotyledous seem to be principally intended for nourishment to the embryo, previous to its sending forth roots which may provide for its nutrition. The seed, when placed in soil, or in any other situation where it can procure the elements necessary for its future nourishment, swells, and, bursting its coats, sends forth two sprouts; the one ascends to greet the face of day, and, on emerging from the surface of the earth, assumes, in most plants, a green colour. This is, in fact, what is commonly called the plant; it is the stem, on which the leaves are to be supported, from which the branches are to be formed, and on which flowers are to be produced to supply the place of their progenitor; when that progenitor has been destroyed to contribute to the well being, or the happiness of man; or when, according to the laws which regulate every animated creature, it shall be deprived of the principle of vitality, and its component atoms dispersed to compose the various particles of other living things. Whilst the stem ascends to the surface, and that with a pertinacity the most remarkable, resisting every means which have been yet, by the ingenuity of philosophers, devised to make it grow downwards; the root with an equal obstinacy descends, and gives off its branches likewise, which disperse themselves in various directions to forage and collect nourishment for their common parent.

We have found that dicotyledinous stems grow in their circumference by the formation of a fresh layer of liber every spring; the layer of the previous year

lime being the product of animal and vegetable secretion. Many plausible theories and observations have been advanced upon this subject; but it is involved in very considerable obscurity, and I shall content myself with observing that I cannot well conceive how an elementary body, previously not in existence, can be produced by the secretory powers of the sap in plants, or of the blood in animals: as easily could I form an idea of how matter was first created by the hand of the Omnipotent. For this is evidently not a case in which, the elements being supplied from known sources, the vital powers of the plant may so combine them as to form compounds infinitely different: we have here to deal with a metal (calcium) in combination with oxygen; the oxygen may of course be derived either from the soil, from water, or from the atmosphere; but whence is the calcium derived? If it be said that it is formed by the vital powers of the animal or the plant, a palpable absurdity, as it appears to me, is involved, viz., that life is capable of creating matter, and that so far from matter being unchangeable in regard to quantity, so far from correct is the old theory, viz., that each atom that composes this earth and all that are thereon, was created in the beginning by the Most High, since which time this earth has neither lost nor gained even a single particle: I say that, were this hypothesis correct, no portion of matter was ever yet gifted with vitality, which did not during each moment of its connection with the vital principle, contribute something to increase the amount of material particles which form our earth.

having been converted into alburnum; the innermost layer of alburnum having been converted into wood. We have only further to remark, with reference to the growth of the stem in those plants, that they grow in height by fresh shoots of fibres consisting, we may say for the sake of clearness, of the layers of bark surrounding the medullary canal; in the next year, the liber will be converted into alburnum, and a fresh layer of liber formed; in the second year, the alburnum will be converted into true wood, a fresh layer of alburnum being formed from the liber of the previous year, and so on. It will be obvious to you from this why our forest trees possess the beautifully tapering appearance, being thickest near the root, and becoming gradually of smaller diameter as they approach the summit.

But monocotyledinous plants have a mode of growth widely different; they form, every year, a bud at their summit, from which shoot the leaves: at the termination of the season these leaves fade, die, and fall off, leaving only their foot stalks; on the ensuing year the new leaves grow from the summit of these foot stalks; and, each successive year, the old leaves fade and new leaves sprout forth, adding thereby to the height of the tree.

It will be obvious to you all that these trees can present no tapering appearance, that they cannot grow in diameter, that they cannot form branches, and that their only leaves must be in a cluster on the summit of the tree. The palm is perhaps the most familiar example which I could give you of this class of plants; and, if you examine its stem or stipe, you will see distinctly the remains of the old leaves; you will see that it is an almost shapeless log; and you will find that its only leaves grow from its summit. But these classes of plants differ from each other not only in their stems, but likewise in their leaves; they, in fact, differ from each other as much, if not more, than a man, in physical structure, differs from the reptile on which he treads.

The leaves of dicotyledinous plants are reticulated, they form a network, in many plants of the most strikingly beautiful description, in fact, their vessels, arranged in bundles, cross and recross each other; not merely to give support to the broad expanded leaves, not merely to give beauty to their structure, but to form junctions with each other, lest by the destruction of one set of vessels the parts supplied by that set should wither, fade, and, from inanition, perish.

In the leaves of monocotyledinous plants we have, however, a structure widely different: in these, the bundles of vessels proceed, with reference to each other, in parallel lines; thus, strange as it may seem, you can at once say whether the seed of a plant have had either one or two cotyledons, by an inspection of the wood composing the stem, or even of the leaves which give the zest to the charms of summer, and the luxurious tints to the rich colouring of our landscapes.

Is it not marvellous that nature should produce works so regular in their structure, in their appearance, or even in their qualities; and that too from materials the least diversified, from elements so few?

LECTURE THE SECOND.

Part the Second.

WE have now to proceed to the last, but not least important division of our subject: viz., the mutual relation which necessarily subsists between plants and animals, their mutual dependance upon each other. It was to put you in possession of that amount of knowledge, which is requisite to a thorough conception of this really interesting department, that the preceding divisions of these lectures have been delivered, and as I have long been fully aware, that if any subject is to be completely understood, it cannot be condensed into too small a bulk, I shall be as brief upon an investigation which is, generally esteemed to be, one of the most interesting which an examination of nature presents; as that investigation, its great importance, its absorbing interest, and my own feelings, will permit.

I shall divide this department into two heads: the first having reference to the respiration, the second to the mode of nutrition, and this hurried and imperfect sketch will be completed by summing up, as briefly as may be, the principal differences, and the most important points of resemblance between the two great classes of animated existence.

We have found that animals consume by respiration a considerable quantity of oxygen: indeed so considerable a quantity that expired air is unfit for the support of combustion, is unfit for the support of the respiration of animals. We have found, on the other hand, that plants, if assisted by the sun's rays, are endowed likewise with the power of decomposing the atmosphere around us; but with results diametrically opposite: seeing that they absorb carbonic acid, and expire oxygen.

Hence what air animals deteriorate, plants re-purify; and vice versâ: and whilst the one class, animals, sets at liberty carbonic acid for the nourishment and support of vegetation; plants expire oxygen for the purification and revivification of the blood in animals. Hence do they act in rendering the air fitted for the existence of each other: and whilst animals could live, on the surface of this earth, but for a short time unaided by the important effect of vegetation upon the atmosphere; so neither would plants be able long to preserve their health, or even their lives, unassisted by animals.

Hence do we find that every creeping insect has its end to perform on the air around it, equally with man himself; and that every plant, however apparently useless both in appearance and properties, has its utility manifested; and that those trackless forests, extended in length, almost interminable, over uninhabited regions, are not without their use: for whilst our lungs expire carbonic acid, which is wafted through the air to supply them with carbon, they, in their turn, expire oxygen, to be wafted through the same medium to us, to preserve our blood in a state of purity, and maintain it in a condition adapted to the important purposes of life.

How plainly do we here see the hand of an Omnipotent Ruler of the universe: how evidently is here displayed a mind, which could not only foresee, but obviate every difficulty; a mind, which could not only reduce a chaos to order, but render each of his creatures an agent subservient to the well being of all the rest; a mind which has not only prepared for the *individual* happiness of his creatures, but has made each, and every one of them conduce to the common weal of the other classes of animated existence.

I know not any subject, within the vast range of philosophical enquiry, more eminently calculated to refute narrow bigoted prejudices against the studies and pursuits of science, under the absurd supposition that such pursuits are calculated to injure the great cause of our common religion, than that which we have just been describing: indeed a review of creation may make a man a Christian, it can never, I may fearlessly say, make him an Atheist.

Do we not see that between plants and animals there exists a constant, and unceasing interchange of good offices; do we not see that each deprives the other of what would be pernicious to its existence, affording that without which it must cease to live: have we not seen that whilst plants must cease to flourish, and ultimately to exist, if unsupplied with carbon; animals must speedily perish, if unfurnished with oxygen? The herbaceous integument of plants may indeed be called the great laboratory of the atmosphere; in which it is freed from its noxious particles, and again placed in that condition which is necessary for the health, for the very existence of animals.

But I should ill indeed discharge the duty, which I have this evening to perform, were I to conclude this branch of my subject without having made a remark which, I doubt not, you will with me consider to be of considerable importance.

While vegetables can live for a considerable period even if unsupplied with carbon; animals, it is well known, rapidly deteriorate the atmosphere by depriving it of its oxygen, and would in a very short time render it unfit for their existence, and they would consequently perish. Now, a knowledge of this fact being premised, let us turn to the account of the creation as given by Moses, under the inspiration of his Omnipotent Master, in the first chapter of Genesis. We shall there find such an account given of the order in which chaotic masses were organized, and separated from the inanimate heaps around them, by the addition of the vital principle; as accords fully even with enlightened philosophic views of the nineteenth century; a period which, it requires no prophetic powers to foresee, will hereafter be called the second "Augustan age" of literary and scientific pursuits.

We find that the inspired writer describes the Almighty as first saying, "Let the earth bring forth grass, the herb yielding seed, and the fruit tree yielding fruit after his kind."

Nor did the Almighty create animals until two days thereafter: it would indeed have been impossible, unless by a miraculous interposition of an Omnipotent hand, for animals to have long lived in an atmosphere, unpreserved in purity by the influences of vegetation.

To every thinking mind how satisfactory must be the reflection, that after so many years of progressive improvement as have intervened between the deluge and our times; the creation, as recorded in our scriptures, should so exactly tally with our present enlightened philosophy? How grateful ought we to be to Him, who has not only condescended to reveal his will to his creatures, but has done so in a way in which no mere man could have accomplished it, in an age so dark and comparatively barbarous; thereby clearly pointing it out as the work of Him alone who created all things, of Him alone who brought light out of darkness, a universe out of chaos.

But we must now pass on to the last division of our subject, viz., to investigate the mutual relation, with reference to the mode of nutrition, which subsists between plants and animals; and here again shall we find ample cause for admiring the wisdom of the Omnipotent.

We all know well that animals derive their nourishment either from the vegetable kingdom, or from each other; that they can live only upon organized matter, upon matter which has previously been endowed with vitality. Water and air, rock crystal, lime, potashes, and soda, would, even by an ascetic, be esteemed "*meagre fare*" indeed.

I have certainly heard and read of some nations who mix clay with their food; but, I apprehend that, were clay the most nutritious of their aliments, they might as well be without even that, or, like plants, try to support themselves upon air and water.

Yet we have found that upon these substances, than which we could "a priori" conceive few to be more deficient in nourishment, plants live, grow, and flourish; that out of these scanty materials the great giants of vegetation attain their amazing magnitude, their luxuriant foliage, and surpassing beauties; and that out of these all the luscious fruits, the nutritious grains, and poisonous juices are, by the wondrous powers of vegetation, formed and produced.

Who, on being made acquainted with this undisputed and indisputable fact, could ever cease to wonder at such things as these? Where is the man who, ignorant of these facts, would not burst forth into senseless ridicule, were we to tell him, that the wine with which he pampers his overfed and almost mindless carcase, that the luscious fruits which minister to his palate, or that the spices which he finds necessary to give temporary vigour to the appetite of which his own indolence and gluttony had almost deprived him; were, in all probability, originally but air and water assimilated by plants, and by their vital powers brought to their present tempting, and truly palatable condition.

Hence then plants are the necessary appendages, in still another point of view, to animal existence; they are, in fact, to repeat a simile which I have before in this lecture made use of, the laboratories in which substances, previously destitute of any powers of affording nourishment to animals, are mixed and variously compounded, in different and divers proportions, and delivered from the work-shop of the mighty mistress, Nature, in states fit, not merely to make up for the wear and tear of animal life; but endowed with flavours to gratify the palate, with condiments to stimulate the appetite, and with medicinal substances to cure or alleviate the numberless diseases to which our frail mortality is liable.

Yes! it must be obvious to you all that, deprived of vegetation, the only resource of animals would be the destruction of each other; only by carrying on a perpetual and sanguinary war with his fellow creatures could an animal procure sustenance; and thus would animals likewise speedily become scarce, and, at no distant period, extinct.

But, even with regard to nutrition, animals, in their turn, benefit vegetables: when deprived of that wondrous and incomprehensible appendage to their frames, viz., life: animals undergo decomposition, and their elements are taken up by vegetables, are by them assimilated, again to become the good of an after race of animals: and as no single particle, not an atom of created matter can be lost, who knows that the fruit which we enjoy, or the bread which we partake of, may not have formed part and parcel of the composition of a former race of men; and, if we but reflect that the elements of our own frames may, in after years, be assimilated by plants, and become part of the composition of some filthy creeping thing, whose progenitor we may perhaps, with feelings of loathing and disgust, have trodden under foot, we should certainly feel what feeble, helpless creatures we ourselves are; we should surely regard the mind more and the person less; we should surely feel, and feel deeply, our utter helplessness if unassisted by Him who alone is Omnipotent.

We have already found that whilst plants and animals resemble each other in having the important principle life added to their frames; that they resemble each other in having a system regularly organized, in being essentially composed

of but few elementary substances, in possessing the power of forming from these few an immense, an almost numberless variety of compounds, which differ from each other in appearance, in character, and in every sensible property. We have found, moreover, that they are not amenable to the laws which govern the inorganic and lifeless masses of matter; that, when deprived of the vital principle, their elements naturally separate from each other, resolving themselves into new combinations; we have found that both plants and animals require a regular supply of materials, which they may take into their compositions, in order to make up for the waste which their frames are constantly undergoing; we have found that they are both endowed with the power of excreting matters which, if retained, would prove noxious to them, and of secreting substances which are requisite either for their own welfare, or for the production of other beings similar to themselves; and that for the due accomplishment of these important purposes they are endowed with a circulatory system, and require a regular supply of atmospheric air, which they decompose; taking into their composition some of its elements, and discharging what are to them, no longer serviceable.

To express, to some degree at least, the same ideas in different words by a quotation from the first lecture which I ever had the honour of delivering before you*, we have been examining a "set of beings whose materials seem to have been violently torn from the inanimate world; which materials are constantly disposed to return to their pristine state and composition; and are only restrained by one great principle, whose essence exists we know not where, whose very being we can only, morally speaking, judge of by induction. We have found this wonderful principle producing a set of actions often contradictory to, and in apparent violation of the ordinary laws of nature; of which we can only judge by its effects; of whose essence we can say nothing unless that it is the work of an Almighty hand. We have found that, connected by a slender thread to matter, this principle no sooner leaves it, than it undergoes certain changes, and is converted into the dust from whence it came."

But although plants and animals resemble each other in so many important particulars, in so many points, in fact, that it is almost difficult for the mind, whilst investigating this subject, to conceive that plants are not animals; and there have been philosophers who have conceived that, in very truth, they differ but little from each other; still, I need hardly say that, differences there are of no trifling importance, and to these it will be my business to direct your attention in this the conclusion of my subject.

Plants then differ from animals in not being like them gifted with reasoning principles; in being destitute of all the organs of sense, unless the irritability, which you know, that the sensitive, and a few other plants possess in a remarkable degree, be deemed worthy of classification with our sense of touch; they differ moreover from animals in their mode of taking in nutriment; they have not, like animals, a complete circulation; since the sap after ascending and descending does not complete the circuit, does not again ascend through the vessels of the wood; their food is inorganic, that of animals is organized matter; but, perhaps the most important and interesting point of difference is that, animals have two sets of functions to perform; to wit, those which are called organic or involuntary: as the heart's action, respiration, digestion, &c.; and so far do plants resemble animals, so far are they endowed with similar powers. But if we go further, if we look for the other organs and functions which are strictly called animal, as voluntary motions, &c.; with the nerves which give rise to these, we shall find that, in these respects, vegetables must yield the palm of superiority to the higher order of animated existence, to animals.

To sum up briefly: vegetables cannot be said to be endowed with either internal, or external sense; they cannot be said to be endowed with the power of voluntary movement; and they cannot be said to have a similarly complex

* Unpublished.

organization. They are indeed debarred from the pleasures, but so are they likewise from the pains of animal existence: and it might be a question of some difficulty, looking on the subject in a mere temporal point of view, to say which were the happier, the preferable, the more to be envied lot. How often does the mind, when racked with the cares, tortured with the anxieties, wearied of the bustle, depressed by the disappointments which are more or less to be considered as the inheritance of man, turn to the quiet serenity of vegetation, and wish itself one of that class which endures no such misery, and is tortured by no such feelings? How often, again, does the mind, when placed in different circumstances, exult in the very consciousness of its own existence, and, so far from repining at the extent and variety of its faculties, wish for powers more extended, for a capacity less confined? Yes! view nature and her works as we may, we must at length come to the conclusion that "whatever is is right;" we must feel the inward conviction that we, of all creation, have the least reason to complain of, what we consider to be, hardships, simply because our superior intellectual powers enable us to judge of them with more acuteness, to scan them with more accuracy: little right indeed has man to complain, whose mind alone, of all earthly creatures, has been permitted to range through all above, beneath, and around; which has, through the medium of revelation, been suffered to reach from earth to heaven, from nature up to nature's God.

I have now concluded my task, and I must confess that it has been to me a pleasing one; for who can turn his attention to nature's ample page without an unequalled sense of gratification, an unequalled sense of mental enjoyment. That it has been so imperfectly executed is, and has, during its completion, been my only regret. To you who have followed me through the rough, the rugged, the even, and the smooth paths of the journey, I have now only to give my sincere thanks; but I cannot refrain from begging of you "to forgive the many faults which a greater ability might have shunned, to pardon the many errors which a more practised attention might have avoided," and I can only say that, if I ever stand behind this table again, and I trust that your kindness will permit me to do so on many future occasions, I will do my best to avoid those faults, and you may rest assured that I shall never cease to remember with gratitude your indulgence.

I will conclude in the words of a highly distinguished lecturer, in order to express my ardent wish that "the light of this institution may continue to be mildly and steadily diffused, until the night of eternity shall darken the world, or these beams of intelligence be absorbed in a still brighter effulgence."

ENTERED AT STATIONERS' HALL.



