A POPULAR TREATISE ON VEGETABLE PHYSIOLOGY.

PUBLISHED UNDER THE AUSPICES OF THE SOCIETY FOR THE PROMOTION OF POPULAR INSTRUCTION.

WITH NUMEROUS CUTS.

PHILADELPHIA:
LEA & BLANCHARD.

1842.

GRIGGS & CO., PRINTERS.

CONTENTS.

CHAPTER VII.

CHAPTER VIII.

CHAPTER IX.

CHAPTER X.

CHAPTER XI.

CHAPTER XII.

ADVERTISEMENT.

This volume was published in London under the auspices of the "Society for the Promotion of Popular Instruction" and the American publishers have much pleasure in offering it to the public. "Feeling assured that it will be found sufficiently simple in its character, and clear in its explanations, to be regarded as an *elementary* treatise, adapted to those who have no previous knowledge of the subject; whilst its systematic arrangement, and the scientific value of the principles laid down in it, render it an excellent introduction to more comprehensive works on the same subject. The general reader, who seeks no more than entertainment or recreation, will find it in this volume, in the copious illustrative facts and interesting collateral information, with which it abounds; whilst to the Agriculturist, the Gardener, and the Domestic Economist, it supplies principles and practical applications of great importance."

Philadelphia, May, 1842.

INTRODUCTION.

Of all departments of Science there is perhaps no single one capable of exercising such an advantageous influence on the mind of its cultivator as Natural History. Every kind of knowledge has in it something that is valuable; for even if it be of no direct utility in the ordinary concerns of the world, the acquirement of it is a useful exercise to the mental faculties, and the possession of it may operate in a most beneficial manner on the habitual feelings, and give a corresponding direction to the whole course of life.

It is desirable to cherish correct views of the benefits of different kinds of knowledge, that those may choose most advantageously for themselves, whom the necessary business of life debars from the extended pursuit of it; and without undervaluing other branches of Science, it may be safely affirmed that Natural History is capable of affording more to interest and instruct, more to refresh and relax the well-disposed mind on a very slight acquaintance with it, than any other pursuit. Not a step can the learner advance in it but he meets with wonders previously unsuspected;—not a height does he gain, from which his prospect is clearer and more extensive, but his notion of these wonders acquires a yet more astonishing vastness. The more he knows, the more he desires to know; and the farther he advances, the more does he perceive how much delight is yet in store for him.

The beneficent Creator of all has not only ordained that every part of his works should be *good*,—should be adapted to answer its designed end, and should contribute in highest degree of which it is capable to the well-being of his creatures;—but he has made every thing "beautiful in its season,"—he has so formed the mind of man that it derives pleasure from the contemplation of the glorious works around him. And it is, therefore, a worthy employment of our faculties to encourage this pleasure, and to place it upon a more solid and extended foundation than that afforded by the mere forms and colours of the objects around us, however beautiful these may be. One great source of the pleasure derived from the inquiry into the structure and mode of existence of the living beings around us, arises from the beautiful adaptation of their parts to each other, and of the whole to the place it has to occupy, which we can easily trace in every one. The Philosopher who studies the motions of the heavenly bodies, and the station of this earth among them, traces these adaptations no less clearly; but it requires profound and long-continued study to be able to comprehend them aright. But the Naturalist can discern them with far less research in every plant that grows, in every animal that breathes; and he meets with a constant variety which prevents him from growing weary of the pursuit. Yet the young are too frequently kept in ignorance of the wonders and beauties around them; and, whilst encouraged to learn many languages, and read many books, they remain unacquainted with the bright volume of Creation, the pages of which are daily and hourly unrolled before them, "written," to use the impressive words of Lord Bacon, "in the only language which hath gone forth to the ends of the world, unaffected by the confusion of Babel. But these pages are not to be read without some study: the alphabet and grammar must be learned, in order that their beauties may be rightly comprehended; and those who are entering upon the inquiry need to be rightly directed by those who are more advanced.

Natural History has been too generally shunned by those whose minds are occupied with the necessary employments and cares of the world, and who seek in the pursuit of knowledge a source of refreshment and relaxation, as a Science of hard names and intricate classification. But the objects of its several departments are not commonly understood. The study includes the examination of the structure, habits, and mode of existence of all the living beings which so thickly people the surface of the globe; and it is only in order to become acquainted with these more readily, that the Naturalist arranges or classifies them, placing those together which have most in common, and separating these from others which are widely different. Classification, therefore, is not the object of Natural History; but a means of gaining that object; and it is very easy to enter upon many interesting inquiries without the slightest knowledge of it. The structure and actions of man, for example, may be examined in the greatest detail, without knowing any thing of his place in the general scale of being (although such knowledge will often shorten the student's labour;) and other kinds of animals and plants may be observed in the same manner. In fact, several of the most valuable and interesting observations we possess upon the habits and actions of particular animals, were made by those who devoted themselves almost exclusively to that special object. Thus it is scarcely out of the power of any one to contribute something to the general stock of knowledge; still less, then, can any be prevented from adopting some department of this pursuit for the health and invigoration of their own minds.

The study of the structure and actions of Plants, constituting what is known as VEGETABLE PHYSIOLOGY, has been less brought under the notice of those who pursue Natural History only for the improvement and recreation of their minds, than it perhaps deserves. In regard to the importance of the Vegetable Kingdom in the economy of Nature, it can scarcely be said to rank lower than the Animal Creation; for all Animals are either directly or indirectly dependent upon Vegetables for their sustenance, and must cease to exist if they were destroyed. The beauty of the external forms of Plants is surpassed by that of their internal structure; and the investigation of the latter is more easy than that of animals, besides being unattended with many drawbacks which must elsewhere be encountered. The objects of the Physiologist are never out of reach; for barren indeed must be that country which affords no shelter to the products of the Vegetable Kingdom. The meanest and most common herbs are in his eyes as interesting as the majestic tree or the rarest flower. The toilsome labours of the Collector, who seeks to bring together in his cabinet as large a number as possible of the different tribes of plants existing on the surface of the globe, are not required by him; nor is his mind fatigued by the difficulties and technicalities of classification. And what renders the pursuit of this branch of Natural History peculiarly adapted to the female sex is its freedom from the necessity of that corporeal suffering, which, however laudable its ultimate objects, the truly humane will always dread to inflict upon beings that have feelings like their own.

The object of the following Treatise will be, therefore, to lead those who may be disposed to adopt our recommendation, to a pursuit which cannot fail to prove a source of interest and improvement. It will be adapted as much as possible to those who have no previous information on the subject, beyond that which all young persons of ordinary capacity may gain by themselves; and it will omit, therefore, several topics of high but less general interest, which those who feel inclined to examine them will find fully treated elsewhere.

Wherever circumstances are compatible with Vegetable existence, there we find plants arise. It is not only on the luxuriant soil, on which many generations have flourished and decayed, that we find the display of their beauties. The coral island, but recently elevated above the level of the sea, speedily becomes clothed with verdure. From the materials of the most sterile rock, and even from the yet recent cinders and lava of the volcano, Nature prepares the way for vegetable existence. The slightest crevice or inequality is sufficient to arrest the invisible germs that are always floating in the air; and the humble plants which spring from these soon overspread the surface, deriving their chief nutriment from the atmosphere. Having completed their allotted period of existence, they die and decay; but *their* death is only a preparation for the appearance of higher forms of vegetable structure. They are followed by successive tribes of plants of gradually increasing size and strength; until, in the course of years, the sterile rock is converted into a natural and luxuriant garden, of which the productions, rising from grasses to shrubs and trees, present all the varieties of the fertile meadow, the tangled thicket, and the widely spreading forest.

No extremes of heat or cold seem to put an entire check upon vegetation. Even in the desert plains of the torrid zone, the eye of the traveller is often refreshed by the appearance of a few hardy plants, which find sufficient materials for their growth in these arid regions. And wherever a spring of water moistens the soil and atmosphere around, a spot of luxuriant verdure is found. These Oases, as they are termed, are the stations at which caravans halt, when crossing the extensive wastes of parching sand; and although their effect upon the mind is doubtless heightened by the dreariness of the preceding journey, there is no question that few spots can present greater richness of vegetation than these. It will hereafter be seen that heat, light, and moisture combined form the circumstances most favourable to the growth of plants; and it is from the combination of the latter of these conditions with the former, that the vegetation of small islands in the tropical ocean is so peculiarly rich. These Oases are like such islands in the midst of a sea of sand; and nothing can be a greater contrast with the desolation around, than "the green pastures" and "still waters" which they afford.

Many remarkable facts might be mentioned, relative to the degree of heat which some forms of vegetation are capable of sustaining, and which, to some species indeed, appears a natural and even necessary condition. A hot spring in the Manilla islands, which raises the thermometer to 187° has plants flourishing in it and on its borders. In hot springs near a river of Louisiana, of the temperature of from 122° to 145°, have been seen growing not merely the lower and simpler plants, but shrubs and trees. In one of the Geysers of Iceland, which was hot enough to boil an egg in four minutes, a species of *Chara* has been found growing and reproducing itself; and vegetation of an humble kind has been observed in the similar boiling springs of Arabia and the Cape of Good Hope. One of the most remarkable facts on record, in reference to the power of vegetation to proceed under a high temperature, is related by Sir G. Staunton, in his account of Lord Macartney's embassy to China. At the island of Amsterdam a spring was found, the mud of which, far hotter than boiling water, gave birth to a species of Liverwort. A large Squill bulb, which it was wished to dry and preserve, has been known to push up its stalk and leaves, when buried in sand kept up to a temperature much exceeding that of boiling water.

Even the extreme of cold is not fatal to every form of vegetable life. In the realms of perpetual frost, the snow which covers mountains and valleys, and whose surface scarcely yields to the influence of the solar rays at midsummer, is in some places reddened for miles together by a minute vegetable, which grows in its substance, and has been supposed, from its very rapid increase, to have fallen from the sky. This will be hereafter described under the name of Red Snow, which is that commonly applied to it. The Lichen which forms the winter food of the rein-deer, grows entirely buried beneath the snow; and its quantity may be judged of by the number of the animals which find in it their sole support during a considerable part of the year.

Plants are found, too, in situations in which some peculiar noxious influence might be supposed entirely to prevent their growth;—as for example, in sulphureous springs. In fact, there are scarcely any circumstances in which there is not some kind of plant adapted to exist. Thus, it is well known that soils, which have any considerable admixture of metallic ores are not favourable to most kinds of vegetation; and among such, those mixed with the refuse of lead mines are the most sterile, so that this substance is often mixed with gravel, to prevent weeds from growing on garden-walks. Yet even on heaps of this material, thrown up around the openings of the mines, the Vernal Sandwort thrives, growing perhaps even more luxuriantly than in any other situation.

The degree in which vitality is sometimes retained by plants, under the most unfavourable conditions, for a period to which it is difficult to assign a limit, is one of the most interesting and curious circumstances in their economy. In the greater part of those inhabiting temperate climates, an apparently complete cessation of activity takes place every year. The leaves wither and drop off; the stem and branches are reduced to a state of death-like barrenness; and all the changes in which life consists appear to have entirely ceased. In some instances, the stems also die and decay, the roots only retaining their vitality; yet from these, with the return of the genial warmth and light of spring, a new stem shoots up, and new leaves and flowers are produced,—in their turn to wither and decay. The torpor is not, however, so complete as it appears, in those durable and woody stems which defy the winter's blast; for late experiments have shown that a slight movement of sap takes place even in a frosty atmosphere. In evergreen plants, on the other hand, this cessation of activity is less marked; but the difference between their summer and winter condition is much greater than is apparent. In all these cases, however, the changes are periodical; and are not altogether dependent on external conditions. For nothing will prevent a plant from shedding its leaves nearly at its usual time; and although by artificial heat, or by removal to a warmer climate, a new crop can be brought out within a short interval, this exhausts its powers, so that few kinds can survive the change of circumstances for any long period. Moreover, the period of inactivity cannot in these cases be prolonged beyond a certain fixed time; for a plant whose growth in spring is checked by the protracted influence of cold, loses its vitality altogether. But there are some instances in which this condition may be greatly prolonged. Bulbs, for example, of the onion, hyacinth, tulip, &c. have been kept for many years in this dormant state, capable of renewing the active processes of vegetation,—of shooting up leaves and flower-stems into the air, and of transmitting their roots into the soil—for many years; and there does not seem any particular limit to this power. Instances have been related of the growth of bulbs unrolled from among the bandages of Egyptian mummies; but there is reason to believe that deception has been practised on this point upon the too-ready credulity of travellers,—still, there is nothing impossible in the asserted fact. Light, warmth, and moisture are the causes of the growth of these curious structures; and when removed from the influence of these, there is no reason why a bulb should not remain unchanged for 100 years if it can for 10; and for 1000 if for 100. We shall hereafter see that the vitality of seeds under similar circumstances appears quite unlimited.

But there are some plants which, even whilst in a state of active vegetation, are capable of being reduced to a similar torpid condition, and of remaining in it for almost any length of time, without injury to life. There is a kind of Club-Moss inhabiting Peru, which is liable to be entirely dried up, when deprived of water for some time. It then folds in its leaves and contracts its roots, so as to form a ball, which, apparently quite devoid of animation, is driven about hither and thither by the wind; as soon, however, as it reaches a moist situation, it sends down its roots into the soil, and unfolds to the atmosphere its leaves, which, from a dingy brown, speedily change to the bright green of active vegetation. The Rose of Jericho is the subject of similar transformations; and the common Mosses exhibit the same in a less degree.

These conditions are not only ones admitting of great variation, and yet most important to the active operations of the vegetable structure. Light is as important as warmth and moisture to the processes of the economy; and yet we find plants adapted to thrive under the almost total deprivation of it. Sea-weeds possessing a bright green colour have been drawn up from the depth of more than 100 fathoms, to which the sun's rays do not penetrate in any appreciable proportion. Many of the Mushroom tribe have been found growing in caverns and mines to which no rays from the sun, either direct or reflected, would seem to have access; and even more perfect plants have been observed to vegetate and to acquire a green colour (which is in general only produced under the influence of strong light) in such situations. On the other hand, we find some plants adapted only to exist where they can be daily invigorated by the powerful rays of a tropical sun, with the complete daily change which results from their total absence during a large part of the twenty-four hours; whilst there are others whose energies, after remaining dormant during the tedious winter of the arctic regions, are aroused into a brief activity by the return of the luminary on whose cheering influence they depend, and whose rays are not withdrawn from them for weeks or even months together. Neither of these tribes could flourish if transferred to the circumstances of the other; and, opposite as these are, we observe that the Creator has adapted living beings to inhabit each, with equal suitableness.

This adaptation of each species to particular circumstances is often seen in an interesting manner on a small scale, on the exterior of large trunks of trees, old towers, &c. which are thickly clothed with Mosses and Lichens. Many of these avoid the light; and their presence indicates the *north* side of the body to which they are attached. To others, again, the light in all its strength is genial; and they frequent the southern aspect; whilst other forms, intermediate in habits, frequent the eastern and western sides; so that, on going round such a tower or large trunk, we observe a succession of different species, which may be compared to that which is presented in the various latitudes, passing from the equator towards the pole. A similar succession on a larger scale is seen on ascending a high mountain between the tropics, such as the Peak of Teneriffe. The lower portion exhibits the vegetation of the surrounding country, in all the luxuriance and richness of an island in the torrid zone. Higher up, the traveller meets with productions similar to those found on the borders of temperate regions; and to these succeed those of the medium temperate zone. Above these are perceived the alpine plants, which in northern Europe are found at a comparatively trifling elevation; and to these succeeds the dreariness of perpetual snow. These five distinct zones are well marked on the Peak of Teneriffe; each having a certain set of plants peculiar to it, as the plants of Northern and Southern Europe, and of Northern and Central Africa, are to those regions respectively.

Thus we see that on no part of the earth's surface, under no peculiarities of soil or climate, is vegetation of some kind or other impossible. Every distinct tribe of plants flourishes naturally under peculiar conditions,—some preferring a warm atmosphere, others a cool one;—some only luxuriating in moisture, and others in the opposite condition of dryness;—some requiring the most intense light, and others only growing in darkness. There are some plants which are very deficient in the power of adapting themselves to slight changes in these conditions; and these are accordingly restricted to certain localities, which are favourable to their growth, and are hence considered *rare* plants. Thus, for example, there are certain species which require that the air surrounding them should contain a minute quantity of salt, dissolved in its moisture;—these only abound, therefore, near the sea-shore; but they are seen to spring up in the neighbourhood of salt-works, even many hundred miles inland,—their seeds being conveyed by the wind or by birds, which have spread them over the whole surface of the earth, but *there only* meeting with the conditions they require for their development. On the other hand, there are many which can grow in almost any situation, and which can adapt themselves to a great variety of circumstances, often exhibiting evident changes of form and aspect, which are due to the influence of these. Such are *common* plants; and many of them are among those most serviceable to man, on account of the improvement which can be effected in them by cultivation. For example, the Potatoe, growing in its native climate—the tropical portion of South America,—does not require for the growth of its young shoots that store of nourishment which, in temperate climates, is provided in its fleshy tubers; and the edible portion is thus extremely small, since the warmth and moisture constantly supplied to it develope the growing parts without such assistance. But when transplanted to colder regions, and to a richer soil, that store is greatly increased in amount, and becomes one of the most important of all articles of food to man. If it were not for this capability of adapting itself to new circumstances, the plant could not thrive in Northern Europe; since its own powers of growth would be insufficient, when the external conditions are so much changed. But it is this very capability which renders it so useful to man. If the large Potatoes of European cultivation be planted again in tropical climates, the produce is little superior to that of the original stock; since, when circumstances no longer demand it, the acquired habit ceases. The Cabbage, Broccoli, Cauliflower, &c., are, in like manner, only *varieties* of one species, greatly altered by cultivation; the plant which was the original stock of all having been formed susceptible of more remarkable changes than most others, and thus rendered at the same time useful to man, and very easy of production.

These instances, to which many more will be hereafter added, will suffice to show that it is not only in their original state that the adaptation of each tribe of plants to particular circumstances is exhibited; since there are many which can thus spread themselves, or may be spread by man, over a large part of the globe. And in this capability, no less than in their original aspect do we recognise the wisdom and power of the Almighty Designer, who willed that no portion of the globe should be unclothed by vegetation, and that from every part the herbage should spring forth for the supply of the Animal creation, which is entirely dependent on it, either directly or indirectly, for its sustenance.

Such, then, being the universal diffusion of these beings, it is obvious that in no spot can he who seeks to make himself acquainted with their structure and habits, be without some subjects for examination. And since the humblest and simplest plants are found, when examined, to display an organization as remarkably and beautifully adapted to the functions they are to perform, and to the conditions in which they are to exist, as is that of the highest and most complicated, there is no reason why any should be neglected, however insignificant they may appear.

The following volume is intended to serve as a guide to those who are inclined to make the wonders of the Vegetable kingdom an object of their regard, either as a source of recreation, or with those higher views to which the student of Natural History can scarcely avoid being led. For although no doubt can be entertained by the reflecting mind that the Power, Wisdom, and Goodness of the Creator are every where operating with equal energy, whether in the simple but majestic arrangement of the heavenly bodies, or in those changes by which our own globe is rendered fit for the habitation of such innumerable multitudes of living beings, no one can help feeling that it is in the structure and actions of these beings themselves, that these attributes are more evidently manifested to the intelligent observer. And although the Animal kingdom has usually been regarded as affording more remarkable instances of their display than the Vegetable world, it may be doubted whether, when the latter is more closely examined, it will not appear equally or yet more wonderful.

CHAPTER I.

OF THE GENERAL CHARACTERS OF LIVING BEINGS, AND THE DISTINCTION BETWEEN ANIMALS AND VEGETABLES.

1. When we examine any common Vegetable, we find that it is composed of a number of parts, differing in their form and structure,—such, for example, as the *stem*, *roots*, *leaves*, and *flowers*. Each of these we might again subdivide into others;—the leaves, for example, into the *footstalk* on which they are supported, and the expanded portion or *blade*. The blade of the leaf may be again distinguished into the *midrib* and the branching *veins* proceeding from it (which form as it were its skeleton,) and the soft fleshy portion which clothes these; and we might farther convince ourselves, by a little examination, of the presence of a kind of skin or *cuticle*, which envelopes the whole. Now these several parts of the structure of a plant, which have their respective uses in maintaining its life,—the roots, for example, being to suck up moisture from the soil through which they spread themselves, and to fix the whole structure in the ground,—the stem to convey this to the leaves, which it elevates into the air, and exposes to light and warmth,—the leaves to convert or elaborate this crude fluid into nutritious sap,—and the flowers to produce seed by which the being propagates its race,—these several parts are termed the *organs* of which the plant is composed; and the uses of these parts—the changes they perform—are called their *functions*.

2. Now it is in the presence of these different organs that one of the chief distinctions exists, between those structures which possess or have ever possessed life, and dead inert matter. In the stone or the mass of metal, we perceive that every part is similar to

every other part; it has the same structure, the same properties. If it possesses the crystalline form, it may be reduced into an almost indefinite number of smaller crystals similar to itself; and as to its properties, the chemist cares not (except as a matter of convenience) whether he examines a single grain or a mass of a ton weight. Nay, of many substances, the properties are so peculiar that they can be rocognised with certainty in quantities so minute as to be scarcely visible: thus, arsenic, when administered as a poison, has been detected after death in a quantity probably less than the hundredth of a grain; and yet the experienced chemist has no hesitation in asserting that this minute crystalline metallic substance *is* arsenic, because he recognises in it the same form and the same properties which a larger mass of that substance would exhibit.

3. Far different is it with regard to a Plant or Animal. These may be divided and subdivided; but they then entirely lose their original character, for the parts or organs no longer bear any resemblance to the whole or to each other, either in form, structure, or properties. Thus, then, we see that the bodies which are formed to exhibit those actions to which we give the general term of Life, are peculiarly distinguished from dead matter by the presence in them of a number of parts or *organs*, distinct alike in their form, structure, and properties; hence such are called *organized* bodies. On the other hand, dead inert matter may be divided with any degree of minuteness into parts similar to each other in form, structure, and properties; hence it is termed *inorganic*, or destitute of organs.

4. There is another peculiarity possessed by living beings in regard to their actions or *functions*. Some of these actions are governed by the same laws as those which operate on inorganic matter; the blood is propelled by the heart of an animal, for example, through its system of branching vessels, just upon the same principle that a forcing-pump drives water through the pipes which convey it over a large city. But the nature of the force is quite different. In the latter case it is merely mechanical. In the former it results from a property peculiar to organized struc-

ture, and especially manifested in that form of it which is called *muscle;*—the property, namely, of contracting, when a stimulus or irritation is applied to it. This and many other properties, therefore, which are exhibited by organized structures, and to which we see nothing analogous in inorganic matter, are termed *vital;* and it is by the operation of these properties, that the series of changes is produced, which constitutes the Life of any organized being, whether Plant or Animal. Thus the heart has the property of contractility, which, when exercised, causes its contraction;—the eye has the property of receiving the impressions of light, which, when exercised, causes sensation;—and so on.

5. It may be asked,—whence do these peculiar properties arise? Are living bodies composed of different *elements* from those which exist around us in the form of dead matter? Or are the elements the same, in a different state of combination? And can we attribute the peculiar properties of organized tissues to the peculiar state in which their particles exist?

6. To this it may be replied, that there is no element entering into the composition of organized bodies, which is not also found in the world around; and farther, that their chief elements are very few in number, compared with those which we find elsewhere. But the state of combination in which they exist is altogether peculiar, and such as the chemist cannot imitate, any more than the mechanic can imitate the arrangement of their parts. In fact, every organized structure with which we are acquainted, had its origin in another, which produced a germ capable of living and growing, and of constructing its peculiar fabric out of the materials it derives from the inorganic world; and this again was produced by a former one;—and so on.

7. We perceive, therefore, that the living organized beings which we now witness around us, being all the descendants of others, whose succession we might trace backwards to their first parentage, their actions are as much the results of the general laws which the Creator of all impressed on the frame of His first-formed creatures, as are the movements of the planets round the sun, of the laws which He impressed on them, when He first set

those glorious spheres in motion. These laws are continually maintained by His superintending agency, without which, all would be anarchy and confusion.

8. It would seem to be a part of the exercise of those laws, that living beings should take from the inorganic world the materials of their structure,—should convert these into parts of their own fabric,—should endow these with properties similar to those which their previous structures possessed,—and should even produce from them the germs of new structures, capable of performing the same changes. Thus, the germ contained in the seed builds up the beautiful form and wondrous structure of the perfect tree, with scarce any other materials than water and air; and of these it not only constructs its own stem, leaves, roots, and flowers, but (what seems yet more extraordinary) it imparts to its seeds, which, when separated from it and dried up, seem as it were dead, the power of repeating for themselves the same operations. When once we understand it, however, as a general law, that it is a property of organized structures to produce the same, there is little difficulty in comprehending how they impart to the elements they employ, properties so different from those which they previously possessed. For we find in every case, that a change of combination in these elements is attended with a change in their properties. Thus an *acid* (such as oil of vitriol) and an *alkali* (such as soda) have properties peculiar to themselves, and in many respects contrary; but when they are brought together, they unite into a new compound, which possesses a form and properties differing from those of either of its elements. Again, sulphur, nitre, and charcoal, when simply *mixed* together in certain proportions, form a product, gunpowder, which possesses properties very different from those of either of its elements. Thus, then, we see that there is nothing improbable in the supposition, which all analogy supports, that the properties peculiar to organized structures depend upon the peculiarity of their constitution; and this peculiarity, which the chemist and the mechanic alike fail to imitate, results, as we have seen, from the general law,—that organized structures can only take their origin from beings already possessed of life.

9. One more preliminary consideration must be adverted to, before we quit these general views. The properties of organized bodies require certain conditions for their operation. Thus, a seed, which possesses vital properties in a dormant or inactive condition, and which may retain these for hundreds or even thousands of years, if placed in favourable circumstances so to do, begins to germinate or grow, as soon as it is submitted to the proper degree of warmth, moisture, and air. These, then, are the conditions requisite for those changes which we call its Life; for the dry inactive seed can scarcely be said to be *alive;* though, on the other hand, it certainly is not *dead*, since it possesses those properties or capabilities which enable it to live when placed in favourable circumstances. Again, suppose a plant to be actively vegetating under the influence of light, warmth, and moisture, and it be suddenly deprived of all these,—by being carried for example, into a cold dark cellar:—all its vital processes receive a check, and it either dies, or, if sufficiently hardy to sustain the shock, it remains inactive until the necessary conditions be renewed. These conditions are technically called the *stimuli* to vital actions; and thus we see that Life is the result of the operation of these stimuli upon organized structures possessed of peculiar properties. In attempting, therefore, to understand the history of Vegetation, we have three things to consider; in the first place, the nature of the *structure* of plants; next, the *properties* which their several kinds of structure respectively possess; and lastly, the operation of various *external stimuli* upon these properties, so as to produce vital actions.

10. In considering the history of Animal Life, exactly the same course will be gone through; but there will then be an additional subject to be treated of; namely the *internal* stimuli, arising from the *will* of the being, which cause those actions that are termed *spontaneous*, since they have no direct dependance upon external stimuli, but originate in the animal itself. In the history of Man, these actions evidently form a large part; but in the lowest animals they are very obscure, and can often scarcely be distinguished from the actions of plants. But even in man we

have no difficulty in recognising a great number of actions analogous to those which constitute the whole life of plants. Thus, the absorption of food, its conversion into a nutritious fluid, the circulation of this through the system, its purification by exposure to the air, and the formation from it of new structures or the reparation of the old,—are all actions over which the mind and will have no direct control, which go on quite independently of it, and which may be regarded as perfectly analogous to the same functions in plants. Hence they receive the name of functions of *vegetative* or *organic* life; whilst those of sensibility and power of spontaneous movement are termed functions of *animal* life, as being peculiar to that division of organized Nature. In fact it is by their presence or absence that the Animal or Vegetable character of a being must really be determined. For though the external peculiarities of the higher kinds of Plants and Animals are quite sufficient to distinguish them from each other, yet there are many forms of the latter so low and simple, and so destitute of all that is regarded as peculiar to the Animal, that they cannot be readily distinguished from Plants.

11. It is in these lowest forms of both kingdoms, that we recognise the nearest approach to inorganic matter. For we gradually lose, in descending the scale, nearly all appearance of distinct organs; so that the simplest plants—that, for example, which constitutes the Red Snow of Alpine and Arctic Regions (§ 48.)—instead of having stems, roots, leaves, and flowers, present us with apparently but a single organ, namely, a globular cell or little bag containing fluid. Even here, however, we shall subsequently find that there is a distinction of parts; and that, whilst the *external* surface is destined to imbibe nutriment from the moisture and air around, the *internal* forms the germs by which this simple little being is multiplied to a prodigious extent.

CHAPTER II.

GENERAL VIEW OF THE VEGETABLE KINGDOM.

12. When we examine, however cursorily, the nature of the Plants around us, we at once perceive that their growth and succession are regulated by certain *laws*. Thus we observe that all have a period of life to which they are more or less closely limited. Many of our commonest cultivated vegetables,—the Corn, the Beans, the Turnips of our fields, and many of the plants which enrich our gardens with their flowers,—live but for a single summer; springing up from seed, uprearing a lofty stem, putting forth expanded and luxuriant foliage, and unfolding gay and numerous blossoms, and finally withering away and undergoing complete decay, in the course of a few months. In others, on the contrary, the duration of life is so great that it *seems* to be unlimited; but there is good reason to believe that the forest trees which lift their massive stems to the light of day through a succession of many hundred years, have an appointed limit to their lives as regular as that of man,—varying like his, in individual cases, according to the circumstances of each. Every plant, then, has a period allotted by the great Creator of all, for its springing from seed, the unfolding of its leaves, the expansion of its blossoms, and its subsequent death and decay; but while death is the lot of each generation that "cometh up and is withered," the perpetuation of the race is accomplished by another law, which provides for the production by each individual, before its own dissolution, of the germs of new individuals, from which plants may arise, that go through their allotted period of life, and in their turn decay after producing the germs of a succeeding generation.

13. Now besides these evident laws, another may be detected by a little observation,—that the beings produced from these

germs are in every essential respect similar to their parents; and that thus, after many thousands of generations, every plant or tree of the present day, may be regarded with certainty as having had a representative, at the period of the creation of the vegetation which now clothes our globe. The exceptions which may seem to exist in regard to this law are so in appearance only. The seeds of any particular kind of Apple, for instance, will not produce the same kind with any certainty, but are as likely to give origin to trees that shall bear very different and far inferior fruit. The same may be said of the cultivated Dahlia, which presents so many beautiful varieties of colour; the seed of a white flower is not much more likely to produce white Dahlias, than one with yellow or purple flowers.

14. But in these and many more such instances, the different kinds are first produced by the influence of cultivation only, and had all originally but one stock; and it is this stock, common to all kinds, which the seed has a tendency to perpetuate, rather than any one of the varieties which have been obtained from it by the art of man; and we never find any tendency to produce a plant of an entirely different kind. Thus, the sour Crab is the stock of all the rich and delicate varieties of the Apple; and if the seeds of any of these be sown in a poor soil, the plant will bear fruit resembling that of the original; but still it will be an Apple, and never a Pear or a Quince, or any other of the kinds most nearly allied. In the same manner, the original stock of the Dahlia is a plant having a very ordinary yellow flower, with but one circle of coloured leaflets; but by the influence of cultivation the number of these circles is much increased, and the colours are deepened and enriched, as well as almost infinitely varied. The seeds of any of these, however, when sown in a poor soil, will produce a plant resembling the *original* parent; and thus it is seen that there is no real exception in such cases to the general law,—that the form of the *species* or distinct kind is propagated without any important alteration through successive generations; so that we may regard all the tribes of plants, really distinct from one another, as having existed in nearly the same form since their first creation.

15. The Naturalist, then, regards as *distinct species* those races of Plants, the differences between which are evident, and are such as are not likely to have resulted from cultivation or any other external cause, and do not exhibit any tendency to alteration in progress of years. Such, for example, are those between the Apple and Pear among Plants, or the Dog and the Fox among animals. Among all the varieties of the Apple, different as they are from one another, there is none which exhibits any close resemblance to the Pear; and of all the kinds of Pear, there is none which so far loses its distinguishing characters as to show any great similarity to the Apple. And yet among the varieties of the latter, there are kinds more different from each other in size, shape, colour, flavour, &c. than some of these differ from the Pear; but while all these show a marked tendency to change under different circumstances of growth, the internal differences between the Apple and Pear never exhibit any such tendency, but remain constant through all the varieties of each. The same may be said of the Dog and the Fox; for, though some varieties or breeds of the former seem to differ from each other more than from the Fox, yet these differences are liable to disappear altogether when the animals return to a wild state, all merging in a form most nearly resembling that of the shepherd's dog; whilst the differences between the Fox and the breeds of Dog most nearly allied to it are constantly manifested.

16. On the other hand, the Naturalist regards as *varieties* of the *same species* Plants and Animals, in the various specimens of which, however dissimilar they may be, the points of difference exhibit such a tendency to variation, that the one kind passes, as it were, into the other. Thus, the Greyhound and the Bull-Dog would be regarded as springing from originally different stocks, if we did not meet with intermediate forms of the Dog which blend the peculiar characters of both. And the Primrose, Cowslip, and Polyanthus have been regarded as distinct species, so considerable are their differences in form and structure; but the Botanist is now aware that many forms exist which are intermediate between these, and that all may be raised from one stock. The same is the case with many other kinds of Plants.

17. This explanation will, it is hoped, make the meaning of the term *species* understood; and it is very desirable that clear notions on the subject should be acquired by the student of Natural History at the very commencement of his attention to the pursuit. It is computed that from 70,000 to 80,000 distinct species of Plants have been collected by Botanists from the surface of the globe; and probably at least as many more remain to be discovered. It is obvious that an acquaintance with the structure and characters of such a vast number of different races will be rendered much easier by classifying or arranging them,—placing those together which have a greater or less amount of general resemblance; and separating others according to their amount of difference. It is only in this manner, indeed, that any one, within the compass of a single life, can become master of the whole. In making such an arrangement those species are first assembled into a group, termed a *genus*, which resemble each other in all the more important particulars, and differ only in minor details. For example, the different kinds of Roses among plants, and the Lion, Tiger, Leopard, and other species of the Cat kind among animals, are considered as belonging to the same genus,—their points of agreement being far more numerous than those of difference. Several genera may, in like manner, be united into a *family;* the various members of which have a common resemblance, though with many subordinate differences. By continuing to pursue the same plan, we form divisions of greater and greater extent; until we are at last brought, by uniting subordinate ones, to the primary divisions into which the whole kingdom may be at once distributed, each of which exhibits a large number of very dissimilar groups, still united together by some common points of general resemblance.

18. Perhaps an illustration may make this subject better understood. If we were to examine the people of any nation in which there had been but little intermixture among its different tribes, (as was formerly the case in Scotland in regard to the *clans*,) we might find a group of persons resembling each other so strongly in countenance, manners, form of speech, &c. and differing so much from all around them, that we should have lit-

tle doubt that they belonged to one family; and, going farther, we might meet with several such groups, each containing several individuals, and each differing in other characters from the rest. But if we were to bring these families together, we should probably be able to trace more general and less marked resemblances among certain of these, which would lead us to associate them in clans, each of them including many families distinguished by certain points of similarity to one another,—as, for example, a strongly-marked feature or a peculiar dialect,—whilst differing in these same points from those of the remaining clans, and also differing from each other in minor points. Again, among these clans we might find some resembling each other and differing from the rest in their complexion or language, and thus forming tribes into which the whole nation might be subdivided. And, lastly, this nation would have certain points of conformity with those inhabiting the same quarter of the globe, whilst yet differing still more strongly from them than its own tribes do amongst each other; and those inhabiting different quarters shall still more widely differ from each other, in general conformation, complexion, language, habits, &c. whilst still exhibiting those characters which are peculiar to *man*, and which separate him from all other animals.

19. The primary division of the Vegetable Kingdom is into Phanerogamia or Flowering-plants, and Cryptogamia or Flowerless-plants. Though these designations are not strictly correct, they serve to indicate sufficiently well the character of the tribes to which they respectively apply. To the former division belong nearly all cultivated vegetables,—the whole of the forest-trees both of our own and other countries,—and a very large proportion of the vegetation that naturally covers the surface of the earth in temperate and warm climates. Many of the tribes contained in it, however, produce no distinct blossom; but these possess the essential parts of the flower (as will be hereafter explained,) and form that perfect seed which is characteristic of this division. In all the Phanerogamia, (save in a few exceptions which stand, as it were, on the border of the division, and con-

nect it with that of Cryptogamia, of which they exhibit some of the characters,) we find a certain number of distinct parts,—such as the stem, roots, leaves, and flowers; and the germs by which they propagate their race come to an advanced state before quitting the parent, and are furnished with a store of nourishment by which they are afterwards assisted in their growth. The *seed* of these plants is, therefore, a complex structure; and the young plant shoots from it in a certain determinate manner.

20. In the CRYPTOGAMIA, on the other hand, the parts concerned in the reproductive process are much less evident, and the germs which they form are much less matured when they quit the parent structure. In the Mosses, Ferns, Sea-Weeds, &c. no *seeds* are produced: but a number of small particles are liberated, which are termed *spores;* and each of these contains within it several minute germs which spring from it without any particular regularity, and which are not assisted in their growth by any such store of nutriment as that provided in the seed. The absence of this is a very important character; for it seems a universal law of Nature, that the higher the grade a living being is ultimately to attain, the longer is the period during which it is assisted, either directly or indirectly, by its parent, during the early stages of its growth. Thus Quadrupeds, which bring forth their young alive, and maintain them afterwards by suckling, are higher than Birds which produce them, in the first instance, in a state far less mature. And Man, who in his adult age rises far above all other animals, is longer dependent upon his parent during the period of infancy.

21. The embryo of the flowering-plant, contained in the mature seed, is so far advanced at the time of quitting its parent, that it possesses one or two distinct leafy bodies, termed *cotyledons*, which, when the seed begins to germinate (as it is called) are pushed up to the surface of the ground, and there turn to a green colour, and perform all the functions of true leaves, until these make their appearance. Now of all trace of these, the embryo of the flowerless-plant is entirely destitute; and the whole group is hence spoken of as *acotyledonous*. On the other hand,

of the Flowering-plants some possess one and others two cotyledons; and this difference in the structure of the seed is accompanied by so many other differences in the structure of the stems, the leaves, flowers, &c. that it serves to mark the two principal subdivisions of this portion of the Vegetable Kingdom. That in which only one cotyledon exists is termed *Monocotyledonous;* and that in which there are two, *Dicotyledonous.* The common Bean or Pea will serve as a characteristic illustration of the former; and the Wheat and other Grass-seeds, of the other.

22. The general aspect of the Flowering-plants is sufficiently well known to render a more minute account of them here unnecessary; since the object of this preliminary view of the Vegetable Kingdom is to render the student, who may have been previously entirely ignorant of the subject, prepared to enter with advantage on that detailed description of the mode in which the several tribes grow and reproduce themselves, which it is the object of the Physiological portion of this volume to communicate. A fuller sketch of the principal divisions of the Cryptogamia will, however, now be given, as few ordinary observers bestow much attention on them.

23. Of all the CRYPTOGAMIA, the *Ferns* approach most nearly to Flowering Plants. The general aspect of those inhabiting this and other temperate countries is well known. They present a small number of leaves,—generally much divided into leaflets, and these again often minutely subdivided,—each arising from the ground by a woody stalk, which is commonly regarded as the stem of the plant. The true stem, however, is buried beneath the ground, or sometimes creeps along its surface; and the branches it sends upwards into the air are really the leaf-stalks. (Fig. 1.) In many Ferns of tropical climates, the true stem rises upright, like that of a tree, and bears at the top a beautiful crown of those peculiarly graceful leaves for which the Ferns are remarkable. The height of these Tree Ferns, which are more luxuriant in the small islands, where they are furnished with a more regular supply of atmospheric moisture than they can obtain at a greater distance from the sea, is sometimes as much as 40 or

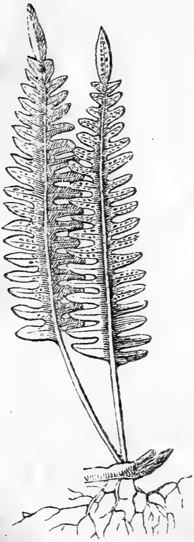


Fig. 1.
Polypodium vulgare,
common Polypody,
or Wall-Fern.

Fig. 2. Tree Fern.

50 feet; so that we must not judge of the whole race by the comparatively insignificant specimens which our own climate affords. These stems do not, however, afford any wood sufficiently solid to be employed in the arts. (Fig. 2.)

24. The organs of reproduction in Ferns have no evident analogy with the flowering system in higher plants. Nothing like a flower is ever seen in this group; and the fructification is incorporated, as it were, with the leaves,—being generally found, when mature, in brown spots or lines on their under surface or at their edges; the nature of the organs composing these will be hereafter described. In most Ferns, all the leaves are concerned in reproducing the fructification; but in some (of which the *Osmunda regalis*, or Flowering-Fern as it is com-

monly but incorrectly termed, is an example) certain leaves are devoted to the production of the fructification, and are termed *fertile;* whilst others only perform the usual functions of leaves, and are called *sterile* leaves, from the absence of reproductive power in them. The term *frond* is generally applied to the leafy portions of the Cryptogamia, as distinguishing them from the true leaves of Flowering Plants, which have only one set of offices to perform. Sometimes the fertile frond of Ferns altogether loses its leafy aspect, its edges being completely rolled in so as to enclose the fructification; and this separation of the reproductive from the nutritive portion of the system, is as complete as any which the Cryptogamia exhibit.

25. One of the most interesting peculiarities of the Ferns is the spiral mode in which its leaflets and leaves are rolled up before their first appearance; each leaflet being rolled up towards the rib which supports it,—the ribs again towards the midrib, and the midrib towards the footstalk. The unfolding leaves, in a state closely resembling those represented at the top of Figure 2, may constantly be seen during spring in spots frequented by this group; and, when examined, display the most provident and beautiful arrangement of the numerous minute parts of which the whole leaf consists. Few *common* objects, indeed, are more interesting than this, which requires neither skill nor the assistance of instruments for the detection of its beauties.

26. Although Ferns constitute but a comparatively small part of the present vegetation of this country, they must have been much more abundant in a former period of the earth's history, especially at the time when the beds of coal were being formed; since their remains now constitute by far the largest part of those which are preserved to us with tolerable perfection in a fossil state. This is partly due, however, to the remarkable power which these plants possess, of resisting the action of water; by which other plants and trees were decomposed,—their remains having contributed to form those immense masses of Coal, which are so important to man, not only for his personal

comfort, but for the arts of life. The Ferns are able to withstand the effects of even a very prolonged immersion in water, with scarcely any change; whilst not only the soft tissue of plants, but the heartwood of most trees, decays so completely under the same circumstances as to leave little or no traces of their character. In tropical islands, the Ferns constitute a most important part of the whole vegetation; being equal in number, in the Sandwich islands, to one-fourth, and in Jamaica to one-ninth, of all the Flowering plants existing in each of these localities.

27. The next principal group of Cryptogamia, that of *Mosses*, is as interesting from the delicacy and minuteness of all the plants composing it, as other tribes of the Vegetable Kingdom are for the majesty of their forms, or the vast extension of their foliage. These are so generally and easily recognised as such, that a minute description of them is at present unnecessary; but it should be stated that the term *Moss* is commonly applied not only to the true Mosses, but also to many Lichens. The true Mosses, however, are always to be known by the green colour they possess except when dried up, while the Lichens are usually grayish in their aspect. Mosses usually possess a sort of stem, round which the minute leaves are arranged with great beauty and regularity; but neither this stem, nor the leaf-stalks of the leaves, have any truly woody structure; and they more closely resemble the simple tissue of the lowest plants, than the complex fabric of those already noticed, to which they seem to bear a greater resemblance in external form. Mosses do not, like Ferns, bear their fructification upon the leaves or modifications of them; it

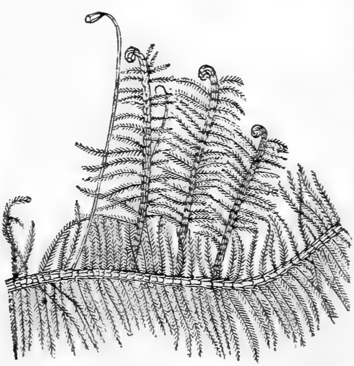


Fig. 3. Hypnum Castrensis, or Feather-Moss.

is enclosed in a little case or *urn*, which is furnished with a lid, and is borne on a long distinct stalk, so as to be very easily observed when full-grown. The interior of this minute organ usually contains a structure of great beauty, which will be hereafter described in detail; but it is interesting to know that it was by the contemplation of this that the heart of Mungo Park, the African traveller, was revived, when the difficulties by which he was surrounded had almost extinguished hope within him. The passage has been often quoted; but, it may be hoped, never without its use; and it does not seem superfluous to introduce it here.

28. This enterprising traveller, during one of his journeys into the interior of Africa, was cruelly stripped and robbed of all that he possessed by banditti. "In this forlorn and almost helpless condition," he says, "when the robbers had left me, I sat for some time looking around me with amazement and terror. Which ever way I turned, nothing appeared but danger and difficulty. I found myself in the midst of a vast wilderness, in the depth of the rainy season,—naked and alone,—surrounded by savage animals, and by men still more savage. I was five hundred miles from any European settlement. All these circumstances crowded at once upon my recollection; and I confess that my spirits began to fail me. I considered my fate as certain, and that I had no alternative but to lie down and perish. The influence of religion, however, aided and supported me. I reflected that no human prudence or foresight could possibly have averted my present sufferings. I was indeed a stranger in a strange land, yet I was still under the protecting eye of that Providence who has condescended to call himself the stranger's friend. At this moment, painful as my reflections were, the extraordinary beauty of a small Moss irresistibly caught my eye; and though the whole plant was not larger than the top of one of my fingers, I could not contemplate the delicate conformation of its roots, leaves, and fruit, without admiration. Can that Being (thought I) who planted, watered, and brought to perfection, in this obscure part of the world, a thing which appears of so small

importance, look with unconcern upon the situation and sufferings of creatures formed after his own image? Surely not.—Reflections like these would not allow me to despair. I started up; and disregarding both hunger and fatigue, travelled forwards, assured that relief was at hand, and I was not disappointed."

29. Mosses are found in all parts of the world in which the atmosphere is moist; but they are far more abundant in temperate climates than in any between the tropics. They are among the first vegetables that clothe the soil with verdure in newly-formed countries; and they are the last that disappear when the atmosphere ceases to be capable of nourishing vegetation. The first green crust upon the cinders with which the surface of Ascension Island was covered, consisted of minute Mosses. This tribe forms more than a fourth of the whole vegetation of Melville Island, one of the most northerly spots in which any plants have been observed; and the black and lifeless soil of New South Shetland, one of the islands nearest to the South Pole, is covered with specks of Mosses struggling for existence.

30. Besides their power of resisting extremes of temperature, Mosses exhibit a remarkable tenacity of life, when their growth is checked by the absence of moisture; so that they may often be restored to active life, even when they have been dried for many years. Hence they offer abundant sources of interest to the observer of Nature, at a season when vegetation of other kinds is almost entirely checked. For it is most curious to observe how gay these little Mosses are on every wall-top during the winter months, and in the early spring,—almost, or perhaps the only things which seem to enjoy the clouds and storms of the season. They choose the most exposed situations, spread out their leaves, and push up their delicate urns, amidst rain, frost, and snow, and yet there is nothing in their simple and tender structure from which we could infer their capability of resisting influences so generally destructive to vegetation. But it is with plants as with Animals.—The more simple and lowly the being, the

greater is usually its tenacity of life under circumstances which depress the vital powers of higher kinds; whilst the influences which they require are often too powerful for it. Thus, Mosses and Lichens, overstimulated by heat and dryness, wither away in summer; but vegetate freely at a season when there is no other vegetation, and when their humble fabrics cannot be overshadowed by a ranker growth.

31. Mosses were fancifully termed by Linnæus, ***servi***, servants or workmen; for they seem to labour to produce vegetation in newly-formed countries, where soil can scarcely yet be said to be. This is not their only use, however. They fill up and consolidate bogs, and form rich vegetable mould for the growth of larger plants, which they also protect from cold during the winter. They likewise clothe the sides of lofty hills and mountain-ranges; and powerfully attract and condense the watery vapours floating in the atmosphere, and thus become the living fountains of many streams. They are sometimes so completely dried up by drought, that they escape notice; and then, when moistened by rain, they appear to have suddenly clothed a barren heath or overspread a dry wall with verdure, on which, however, they really existed before.

32. Closely connected with the Mosses is the tribe of ***Liverworts***, the lower forms of which are nearly connected with the Lichens. Some of them differ but little in their general characters from Mosses, being distinguished by certain peculiarities of fructification. Others, however, have no distinct stem or separate leaves; but extend horizontally into a flat leaf-like expansion; the fructification is sometimes elevated above this on a little stalk; but in the tribes most nearly allied to the Lichens, it is imbedded in it, as it is in that group. Their general habits closely resemble those of the Mosses. Their leafy expansions are soft and green; differing much, therefore, from the dry scaly crusts of the Lichens. They are capable of reviving, like the Mosses, after being dried up; and, from the rapidity of their growth, and a peculiarity in their mode of propagation, they are often seen to spread over a damp surface with great rapidity.

Fig. 4.
Marchantia polymorpha, one of the commonest of the Liverworts.

One of the most common species is the *Marchantia polymorpha*, which will be often referred to in this treatise, on account of the many interesting facts which the attentive study of it has disclosed. It is usually found growing on moist surfaces, and often where there is little or no soil; it is very common in the chinks between paving-stones in unfrequented places and on the surface of the earth contained in garden-pots as also upon walls which from any cause are kept constantly damp.

33. Besides the regular fructification, this little plant has a very curious apparatus for the production of small leafy bodies, which may be regarded as buds, and which spontaneously separate from the parent structure and develope themselves into new beings. As these, when mature, are liable to be washed out of their receptacle by rain, and to be carried to different parts of the neighbouring surface, and as they grow very rapidly whilst supplied with moisture, the rapid extension of the plant under such circumstances is easily accounted for. The little receptacles, of a basket form, in which these are produced, may be generally seen in some stage of their growth on the upper side of the leafy expansion of which the plant consists; and they constitute beautiful objects for a low magnifying power of the microscope. The bud-like bodies, having the form of flat disks like coins, may often be seen to grow whilst still contained in their receptacle, and even to unite themselves, as it were, with the parent plant.

34. The group of Cryptogamic plants termed *Lichens* are mostly dry, hard, scaly crusts, destitute of leaves and stems, and even of any thing bearing a resemblance to them; they grow upon bare walls, the trunks of old trees, and other such situations, in which they are much exposed to light, and not abundantly supplied with moisture. In their general structure they

nearly approach to the Sea-weeds; and differ from them chiefly in being adapted to live in air instead of in water. The dry hard crust is usually of a grayish colour; its upper surface, being exposed to the light and warmth of the sun, performs the functions of leaves; whilst from beneath it there proceed a number of minute hair-like filaments, which serve both to fix it by clinging to the substance on which it grows, and also, it may be believed, for the absorption of fluid—the chief uses of the roots in the Flowering-Plants. Lichens are among the slowest in growth of all plants, and the least subject to alteration from decay. Whilst alive, they scarcely exhibit any change through a long series of years; and when dead, their forms and colours are scarcely altered by being dried.

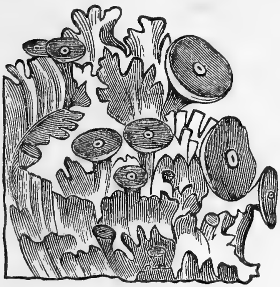


Fig. 5.
Parmelia perforata,
Lichen with projecting shields.

35. There can be no doubt that the greater part of this tribe derive their nourishment from the atmosphere and its contained moisture alone; flourishing as they do upon sterile rocks, without a particle of soil or mould in their neighbourhood. There are many species which ordinarily grow upon the trunks of trees; and these are commonly spoken of as Mosses,—but incorrectly so. The shaggy appearance of the apple-trees of an old Orchard is in general entirely due to Lichens, although a few Mosses may sometimes be found among these. Of such Lichens, by far the greater part vegetate indifferently on all kinds of trees, and they flourish equally well upon a damp wall; so that there is no reason to suppose that they derive any more nutriment from the stems on which they grow, than is afforded by the moisture covering their surface. There is no doubt, however, that some trees are much more favourable to their growth than others. Thus, the Beech, Elm, Sycamore, and Lime, are comparatively seldom found infested with the common *Beard-moss*, which clothes so profusely the Fir, Ash, Oak, or Birch;

so that the poet's epithet of "rude and moss-grown beach" is by no means appropriate.

36. The fructification of the Lichens is not much raised above the general surface, but is usually imbedded in certain parts of it, somewhat differently formed from the rest, and termed *shields*. The early growth of these plants is favoured by darkness; but for the ripening of the reproductive bodies a considerable quantity of light is required. The development of the shields, which takes place under its influence, is frequently accompanied by so great a change in the general appearance of the plant, that the same species growing in dark and moist places, in which the fructification was not evolved, has been considered to belong to a distinct kind from the perfect specimen. No true Lichens are ever found in mines, caverns, or other places deprived of light; nor are there any that grow entirely under water, although some species, which connect this group with the Sea-Weeds, grow on the sea-shore, where they are alternately submersed and left dry by the tide.

37. To the Lichens may well be applied the title of *Vernaculi* or bond-slaves, which Linnæus fancifully gave to the Sea-Weeds, regarding them as fettered to the rocks on which they grow. For the Lichens seem as it were chained to the soil which they labour to improve for the benefit of others, although they derive no nourishment from it themselves. The mode in which they prepare the sterile rock for the reception of plants which require a higher kind of nourishment, is most remarkable. They may be said to dig for themselves graves, for the reception of their remains, when death and decay would otherwise speedily dissipate them. For whilst living, these Lichens form a considerable quantity of oxalic acid, (which is a peculiar compound of carbon and oxygen, two ingredients supplied by the atmosphere;) and this acts chemically upon the rock, (especially if of limestone,) forming a hollow which retains the particles of the structure, when their term of connected existence is expired. The moisture which is caught in these hollows finds its way into the cracks and crevices of the rocks; and, when frozen, rends

them by its expansion into minute fragments, and thus adds more and more to the forming soil. Successive generations of these bond-slaves continuously and indefatigably perform their duties; until at length, as the result of their accumulated toil, the barren and insulated rocks, or the pumice or lava of the volcano, become converted into fruitful fields. For when Flora's standard has once been planted on tracts thus claimed, they are soon colonized by plants of other tribes. The Mosses, Ferns, and other Cryptogamia follow them; and, at last by the growth and decay of successive generations of plants, a sufficient thickness of soil is produced for the nourishment of the luxuriant herbage and the support of the lofty forest-tree. And thus, by the labours of these apparently insignificant plants, men are enabled to reap their harvest, and to supply themselves with timber from the forests, and cattle increase and multiply, on what was formerly but a naked and desolate rock.

38. One of nature's truest though least attractive delineators has thus faithfully described such a process as it occurs on ruined buildings. It should be remarked, however, that the terms *seed*, *foliage*, and *flower*, are not strictly correct as applied to the Lichens, which have none of these.

> "Seeds to our eyes invisible, will find
> On the rude rock the bed that fits their kind;
> There in the rugged soil they safely dwell,
> Till showers and snows the subtle atoms swell,
> And spread th' enduring foliage; then we trace
> The freckled flower upon the flinty base;
> These all increase, till in unnoted years
> The stony tower as gray with age appears,
> With coats of vegetation thinly spread,
> Coat above coat, the living on the dead.
> These then dissolve to dust, and make a way
> For bolder foliage, nursed by their decay:
> The long-enduring ferns in time will all
> Die and depose their dust upon the wall:
> Where the wing'd seed may rest, till many a flower
> Shows Flora's triumph o'er the falling tower."

CRABBE'S BOROUGH.

39. Besides this important office in the economy of Nature some of the Lichens are peculiarly useful to man, on account of the valuable dyes they afford him. The blue dye termed Archil or Litmus, which is changed to a bright red by the action of acids, is obtained from a species of Lichen growing in the Canary islands; and many other species not at present regarded might probably be converted with advantage to the same use. To the Laplanders the tribe of Lichens is of peculiar utility; indeed on it they depend for their subsistence. For though it is not an article of their own diet, a humble Lichen commonly known as the Reindeer Moss supplies the animal, on which they depend for almost all their means of existence, with food throughout their dreary winter, its vegetation not being checked by the snow beneath which it grows. A species of Lichen growing on the rocks of the Arctic regions of North America, has afforded subsistence for many days to some of the adventurous explorers of that desolate country, when other provisions could not be obtained.

40. The group of *Algæ*, or Sea-Weeds, includes the very lowest forms of vegetable organization; but it also comprehends some plants whose structure possesses great complexity. The Algæ may be considered as Lichens formed to exist in water; their general structure, and the arrangement of their parts being much alike. The hard scaly crust of the Lichens, formed under the influence of the sun and air, and never attaining any great extent, seems to bear a remarkable contrast with the immense leaf-like expansions, composed of soft, easily decomposed tissue, presented by the Algæ; yet wherever any of the former group inhabit damp shady places, their character much approaches that of the latter; and in regard to some plants, it is difficult to fix the group to which they belong. Although the term Sea-Weed is that usually considered equivalent to Algæ, it should be understood that the class includes many species which are inhabitants of fresh water. Of this kind are the *Confervæ*,—the long green hair-like filaments of which are almost constantly found attached to stones at the sides or bottom of running streams. These are among the simplest forms of vegetation. Each filament consists

of a single row of minute cells or vesicles, attached to each other end to end. Each of these vesicles is capable of growing by itself, and of reproducing its kind; for at a certain period a minute orifice appears in its walls, from which issue forth some of the little green particles it contains; and these become the germs of new plants of the same description.

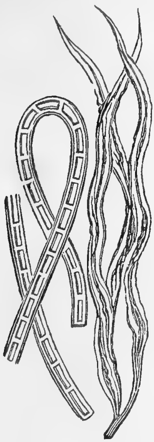


Fig. 6. Confervæ, with separate filament magnified.

41. The higher kinds of Algæ inhabit Sea-water only. They often assume the forms of more perfect plants, presenting an appearance as of roots, stems, and leaves. But these parts have not those differences of structure which are characteristic of them when truly formed, and which will be hereafter described; on the contrary, they all consist of the same kind of simple and similar texture as that of the Confervæ;—the expanded leaf of a Sea-weed being composed, as it were, of a number of filaments of the Confervæ laid side by side. The structure of these apparently different parts being thus so nearly he same, their functions or uses have an equal conformity; for the root-like fibres at the bottom of the stem only serve to fix the plant to the rocks or stones to which it is its habit to attach itself, instead of absorbing or sucking up nourishment as in the flowering plants. The cause of this difference is obvious. Where the *whole* plant is constantly immersed in the fluid which affords it the materials of its growth, no one part of it need be specially endowed with

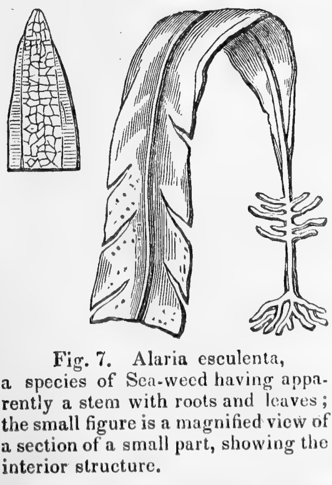


Fig. 7. Alaria esculenta, a species of Sea-weed having apparently a stem with roots and leaves; the small figure is a magnified view of a section of a small part, showing the interior structure.

the power: and it will be hereafter shown (Chap. IV.) how strong the contrast is between the functions of the true roots of Flowering plants and the root-like organs of the Algæ.

42. The higher Algæ sometimes attain a prodigious extent of development, forming vast sub-marine forests of the most luxuriant vegetation. Thus the *Chorda Filum*, a species common in the North Sea, is frequently found of the length of 30 or 40 feet; and in the neighbourhood of the Orkneys it forms meadows through which a boat forces its way with difficulty. It grows in the form of a long and even cord (whence its name) about the size of a quill, attached at one end to the bottom or shore, and the rest supported by the water. This is nothing, however, to the prodigious extent of the *Macrocystis pyrifera*, which is reported to be from 500 to 1500 feet in length, the long and narrow fronds having an air-vesicle at the base of each, the stem not being thicker than the finger, and the upper branches from it as slender as common pack-thread. Another tropical species attains the length of 25 or 30 feet, with a trunk as thick as a man's thigh. Sometimes these stems are solid, and sometimes hollow; the tubular stem of one species of Laminaria, found near the Cape of Good Hope, has been used by the natives as a trumpet when dried. Another species furnishes the natives of some parts of Australia, with a large proportion of their instruments, vessels, and even of their food.

43. The marine Algæ differ much in their habits. Some species grow altogether beneath the water, attaching themselves below the lowest tide-level. Others fix themselves where their fronds may float on the surface, and be exposed in some degree to the direct influence of the air. Others again frequent a height at which they are left dry at every retreating tide; and some are found in situations in which they are scarcely ever covered by water, thus approaching in habits, and in character also, to the Lichens. Although most attach themselves to rocks or other solid masses, frequenting the shores or shallows rather than the open sea, there are some exceptions, among which one of the most remarkable is the *Sargasso* or *Gulph Weed*, which floats on the surface of the ocean, in the Gulph of Mexico, and in the

current which sets from it towards the north. Immense fields of it are seen by the navigator, extending as far as the eye can reach, and conveying the idea of rocks and shallows,—dangers far distant. It is sometimes so abundant as seriously to interfere with the progress of the ship through the water; and it was this which alarmed the crew of Columbus, in his first voyage of discovery.

44. The distribution of different species through the ocean is influenced by latitude, by the depth of water, and by currents, nearly in the same manner as the higher plants are affected by temperature, elevation above the sea-level, and the conditions of the atmosphere as to dryness and calmness. Some species can thrive well under considerable variation in these conditions; whilst others are dependant upon certain states of them for their existence. The former, therefore, are extensively diffused, being found along many shores, whilst the latter are rarer, and only inhabit particular spots, in which these conditions are met with. Contrary to what might have been expected,—considering that the Algæ do not imbibe any nourishment by the spreading root-like fibres which attach them to the solid masses of the shore,—it has been ascertained that they do not grow indifferently on all kinds of rocks; but that if, for example, along the same line of coast, there be an alternation of limestone and granite rocks, some species will attach themselves in preference to the former, and others to the latter. This curious fact can only be explained by the supposition that small quantities of the mineral matter are dissolved by the water of the neighbourhood; and that in this manner they act upon the plant.

45. Of all tribes of plants, the Algæ are commonly reputed the least useful; in fact their inutility was proverbial among the ancients. Yet neither in regard to the general economy of nature, nor as to the wants of man, are they to be so considered. They supply food to a large number of marine animals, which browse upon them as those inhabiting the land do upon its most luxuriant pastures. Cattle have been very profitably fed on some species abundant on the northern shores; and even become so fond of this diet as greedily to seek for it. Many kinds furnish a wholesome and palatable food for man, and are employed by

the poorer classes along the shores of the North of Europe; whilst others are reckoned a luxury by the rich. The Laver of this country, the Carrageen, or Irish Bog Moss (as it is erroneously called,) and other edible substances, belong to this group; and from other species of it are formed the edible birds'-nests which are considered so great a delicacy by the Chinese,—the best being sold for nearly their weight in gold. These nests are constructed by a bird resembling the Swallow, which reduces the Sea-Weed in its stomach to a sort of gelatinous mass, before employing it for this purpose.

46. But all these uses are comparatively trifling, when the other modes in which the Algæ may be made beneficial to man are considered. The *kelp*, from which until recently the glass-maker and soap-boiler derived most of the alkali which they required for their manufacture, is nothing but the ashes of Sea-weeds, which contain a large proportion of this substance, derived from the water in which they grow. Other means of obtaining soda from sea-water have now partly superseded this; but until recently it was almost the only method. The account handed down by tradition of the mode in which glass was invented, whether it be itself true or false, serves to illustrate the properties of the Sea-Weed. It is said that some sailors cast ashore by shipwreck, having kindled a fire on the sand, supplied it with some dry sea-weed as fuel; and that under the ashes a mass of vitrified matter was afterwards found, resulting from the union at a high temperature, of the soda of the sea-weed, with the silex of the sand. Many Algæ also constitute a very valuable manure; and might be much more used than they are. But one of their greatest benefits to man consists in the Iodine with which they supply him;—a substance which is of the most important use to the physician in the treatment of many diseases, and which is a nearly certain cure for some which were formerly considered almost irremediable. One species, moreover, which abounds on the shores of China, furnishes a glue and varnish to the Chinese, even superior to that which is obtained from animal matter in this country. It seems, when once dried, to resist the action of water; for it is employed to fill up the lozenge-shaped interstices

in the network of Bamboo of which windows are frequently constructed; as well as to strengthen and varnish the paper of their lanterns. A species abounding on the southern and western coasts of Ireland furnishes a good *size* for house-painters; and there are many others which contain an amount of gelatinous matter that might be rendered useful in various ways.

47. Besides the tribes of whose character a sketch has been thus given, there are others of a doubtful nature, which are generally referred to this group; although some peculiar characters which they exhibit, and their similarity to certain *animal* forms, render it doubtful whether they ought not to rank with that kingdom. They are mostly formed of cells jointed together, as the Confervæ; but some of them seem to possess a different interior structure; and others exhibit very curious motions, which can scarcely be distinguished with certainty from those of animals. In one of these groups, a large quantity of flinty matter is contained in the walls of the cells; so that they perfectly retain their form after all the vegetable structure has been destroyed by the action of heat and acids. The cavity of the cells, too, is sometimes seen to be partly occupied by large angular crystals. All the plants (if such they be) of this group are very minute.

48. There is, however, a group yet simpler than these, of the vegetable nature of which there is no doubt. On the damp parts of some hard surfaces is not unfrequently seen a greenish or reddish slime, which, when examined with the microscope, is found to consist of a number of minute cells, having little connexion with each other, but imbedded in a sort of jelly, which surrounds and connects them. On some minute variations between these simple plants, various distinctions have been formed; one is known under the name of *gory dew*, from its red colour; and another, which appears on the surface of snow, tinging extensive tracts with a deep crimson, is known as *red snow*. This sometimes appears so suddenly, and over so large a space, as to lead to the belief that it had fallen from the sky; but its growth and multiplication are so rapid as to leave no difficulty in accounting for its appearance. This plant, which may be regarded as one

of the simplest forms of vegetation, if not the very simplest, consists of a little bag or membrane, forming what is called a cell. A large number of these are commonly found together; but each one is separate from the rest, and is to be regarded as a distinct individual. It obtains its own nourishment by absorbing the fluid around, and grows and comes to maturity without any other support or assistance than that afforded by the air and moisture with which its surface is in contact. When come to maturity, a number of minute granules may be seen within it; these are the germs of new plants; and, when liberated by the rupture of the parent-cell, they go through precisely the same series of changes. This little plant will be often referred to in illustration of the simplest conditions in which the processes of the vegetable economy can be performed. In its habits,—flourishing as it does only in very damp situations, though partly exposed to the air,—it must be regarded as belonging to the Algæ; but it bears a close correspondence with the lowest forms of a group that now remains to be considered, whose conditions of existence, however, are very different.

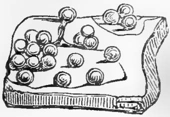


Fig. 8.
Protoccocus nivalis, or Red Snow, highly magnified; showing its separate cells or vesicles partly imbedded in a slimy jelly.

49. In their general simplicity of structure, the *Fungi*, (the tribe including Mushrooms, Puff-balls, and many kinds of blight, mildew, and mould,) correspond with the Algæ and Lichens; but they differ remarkably in habits, and in the character of their fabrics. Fungi will not grow with the simple nourishment which serves for *their* support, but require to be fed with decaying animal or vegetable matter of some kind; and they chiefly frequent situations in which decomposition is going on with rapidity, and which are at the same time dark and warm. It is very remarkable to observe the constancy with which particular species make their appearance on particular substances. Thus, no fungus but the common edible Mushroom ever grows upon the

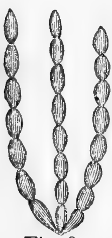


Fig. 9.
Common Blue Mould greatly magnified; its stems consisting of single cells loosely jointed together.

mushroom-spawn (as it is called;) though this does not contain its germs, being merely a kind of manure composed of various decaying substances which prepares the soil to receive them from the atmosphere. Again, there is a species of mould which is only found on the surface of the dung of cats deposited in moist and obscure places. Almost every tribe of plants has its peculiar species of blight or rust, to the attacks of which it is liable, and which differ from the kinds infesting nearly similar vegetables.

50. The universality of the appearance of the simpler kinds of Fungi,—such as mould, mildew, &c.—upon all spots favourable to their development, has given rise to the belief that they were *spontaneously* produced by the decomposing substances. But there is no occasion for this mode of accounting for it; since the extraordinary means adopted by Nature for the production and diffusion of their germs suffices to explain it. The duration of the lives of individuals among the Fungi is very brief; the tissue is soft and succulent, sometimes containing so little solid matter as almost to melt away when broken down; and never possessing any considerable amount of firmness. Now in the Algæ, where we have seen the development of the individual taking place to such an enormous extent, the fructification is generally obscure, and sometimes even scarcely perceptible. But in the Fungi, all the energies of the plant seem directed to the production of the germs of new ones; its own size seldom attains any great extent; but the number of these germs is often almost incalculable. Thus, the fine dust which issues from the common Puff-ball when mature, consists entirely of these little bodies, which are diffused through the air, and seem to float about in it, ready to develope themselves when they meet with the fitting conditions. In a single Fungus above ten millions have been counted; and these were probably by no means the whole number contained in it. When these minute germs are once spread through the air, there are so many means provided for their diffusion, that it is difficult to conceive of a place from which they should be excluded.

51. However improbable, then, it may at first sight appear,

that every portion of the air we breathe should contain the germs of a large number of species of Fungi, ready to develope themselves whenever the peculiar conditions adapted to each kind are presented, there seems good reason to believe that such is the case; and in this manner we may account for several facts of some practical importance, relative to the production of those very troublesome forms of vegetation known by the names of mould, mildew, &c. It is well known that fruit-preserves are very liable to be attacked by the common *bead-mould;* which no care employed in completely closing the mouths of the jars can prevent. It has been remarked, however, that they are much less liable to suffer in this way, if not left open for a night before they are tied down; and it is therefore probable that the germs of the mould sow themselves, as it were, in this luxuriant soil, before the jar is covered. Again, there is a particular kind of cheese, much valued by some epicures, which derives its peculiar flavour from the quantity of fungous vegetation it contains. It is prepared simply by breaking up the curd, and exposing it for a day or two, in small lumps laid upon a cloth, to the sun and air; it there seems to receive the germs of Fungi, which afterwards vegetate in it, and spread their growth through the mass whilst it is yet soft.

52. In all these instances, the Fungi derive their nutriment from organic matter which is either already in a state of decay, or will readily decompose. There can be little doubt that their development hastens decay when it is slow, or even causes decomposition in substances which previously exhibited none. Thus, a fruit-preserve, in which no *mould* finds its way, may remain sweet for many years; but the growth of the mould produces chemical changes in it, which are of a kind to supply the plant with the materials it requires. There is another very remarkable group of Fungi, which developes itself in the midst of the tissues of living plants and animals. To it belong, amongst others, the *mildew*, *rust*, *smut*, &c. of corn, which are distinct plants, having all the characters of true Fungi, but growing from the ears, stems, &c. of those they infest, so as to appear like a

part of themselves. In fact the question has been raised whether they are really produced from separate germs, or whether they are not diseased parts of the structure on which they appear. But there seems little doubt that distinct germs are introduced from without. They can be communicated from one plant to another; and they may perhaps enter through the stomata or breathing pores hereafter to be described; though experiment shows it to be more likely that they are conveyed in the water which drains through the soil, and that they are introduced into the system with the fluid which is absorbed. In that case they must be almost immeasurably small; since it is known that the minutest particles of any substance which can be artificially obtained, are usually rejected by the roots, as too large, when diffused through water which is being absorbed through their pores.

53. Animals are liable, as well as plants, to the growth of Fungi within their bodies. There is a species of Wasp in the West Indies, of which individuals are often seen flying about with plants of their own length projecting from some part of their surface, the germs of these having been originally introduced, probably through the breathing pores at their sides, (which greatly resemble those of plants,) and taking root, as it were, in their substance, so as to develope a luxuriant vegetation. In time, however, the fungous growth spreads through the body, and destroys the life of the insect; and then it seems to grow more rapidly, the decomposing tissue of the dead body being still more adapted than the living structure to afford it nutriment.

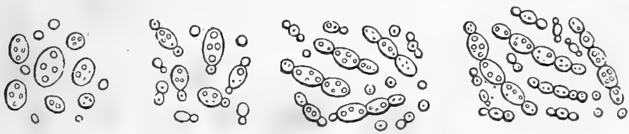
54. A very curious example of the growth of Fungi within the living animal body has lately been detected; and the knowledge of it has proved of great importance. The Silk-worm breeders of Italy and the South of France, especially in particular districts, have been subject to a considerable loss by a disease termed *Muscardine*, which sometimes attacks the worms in large numbers, just when about to enter the chrysalis state. This disease has been ascertained to be due to the growth of a minute vegetable of the Fungus tribe, nearly resembling the common

mould, within their bodies. It is capable of being communicated to any individual from one already affected, by the introduction beneath the skin of the former of some particles of the diseased portion of the latter; and it then spreads in the fatty mass beneath the skin, occasioning the destruction of this tissue, which is very important as a reservoir of nourishment to the animal when about to pass into a state of complete inactivity. The plant spreads by the extension of its own structure; and also by the production of minute germs, which are taken up by the circulating blood, and carried to distant parts of the body. The disease invariably occasions the death of the Silk-worm; but it does not show itself externally until afterwards, when it rapidly shoots forth from beneath the skin. The Caterpillar, Chrysalis, and Moth are all susceptible of having the disease communicated to them by the kind of inoculation just described; but it is only the first which usually receives it spontaneously. The importance of this disease to the breeders of silk-worms, led, as soon as its true nature was understood, to careful inquiry into the circumstances which favour the production of the fungus; and it has been shown that, if the bodies of the caterpillers, which (from various causes) have died during breeding, be thrown together in heaps, and exposed to the influence of a warm and moist atmosphere for a few days (as has been very commonly the case,) this fungus almost invariably appears upon them, just as other kinds of mould appear on other decaying substances; and that it is then propagated to the living worms by the diffusion of its germs through the atmosphere. The knowledge of this fact, and the precautions taken in consequence, have greatly diminished the mortality.

55. Another very curious example of vegetation of a fungous character in a situation where its existence was not until recently suspected, is presented in the process of fermentation. It appears from microscopic examination of a mass of *yeast*, that it consists of a number of minute disconnected vesicles, which closely resemble those of the Red Snow, and appear to constitute one of the simplest possible forms of vegetation. These, like

seeds, may remain for almost any length of time in an inactive condition without losing their vitality; and their power of growing when placed in proper circumstances is not destroyed by being entirely dried up, nor by being exposed to such extremes of temperature as the boiling point of water and seventy-six degrees below zero. When these bodies are placed in a fluid in which any kind of sugary matter is contained, they commence vegetating actively, provided the temperature be sufficiently high; and the decomposition which they effect in the fluid, the nature of which will be presently explained, is that which constitutes its *fermentation.*

56. If a small portion of a fluid in this state be examined at intervals with a powerful microscope, it is observed that each of the little vesicles contained in it puts forth one or more prolongations or buds, which in time become new vesicles like their parents; these again perform the same process; so that, within a



a *b* *c* *d*

Fig. 10. Different stages of the vegetation of Yeast; *a*, single cells of which it at first consists; *b*, cells with buds; *c*, the same more advanced; *d*, rows of cells corresponding to those of Fig. 9.

few hours, the single vesicles have developed themselves into rows of four, five, or six. This is not the only way, however, in which they multiply; for sometimes the vesicles are observed to burst, and to emit a number of minute granules, which are the germs of new plants, and which soon develope themselves into additional cells. By the time that five or six vesicles are found in each group, the fermentation is sufficiently far advanced for the purposes of the brewer; and he then takes measures to check it, by which the vegetation of the yeast is suspended. The groups of vesicles then separate into individuals resembling those which first constituted the yeast; and thus a greatly-increased amount of this substance is the result of the process.

57. The process of fermentation consists, as regards the fluid, in the conversion of the solution of sugar into alcohol or spirit of wine; and this is effected by the action of the vegetating fungus, which withdraws from the fluid, for the supply of its own growth, that portion of its elements which constitutes the difference between sugar and alcohol. A process very similar to this takes place when the common Mould, growing upon the surface of a sweet preserve, causes its fermentation. The little plant bears considerable resemblance to the Red Snow; but differs from it in the following two important particulars.

58. The Red Snow can flourish when supplied with air and moisture alone,—the conditions which have been mentioned as favourable to the growth of the Algæ; whilst this Yeast-plant can only grow in the solution of vegetable matter which is ready to undergo decomposition, and to yield it a kind of nutriment which the Red Snow does not require, but which is necessary for the growth of all the Fungi. This is an instance, then, of what was formerly stated respecting the close resemblance between the lowest forms of these simple tribes, which differ from one another more in the conditions necessary for their respective growth, than in their own structure. The other point of difference consists in the extension of the Yeast-plant by buds, that is, by the formation of new cells as continuations from the old one, as well as by the formation of separate germs; whilst the Red Snow is propagated by the latter only. It is interesting to trace, in a being so extremely low in the scale, the two kinds of reproduction which are performed in a manner so much more complex, and apparently so different, in the higher plants.

59. Of all the Cryptogamia, the Fungi are the most important to man; and their influence seems at first sight exerted rather to his injury than to his benefit. Those minute species which constitute mildew, blight, rust, &c. often destroy to an immense amount the fruits of the earth upon which he relies for his chief support. An instance has been just recorded in which the lives of animals that administer to his luxury are also destroyed in large numbers. The decay of timber in the mode commonly termed *dry-rot*, is caused by the growth of Fungi, of which several spe-

cies are frequently concerned in effecting this most injurious process. The ravages which they commit in ships and in every kind of wooden structure, as soon as a settlement is made, can only be conceived by those who have witnessed and examined them. The devastations they have committed on our navy and merchant vessels excited attention to the subject, and led to the invention of the process now known by the name of *Kyanizing** (from the name of its inventor;) but their destruction of house timbers is quite as rapid and complete, though less common. "I knew a house," says Mr. Burnett, "into which the rot gained admittance, and which, during the four years we rented it had the parlours twice wainscotted, and a new flight of stairs; the dry-rot having rendered it unsafe to go from the ground-floor to the bed-rooms. Every precaution was taken to remove the decaying timbers when the new work was done; yet the dry-rot so rapidly gained strength, that the house was ultimately pulled down. Some of my books which suffered least, and which I still retain, bear mournful impressions of its ruthless hand; others were so much affected, that the leaves resembled tinder, and, when the volumes were opened, fell out in dust or fragments." The decay of the wood seems partly due to the growth of the fungi in its substance, which is decomposed by it, as are the fluid and half-solid matters already spoken of; and partly to the moisture which they are the means of introducing into its interior. The germs of these plants fall into the chinks of the timber, where they take root; and in their growth, they greatly widen these chinks, and thus give admission to moisture from without, as well as to a new set of these minute germs, which may prove even more destructive; and by a continuance and repetition of these processes, the whole strength of the timber is at last destroyed.

60. The power of expansion which these plants possess, soft

* This process consists in soaking the wood or other material in water in which corrosive sublimate has been dissolved; and in this manner a change is effected which seems to deprive the germs of Fungi of the power of obtaining nutriment.

as their tissues seem, is truly wonderful. Some years ago the town of Basingstoke was paved; and not many months afterwards the pavement was observed to exhibit an unevenness which could not easily be accounted for. In a short time after the mystery was explained; for some of the heaviest stones were completely lifted out of their beds by the growth of large toadstools beneath them. One of these stones measured twenty-two inches by twenty-one, and weighed 83 lbs.; and the resistance offered by the mortar which held it in its place would probably be even a greater obstacle than the weight. It became necessary to repave the whole town, in consequence of this remarkable disturbance.

61. But though in these and many other ways Fungi are injurious to man, the benefits they confer upon him far outweigh their occasional devastations; and it is only through the constancy of the former that they are overlooked and unappreciated. It is not only to man that they are of the most essential service, but to the whole animal kingdom. To Fungi may be justly applied the designation which has been conferred upon Insects, that of the "scavengers of nature;" for, like insects, they labour with the most astonishing effect in the removal of refuse and decaying substances, which, were they left upon the surface of the earth, would prove not merely useless tenants but injurious incumbrances. Their vapour-like germs float about in the atmosphere in countless myriads, only waiting for the presence of a fitter soil on which to alight and grow. As long as there is no refuse decomposing matter to be removed, these spores remain inactive and undeveloped, ("the scavengers are unemployed;") but as soon as any quantity, large or small, of decaying animal or vegetable matter, is left exposed, it is soon covered with a deposition of spores, which rapidly develope themselves into fungi of various kinds.

62. Their astonishing fertility, and the rapidity with which they arrive at maturity, are among the most remarkable characters of this tribe of plants. Of the former, some account has already been given. Of the latter many instances are recorded. Thus one species has been known to attain the weight of 34 lbs.

in six weeks; and on the continent, Fungi of this tribe have grown to upwards of 100 lbs., having begun from a point not perceptible to the naked eye. A large fungus of the Puff-ball tribe has been seen to grow in one night from a minute speck to the size of a large gourd. No other living beings have powers of growth at all to be compared to this. The more rapid the decomposition, and the greater the quantity of noxious exhalations which would thus be spread through the atmosphere, the greater is the tendency to multiplication and luxuriant growth in these humble plants, to which such exhalations serve as the most appropriate food.

63. Hence what has been said by Naturalists of Insects, applies with equal truth and force to these humbler tribes; and we may adopt with slight modification an interesting statement which has been given of the agency of Insects, as a striking delineation of the operations of the Fungi.

64. "The peculiarity of their agency consists in their power of suddenly multiplying their numbers, to a degree which could only be accomplished in a considerable lapse of time by any larger beings; and then as instantaneous relapsing, without the intervention of any violent disturbing cause, to their former insignificance. If, for the sake of employing on different but rare occasions a power of many hundreds or thousands of horses, we were under the necessity of feeding all these animals at a great cost in the intervals, when their services were not required, we should greatly admire the invention of a machine, such as the steam engine, which should be capable at any moment of exerting the same degree of strength, without any consumption of food during the periods of inaction; and the same kind of admiration is strongly excited when we contemplate the powers of Insect and Fungous life, in the creation of which Nature has been so prodigal. A scanty number of minute individuals, only to be detected by careful research, and often not detectable at all, are ready, in a few days or weeks, to give birth to myriads, which may repress or remove the nuisances referred to. But no sooner has the commission been executed, than the gigantic

power becomes dormant; each of the mighty host soon reaches the term of its transient existence; and when the fitting food lessens in quantity, when the offal to be removed diminishes, then fewer of the spores find soil on which to germinate; and when the whole has been consumed, the legions before so active all return to their latent unnoticed state,—ready, however, at a moment's warning again to be developed, and, when labour is to be done again, again to commence their work either in the same districts, or to migrate in clouds like locusts to other lands. In almost every season there are some species, but especially in autumn there are many, which in this manner put forth their strength; and then, like the spirits of the poet, which thronged the spacious hall, 'reduce to smallest forms their shapes immense.'"

65. Among the uses of Fungi to man, their service as food must not be forgotten. In chemical composition they more nearly resemble animal flesh than do any other vegetable substances; and, accordingly, those of them which are free from injurious properties furnish a highly nutritious article of diet, and some of the rarer species are greatly valued as dainties by the epicure. There is much difficulty, however, in distinguishing the innocent from the noxious species of Mushroom; and many fatal accidents have occurred from the employment of the poisonous kinds. Amongst the Fungi remarkable for their peculiar properties may be mentioned one which is of great service, from its astringent properties, as a styptic, to check the flow of blood; and another which has the power, even when dry, of producing a curious kind of intoxication, and is used for that purpose by the Tartars.

CHAPTER III.

OF THE ELEMENTARY STRUCTURE OF PLANTS.

66. When we examine yet more closely into the conformation of the different parts of which an organized structure is composed, we find that, though the several organs are variously constructed, and are adapted for different offices or functions, they are built up, as it were, of the same materials. With the same bricks, stones, mortar, and timbers, a church, a palace, or a prison may be reared. Just so it is in organized structures. We do not find that each organ is entirely different from the rest, though it has usually something peculiar to it; but we are enabled to separate it into many distinct portions, something similar to which, if not exactly correspondent, may be recognised in other parts. Thus, for example, it was formerly stated that the leaf consists of a midrib and veins proceeding from it, a fleshy substance filling up the interstices, and a cuticle or skin covering the whole. Now the midrib and veins, as well as the footstalk of which these are a prolongation, consist of three kinds of structure;—*woody fibre*, to which they owe their toughness, and by which they are adapted to give support to the softer structures;—*ducts* or canals for the transmission of fluid;—and *spiral vessels* which are designed to convey air. On tracing these to the stem, it will be found that they all exist in it under the same form, and that these portions of the leaves are in reality but continuations of it. Again, if we examine the fleshy substance which lies amongst them, we shall find that it corresponds very closely in character with the pulp of soft fruits, or the pith of the stem. And if we strip off the cuticle and investigate its structure, we shall perceive that it is but another form of the substance, and that it corresponds with the skin which covers all

the newly formed parts of the stem and branches, as well as the various parts of the flower, and even the roots.

67. These several kinds of structure are termed the *primary tissues*, being the elements, as it were, of which the edifice is built up; and they are to the vegetable fabric what the bones, muscles, fat, blood-vessels, nerves, skin, &c. are to the animal.

68. Even these primary tissues may be regarded as consisting of other parts still more simple,—namely, *membrane* and *fibre.* The fleshy portion of the leaf, for example, or the pulp of fruits, consists of a number of little bags adhering together: each bag or vesicle consisting of a delicate membrane, without any perceptible orifice, and containing fluid. The membrane which encloses an egg after the shell is removed, will afford a good illustration on a large scale of the nature of these vesicles; they may, however, be readily distinguished and separated in an overripe orange, where they are of considerable size. Now the membrane which composes their walls may be regarded as one of the very simplest forms of vegetable tissue. Again, if the stalk of a strawberry or geranium leaf be carefully cut *round* but *not through*, and the two parts be then pulled asunder for a short space, a number of glistening fibres of extreme delicacy will be seen running from one portion to the other. If these be put under the microscope, it will be evident that they had lain in spiral coils, which are partially straightened when they are thus drawn out, just as when a spiral spring is strained. These were coiled within the membranous tubes that constitute the external sheath of the spiral vessels, which have been mentioned as existing in the leaf-stalk; and thus we are able to separate these vessels into the two other elements, *membrane* and *fibre.* These very minute delicate spiral fibres must not be confounded with the woody fibre, of which mention has been made, and the nature of which will be presently explained.

69. The delicate *Membrane*, of which, in combination with fibre, all the tissues of plants may be regarded as consisting, when they are newly formed, is of variable thickness and transparency. In general, however, it is quite sufficiently transparent to allow

the colour of fluids in contact with it to be distinguished on the other side; and accordingly, though itself colourless or nearly so, it often appears tinged, in consequence of the cells or vessels which it forms being filled with coloured fluid. Thus, the cells of leaves appear green, those of the parts of flowers, yellow, blue, red, &c.; not because that colour exists in the membrane of which they are composed (which, if they could be emptied, would appear almost colourless) but on account of the minute colouring particles diffused through their contained fluids. One of the most remarkable properties of vegetable membrane is its power of allowing fluids to pass slowly through it, even though no visible pores or apertures can be detected in it. Sometimes the appearance of such apertures exists, when membrane is highly magnified; but this appearance is sometimes produced by grains of semi-transparent matter sticking to it; and is sometimes due to that portion of the membrane being thinner than the rest, through the deposition of new matter upon certain points, subsequent to the first formation, of which several examples will be presently given.

70. Elementary *Fibre* may be compared to hair of extreme delicacy; its diameter often not exceeding the 1-12000 of an inch. It is generally transparent and colourless, and is usually disposed in a spiral direction. Its peculiar property is elasticity, combined with a degree of firmness which, for its diameter, is very considerable. Accordingly we find its chief use to be the keeping open, like an interior spring, the delicate membranous tubes through which air is to pass, and the preventing these from being pressed together by the growth of neighbouring parts. Not unfrequently, however, it seems less elastic than usual, and is broken during the processes of growth into several smaller fragments, which then exhibit a peculiar tendency to grow together in various irregular forms. In this way several peculiar kinds of tissue are produced, which will now be noticed.

71. The one most universally present, no kind of plant being without it in some form or other, and many being entirely composed of it, is that called *cellular* tissue, from its being made up

of a number of separate cells or minute bags adherent together. These, when first formed, are usually nearly globular, or of a

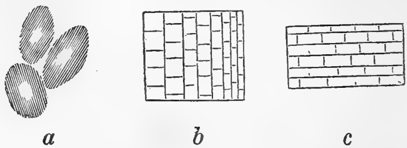


Fig. 11. Various forms of cellular tissue; *a*, separate vesicles of an egg-shaped form; *b*, section of cubical cellular tissue of pith; *c*, section of muriform cellular tissue.

figure resembling an egg; so that, if cut across, their walls would exhibit a series of circles touching each other at certain points. Afterwards, however, they are gradually pressed against each other, and their sides become flattened. Their form will then depend upon the amount of the pressure on the respective sides. If it have been equal in all directions, the cell will sometimes be cubical as it is often found in pith; or it will have the form termed the dodecahedron, which is a solid having twelve equal sides. But if it be pressed more on one side than another, it will be narrowed in that direction and elongated in the other. Thus the original form of the cell may become greatly modified during the growth of the plant. In general, the greatest elongation takes place in the direction of most rapid increase; but this is not always the case; for in the stems of most trees in this climate, there is a peculiar set of cells extending from the pith towards the bark, which have their greatest length in a horizontal direction; and the cells being of an oblong flattened form, and arranged like bricks in a wall, this kind of structure has been called *muriform* (wall-like) cellular tissue.

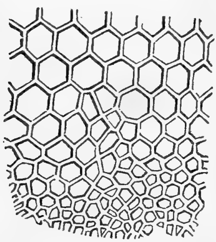


Fig. 12. Section of irregularly compressed cellular tissue; the honey-comb appearance of the greater part is due to the 12-sided form of the cells, the walls of which, when cut across in any direction, present hexagons or 6-sided figures.

72. From what has been said of the *permeability*, or power of giving passage to fluids, which vegetable membrane possesses, it may be inferred that this power is also possessed by the simple modification of it just described. Accordingly we find this to be the case,—fluids being conducted through it very readily from one part to another: but still it affords a sufficient degree of resistance to cause the transmission of fluids most readily in the direction of the greatest length of the cells, where, of course, there will be the fewest partitions in a given space. Thus, therefore, fluids absorbed at the bottom of a stem, will pass upwards through its cellular tissue more readily than in any other direction, except in the case of the *muriform* cellular tissue, which conducts fluids horizontally with the greatest readiness; and the object of this peculiar adaptation is to convey the nutritious sap which is passing down the bark into the interior of the trunk. It will be more fully described in Chap. VI. where the structure and offices of the different parts of the stem will be severally detailed.

73. In the fabric of the lowest tribes of Plants, such as Seaweeds, Lichens, the Fungi (or Mushroom tribe,) Liverworts, and Mosses, little besides cellular tissue and its simple modifications can be found; and it forms a large proportion of that of even the highest tribes. Thus in every Plant, the leaves, flowers, bark, pith, and fruit, consist almost entirely of cellular tissue; and it is even found in the woody part of the stem and roots, besides forming the largest proportion of those soft succulent stems which are only of short duration, dying as soon as the fruit they bear has ripened. The whole of the young plant, too, even of the highest tribes, consists, like the permanent forms of the lower, of this kind of structure. It is only when the true leaves have been unfolded and are actively performing their functions, that the other kinds of tissue show themselves. In all newly-forming parts, also, the foundation, as it were, is laid with this tissue, in which the others subsequently appear. So universally is it present, even in the adult fabric, that, if it were possible to abstract all the others from it, the original form would still be retained, except where it would give way with its own weight.

74. But, although cellular tissue is, in its regular state (of which the pith of young twigs, or the pulp of fruits are characteristic examples) soft and spongy in its character, it does not always remain so, but often acquires considerable hardness. This is the case, for example, in the *prickles* of the Rose and other plants, which are merely connected with the cuticle and are not prolonged from the wood beneath. It is the case also in the *stones* of the Plum, Peach, Cherry, &c.; and in the gritty matter in the centre of the Pear. In all these parts, the processes of vegetation are no longer going on; but the power of firm resistance is required in their place. This is effected by the deposition of solid matter within the cells. Sometimes the new product lies in regular layers, one within another, covering the whole membrane; sometimes it is deposited in what appears a less regular manner, certain points of the membrane being left uncovered by it. In this last case, however, an additional object is attained; for the cells, though the greatest part of their walls is so much thickened, are still in a degree permeable to fluid, through the spots of the membrane on which no deposite has taken place. These spots in the walls of contiguous cells generally correspond with each other; so that fluids can find their way from one cell into the cavities of the neighbouring ones; though so large a proportion of their contents has become solid. When the walls of cells have been thus strengthened in particular parts, the membrane has a *dotted*

Fig. 13.
Round cells thickened by internal deposites arranged regularly in circles.

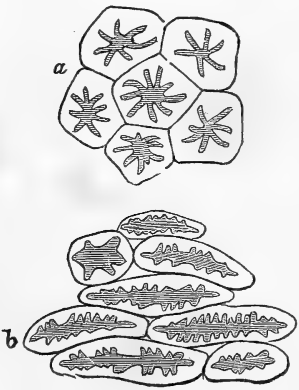


Fig. 14.
Sections of cells strengthened by internal matter irregularly deposited; the shaded portion indicates the remaining cavities: *a*, cells from the gritty centre of the pear; *b*, cells from the stone of the plum.

appearance, the thinnest portions seeming almost like perforations.

75. The size of the cellules of this tissue is extremely variable; they are usually from 1-300 to 1-500 of an inch in diameter; but may be found of all sizes, from 1-30 to 1-3000 of an inch. One of the most interesting modifications of it is found in the Sphagnum or Bog-Moss; and in the coverings of some seeds. This consists in the presence, within the membranous wall of the cell, of a spiral fibre, coiling from one end to the other. In some of the seed-coats in which these spiral cells exist, the *membrane* of the cells is so delicate as to be easily dissolved away; so that, if a portion be put into water, the fibres spring out very beautifully by their own elasticity.

76. The next form of elementary tissue to be described is that called *Woody Fibre.* It has received the name of *fibre*, because it always exists in an elongated form, and several of the tribes of which it consists adhere together continuously so as to form cords. This is seen in the common flax thread, for example. If the finest thread that could be separated with the naked eye were submitted to a microscope, it would be seen to consist of several other fibres adhering together; none of these have any great length; but by the manner in which they adhere, side by side, and end to end, a continuous cord is produced. Each of these minute fibres, when more closely examined, is seen to consist of a slender transparent tube, tapering to a point at each end. It thus resembles a greatly elongated cell. It differs from cellular tissue of similar form, in the much greater strength of the membrane forming the walls of the tubes, though it is at the same time thinner. There are many intermediate forms, however, between one and the other. Woody fibre is evidently destined to convey fluid in the direction of its length, and is easily permeated by it. Minute openings have sometimes been detected in the points of the tubes, so as to connect one cavity with another, and thus to render the passage of fluid more easy. It is, however, especially destined to give firmness and elasticity to the parts of the struc-

Fig. 15. Bundle of Woody Fibre.

ture which require support; and we almost constantly find *vessels* protected by it wherever they exist.

77. In all plants with permanently-elevated stems, this tissue is very abundant in the adult state. It forms a large proportion of the wood of the stem and roots; it partly composes the leaf-stalk, midrib, and veins of the leaves, and may even be traced in flowers; to many fruits, also, it imparts firmness and consistence. When no longer required for the conveyance of fluid, additional firmness and toughness are given to it, as to cellular tissue, by the deposition of various secretions within its tubes; and it is in the presence or absence of these that the difference exists between the heart-wood and sap-wood of a trunk. The woody tubes of the former are entirely choked up with the hard matter deposited in their cavities; and the sap rises through the latter only. This hardened tissue may be in some degree compared to the cartilage or gristle of animal bodies.

78. A peculiar form of woody fibre is found in the stems of resinous woods, especially the Pine and Fir tribe. The diameter of its tubes is much greater than that of any other woody tissue; and they alone perform the office of transmitting the sap upwards through the stem, the wood of these trees being destitute of the ducts or canals (presently to be described) which in other kinds of trees assist in this function. But it is by a peculiar set of dots seen along their course, that these woody tubes may be readily distinguished from all others. These dots appear to be formed by the adhesion of some little bodies to the interior of the tube, or by their growth on the exterior so as to project into the cavity by the pressure of two adjacent tubes. Whatever be their character, which is not yet certainly ascertained, they are of great interest, as aiding to establish the true nature of coal.

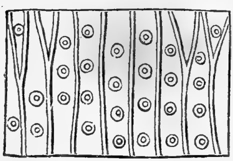
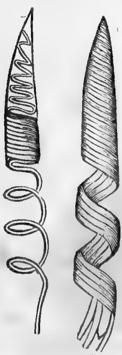


Fig. 16.
Glandular Woody Fibre of a Deal Shaving.

79. That this substance had a vegetable origin has long been generally admitted; but from the comparative frequency and perfection with which the remains of Ferns occur in it, it has been supposed to have been produced by the decay of vast forests of

this tribe of plants. As Ferns do not form resins, however, this hypothesis would not account for the large quantity of bituminous matter which coal contains; and hence it was supposed that coal must have been formed from resinous woods, even though the remains of such were very scanty and imperfect. Now on applying the microscope to transparent sections of such fragments of coal as most distinctly exhibit the fibrous structure, it is seen that they present the character which has been described as peculiar to the resinous woods,—the *glandular* form of woody fibre, as it is technically termed; and hence it is established beyond doubt, that the immense masses of coal which now contribute so much in every way to the comfort and the social improvement of the human race, are but the remains of vast forests, probably the growth of many successive centuries, which chiefly if not entirely consisted of trees of the Pine and Fir kind. It is even possible, by the peculiarities of the arrangement of the dots, to say which of the subdivisions of that tribe at present existing, those primeval trees most nearly resembled.



a *b*

Fig. 17. Portions of Spiral Vessels; *a*, common form, with single fibre partly drawn out; *b*, from Nepenthes, with quadruple fibre.

80. The third kind of primary tissue is that denominated the *Spiral Vessel*, with its modifications. Its essential character is the possession of a spiral fibre coiling within its thin membranous tubes from one extremity to the other. This fibre is not always to be traced, however, with the same regularity. The true spiral vessel much resembles the woody fibre in form, being a long narrow tube drawn to a point at both ends. But the membranous wall is much thinner, and is easily torn asunder. The spiral filament is usually single; it is sometimes, however, double, or even triple; and in the very large spiral vessels of the Chinese Pitcher-plant (Nepenthes § 242,) it is quadruple. These tubes in their perfect state contain air only, which finds its way from one to another, like fluid through the woody tubes. They are found in the leaf-stalks, from which their spiral fibres can be uncoiled in the manner

already described. They are found also in a delicate membrane surrounding the pith of those which possess one (§ 135;) and in the midst of the woody bundles which form the *strings* of such stems as the Asparagus. From this plant, indeed, they may be obtained more readily, perhaps, than any other. If a stem be boiled, or softened by soaking in water for some time, and these bundles be separated from the soft tissue which surrounds them, the parts of each may be farther separated from each other by rubbing them, with a little water, between two plates of glass. On looking at them with a magnifying glass, some portions of these bundles will be seen to present a dark appearance if still under water. This is caused by the air they contain; since bubbles of air in fluids viewed with the microscope, will appear dark to the observer, for reasons which will be mentioned in the Treatise on Light. If one of these threads be then carefully torn, with a pair of small needles fixed in handles, into finer ones, whilst under a powerful single magnifier, it may be separated into the individual spiral vessels which compose it, just as the thread of flax may be resolved into its woody tubes.

81. It is an interesting circumstance that the air-tubes of Insects are formed upon nearly the same plan with these spiral vessels of plants. The former consist, like the latter, of an external membrane, which is maintained in its tubular form, in spite of pressure from without, by the elasticity of a fibre spirally coiled in its interior. The principal difference between the two structures is, that the air-tubes of plants are closed vessels, and that their contents find their way gradually from one to another, permeating the delicate membrane of their walls; and that they give off, therefore, no branches: whilst the air-vessels of insects, whose office it is to convey air with great rapidity into all parts of the structure, form a set of continuous tubes, which branch and ramify with the most wonderful minuteness even in the smallest organs of the smallest Insect.

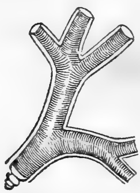


Fig. 18.
Branching Air-vessel of Insect.

82. The other kinds of tissue which we find in plants may be

regarded as modifications of the foregoing; but still they are sufficiently distinct in their character and offices to require a separate consideration. The first of these consists of the long straight non-branching canals which are found in the stems and leaf-stalks of the higher kinds of plants, and are termed *Ducts.* These appear to be originally formed by the breaking-down of the partitions between large cells that were laid end to end, so that a continuous tube is produced, for in many instances the remains of such partitions can be detected. Sometimes these ducts remain, like the cells from which they originated of a simply membranous character; but more commonly their walls are fortified by an interior deposite, which does not, however, entirely line them, but leaves the membrane bare at certain points, giving that dotted appearance already described in treating of the cells. Hence these vessels are commonly termed *dotted ducts.* It is through such as these, that the sap principally rises in the stem and branches, and is conveyed to the leaves. They are by far the largest vessels contained in the vegetable fabric, and their open mouths are visible in almost any stem when cut across. They are of particularly great diameter, when the stem itself is small and long, but bears a considerable amount of leaves, as is the case in the Vine and the common Cane; in these, their orifices at once strike the eye; and, if the stem of a growing plant be cut across, the oozing of the sap from their mouths will be easily distinguished.

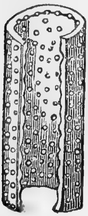


Fig. 19.
Section of a large Dotted-Duct showing that the dots are thinner spaces of its walls.

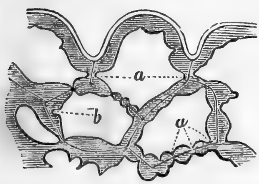


Fig. 20.
A bundle of such ducts cut across; *a*, *a*, pits in their sides corresponding with pits in the adjoining cells; *b*, a depression without a corresponding one on the other side.

83. But there are other kinds of Ducts, which seem to belong rather to the third form of Elementary tissue—the class of Spiral Vessels; since they exhibit more or less perfect traces of the presence of a spiral fibre within the membrane of the tube. These are the

cases in which the fibres show the greatest want of elasticity. In Ferns we find Ducts which very closely approach the spiral vessel in character; having an unbroken coil of spiral fibre throughout their whole extent; but, besides the important difference that these Ducts are long continuous tubes, they are farther distinguished by the brittleness of the spire, which snaps if we attempt to unrol it. Such ducts are found in many other plants, and may be easily distinguished in the leaf-stalk of the Rhubarb. Now there are others in which we see an irregular spiral,—the coil sometimes terminating in a ring, and then commencing again with perhaps the intervention of two or three rings. Here it would seem as if the membrane had grown faster than the spire could follow it; so that the fibre, not being elastic, had been occasionally broken. In other ducts, again, we find no traces of a *spiral* fibre; but the membranous walls are distended by rings at intervals sometimes tolerably regular. These are called *annular* or ringed vessels.

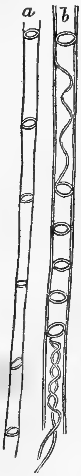


Fig. 21. Ducts with internal fibre; *b*, spiral, with rings at intervals; *a*, annular throughout.

84. These two forms are especially interesting from the analogies which can be found to them in the animal structure. The close correspondence between the spiral vessels and the *tracheæ* or air-tubes of insects, has been already pointed out. On the other hand, the annular duct corresponds with the wind-pipe of higher animals, the membranous walls of which are prevented from falling together by means of rings of cartilage disposed at regular intervals. And the half-spiral half-annular duct which is the intermediate form in plants, precisely corresponds with the structure of the wind-pipe of the Dugong (one of the Whale tribe) in which we find a *spiral cartilage* terminating at intervals in rings.

85. There are other forms of ducts, again, in some parts of which the traces of the spiral structure are very obscure; whilst in other portions of the same tube they can be easily distinguished.

In these it appears as if the spiral fibre had been broken up into small fragments, and that these had served as centres round which new deposites had accumulated, so that they had grown irregularly together, leaving interspaces in which the membrane is uncovered (as in the dotted duct) by this secondary wall. In fact it often happens that a duct, which exhibits in one part distinct remains of the spiral structure, approaches the character of the dotted duct so closely in another part, that they can scarcely be distinguished; and it is probable that the interior deposite which gives to the latter its peculiar character may have originally taken place around the fragments of a spiral fibre.

86. The office of all these ducts is the same,—that of conveying fluid. It is only in the true spiral vessel that we find air. These varieties have been described with somewhat greater minuteness than may appear necessary; because the young observer who examines the vegetable structure for himself, as it is hoped that many will be led by these pages to do, will be liable to be perplexed by meeting with them if not previously acquainted with their characters.

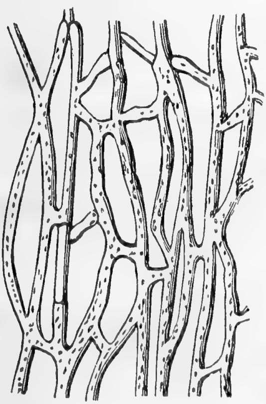


Fig. 22.
System of branching vessels for the conveyance of the *latex* or nutritious juice.

87. One other form of elementary tissue now remains; and this differs from all the rest. It is a system of *branching* vessels, confined to the under side of leaves, and to the bark, and serving only for the conveyance of the nutritious sap, which is carried by it from the leaves where it is produced, down the bark and thence to all parts of the structure. The walls of these branching vessels are extremely delicate, so that they can be scarcely separated from the tissue around; hence it was long supposed that the nutritious sap, or *proper juice* as it is generally termed, flowed in mere spaces amongst other tissues,

and not in distinct tubes. The existence of these, however, is now well established; and there can be little doubt that, like the straight ducts, they take their origin from cells, the partitions between which are broken down, so as to form a complete network of canals.

88. In future chapters, the combinations of these tissues in the several organs, such as the Stem, the Leaves, the Flowers, &c. will be described; but it may be well here to speak of one peculiar modification of cellular tissue which is seen in all these parts,—that, namely, which forms the *cuticle* or skin in which they are enveloped. The existence of this is easily shown in many leaves without preparation. From the leaf of the common garden Iris, for example, it may be easily stripped, or from the under side of that of the London Pride; and from every leaf it may be easily removed after being soaked for a few days in water. This cuticle is found to be usually transparent and nearly colourless. If when separated it should appear coloured, this is due to the adhesion to it of some of the cellules of the fleshy portion (or *parenchyma*) of the leaf; these will afford an opportunity of examining the form and structure of these cellules; and they may then be wiped away, leaving the membrane perfectly smooth and colourless on both sides. Now when this is examined with a sufficient magnifying power, it is seen to consist of a number of flattened cells in close contact with each other; and these cells contain no fluid, but are filled with air. Their form is very different according to the kind of plant examined. Sometimes they are of a regular oblong and their sides straight; whilst in other instances they are of very irregular form, and lock into one another like the pieces of a dissected map.

89. Though the cuticle usually consists but of *one* layer of cells, it sometimes contains *two* or even *three*, especially in plants naturally growing in warm climates; and in the Oleander *four* may sometimes be distinguished. Its office appears to be to prevent the moisture of the soft succulent tissues beneath from evaporating; since, if they were to dry up, their vital properties would be lost. Accordingly we find it absent in plants which

habitually live beneath the surface of the water; and from those parts of others which are usually submerged; whilst it is present on those parts of the same plants which are lifted into the air, as well as on all the soft parts of those which are habitually and entirely exposed to it. Its use is at once seen when a portion of a plant destitute of it is exposed to the air;—it speedily dries up and withers. On the other hand, the Oleander, exposed to the intense sunshine of tropical Africa, maintains its verdure, even in arid situations, by the great resistance to evaporation which its thick and almost leathery cuticle interposes. The best mode of separating this cuticle, so as to become acquainted with its remarkable firmness, is to soak a leaf for a few days in water rendered sour to the taste by a few drops of nitric acid; and it may then be easily stripped off. But its different layers can only be seen by magnifying a very thin slice of the leaf cut across, so that its thickness, not its surface, is exposed to view.

90. The entire of the softer portions of all plants growing in air is covered by cuticle; and in the young plant the whole surface. It is only when the stem increases in diameter, and the bark becomes hard and rugged and occasionally scales off, that the cuticle can no longer be distinguished. It is evident on young shoots as on the leaves, and may be traced downwards to the point of the root; but *this* it does not cover. It also protects all the organs of which the flower is composed; but it is absent at one point, for reasons hereafter to be stated.

91. The tissues protected by the cuticle are not entirely cut off by it, however, from the external air; for it has certain apertures of a very peculiar character, which open or close under the influence of light. The apertures are called *Stomata* (mouths.) They are usually of an oval form, and are bounded by two kidney-shaped cells containing green matter; and it is by the expansion or contraction of these that the orifice is diminished or increased. Sometimes, however, the opening is round, and is bounded by a ring of four or five such cells; and in the very curious stomata of the *Marchantia polymorpha*, one of the commonest of the Liverwort tribe (§ 32,) there are five such rings,

one beneath the other, the aperture resembling a funnel, and the lowest ring being the one which regulates the amount of communication between the chamber into which it opens, and the external air.

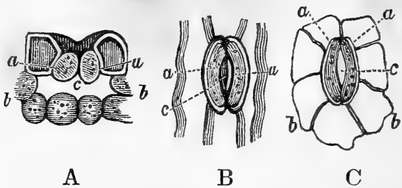


Fig. 23. Views of Stomata. A, vertical section of stoma of Iris; *a*, *a*, green cells bounding the orifice; *b*, *b*, cells of the parenchyma; *c*, air chamber. B, view of the same from above; *a*, *a*, green cells of the stoma, lying between long cells of the cuticle; *c*, opening between them. C, similar view of a stoma of apple-leaf; *a*, cells of the stoma; *b*, *b*, cells of the cuticle; *c*, opening of stoma.

92. Stomata are always placed over interspaces in the tissue, which are called *intercellular passages;* they are never found on the midrib or veins of a leaf, nor in fact over any hard woody portion of the structure. They are chiefly disposed over the soft green tissue of leaves and young shoots; but they are found also on the parts of the flower. When the leaves are absent, and the stem performs their functions,—as in the Cactus or Prickly-pear tribe,—stomata are found on its surface. They are generally most abundant on the *under* surface of leaves, and are sometimes altogether absent from the upper. This is partly due to the fact that the tissue lying beneath the upper surface of leaves is so closely packed together, that there are scarcely any intercellular passages, into which the stomata might open; whilst the tissue in contact with the lower cuticle is extremely loose in comparison, and abounds with such passages; hence it is that the colour of the upper surface of the leaf is usually so much deeper than that of the lower. But in leaves of which the two sides are equally exposed to the air and light, such as those of the Iris and of the common Flags growing by the sides of brooks, the general structure is nearly the same on the two sides, and the stomata are equal in number. Again, in Plants, the circumstances of whose growth are such that the atmosphere commonly comes in contact

with the upper side only of the leaf,—as in the case of the Water Lily, the leaves of which float on the surface of the water,—the stomata are disposed on that side alone.

93. As there is no cuticle to protect the tissues of plants growing altogether beneath the surface, so there is no occasion for stomata to admit the passage of air to these; and accordingly in the whole tribe of Sea-Weeds we find no vestige of them. Neither can they be distinctly traced in the Mushroom-tribe, nor in Lichens; but in the Liverworts they present themselves in the most remarkably complex form which we any where witness; in the Mosses they have only been detected on the stalk which bears the fructification; whilst in most Ferns, as well as in Flowering Plants, they abound.

94. Of the very minute size of these curious organs, some idea may be formed from the fact that in some leaves it is estimated that 70,000 occur in a square inch of cuticle. The largest known are about the 1-500 of an inch in length; whilst the smallest are not 1-3000. Their function is evidently to allow of that limited evaporation of water from the soft tissues of the plant which will hereafter be shown to be one of the most important of the processes by which the crude fluid absorbed by the roots is converted into the nutritious sap or proper juice. The influence of light upon the stomata causes them to open, whilst they contract and even close in darkness.

95. It has also been shown that light has a most important influence on their first production. In the young plant of the Marchantia (§ 33,) when first separated as a kind of bud from its parent, no stomata or roots exist. It has been ascertained by repeated experiments, that stomata and roots may be caused to develope themselves in either of the two sides, the stomata being always formed on the upper surface, under the influence of light, and the root-fibres proceeding from the lower towards darkness. But if the surfaces be reversed *after* the respective organs have been developed to a certain point, so that the stomata be directed towards the ground, and the roots be made to rise into the air, the little plant will right itself by twisting itself round, so as to bring its surfaces to their former position. Farther, when plants of a

higher description are grown in darkness, the stomata are developed very imperfectly or not at all. Thus, we have an example of the very important effects of the stimulus of *light* upon the vegetable structure, not only in governing its actions, but in influencing its development.

96. With the cuticle may be advantageously considered those appendages which are developed from it, as *hairs*, *prickles*, *stings*, &c. The leaves and stems of many plants are covered with hair, which is sometimes bristly, sometimes soft and downy, and sometimes scattered very thinly. The structure of these hairs is various. Sometimes each forms but one long cell; whilst in many other instances, every hair consists of a row of cells placed end to end, and sometimes these send off minute side branches. The cells of the hairs are usually, like those of the cuticle, destitute of fluid contents, except during the period of their formation. Their analogy with those of the cuticle is farther shown by the curious fact, that many plants are hairy or not according to the circumstances in which they grow. Thus, when they are found in dry exposed situations, their stems stunted in growth, and their leaves small, their surface is covered

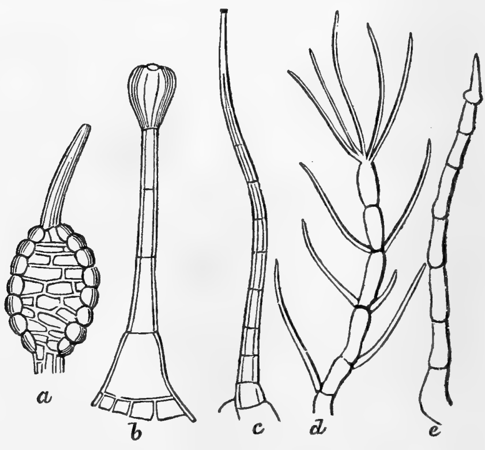


Fig. 24. Hairs and Glands of various kinds ; *a*, gland surmounted by a hair; *b*, small gland at the top of a hair; *c* and *e*, simple hairs; *d*, branching hair.

with hairs, as if the cells which would have otherwise formed a larger cuticle had taken the shape of hairs: whilst in damp shady places, which favour the extension of the leaves and stems, their surface is quite smooth, all the material being then required to form cuticle.

97. Sometimes the hairs are tubular and pointed, and are fixed upon minute glands in the cuticle which secrete an acrid fluid; and if but very slightly touched, the reservoir at the base is compressed, and the fluid forced up through the tube into the wound made by its pointed extremity. Such hairs are termed *stings;* and the Nettle affords a familiar example of them. The *prickles* of the Rose and other shrubs are also appendages of the cuticle, with which they are stripped off, and from which it is easy to detach them. They are thus distinguished from *thorns*, which proceed from the wood of the branch, and which, as will be hereafter stated, may be regarded as stunted leaf-buds. Prickles, after being once formed, and hardened by the process already described (§ 74,) undergo no subsequent enlargement; and, accordingly, if the cuticle on which they are fixed should be extended, their base is not able to expand in the same proportion, and they drop off.

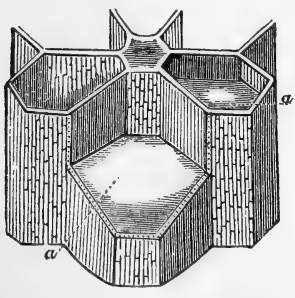


Fig. 25. Air chambers of aquatic plant, the vertical walls formed of muriform cellular tissue *a*, *a*, horizontal partitions.

98. Another interesting modification of cellular tissue is that which surrounds the spaces or cavities formed in certain plants for special purposes. Thus in the Duckweed, the leaves are provided with a set of air chambers, which give them great buoyancy; and nothing can be more beautiful than the manner in which the walls of these chambers are built up of *muriform* cellular tissue. In other cases, these cavities appear to be formed as receptacles for certain secreted products; and here, too, they are very beautifully partitioned off from the surrounding

tissue, by a peculiar disposition of the cells. A good illustration of these is found in the rind of the orange and lemon; the odour and flavour of which are derived from the minute drops of volatile oil stored up in a vast number of these little cavities. The turpentine of resinous woods is collected in larger channels of the same description.

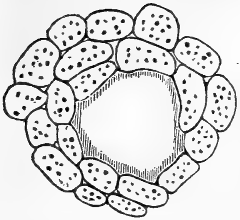


Fig. 26. Receptacle for fluid secretion; a cavity bounded by cellular tissue.

99. It is scarcely possible to observe the number of different forms (of which many have been left unnoticed) resulting from the varied combinations of the simple elements—*membrane* and *fibre*,—each of them probably having its peculiar function in the vegetable economy, without being struck with the simplicity of the plan by which Creative Design has effected so many marvels, as well as with the extreme beauty and regularity of the structures which are thus produced. The comparison of such specimens of Nature's workmanship as the meanest plant affords, with the most elaborate results of human skill and ingenuity, serves, only to put to shame the boasted superiority of man; for whilst every additional power which is applied to magnify the latter serves but to exaggerate their defects, and to display new imperfections, the application of such to organized tissues has only the effect of disclosing new beauties, and of bringing to light the concealed intricacies of their structure.

We shall next pass on to consider the structure of the *compound organs* of the Vegetable fabric, and their several purposes and uses.

CHAPTER IV.

STRUCTURE AND FUNCTIONS OF THE ROOTS.

100. The *Roots* are the parts of the plant on which it is chiefly dependent for the supply of the moisture which its growth requires; and they also serve to fix it in the earth. That they absorb or suck up fluid with great rapidity may be easily shown in the following manner. Take any small plant that is growing in the soil, and immerse its roots (first clearing them of earth) in a tumbler of water. If the plant be exposed to the light of day, and especially if the sun shine brightly upon it, the water will disappear very much faster from the glass, than from one exposing the same surface, and placed in the same circumstances, but without the plant. And if the specimen continue to grow and flourish, it will take up many times its own weight of water in a short period. Thus, four plants of Spearmint, grown during 56 days with their roots in water, and themselves weighing altogether but 403 grains, have been observed to take up 54,000 grains, or about seven pints of the fluid.

101. Of the water thus absorbed, a small proportion only is retained within the plant, serving as a part of its food. The greatest part of it is sent off again from the leaves, by a process hereafter to be described, termed Exhalation; and the rapidity of Absorption is in part governed by the rapidity of Exhalation. The latter is nearly checked by the absence of light; and, accordingly, plants are found to absorb but little in the night, or in a dark room. Any of the causes which will be subsequently stated to influence the latter, affect the former in a nearly corresponding proportion. The object of the introduction of a quantity of fluid

into the vegetable system, so much larger than it retains, appears to be this;—the solid mineral matters which constitute an important part of the food of the plant, are contained in the water which reaches its roots in excessively minute proportion; and it is therefore necessary, in order that a sufficient amount of these may be obtained, that all the water in which they are dissolved should be introduced. As this is by far too much for the other wants of the plant, a large part of it is got rid of by Exhalation.

102. It is only in the more perfect plants, however, that we find a restriction of this power of absorption to one particular portion of the structure. In the Sea-weeds, for example, the whole surface appears equally endowed with this faculty; and there is, therefore, no occasion for that transmission of fluid from one part to another, which is characteristic of those in which we find a stem (or something correspondent with it) bearing roots at one end, and leaves at the other. Accordingly, that which is the natural condition of the latter, is fatal to the stemless plants; for if a Sea-weed be suspended partly out of the water, the upper portion will die from drought, whilst that which remains immersed will continue to live and grow, without transmitting any of its moisture to the rest. Not unfrequently we observe the *form* of a stem and roots in Sea-weeds; but this is only for their attachment to rocks, or other solid substances; and the root-like portion has no special power of absorption, nor the stem of transmission.

103. In some of the Cryptogamia a little higher in the scale, however, we find a condition much more approaching that of the Flowering-plants. Thus, in the Mushroom, we observe a soft stem, which sends off fibres into the ground; and these appear to absorb by their whole surface, and to transmit the fluid they have acquired to the portion which is elevated in the air. In the Mosses, the tissue of the stem is firmer, and the rootlets which proceed from it are more woody; these not only proceed from the stem but also from the under surface of the leaves; and thus the dryness of the situations in which these interesting little plants find their subsistence is in some degree compensated for.

In Ferns we have a woody stem and widely ramifying roots, like those of the Phanerogamia.

104. If we examine the roots of any common plant with a branching woody stem, such as the Rose, we shall find that they subdivide and spread beneath the ground, very much upon the same plan with the branches above. Moreover, it will be seen that, from the sides and extremities of these underground branches, there proceed a number of delicate fibres; and if the extremities of these be carefully examined, they will be found to be much softer than the rest of the structure. Now these fibrils are the true roots; and their soft succulent extremities, which are called *spongioles*, are the parts by which alone they absorb or suck up fluid. This is easily proved. If a growing Radish be carefully removed from the ground, and the fleshy portion be bent in such a manner that it can be covered with water, whilst the leaves and tuft of fibres at its point are not immersed, it will be found that the whole of this large surface does not absorb moisture enough to keep the plant alive. But, on the other hand, if this tuft of fibres be only so far immersed in the water that their points may touch it, whilst the rest of the root is above the surface, the plant will continue to flourish.

105. The fact is that this absorption takes place with the greatest rapidity through soft newly-forming tissue; and this is what gives the spongioles their peculiar power. They are, in fact, the *growing points* of the rootlets, which are constantly increasing in length, and which in this manner go in search, as it were, of the supplies of food of which they have exhausted the soil that previously covered their extremities. As this growth continues, the tissue at first formed gradually becomes consolidated; and when it has become hardened, it is no longer adapted for absorption in more than a very trifling degree; so that to the newly-forming point of the fibre this power is always nearly restricted. But in the young plant there is an interesting correspondence with the condition of the lower tribes; for the soft roots, which are first sent down from the seed when it is commencing to grow or germinate, are, like the fibres proceeding from the base of the

Mushroom-stem, capable of absorbing by their whole surface; and it is only when woody fibre begins to be formed in them, that the power is restricted to their extremities.

106. The knowledge that the delicate fibres, proceeding from what are commonly known as roots, are the true and only organs of absorption, has an important practical application. It very commonly happens that in *transplanting* shrubs or trees, of which the roots extend a good way into the soil, enough care is not taken to preserve these; and the plant either languishes for some time, until it is able to form new ones, or dies altogether. It is seldom that, under common treatment, a fruit tree will bear in the first season after transplantation. The following instance, however, will show what mode of proceeding is directed by the knowledge just communicated, and what success attends it. A gentleman in Shropshire had some valuable vines, which he wished to remove to a new property on which he was going to live in Norfolk. He had a trench dug around them, at such a distance as, it was believed, would include all their roots. The earth within this was then removed, not with spades and trowels, but with the fingers,—every fibril being thus uncovered without injury. The mass of roots was then wrapped in moist matting; the vines were carried across England, and then planted; and in the ensuing season they bore an abundant crop.

107. It is often observed that the growth of roots takes place in the direction best adapted to supply them with moisture; and it has been supposed that plants possessed a kind of instinct, or consciousness, which caused them to select this. Many of these cases, however, can be explained without having recourse to such a supposition; and it is probable that, with the advance of knowledge on this subject, the remainder will be also. In fact, to attribute such an instinct to plants is to place them above the lower animals, which do not exhibit the power of making a choice of this kind. The most common cases are those most easily explained. A plant is in a dry soil, and it sends out its roots into a moister one; or it it is in a garden pot, and its roots project through the hole at the bottom, into the water which the pan below it may con-

tain, or into the moist earth with which it may be surrounded. Now this is explained upon the following simple principle. The addition which is constantly being made to the extremities of the fibres, takes place in the direction *of least resistance;* and, when the roots are making their way through a hard dry soil, the direction of least resistance will be that in which the earth is loosened by the flow of water; towards the source of that moisture, therefore, the growth of the roots will be directed.

108. The same principle has another curious application. Roots have been known to insinuate themselves into the crevices of walls, or even into chinks in the stones themselves; and to burst asunder the walls of these after some time. Now when a root meets with such an obstacle as this in its growth, it is turned aside for a time, and endeavours, as it were, to creep round it. But should a chink give the opportunity for the new tissue to be deposited without obstacle in its original direction, the root will find its way into it. The fibril will grow, by the nourishment sent to it, and by its own absorption, until it can no longer increase without the separation of the walls which confine it; and this is accomplished by the force with which it imbibes fluid, which causes it to distend itself with great violence.* This distention is of the same character as that of a piece of dry wood when exposed to moisture.

109. The foregoing explanations will apply to a case of no unfrequent occurrence, in which a tree growing on one side of a road sends out roots to a ditch or stream on the other,—these roots dipping deep beneath the hard bed of the road, and rising again on the farther side. It is evidently by the slight drainage or percolation of water, which will take place along this line, that the roots follow the same course. A more remarkable case, however,

* It is by this same kind of force, resulting from *Capillary Attraction* (see Physics, Vol. I.) that mill-stones are split in quarries. A long cylinder is first cut out; and grooves are then chisselled in its circumference, at the points where it is desired to divide it. Wedges of wood are then driven into the grooves, and these are moistened; by their violent expansion, the stone is split into the required number of parts.

which has been more than once observed, is where the roots direct themselves along a naked rock, to reach water at a distance of perhaps twenty feet. It is not improbable that the constant ascent of vapour into the air in that direction, may be in part the cause of this curious mode of growth. An instance occurs in Leigh Woods near Bristol, which remarkably illustrates this tendency of roots to grow towards the spot most fitted to afford them nutriment. In a little hollow on the top of the shell of an old Oak, the outer layers of which, however, and the branches are still vegetating, the seed of a Wild-Service tree was accidentally sown. It grew there for some time, supported, as it would appear, in the mould formed by the decay of the trunk on which it had sprouted; but this being insufficient, it has sent down a large bundle of roots to the ground, within the shell of the Oak. These roots have now increased so much in size, that, as they do not subdivide until they nearly reach the ground, they look like so many small trunks. In the soil, however, towards which they directed themselves, there was a large stone,—about a foot square; and, had their direction remained unchanged, they would have grown down upon this. But about half a yard above the ground, they divide, part going to one side, and part to the other, and one of them branching into a fork, of which one leg accompanies one bundle, and one the other; so that on reaching the ground, they enclose the stone between them, and penetrate on the two sides of it.

110. This example serves to show another fact,—that it is not in every case that we are to regard the parts of the axis which are above ground as Stems, and those which are beneath it as Roots. There is a tree peculiar to tropical climates, called the *Pandanus* or Screw Pine, in which the roots are always formed in somewhat of this manner. The stem is smallest at its lowest part, and it enlarges considerably above; hence it would be very unsteady without some additional support; and this is provided for by the transmission of the roots, not only from the bottom of the stem, but at different parts of its ascent. These grow downwards in the air, and are provided at their extremities with a kind of cup which catches the rain and dew by which they are

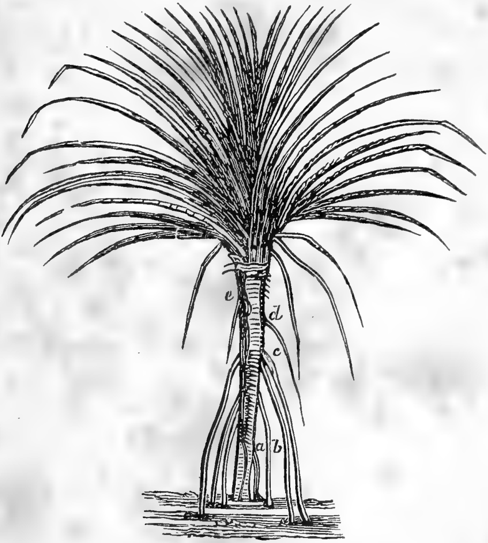


Fig. 27. Pandanus, or Screw Pine; *a*, *b*, *c*, aerial roots partly serving as stems; *d*, *e*, roots not yet reaching the ground.

partly assisted in their elongation; when, however, they have reached the ground, this falls off, and their extremities become true spongioles. When they begin to absorb nourishment from the earth, they increase greatly in diameter, and seem like so many assistant-stems.

111. The general fact is, that the root is the portion of the axis which has a tendency to grow downwards towards moisture, and away from light, whilst the stem is the portion which tends to grow upwards, into the dry air, and towards light. This tendency is manifested during the earliest period of the growth of a plant from seed. Two parts always originate from it; one of which, termed the *plumula* (from its resemblance, when just unfolding to a little feather,) is the rudiment of the stem and leaves, whilst the other, called the *radicle*, is the young root. The first of these exhibits from the commencement a tendency to grow upwards,

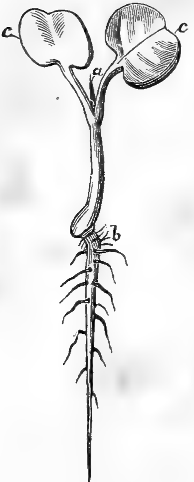


Fig. 28.
Germinating seed.
a, plumula; *b*, radicle.

and the second a similar tendency to descend. The late ingenious experimenter, Mr. Knight, devised a means of showing that the direction of the roots is in part owing to the force of gravity. He placed some germinating beans on the circumference of a vertical wheel, and made this revolve rapidly and continuously for several days. From the constantly varying position of the seed, the force of gravity was here neutralized; but a new force, was substituted for it,—the centrifugal force, or tendency to fly from the centre, which a stone (for example) let loose from the circumference of such a wheel whilst revolving would exhibit.* The root, influenced by this force as ordinarily by that of gravity, grew, in every instance, away from the centre of the wheel, whilst the stem grew towards it.

112. In another experiment, the wheel was made to revolve horizontally, so that the force of gravity continued to operate, but in combination with the centrifugal force; in this instance, the direction of the radicle showed the evident influence of both; for it pointed downwards and outwards. *Why* the radicle should be thus influenced by the force of gravity, when the plumula grows in opposition to it, is a question that has not yet been answered; but it is interesting to know the fact. We are as completely ignorant of the ultimate causes of the most common occurrences. We do not know, for example, *why* the earth should attract the bodies on its surface, or why it should itself be attracted by the sun. We only know the general fact that all masses of matter attract one another.

113. Roots are ordinarily distinguished from stems, not only by their direction, but also by the presence of the absorbing

* See PHYSICS, vol. I.

fibres, and by the absence of buds, which last are so characteristic of the stem, that any part on which they appear may be ordinarily considered such, even though it is growing underground. In general, however, the stem possesses the power of sending out root-fibres, as is shown by breaking off a slip of a branch and sticking it in the ground; when, if properly attended to, it will usually form roots for itself, and soon become a new plant. But it is more rare to find the roots capable of forming leaves and flowers; this, however, is the case in some instances, such as the Maple—a tree which may be completely inverted, the branches being buried in the ground, and the roots spread forth into the air, without being destroyed.

114. The structure of the root-fibre, and of the spongiole which terminates it, may be beautifully seen in the common Duckweed, in which a single such fibre hangs from the under surface of every leaf, for whose nourishment it is destined. On looking at it with a magnifying glass, or microscope, a dark line is seen along its centre; this consists of the bundle of vessels by which that part is occupied. These are enclosed in a firm sheath of cellular tissue; and at the point, this tissue is observed to be softer, more spongy, and less regularly formed. The extremities of the fibres are often seen to be covered with a little cap, which corresponds with the cup which the aerial roots of the Pandanus have been spoken of as possessing (§ 110.)

115. The wide-spreading roots of a forest-tree do in reality consist but of bundles or collections of such fibres, strengthened by woody structure resembling that of the stem, and arranged in the same manner. The structure of the woody roots corresponds mainly with that of the stem, being Exogenous in Exogens, and Endogenous in Endogens (Chap. V.;) but in the former no pith exists in the roots, their centre being occupied by vessels. The spread of the roots from the stem is usually greater than that of the branches; so that the rain which is prevented by the latter from falling direct upon the ground, is directed just to that part through which the root-fibres are distributed, ready to suck it up.

116. The force with which the roots absorb fluid is very

considerable. If a Vine be wounded in the stem when the sap is rising in the spring, a large quantity will flow out, and will continue to do so for some time. An Elm tree, from which a portion of the bark and outer layers of wood had been accidentally torn off, has been known to pour forth from the wound many gallons in a few hours; and the loss could only be restrained by nailing a leaden plate very firmly over the part. If the stem of a Vine be cut through, when the sap is ascending, and a piece of bladder be tied over the surface of the lower part, this is soon distended with fluid, and, in a few hours will burst. Or if to this portion be fixed a bent tube, in such a manner that the fluid which rises shall have to lift a column of mercury, the absolute force may be measured, and this is found to be very great.

117. The question, then, arises,—by what power do the roots thus absorb and force upwards through the stem the fluid of the surrounding soil? Is this power peculiar to the living system, or can we in any way account for it on the laws of mechanics? Something analogous may be effected by the experimenter, with materials which he obtains from dead structures, or even from inorganic matter. If a glass vessel, of the shape delineated in the figure have its wide open mouth covered with a piece of bladder, and its cavity filled with rather thick sirup or gum-water, whilst the under side of the bladder is immersed in simple water, the volume of fluid within the glass will be much increased by the passage of water from without, through the bladder, to mix with the fluid in the interior; and this entrance will continue as long as there is much difference in density between the fluids on the two sides of the bladder. But there is also a contrary current to a less amount,—the interior fluid passing out to mix with the surrounding water. The increase in the volume of the fluid within the vessel is, therefore, equivalent to the difference in the amount of the opposite currents. If, on the other hand, the glass were filled with water, and immersed in sirup, it would be partly emptied by this action.

Fig. 29.

118. The principal current is termed *Endosmose* (flow inwards;) and the lesser one is called *Exosmose* (flow outwards,) Bladder or animal membrane is by no means the only porous substance which may be used for this purpose, though it is the most fitted to exhibit the experiment, from the rapidity of the action which takes place through it. Half-baked porcelain, and a peculiar porous limestone, have been shown to have the same properties; so that it is evident that this curious result is not dependent upon any modification of *vital* power. It is, in fact, but a peculiar form of *capillary attraction*.*

119. Now the conditions requisite for this action are two fluids of different densities, separated by a *septum* or partition of a porous character. This we find in the roots. The fluid in their interior is rendered denser than the water around by an admixture (as will be hereafter explained) of the descending sap; and the spongiole supplies the place of the partition. Thus, then, as long as this difference of density is maintained, the absorption of fluid may continue. But if the rise of the sap is due to the action of Endosmose, there ought also to be an Exosmose. This is found to take place; for if a plant be grown with the roots in water, the fluid surrounding them is soon found to contain some of the peculiar substances they form, and which are contained in the descending sap; thus, a Pea or Bean would disengage a gummy matter,—a Poppy would communicate to the water an opiate impregnation,—and a Spurge would give it an acrid taste.

120. Thus we see how beautifully and how simply this action, extraordinary as it seems, is accounted for, when its whole history is known, on principles which operate in other departments of Nature. It has been asked,—why should not Endosmose take place when the roots of a dead plant are put in water? This question may be answered by another; why does the wick of a lamp suck up oil only when it is lighted. The answer to both is, that it is only when the fluid already absorbed is in some way removed, that absorption can go on. In the latter case, as fast as

* The attraction which causes fluids to rise into very minute tubes or pores. (See PHYSICS, Vol. I.)

it is withdrawn by combustion, the lower part of the wick raises it by capillary attraction. In the former, as fast as the fluid is got rid of by exhalation from the leaves (Chap. VIII.,) the Endosmose below will keep up the supply; but if the demand is suddenly checked, (as when the plant is withdrawn from the influence of light, or its vitality be destroyed by an electric shock,) there is no room for any additional fluid within the system, and the absorption is checked also.

121. When the upper part of the stem is cut off, the sap will continue to rise by the force of Endosmose in the roots, so long as the fluid *within* is of greater density than the fluid *without.* But that will soon cease to be the case, the actions of the leaves being destroyed, and no descending sap being intermixed to keep up the force. These two causes, then,—the absence of any demand for sap in the leaves, and the cessation of the condition necessary for the maintenance of Endosmose,—are quite sufficient to account for its absence in the dead plant; and its performance soon becomes impossible for another reason,—the decay of the soft tissue of the spongiole through which it is performed.

122. The nature of the fluid absorbed by the roots of plants will be more fully discussed in Chapter VI., when their food and the mode in which they are nourished by it will be described. It may, however, be stated here, that they appear to have a certain power of *selection*,—some of the substances dissolved in the fluid which surrounds the roots being absorbed, and others being rejected. Thus, if a grain of Wheat, and a Pea, be grown in the same soil, the former will obtain for itself all the *silex* or flinty matter which the water can dissolve; and it is the deposition of this in the stem, which gives to all the Grasses so much firmness.* On the other hand, the Pea will reject this, and will take up whatever *calcareous* substances (or those formed of lime and its compounds) the water of the soil contains,—these being rejected by

* There is enough silex in a Wheat-straw to make a bead of glass when melted with potash with the blowpipe; and in the Bamboo it is sometimes collected in the knots in large masses, forming the substance called *tabasheer* in the East.

the Wheat.—Again, if the roots be placed in water coloured by any substance of which the particles are very minute, the finest of these will be absorbed with the fluid, and will be carried to the leaves; whilst the coarser ones are left behind. In the same manner, if the roots be immersed in a solution of gum or sugar, a certain proportion only of these substances will be taken up with the fluid in which they are dissolved; and that which remains will thus become gradually thicker.

CHAPTER V.

OF THE STRUCTURE AND FUNCTIONS OF THE STEM.

123. The chief office of the stem appears to be, to elevate the leaves—which are organs destined to convert the crude fluid absorbed by the roots into nutritious sap for the supply of food to the structure,—and the flowers,—in which this sap is applied to the production of new individuals,—into the most favourable position for receiving the influence of light, heat, and air, on which their due actions depend. Accordingly we usually find it most developed in those kinds of plants in which one portion of the surface is set apart for the absorption of fluid, and another for its exposure to these influences. In the little plant which constitutes the Red Snow, and in others of a similar grade of organization, we find the whole surface adapted to absorb, and the whole surface equally exposed to air; there is, therefore, no necessity for a stem. But as soon as, in the Mushroom tribe for example, the plant sends roots into the earth, it elevates the other portion above it by means of a stem; and in this stem there is a set of channels or passages, which serve to convey the absorbed fluid from below upwards. But in these humble plants, destined to live but for a short time, and then speedily to decay, there is no necessity for providing the short stem with the toughness required in the trunk of the lofty forest-tree, which braves the storms of centuries. And accordingly we find that, whilst in the former the tissue is soft and cellular, resembling that of the rest of the structure, in the latter it is firm, and consists almost entirely of woody fibre, and this is consolidated by the deposition of hard matter within its tubes.

124. Between these two extremes of softness and toughness,

there are a great many intermediate conditions. In Flowering-plants which only live for one year, and are hence known as *annuals*, the stem is usually *herbaceous*;—that is, it consists almost entirely of soft cellular tissue, but contains, however, some bundles of woody fibre and vessels, which may be traced to the stalks of the leaves. These are commonly known as the *strings* of vegetables whose stalks or roots, are eaten, such as Asparagus or Turnips; and that degree of *stringiness* which makes such plants unfit for the table when their growth is too far advanced, results from the increased formation of woody fibre which takes place towards the end of the season. In plants, however, the duration of whose life is greater, the stem gradually becomes consolidated by the formation in each year of a new set of these bundles, so that in time the soft cellular part bears but a small proportion to the whole. All stems, however, begin upon the same plan, whatever be their duration and ultimate density; and the structure of a first-year's branch of an Oak, for example, is essentially the same with that of the stem of an annual Pea. The foundation is laid, as it were, by an extension of the cellular tissue from which it springs, this being the kind of structure which most rapidly increases; and the consolidation of this is then gradually effected by the deposition of woody fibre in its substance.

125. But the stems of Flowering-plants are not all formed upon the same plan; in fact there are two different and nearly opposite modes in which the woody bundles are arranged in the stem; and to one of these, they may be all referred. If the stem of the Asparagus be cut across, it will be seen that they are distributed at intervals through its whole substance. On the other hand, in the stem of a Pea they would be seen regularly arranged in a circle, a little beneath the exterior. The former, if it continued to live and grow, would have its new bundles deposited in the *interior* of the stem; whilst the latter, if it survived a second summer, would have a new circle of woody bundles deposited on the *exterior* of the first. The former is then called an Endogen, (growing from within;) the latter an Exogen, (growing outside.) To the first division belongs the Palms, Bamboos, Canes, and

many other hard-stemmed and lofty tribes inhabiting tropical climates; but scarcely any except herbaceous plants belonging to this division exist in temperate regions; the chief tribes which it includes in this country are the Lilies, and most other bulbous-rooted plants, and the Grasses. To the second belong all the trees and shrubs, and a large proportion of the plants of temperate climates; whilst between the tropics its place is partly occupied by the other. The last, as being the best known in this country, will be first described.

126. If we cut across a young twig of any common tree or shrub, such as the Ash, Elder, &c. we shall observe that it consists of three distinct parts, ordinarily known as the *Pith*, *Wood*, and *Bark*. The *pith* is a soft spongy substance occupying the centre; if a thin slice of it be cut, either across or vertically, and magnified, it is seen to consist entirely of cellular tissue, the cells of which are mostly of a very regular form. When young it contains a good deal of fluid, and has a greenish hue; when the branch is older, it becomes white and dry; and in an old stem or branch, it is often found to have shrivelled up and almost entirely disappeared.

127. Now this pith is the first-formed portion of the stem, being in fact the remainder of that cellular structure, of which the whole was originally composed, but which gradually gives place to the woody portion; and whilst at first it has to impart nourishment to the organs which are growing from it, this function is performed more perfectly by the vessels as soon as they are developed in the stem, and the pith becomes of no farther use. The pith of a branch is always an extension of that of the branch or stem from which it sprang; and if the latter be cut through, just where a bud is rising from it, this will be seen to consist at first almost entirely of a kind of prolongation of the cellular portion which occupies its centre. The pith of trees is applied to no important use. One curious product is obtained however from the large pith which constitutes nearly the entire stem of a herbaceous plant; this is the substance known as *Rice Paper*, which is made by cutting the soft portion of the stem with a sharp knife in a

spiral manner, so as to cause it to spread out, as if a sheet of paper were being unrolled from a round ruler. It is then flattened out by pressure; but its character, as cellular tissue like that of other piths, may be easily shown by magnifying a small portion of it.

128. The pith is surrounded by the *woody* layers, the number and thickness of which depend upon the age of the branch or stem. In the herbaceous stem, the woody portion (as already stated) presents itself in the form of distinct *strings*, arranged in a circle between the large pith and the external skin or bark. Each string is separated from its neighbours by a prolongation of the pith, which thus maintains its connexion with the bark. In the stem of a second year, however, these bundles are found to form a second ring, enclosing the first but still beneath the bark, which is carried outwards, as it were, to admit it. The prolongations of the pith still exist; but they become narrower in each ring, and at last appear merely as lines diverging from the centre. They are called *medullary rays* (or rays passing off from the *medulla* or pith; and their office is to maintain a constant connexion between the pith and interior of the stem and the bark or exterior, for an important purpose hereafter to be mentioned. The thin plates which they form, crossing as they do the direction of the fibres of the wood, are known as the *silver grain* by Carpenters. In many instances they add greatly to the beauty of the wood. (See Fig. 32.)

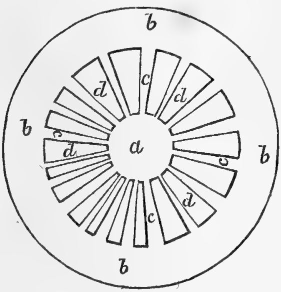


Fig. 30. Diagram illustrating the formation of the stem; *a* pith; *b*, bark; *c*, *c*, *c*, plates of cellular tissue connecting them, termed medullary rays; *d*, *d*, *d*, woody bundles interposed between these.

129. The number of rings or layers of which the wood of any stem or branch consists, is in general easily reckoned by cutting it across; and they correspond exactly in this climate with the number of years which the part has existed. There is reason to believe, however, that,—though in temperate climates, the trees

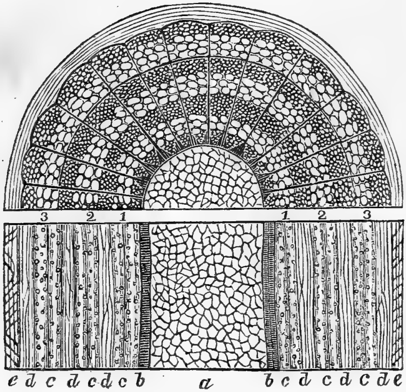


Fig. 31. Horizontal or transverse, and perpendicular section of the stem of an Exogen of three years growth. In the centre of each is seen the pith, *a*, composed of cellular tissue; surrounding it is the medullary sheath, *b*; and exterior to it are three rings of wood, each consisting of *c*, *c*, dotted ducts, and *d*, *d*, woody fibre. The last-formed is in contact with the bark, *e*, *e*, in which the layers are indistinct.

of which shed their leaves and renew them once a year, a layer is formed no oftener,—in tropical climates, where many kinds of trees have two or three successions of leaves in a year, a corresponding number of layers will be formed. In this way we can account for the extraordinary number of layers in the Baobab trees of Senegal, without having recourse to the supposition that they were above 5000 years old, as we must otherwise regard them.

130. Each layer of wood consists partly of vessels or ducts, and partly of woody fibre. The former always lie next the centre,

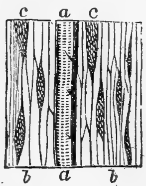


Fig. 32. Vertical section of a portion of an Exogenous stem in a direction crossing that of the medullary rays; *a*, *a*, dotted duct; *b*, *b*, woody fibres; *c*, *c*, cut ends of the medullary rays.

and are the parts earliest formed; the latter protects them on the outside, and is produced towards the end of the season. The mode in which these are arranged, however, varies in different trees; and it is principally this which gives that beautiful variety observed in sections of many woods, when examined with the microscope. The ducts are at once distinguished by the large size of their orifices; and the woody fibres by their comparative minuteness. Amongst the ducts, however, we usually find lying some elongated cells, which fill up the spaces between them, and which sometimes resemble woody fibres in form, but differ in the firmness of their walls. Whatever be the number of annual layers, they are always traversed by the medullary rays, which continue to extend outwards, with every addition to the diameter of the stem, even when the pith and the inner layers of wood have decayed away.

131. In most trees, of which the wood is used as timber, the inner and older portion is much harder and dryer than the exterior. Sometimes there is an evident line of demarcation between the *heart-wood*, or *duramen*, as it called, and the *sap-wood*, or *alburnum;* this is seen, for example, in the lignum vitæ, and coco wood, which are much employed by turners. But in most cases, the change of character is more gradual. This change is due to the consolidation of the interior wood, by the deposition in its tubes of resinous and other matter secreted by the plant. The portion of the stem in which this has taken place thus acquires great toughness and durability, but it is no longer fit to perform any office in the living system, save that of mechanically supporting the rest; since no fluid can pass in any way through the now-filled-up channels. It is through the newer layers, or sap-wood, therefore, that the sap entirely ascends; and these, in their turn, become enclosed by others, and are at last consolidated, like the more aged ones, into duramen. The heart-wood alone is used by the artisan; for the sap-wood soon splits and decays.

132. As the pith and the inner layers thus gradually lose their original employment, and as in the outer part of the stem alone any active processes of vegetation go on, the former may be removed without injury to the latter; and this is often naturally accomplished by decay, which destroys the *heart* of an aged tree, with some portion of the exterior of the stem, but leaves the remainder a mere shell, still capable, however, of putting forth buds and branches, and of adding to its own thickness.

133. The chief important variety in the structure of the Exogenous stem is that exhibited in the Pine and Fir tribe. No ducts exist in their wood; whilst the diameter of the tubes of the wood itself is greater than in other cases; so that a horizontal section of the stem shows a series of openings of the same size,

arranged with beautiful regularity, the division into annual layers being usually well-marked. As a general rule it may be stated that these are separated by the most distinct line in trees inhabiting temperate or cold climates, whose vegetating processes are entirely suspended by the cold after each layer is formed, whilst in trees of warmer regions, they pass into one another more gradually. In the former, too, there is often a considerable difference in the thickness of the respective layers, according as the seasons have been favourable, or otherwise, to the formation of wood; whilst in the latter their thickness is in general nearly uniform.

134. These facts come to be of much interest, when we examine the structure of the fossil plants, which are not unfrequently found imbedded in solid rock; for they thus afford evidence that the temperature of this quarter of the globe was both higher and more equable at the time they grew here, than it is at present;—an opinion which is equally supported by the nature of the fossil remains of Animals existing at the same period.

135. Between the pith and the adjacent layer of wood, a delicate membrane may be traced, which is termed the *medullary sheath.* This consists almost entirely of spiral vessels, which are seldom found in any other part of an Exogenous stem, except when they pass off from this towards the origins of the leaves. Their office is a very important one, as will be hereafter seen.

136. The wood is enclosed by the *bark*, which is, like it, formed in regular layers, though these are much thinner, and cannot be so plainly distinguished. The layers of bark are formed from the *interior*, so that the oldest are on the outside. These are gradually lost, either by decay, or by falling off; so that it is very seldom that the same number can be traced in the bark as in the wood, although an additional one is formed in each at the same time. As the new layer of wood is formed on the *outside* of the previous one,—at the point, therefore, at which it is in contact with the bark—and as the new layer of bark is added to the *inside* of the previous one,—at the point, therefore, at which it was in contact with the wood,—it is obvious that they are produced at the same spot, and that the newest layers of both will always be in

contact with each other. Their production seems to take place in somewhat of this manner. At the end of the spring, the bark becomes loosened from the wood, with which it was previously in close contact, and a glutinous fluid, termed the *cambium*, is found between them. This may be observed by stripping the bark from almost any twig at that season. The cambium is gradually organized into cells, and from these are formed the ducts and cellular portion of the woody layer, and the cellular portion (which is much the greatest) of the layer of bark. Later in the year, the woody tubes grow downwards from the leaves, obtaining nourishment from the fluid portion of the cambium as they descend, and at last partly uniting themselves with the vessels, &c. of the new woody layer, and in smaller proportion, with the tissue of the bark.

137. In some kinds of trees, the bark contains a great deal of cellular tissue, and is therefore thick and spongy; this is the case with those that furnish *cork*, which may be regarded as a sort of external pith. The inner layers, however, to which the name of *liber* is given, are usually thin and delicate in their texture, and have been applied to various useful purposes. One of these is indicated by the meaning of the term *liber* in Latin, which signifies *a book;* and thus in that language a book and the inner bark of a tree had the same name. The fact was that, before the invention of paper, the inner bark was one of the substances used by the Romans for the same purposes, as the leaves of the *Papyrus* (from which the term *paper* is derived) were employed in Egypt. It is the liber of other trees which is used by the islanders of the Polynesian Archipelago for cloth, mats, sails, &c. A very beautiful kind of liber is that obtained from the Vegetable-Lace tree (as it is called) of Jamaica; when its layers are unfolded, it has the appearance of a delicate lace.

138. From what has been stated as to the successive formation of new layers within, and the gradual loss of those on the exterior, it is evident that each layer of bark will in its turn be brought to the surface and be thrown off. On the other hand, each layer of wood is gradually being imbedded more deeply. Hence it follows that, if any substance be placed in the newest layer of wood, it

will gradually be covered by others; so that if the tree be cut down at any future time, the number of years that have passed since it was imbedded may be known by counting the number of layers on its exterior. On the contrary, if the substance be not driven into the wood, but remains in the newest layer of bark, it will be gradually brought to the surface and will fall out. Such experiments have been tried for the purpose of showing the mode in which these two parts of the stem respectively grow.

139. As the bark is sufficiently distensible to admit of the increase of diameter of the interior of the stem, there is no necessary limit to the age of Exogens; and there are many unquestionable examples of such trees having attained an enormous longevity. In this country the Oak and the Yew appear to be the longest lived. At Ellerslie, the birthplace of Wallace, exists an Oak which is celebrated as having been a remarkable object in his time, and which can scarcely, therefore, be less than 700 years old. Near Staines, there is a Yew tree older than Magna Charta; and the Yews at Fountains Abbey, in Yorkshire, are probably more than 1200 years old. Eight Olive trees still exist in the Garden of Olives at Jerusalem, which are known to be at least 800 years old. But the rate of increase in old trees is by no means the same as in young; so that when they are grown for the profit to be derived from their timber, it is not advantageous to let them pass a certain age. Thus the rate of growth in the Oak diminishes greatly after about seventy years; that of the Larch after sixty; and that of the Elm after about sixty-five.

140. It is in the vessels and woody tubes of the alburnum that the fluid absorbed by the roots is transmitted to the opposite extremity of the stem; and these vessels communicate with those of the leaves, which receive it from them. In the liber, on the other hand, the fluid which has been converted in the leaves into nutritious sap, descends again through the trunk, for the purpose of nourishing its different parts. Of this descending sap, a part is carried inwards by the medullary rays, which thus diffuse it through the whole stem, as also through the substance of the roots, down which it is conveyed by their bark. In this descent, it

mixes with the ascending current, especially at its lower part; and being much superior in density, it adds to the density of that fluid, and thus maintains the conditions requisite for endosmose (§ 119.) The vessels down which the sap moves in the bark are of the branching character described as peculiar to those which convey the nutritious fluid (§ 87.) They form a complete network, in which the fluid may be seen to move in various directions. For this motion no definite cause can be assigned. It does not depend on any impulse from above, corresponding to that action of the roots which raises sap in the stem; for there is no power in the leaves to give any such force. It has been supposed to depend upon the gravity of the fluid, which will cause it to descend simply by its own weight; but if that were the case, it would not *ascend*, as it often does, in the bark of the hanging branches of such trees as the Weeping Ash or Willow. It is only one, however, of numerous cases in which a movement of nutritious fluid, through channels in the solid parts it supplies, takes place without any evident cause, in animals as well as vegetables.

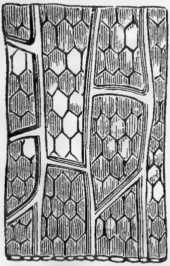


Fig. 33.
Branching vessels of the Bark.

141. The stems of Endogens is formed upon a very different model. As already stated, the woody bundles in the stem of a year's growth, such as that of the Asparagus, are distributed through the whole of the cellular mass which originally constituted it; and a similar arrangement will be found in the stem of a Palm or other aged tree. Instead of being united into rings, these bundles remain separate; and it is only on the exterior of the tree, where they are closely pressed together in consequence of the continual addition of new woody matter to the interior, that they form any thing like hard wood; and even this, though very useful for some purposes, does not possess the kind of texture which adapts it to the work of the artisan. Each annual set of woody bundles, which proceed (as in Exogens) from the leaves, passes downwards in the softest part of the stem, which is its

interior; but after proceeding for some distance in this manner, it turns outwards, and interlaces itself with those which were previously formed. In this manner, the lower part of the exterior of a Palm stem becomes extremely hard; partly from the pressure from within, to which it is not elastic enough to yield; and partly from the constant interlacement of these new fibres, which wind themselves in among the dense tangled mass of the old, like roots seeking to pass through a stone wall. This density is sometimes so great, as to resist the blow of a sharp hatchet.

142. The cellular portion of the stem, which in Exogens was separated, by the first introduction of wood, into pith and bark, here remains intermingled with the wood through the whole duration of life, as is shown in the accompanying figure. Each woody bundle contains ducts and spiral vessels, besides woody fibre; and these are arranged in such a manner that the spiral vessels are on the side next the centre, and are protected by the woody fibre on the exterior. The same elements, therefore, exist in this stem, as in that of the Exogen, but they differ in their mode of arrangement. From their peculiar structure, they increase very little in diameter, the hardness of the exterior not permitting their enlargement. The consequence of this is, that there is a limit to their age; for the continual addition of new woody bundles to the interior so much compresses those which were previously contained in the stem, that they are no longer pervious to fluid, and the tree dies. Na-

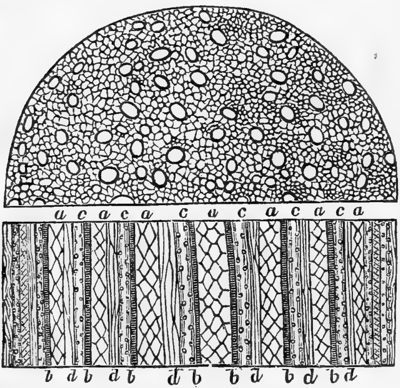


Fig. 34. Horizontal and vertical section of the stem of an Endogen, showing the bundles of ducts, woody fibre, and spiral vessels irregularly disposed through the whole stem; *a*, *a*, portions of cellular tissne; *b*, *b*, spiral vessels; *c*, *c*, dotted ducts; *d*, *d*, woody fibre.

ture sometimes provides a remedy for this, in the splitting of the hard envelope, which allows the interior to dilate; and this has been successfully imitated by art,—vigour having been restored to a Palm which had begun to languish, by splitting down the exterior of its stem with a hatchet.

143. Although no complete distinction exists between the cellular and woody portions of the stem in Endogens, yet it is in the interior that the former predominates; and hence some Palm-trees, as that which produces Sago, have been said to have a pith, which is (strictly speaking) erroneous. Through what channels the ascending and descending sap of Endogens respectively move has not been ascertained; but there can be little question that it is chiefly through the ducts that the former rises, whilst the latter finds its way downwards through the cellular interspaces. From the cellular portion of the stem, in Endogens as in Exogens, the buds take their origin; whilst the roots are chiefly prolongations of the bundles of wood and vessels. This is well seen in the Pandanus, where the bundles that ordinarily make their way downwards within the stem, and would there form part of the wood, pass outwards and become aerial roots (§ 110.)

144. The same cause which sets a limit to the age of Endogens exempts them from the injurious effects which Exogens often experience from the compression of their stems by ligatures of various kinds. If a cord be tied tightly round the trunk of an Exogen, it will offer little impediment to the ascent of the sap; but it will obstruct its descent through the bark. In consequence, there will be a deficiency of nourishment to the parts beneath, and a superfluity above; so that a protuberance will arise from the stem just at the point where the downward flow of the sap is checked. This protuberance will increase in progress of years, if the tree survive, so as almost to bury the cord beneath it; but most commonly the tree is destroyed ere long, by the insufficient supply of nourishment to the roots.

145. Now such obstructions not unfrequently arise from natural causes. There are several creeping plants, whose habit it is closely to embrace the stems round which they coil; such is the

common Bindweed of this country; and in tropical climates these creepers are more numerous, and their stems more woody. These seldom wind in complete rings, but in a spiral, growing like a corkscrew; and thus the descent of the sap is rather obstructed than prevented. But an accumulation of the nutritious fluid takes place above the whole line of the spiral: so that, when the creeper is removed, the stem presents the curious appearance of a deep indentation passing round it from one end to the other, and on the upper edge of this a corresponding elevation. Endogens are subject to no such alteration; as the sap does not pass down the exterior of the stem, and its diameter increases but little.

146. Such creepers are exceptions to the general rule that it is the tendency of stems to grow vertically or right upwards. This tendency is sometimes shown in a very curious manner. If the trunk of a young tree be artificially bent, by drawing it (for instance by a cord to one side, the branch which then most nearly approaches the vertical direction will increase more than the rest, and will at last appear quite continuous with the lower part of the stem. Again, if the trunk of a tree which usually throws out its branches almost horizontally, such as the Elm, be broken off, the highest branches will gradually approach the upright position, so as to appear like continuations of the broken trunk. In coiling stems, however, it would appear as if some tendency to turn to one side was constantly operating in conjunction with the upright growth; so that a cork-screw-like form is produced.

147. It is a little remarkable that, though this turn is usually in the contrary direction to that in which the sun appears to move, (as is the case in the common Bindweed, most plants of the Pea tribe, the Passion-flower, the Dodder, and many others,) it is sometimes the same with it, as in the Hop. Almost all flowering plants, however, exhibit some tendency to a spiral growth in their stems. It will be hereafter shown that the *regular* arrangement of leaves on the stems and branches is in a spiral line. Moreover, in many smooth-trunked species, as the Cherry-tree, the bark is more easily torn off in a spiral than in any other direction. In trees having few branches, such as the Fir, it is not uncommon to

see the same tendency manifested by spiral fissures in the wood, when the bark has been for some time removed. The direction of this kind of twist seems to be as constant in straight stems, as in those which manifest it by coiling; thus, the Common Chestnut and the Horse-Chestnut have been observed always to twist in contrary ways.

148. The stem is not always solid, either in Exogens or Endogens. Thus among the former, the well-known tribe of Umbelliferous plants presents many instances of a hollow stem, as in the common Hemlock; and in the latter, the Grass tribe affords a corresponding example. In these instances, the hollowness of the stem is due to the expansion of the outer portion faster than the interior can keep pace with it. The young stem is not hollow in either case; and it is a beautiful instance of mechanical contrivance, that, in these rapidly-growing plants, which are to be rendered independent of support from others, the limited quantity of hard tissue which they form should be disposed at such a distance from the centre, as to give the greatest strength with the least expenditure of material. If the material of a Wheat-straw, for example, were disposed in a solid form, it would make but a thin wiry stem, which would be snapped with extreme facility. In the hollow-stemmed Endogens, such as Grasses and Bamboos, and in many others, as the Sugar-cane and other Canes, we observe certain divisions of the stem, which are called *nodes* or knots. Where the remainder of the stem is hollow, it is always solid here; and the partition has a peculiar degree of firmness, derived from the interlacing of fibres from all sides. And where the remainder of the stem is filled up (as in the Sugar-cane) with soft spongy tissue, there is still the same kind of firm division at the node. The space between the node is termed the *internode;* and from each one of these divisions, we usually find a single leaf-bud, or pair of leaf-buds, originating. The division into nodes is not so perceptible in Exogens; but it may be regarded as always existing. It is best seen in the young shoots of the Vine; where the fact that, from each internode but a single bud or pair of buds originates, is equally evident. Hence, when the stem itself does not

exhibit any distinct division by nodes, the Botanist is accustomed to regard them as existing near the points from which leaves or branches arise; and to consider as internodes the spaces between these.

149. Many parts are commonly regarded as roots, which are in reality stems. Their position, whether above ground, or beneath the surface, is no criterion as to their real nature. It has been seen (§110) that roots sometimes grow in the air, and it is equally true that stems frequently grow in the earth. What are ordinarily called *bulbous roots*, for example, such as those of the Onion, Hyacinth, Lily, &c. are in reality underground stems. It was formerly stated (§111—113.) that the real distinctions between the root and the stem consist in the contrary directions of their growth, and in the tendency of absorbing fibres to arise from the former, whilst the latter gives origin to leaf-buds. Now the base of the bulb is the real point of division between the stem and root; for, whilst all below it,—namely the fibres which really constitute the roots,—has a tendency to grow downwards, the mass of the bulb, together with all above it, has a tendency to grow upwards. Farther, the *scales* of the bulb are in reality but *leaves*, changed from their usual character and aspect, or *metamorphosed;* and at the base of every one of these scales is found a little *bud*, occupying the same position in regard to it as the buds to the leaves on the higher parts of the stem. (§ 301.) Thus we perceive that here the stem is in a very contracted state, the internodes not being developed, and the leaves and buds of several nodes arising close together. The difference between one of these scaly bulbs, therefore, and the solid fleshy expansion of the root which constitutes a turnip or turnip-radish, is at once evident.

150. But stems are sometimes so completely changed in their direction as well as form that they can scarcely be recognised as such, except by their tendency to produce leaf-buds. Thus they sometimes creep along the ground, or even just beneath it, sending up buds, which develope themselves into branches, at intervals. Of this kind is the *rhizoma* or root-stock of most British Ferns, which creeps above ground in some species, and below in

others; and the Ginger-plant of tropical countries has a stem of the same character, which really furnishes Ginger, although this is commonly spoken of as the *root* of the plant, being partly buried beneath the ground. The *runners* of the Strawberry, again, are but trailing stems, which send down roots and develope buds at intervals, and thus extend the plant. This tendency, which is serviceable to man in this instance, is very troublesome to him in another; for in the same manner the Couch-grass overruns pasture lands, exterminating, if its increase be not checked, their original vegetation. As every internode of these trailing stems possesses the power of developing both roots and buds, it is useless to attempt to destroy the plant by chopping the stem into pieces; for this is in reality only multiplying it. It is well to mention, however, that, though usually regarded as a very rank weed, the underground shoots of this plant constitute a peculiarly nutritious food for cattle.

151. One of the most distorted forms of the stem is that which presents itself in the Potatoe. This plant grows with an underground stem, sending up its flowering branches into the air, and sending its roots downwards into the earth; but on this stem it forms at intervals the *tubers* or knobs, which constitute such an important article of food to man. That these tubers are still parts of the stem, is shown by their power of originating buds, from the points commonly known as the *eyes* of the Potatoe. When, therefore, we divide the tuber into pieces, keeping an eye in each, from every one of which we expect a young plant to spring, we follow in fact the same plan as that adopted in planting Sugar-Canes, which are not propagated from seed, but by dividing the stem into its internodes, and laying each of these separately in the ground. And thus it is seen that the division of the creeping stem of the Couch-grass effects in reality the same end. The quantity of fleshy matter deposited in the Potatoe serves for the nourishment of the growing buds before their roots are formed; and thus it is that, if exposed to a warm and moist atmosphere, they are liable to sprout, without the contact of earth. It is remarkable that in their native climate (the tropical part of South-

America) the tubers of the Potatoe are extremely small, and that they become so when plants are raised from British stocks in any countries equally hot.

152. In all these instances it is seen that not only buds but roots may arise from different parts of the stem and branches. But this tendency is by no means confined to such as grow on or beneath the ground. There are many trees of which the branches naturally hang downwards; and if these reach the ground, they give origin to a new set of roots, which serve for their own nourishment, and for that of the shoots they send off, so that they become so many secondary stems. The most curious examples of this kind are the Banyan trees of the East Indies, of which one individual sometimes constitutes a miniature forest. The most celebrated specimen is that of Cubbeer-bur, which many years since, possessed 350 principal trunks, and smaller stems amounting to more than 3000, every one of which was casting out new branches and hanging roots, to form future trunks. The space of ground which it covered was such, that it was estimated that 7000 persons might have found ample room to repose beneath its shade. These trees are held by the Hindoos in superstitious reverence, and are dedicated to religious observances. Our own sacred poet, Milton, has given a beautiful delineation of it.

> "The fig-tree; not that kind for fruit renown'd;
> But such as at this day to Indians known
> In Malabar or Deccan, spreads her arms,
> Branching so broad and long, that in the ground
> The bending twigs take root, and daughters grow
> About the mother tree, a pillar'd shade,
> High overarch'd, with echoing walks between."

153. The only Cryptogamia at present existing, which form true woody trunks, are the Tree-Ferns of tropical climates. In these, the stems which creep along or under the ground in the species inhabiting temperate climates, erect themselves into the air, and bear a beautiful crown of leaves. These stems are sometimes hollow, and sometimes contain a sort of spongy pith. Their

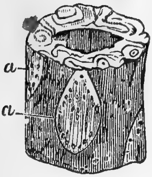


Fig. 35.
Portion of the stem of a Tree-Fern; *a*, *a*, scars of former leaves.

mode of growth is different from that of either Exogens or Endogens; and appears of a simpler character. The stem, when cut across, is seen to consist of a number of hard woody plates adhering rather loosely together; and these, if traced upwards, are found to be either continuations of the flattened footstalks of the leaves which crown the summit, or to be the remains of those which have dropped off. Every year the leaves decay away, and are replaced by a new set formed above; so that the stem continues increasing in length, but undergoes little change in diameter. The marks seen on the exterior of the trunk are the scars of the former leaves; and by the relative position of these it is seen that, though the portion of the stem first formed increases but little in diameter, it receives some addition to its length, its scars being separated from each other by a much wider interval than in the newly-formed part. However, it is the general rule in these and other Cryptogamia, that the portions first produced undergo little subsequent change; hence, whilst the names Exogens and Endogens are used to indicate the modes of growth respectively peculiar to the chief divisions of flowering plants, the flowerless plants may be included under the general term Acrogens, which intimates growth by the point, or by addition to the extremities only.

CHAPTER VI.

OF THE FOOD OF PLANTS, AND THE MANNER IN WHICH IT IS OBTAINED.

154. A plant or tree can no more exist without *food* than can an animal; and it is only because the mode in which they receive it is less evident to us, that we do not commonly think of vegetables as equally dependent with animals upon the materials supplied to them by the elements around. We are constantly witnessing the act of feeding in all the animals that are under our notice; but the growth and reproduction of plants *seem* to take place with so slight an introduction of solid matter into their system, that it cannot be comprehended without farther examination how they derive the means of uprearing the gigantic masses of wood and foliage which many of them present to our admiring view. It cannot be shown that any solid matter is ordinarily taken up by the roots, except certain mineral ingredients which most plants require, and the use of which will be presently stated. How then, do they obtain the materials of the firm wood of their stems, roots, and branches,—of the soft but still firm tissue of their leaves and fruits,—of the fleshy seeds they generate in their flowering system,—and of the various hard substances which they produce in their different tissues? This question will now be answered.

155. In the first place it may be laid down as a fact beyond doubt, that neither plants nor animals have the power of creating or producing matter which did not before exist. Living beings are entirely dependent upon the supplies they obtain from without, for the maintenance and enlargement of their own structures;—they greatly alter the form and properties of the elements they take in;—but they can *create* nothing. It is easy to say whence

every particle of which a living body consists is obtained by it; for, by placing it in a variety of circumstances, and observing the changes in its mode of life which these produce, we can determine the influence of each. Thus, an Animal may be fed exclusively on some one kind of aliment, as for instance sugar or gum; and it is found that, however nutritious when combined with others such an article may be, it has not the power of supporting life for any length of time by itself, unless it contain (which no single article of food except *milk* does) *all* the substances required by the animal for the right maintenance of its structure. So, also, on the food of Plants we may experiment, by placing them in different soils, and in different kinds of air, and supplying them with variable quantities of water; until we have discovered what is absolutely necessary to their growth,—what favours it, and what is superfluous or injurious.

156. Before, however, we enter upon these inquiries, we shall derive much guidance from the knowledge of the substances actually contained at any given time in the vegetable structure. When we examine a seed, we find that it contains the germ of the new being; but that it principally consists (like the egg) of a nutritious substance prepared by its parent for the support and development of its offspring, until it is able to acquire food for itself; and it is by this means, as we shall hereafter see (Chap. XII.) that the young plant is enabled to push its first roots into the soil, and to elevate its first leaves into the air. By the time it has done this, however, all that store of aliment is exhausted; and henceforth it is entirely dependent upon what it acquires for itself. The lowly plant developes itself in progress of years, by the wonderful power with which it is endowed, into the gigantic tree, increasing its weight from a few grains to many tons. Of what does its massive structure then consist?

157. The inorganic elements and mineral matter composing the solid earth on which we live, contain a certain number of substances which are termed *simple*, because they cannot, by any known chemical process, be shown to consist of others united together. Such, to take familiar examples, are the various metals,

with sulphur, as well as many other less common bodies. But the greater part of the substances which surround us are termed *compound*, because they can be separated into two or more simple or elementary bodies. Limestone, for example, when exposed to heat, is much changed in its character; it gives off a kind of gas or air, termed *carbonic acid* gas; and *lime* remains—a substance which is no longer safe to handle, on account of its possessing the power of destroying (or, as commonly said, burning) animal flesh, whence it is commonly termed quick-lime. But neither of these two substances are simple, for it is easily shown that carbonic acid is composed of two others, of which one is *carbon*,—a solid substance of which the diamond is the purest form, but which is nearly the same with charcoal; whilst the other is *oxygen*, a gas which forms part of the air we breathe. Again the lime may be shown (by a process of much difficulty) to consist of a metal, termed *calcium*, united with some of this same *oxygen*.

158. Carbonic acid is the gas known as *fixed air*,—or in mines as *choke damp*. It is very injurious to the life of animals, acting as a sort of poison to them. It is formed during the combustion or burning of every substance containing carbon; for this combustion consists of the union of carbon with oxygen, which, when it takes place rapidly, is accompanied by light and heat. Thus, if a pan of charcoal be burned in a closed room, a large proportion of the oxygen of the air will be converted into carbonic acid; so that any human being, and almost any air-breathing animal, would rapidly lose his life in such an atmosphere. In this manner many persons have been suffocated. Charcoal, however, is not the only form in which carbon exists; coal contains a very large proportion of the same element; and carbonic acid is accordingly formed by its combustion. It also exists in the gas now so commonly used in towns for lighting, which is usually made from coal, though sometimes from oil; this gas consists of carbon in union with *hydrogen*, another kind of element presently to be noticed; and when it is burned it forms carbonic acid, together with the vapour of water, which is produced by the union of the hydrogen with the oxygen of the air.

159. Carbonic acid gas is also given off by all animals, which form it during the process of respiration or breathing; for a portion of the oxygen which is taken into the lungs is there combined with carbon which the animal system wants to throw off, and then breathed out again in the form of carbonic acid. The presence of this gas in the air returned from the lungs is easily shown by breathing out through a tube, the end of which is immersed in a deep glass containing lime-water, which is water having a small quantity of quick-lime dissolved in it. After the lungs have been a few times emptied through this tube, the water becomes quite turbid, by the union of the carbonic acid with the lime, and the consequent formation of a carbonate of lime, which, not being soluble in water, falls as a white powder resembling pounded chalk. It will be hereafter shown that vegetables, like animals, form carbonic acid during the whole course of their lives, by causing the oxygen of the air surrounding them to combine with carbon which they have to give off (Chap. VIII.)

160. Now the carbonic acid thus combined with the lime might be separated again by heat, or in other modes. If we pour a little vinegar upon limestone or chalk, a bubbling or effervescence is produced, which is caused by the acid of the vinegar combining with the lime, for which it has a greater attraction than has the carbonic acid; and as they cannot both be combined with the lime, the latter is set free. It is set free, also, in large quantities, during the process of fermentation; and this it is which renders it dangerous to walk over a vat in which fermentation is going on, and which extinguishes a candle held in such a situation. Putrefaction, too, is a kind of fermentation; and carbonic acid is given off in this process. In fact, the respiration of plants and animals may be regarded as designed to carry off the carbonic acid produced by a kind of slow putrefaction or decomposition, which is always going on within the body; for it is a peculiar characteristic of the compound substances of which vegetable and animal structures are made up, that they have a tendency to separate themselves into their elements under the ordinary circumstances of warmth, moisture, &c. to which mineral bodies may be exposed

for centuries without change. This tendency to separation it is, which causes the decay of animal and vegetable substances after death; for the elements that were previously combined in ways which no chemical pocesses can imitate, then pass off in simpler forms, of which carbonic acid is one of the chief.

161. Different parts of the animal and vegetable framework display this tendency in varying degrees. Thus the bones of an animal, and the heart-wood of a tree, may remain almost unchanged for centuries, and thus exhibit nearly the same permanence as the limestone rock; whilst the soft flesh of the animal, and the pulpy portions of the plant pass into decomposition almost immediately upon the death of the being. This decomposition, however, is chiefly remarkable after death, only because it is not then counteracted by the processes which form an essential part of the functions of life. The object of those functions is not only to provide for the *growth* of the structure, and for the production of new individuals which shall continue and extend the race; but to maintain in constant perfection and vigour the parts already formed. This is accomplished by the removal of the portions which have exhibited the slightest tendency to decay, and by the deposition of freshly-formed substances of a similar character in their place. The particles which are removed are carried off in the blood of the animal or the sap of the plant; and are separated from this in part by the process of respiration, which gets rid of the carbonic acid, and in part by other means of a corresponding nature.

162. The rapidity of these processes of deposition and removal in the several parts of the living body bears a very close proportion with the natural tendency to decay which they respectively manifest. Thus, the bones of an animal are in general sparingly supplied with blood, and seem to undergo little change except as the result of disease or injury; but the supply of blood is greatly increased when any circumstances demand a new formation of this tissue. So, in the heart-wood of a plant, the circulation almost ceases; for so long as no air or moisture from without find access to the interior of the stem, this part retains its

firmness unchanged, and its particles require no renewal. But the soft tissues of an animal are largely supplied with blood, and also with absorbing vessels; and the greatest part of the food taken in by one which has attained its full growth, is devoted to the maintenance of these parts in their right condition, which is essential for the proper performance of their functions. Of all these soft tissues, that which forms the brain and nerves is supplied with the largest proportion of blood, and undergoes the most rapid changes during life; and it is this which most speedily decomposes after death. The soft tissues of plants do not so quickly decay as those of animals, and the circulation of nutritious sap through them is less active; but still a movement of fluid takes place, and the same object is attained by it.

163. Thus we perceive that *food* has for its object,—in the first place, to supply the materials of the growth and extension of the system, enabling the minute germ containing the seed to develope itself in time into a lofty tree;—next, to maintain the parts so formed in their healthy state, by affording the materials by which those which have begun to decay may be replaced,—farther, to provide a store capable of supplying the occasional extraordinary demand for reparation which disease or injury may produce;—and, lastly, to enable the being to develope the germs of new individuals, and to supply them with a store of nutriment on which they may live until able to provide for themselves. Now of the 55 simple substances into which the solids, fluids, and gases, of the inorganic world may be separated, vegetables are principally made up of four; and of these only three exist in any large proportion. These three are carbon, oxygen, and hydrogen; and the fourth is nitrogen.

164. Of all these, CARBON is by far the most abundant. It is, as already mentioned, nearly identical with *charcoal*, which consists of the carbon of the wood, mixed up with a small quantity of earthy matter. If this charcoal be burned, it passes off in the form of carbonic acid gas, leaving a minute portion of white ash, which is principally of a mineral nature. It is chiefly to the carbon which it contains that the hardness and solidity of wood are due. In so large a proportion does it exist in that tissue, that when the other

elementary bodies (the oxygen and hydrogen) have been separated, the carbon retains the form of the tissues in great beauty and perfection, so that a section of a piece of charcoal will indicate the character of the wood from which it was made, nearly as well as would a section of an unburnt branch. On the other hand, in proportion as the tissues of the plant are deficient in carbon, do we find them deficient in firmness of structure.

165. When we consider the large quantity of carbonic acid extricated by the respiration of animals, and by the immense amount of combustion of coal which is constantly going on in our large towns, there would seem no difficulty in understanding how it may be supplied to plants; but so vast is the extent of the atmosphere through which the carbonic acid has to be diffused, that any given bulk of air only contains about 1-1000th part of this gas. Hence it might be supposed impossible for the gigantic mass of carbon contained in the wood of a wide-spreading forest, to have been derived chiefly, if not entirely, from this source; and yet such will be seen to be the case. For, although the soil may contain carbon, none of it is taken up in a solid form; and its quantity rather increases than diminishes in the course of years.

166. Oxygen is contained largely in plants; and the presence of it in the air which surrounds them is very necessary to their healthful existence,—chiefly as affording the means by which, as already explained, the superfluous carbon is removed. This element is equally necessary to animals, and it constitutes about a fifth part of the air we breathe. A portion of this air is dissolved, as it were, in water; and it is in this manner that fishes and other aquatic animals as well as plants are supplied with oxygen. Most if not all, however, of the oxygen which is contained in vegetable substances, is taken up by them either in combination with carbon, or in union with hydrogen,—a body which with it forms water.

167. Hydrogen is also contained largely in plants; and, in most of the substances into whose composition it enters, it is combined with oxygen nearly in the same proportion as in water. Although it is probable that a small quantity is introduced with

nitrogen in the form of *ammonia* (the pungent gas which gives strength to harts-horn, smelling salts, &c.) we may regard the water introduced into the substance of plants by their roots, and also in part absorbed by their general surface, as the chief source of this element, as well as of the oxygen contained in the vegetable structure.

168. Nitrogen has not been commonly regarded as an important element of the vegetable structure; but it has been lately shown to exist largely in the growing parts of plants; and there seems reason to believe its presence to be essential to the increase of their fabric by the formation of new parts. It is an important ingredient in the substance called *gluten*, which exists largely in the seeds of the various kinds of corn, and most of all in wheat; and it is in part on this account that wheaten bread is the most nutritious of all vegetable substances ordinarily used as food,—since it approaches nearer in composition than almost any others to animal flesh, which contains a much larger proportion of nitrogen than exists in most vegetable substances. It is, indeed, on account of their entire deficiency in nitrogen, that gum, sugar, and other similar products are not fit to maintain animal life by themselves. Nitrogen constitutes four-fifths of the atmosphere; but it does not seem to be taken in by the plant in its simple form. This gas with hydrogen forms *ammonia*, of which a minute quantity always exists in the atmosphere, being chiefly supplied to it by the decomposition of animal matter; and this is absorbed by the soil and taken up by the roots, in the manner hereafter to be described. It is in the supply of ammonia which they yield, that the principal benefit of animal manures seems to consist.

169. Besides these elementary substances, which all plants contain, and of which the vegetable tissue may be regarded as essentially consisting, almost all plants contain some mineral ingredients, the presence of which is necessary to their healthy existence. These remain as ashes, when the other parts of the structure are set at liberty by combustion;—the *carbon* uniting with the oxygen, and with some additional oxygen from the air, passes off as carbonic acid;—of the *hydrogen*, part unites in the

same manner with oxygen, and passes off as watery vapour;—the *oxygen* is thus entirely carried off,—and the *nitrogen* unites with the remainder of the hydrogen to form ammonia. Thus there remains nothing of the vegetable tissue but the incombustible matter, and the nature of this varies in different plants. Thus, in the Grasses, (including Corn, the Bamboo, Sugar-cane, &c.) the ashes consist principally of minute particles of flint. In most other plants growing inland, we find some compound of the alkali potash; and it is from this source that the greatest quantity of the *pearl-ash* that is largely used in various manufactures, such as soap and glass, is derived. On the other hand, in plants growing near the sea, the potash is replaced by soda, which has nearly similar properties. Again, in most plants there is a small quantity of carbonate of lime, and in others there is a large quantity of lime combined with other acids; thus, in Rhubarb we find large crystals of oxalate of lime; and in the Corn-grains there is a considerable amount of phosphate of lime, by which their power of nourishing animals is greatly increased, since this substance constitutes the earth of bones.

170. Of these different mineral ingredients, each plant seems to have some one or more that are as essential to its growth as in any other article of its food; but the quantity required is sometimes extremely minute, so as to be scarcely detectible,—only a very small quantity of ash remaining after the tissue has been burned. In other instances, again, the mineral matter is so abundant as to present itself in the form of large crystals, which are deposited between the cells of the tissue. But that which seems its proper office is to form part of the membranous walls of every cell and tube of the whole structure, however delicate these may be. If a thin portion of almost any plant be burned in such a manner that free combustion of all its gaseous elements may take place, without disturbing the place of those which remain, a beautiful skeleton, consisting of extremely minute particles of mineral matter, will be seen, in which the form of all the cells, vessels, &c. may be distinctly traced. These particles would seem to be dispersed throughout the minutest parts of the vegetable tissue;

and they probably serve the purpose of conferring additional strength upon the delicate framework of which it consists. Even in the finer ashes left by the combustion of common coal, a person to whom the forms of the elementary tissues of plants are familiar will often succeed in detecting with the microscope fragments of such skeletons, which thus add to the evidence—otherwise sufficiently strong, of the vegetable nature of that substance.

171. Now that we are acquainted, therefore, with the elements of which the vegetable structure is composed, and have some knowledge of the sources whence these are derived, we are prepared to inquire more minutely in what manner they are severally received into the organism and made parts of its structure. This is an inquiry of the highest consequence in Agriculture—an art which, as it has been justly observed, is superior in importance to every other, since on it man entirely depends for his subsistence, and in great part also for the wealth and power obtained by commerce, and for the materials of his various manufactures.

172. From what has been stated, it would appear that water, carbonic acid, and a minute quantity of ammonia, supply the ingredients of the new compounds which are formed in the living plant; but that, in most cases, mineral substances of some kind are required in addition. There are some plants which derive a sufficient quantity of all these elements from the atmosphere alone, to be able to maintain life, and even to flourish, without any other kind of supply. The water is absorbed by the general surface, but especially by the roots, which in such plants are usually long and of soft tissue throughout; the carbonic acid is taken in through the green parts from the atmosphere alone, in the manner which will be described in the next chapter; and the minute quantity of ammonia also contained in the atmosphere, which is probably dissolved in water and taken up with it, affords a sufficient supply of nitrogen. Such aerial plants usually contain but a very small quantity of mineral matters; and these, too, are probably derived from the atmosphere, in which, as will be hereafter mentioned, their particles are suspended.

173. These aerial plants, clustering round the branches of

lofty trees, and hanging to a great depth beneath them, are extremely common in tropical climates, in which the atmospheric moisture is much greater, and where they constitute an important part of the vegetation; and they are not wanting in this country. Many trees and plants which do not ordinarily grow in this manner may be caused to do so by accident or design; and may even thrive extremely well. At New Abbey in Gallowayshire, in the year 1817, there was growing on the top of a stone wall which measured ten feet in height, a plane tree, which measured twenty feet in height; and, as it soon exhausted the bare and scanty soil in which the young plant grew, it sent down roots which clung to the side of the wall, and threw out neither bud nor branch until they reached the ground, which was not until several years had elapsed, during all which time the tree must have lived upon the materials supplied by the atmosphere alone.

174. In one of the hot-houses in the Botanic Garden of Edinburgh, a plant of the Ficus Australis (the Fig of New Holland) was caused to grow entirely without earth, by gradually withdrawing from the pots the several roots contained in them. The plant was well watered twice a-day, and put out roots freely from all parts of the stem and branches, by which it appeared to gain an ample supply of nourishment, for it produced a very full crop of fruit in the autumn after the earth was removed from the last set of roots. Even when a plant attaches itself by roots to the soil or rock, these may serve only for its support, and may not contribute any thing to its growth.

175. Many succulent plants of warm climates exist in this manner; clinging to the faces of the barest cliffs, or rising out of the most dry and barren sand; deriving their supplies of moisture and other aliment entirely, therefore, from the atmosphere. It is interesting to remark that most of these plants contain in their juices the substance caoutchouc (commonly known as Indian-rubber) and also wax; and the moisture obtained from the atmosphere is prevented from evaporating (which even the thick cuticle would not prevent it from doing under the influence of a burning sun) by a thin layer formed by the drying of these juices around

them, which, like a waterproof cloak, keeps in the vapour that would otherwise be raised, so that the tissue of these plants becomes turgid with their juices, although so little is absorbed.

176. But the majority of vegetables require a larger and more certain supply of their various kinds of aliment than the atmosphere can furnish; and, by the prolongation of their roots into the soil, they are enabled to obtain this,—in a manner, however, which requires some little explanation. What is commonly termed *soil* or *mould* consists of two kinds of ingredients;—it is partly composed of the materials of the rock beneath, the particles of which are gradually separated from each other by the action of the atmosphere, of water, and of the roots of growing plants, as formerly explained (§ 108;)—and partly of the remains of former races of plants, which are in process of decay. The former sometimes exist almost alone; and the latter, in land which has long been cultivated, often constitute a very large proportion. The two together, or either singly, will form *a soil*, the first use of which is to afford to the plant the power of affixing itself; so as to raise its stem, leaves, and flowers, into the most direct influence of the air and light. The next object which it should fulfil is to supply the roots with a sufficient and regular amount of water; and this will be effected according as it is capable of imbibing water readily from the atmosphere and from the neighbouring springs, ponds, or streams.

177. Soils may be divided into the clayey, the calcareous (those containing much carbonate of lime) and the sandy. A stiff soil opposes the ramification of the roots, whilst a sandy one does not afford them sufficient hold; it follows, therefore, that no plants will grow advantageously in the former but those whose roots do not naturally extend far, and whose vegetation is slow; whilst those are most suited to a sandy soil whose roots spread extensively. It is by means of the *Arundo arenaria* or Sea-reed, that the Dutch attempt to check the progress of the drifting sand-hills which threaten desolation to large tracts of country; and when the soil is once fixed by it, and improved by the decay of the individuals first produced, it affords support to vegetation of more value.

178. Again, every one knows that a stiff clay will retain its

moisture for a long time, and that it parts with it or receives more with much difficulty; whilst, on the other hand, a sandy soil absorbs much water, but soon loses it again. In climates where rain occurs pretty often, a calcareous soil is usually preferred, as retaining its moisture sufficiently long, and yielding it with facility; if, however, the temperature of a country be high, and rain fall but rarely, a stiff soil is to be preferred, as it will not become dry in the intervals; whilst, on the other hand, a sandy soil answers better in a region where showers frequently descend. The defects of one soil in regard to its power of supplying vegetation with moisture may be in some degree remedied by admixture with another; this process is called in agriculture the *tempering* of soils. Thus, a stiff clayey soil may be tempered by mixing with it chalk, ashes, or sand, by which it is rendered more permeable to water; whilst, on the other hand, a loose sandy soil may be advantageously tempered with clay.

179. The supply of moisture to the roots, however, is not the only important object which the soil should answer. It ought to afford carbonic acid also; since it is essential to the rapid growth of a plant that this part of its nourishment should be taken in by its roots as well as by its leaves. The carbonic acid may be furnished in two ways; either the soil may absorb it from the atmosphere, or the decay of some of the matter contained in it may disengage this product. It is a remarkable property possessed by several porous substances, of absorbing gases, and especially carbonic acid gas, to the amount of many times their own bulk. Of all these, charcoal is one of the most powerful in this respect; and it has been found that many plants may be grown in powdered charcoal, if sufficiently supplied with water, more luxuriantly than in any other soil. The charcoal itself undergoes no change, but it absorbs carbonic acid gas from the air; this is dissolved by the water which is taken up by the roots, and thus it is introduced into the system. In such cases the plant derives its solid matter as completely from the atmosphere alone, as if its roots were entirely exposed to it; for not a particle of the charcoal is dissolved, and it, therefore, affords no nutriment to the plants.

180. It may be thought incredible that the enormous quantity of carbon which enters into the composition of a single tree, much more of an extensive forest, and much more still of the immense succession of such luxuriant forests as those which formed our beds of coal,—should ever have been contained in the atmosphere; since any given quantity of air contains only about one-thousandth of its weight of carbonic acid, and this gas is composed of only about 27 parts of solid carbon in every 100. But it must be remembered that as the weight of the air pressing upon every square inch of the earth's surface is 15 lbs., that pressing upon a square foot will be 2160 pounds; and as the surface of the earth can be almost exactly calculated, it may be shown that, in the whole of the atmosphere surrounding it, at least three thousand million million pounds of solid carbon must be contained,—a quantity which amounts to more than the probable weight of all the plants, and all the beds of coal which exist upon the earth. The quantity of carbon existing in sea-water is proportionably greater.

181. The readiness with which the atmosphere yields a large quantity of carbonic acid to any substance having a strong attraction for it, is shown when the walls and ceiling of a room are white-washed, or coated with a thin layer of quick-lime. This coating becomes very speedily converted, by combination with the carbonic acid of the air, into carbonate of lime. It may be thus shown that the atmosphere is capable of yielding to a coating of lime, extended over a given surface, and renewed as fast as it is converted into carbonate, three times as great a quantity of carbonic acid as that which is taken in by the leaves and roots of plants growing upon a similar surface during the same time.

182. The constant maintenance of this ingredient in the atmosphere, so as to supply the enormous drain upon it which active vegetation induces, is owing to changes of an opposite character taking place as constantly. Every animal is incessantly engaged in converting the oxygen of the air into carbonic acid, by the process of respiration or breathing. Of the solid carbon taken in as food, which is all derived, either directly or indirectly, from vegetable matter (since every animal is supported either upon

vegetable substances, or upon the flesh of other animals which subsist on them,) a portion is constantly being restored to the gaseous form in this manner. A single man daily converts 45,000 cubic inches of the oxygen of the air into carbonic acid by the carbon disengaged from his lungs; and the enormous amount that must be daily formed by the whole human and animal population of the globe may thus be perceived. Again, the combustion of vegetable substances,—coal, wood, &c.—is a vast and continual source of the renewal of the supply drawn by vegetation from the atmosphere. It has been calculated that the small town of Giessen in Germany, possessing a population of about 7000 inhabitants, yearly converts more than 1000 million cubic feet of oxygen into carbonic acid, by the combustion of wood as fuel; and in an English manufacturing town, where the proportion of coal used is far greater, the amount would be at least twice as much in proportion to the size.

183. Now if it were not for the constant check which the processes of vegetation afford to the accumulation of this ingredient in the atmosphere, it would go on increasing, until the air became unfit for the support of animal life. But it is the fact, ascertained by the careful examination of the air preserved in some empty jars which had been buried with the city of Pompeii, that the proportion of the gases composing the atmosphere can be proved to have undergone no change during the last 1800 years. It is scarcely possible to contemplate all this wonderful system of mutual action, upon a scale so immense, without being struck with the simplicity and harmony of the design, and the perfection with which it operates. The plant is constantly withdrawing from the atmosphere its carbon, and converts it into the material of its own solid structures. Of the substances thus produced, a part is employed as food for animals and man, a part serves as fuel, a part is applied to various purposes in arts and manufactures, and a part decays without being removed from the place where it grew. Now nearly all the carbon taken in as food by animals is restored in a gaseous form to the atmosphere, either by the process of breathing during life, or by the decomposition of

their tissues after death;—all that is used as fuel is converted into carbonic acid gas,—as does nearly all that decays where it grew;—there only remains, therefore, the amount employed, chiefly in the form of timber, for various purposes by man, and this is more than supplied by the combustion of that which has been stored up ages ago for his use in the form of coal.

184. It is from the decay of vegetable and animal matter that plants (at least under ordinary circumstances) derive whatever supply of carbonic acid they obtain in addition to that afforded by the atmosphere. Vegetable mould consists of decaying portions of the tissue of plants; and is constantly liberating carbonic acid in the progress of its decomposition. This is dissolved by the fluid of the soil, and is taken up by the roots. The supply of carbonic acid thus obtained seems chiefly important to the plant when its leaves are undeveloped, as is the case in the early stages of its growth, as well as in every succeeding spring with all but evergreens. For it will hereafter be shown that it is almost entirely through their leaves that plants obtain carbon from the atmosphere; and when these are fully expanded, the absorption of carbonic acid by the roots may be dispensed with.

185. But the decomposition of the vegetable matter of the soil requires the free access of air to every part of it. If any substance, however rapid its tendency to decay, be completely secluded from the atmosphere, little or no change in it will take place.* Every particle of the soil needs to be surrounded with oxygen, for the production from it of carbonic acid; and to produce this condition is one of the chief objects which is effected by tilling and loosening the soil. In this respect it is manifest that a clayey soil is inferior to all other kinds; and its injurious character can only be remedied by admixture with other substances, or by laborious cultivation. The necessity of unimpeded access of air to the part of the ground through which the roots are distributed, is shown in an interesting manner when trees are planted too deep in the soil,

* It is on this principle that various articles of food are now preserved for subsequent use in tin cases completely closed; and possess their perfect flavour after exposure to all varieties of temperature for several years.

or when their roots have been covered with an additional quantity of earth. If the tree be old or sickly, it generally dies; but if it be vigorous, it sends out a new set of roots nearer the surface, and the extension of the old ones ceases.

186. Notwithstanding, however, the gradual conversion of the carbon contained in vegetable mould into carbonic acid, and the absorption of this by the roots, the quantity of carbon in a soil which supports a flourishing vegetation is progressively increasing rather than diminishing. The addition takes place in several ways. The roots themselves throw out (as already stated § 119,) a considerable amount of matter formed in the vegetable itself, and corresponding in character with its peculiar secretions; and this gradually undergoes decomposition, furnishing a large proportion of carbon. The leaves of plants which fall in the forest in autumn, and the old roots of grass in the meadow, are likewise converted into a rich vegetable mould, capable of yielding a large supply of carbonic acid; and thus it becomes evident that plants must absolutely derive more carbon from the atmosphere than they fix in their own tissues, since they are continually increasing the amount of vegetable mould on the surface of the earth.

187. Thus we perceive that no matter which has been organized can serve as the food of plants until it has undergone decomposition; and that it is solely in the constant and regular supply of carbonic acid it affords, that vegetable mould is more adapted for the support of vegetable life than any other kind of soil. If we could form one of mineral substances only, in every portion of which carbonic acid should be slowly liberated, and which would be equally fit in other respects, it would equally contribute to the growth of the plants it supports. And thus we see a very important difference in the characters of the Animal and Vegetable Kingdom; for, whilst the beings of the first group are entirely dependent for their nourishment upon matter that has been previously organized, and thus derive their support either from animal or vegetable bodies,—those of the latter are dependent for their growth only upon the materials supplied by the inorganic world, although their increase may be advantage-

ously assisted and stimulated by those which they derive from the decay of the former.

188. And here again do we trace a beautiful harmony between the various parts of the grand scheme of Creation; for had vegetables been dependent, like animals, upon organic matter, both classes of beings must have gradually disappeared from the face of the earth, since the spontaneous death and decay of a large proportion of them is constantly restoring to the inorganic world the elements they have for a time held in those peculiar forms of combination which are termed organic; and thus the amount of organic matter would be continually diminishing. But vegetables, holding an intermediate station between the mineral and animal creation, bring them, as it were, into connexion with each other; preparing, from little else than the air and the water of the globe, the materials for the sustenance of the countless millions of beings which move upon its surface, and which, when their allotted period of existence has expired, restore by their decay the elements that are required for the support of vegetable life.

189. No organic substances can be said to serve as food to vegetables in the same manner as to animals; for they all need to be separated into nearly their simplest forms, before they can be reunited into the peculiar compounds which are required by the tissues of the plant for their nourishment and extension. If it were otherwise, we should expect that those would act as most serviceable manures which are most similar in composition to vegetable tissue; just as animal flesh is the most easily digested of all food by the animal. But this is not the case; for the richest manures are well known to be those which (supplying also certain ingredients presently to be mentioned) are continually evolving by their decay a large quantity of carbonic acid. It is in part by hastening the separation of the elements of some substances which might otherwise resist decay for a long time, that lime acts as a valuable manure; and yeast is a still more powerful agent of the same kind, occasioning a kind of fermentation in the vegetable matter of the soil, by which a large quantity of carbonic acid is liberated. On the

other hand, the carbonic acid produced by a manure may be too rapidly set free, and thus the plant becomes, as it were, gorged with food; whilst, at a subsequent time, it is starved by the deficiency occasioned by the too great energy of the change at its commencement. In such cases, the addition of some substance (such as charcoal made from bones) which has the power of retarding decomposition, renders the operation of the manure more equable, and more correspondent with the progress of vegetation. In general, rich manures are most serviceable to plants which, being only annual, naturally grow rapidly; and those which decompose slowly best suit a vegetation which increases with more regularity.

190. These facts have an important influence on the operations of the cultivator, whether they be on the large scale of the farmer, or the small one of the gardener. No manure is more serviceable in yielding carbonic acid, than that which consists of decaying vegetable matter; and this is much more abundant than is commonly imagined. A small garden attached to a dwelling-house may be furnished with an ample supply of rich manure, by throwing into a pit all the refuse vegetable matter of the kitchen, and that supplied by the garden itself, in the form of weeds, dead leaves, prunings of fruit trees &c.; these should be lightly covered with earth, and kept slightly moist, and frequently exposed to the air by being turned over with the spade. And in a farm there will seldom be any deficiency of similar materials, if none are wasted. Weeds, for example, should not be burned, unless they are in seed; for they may be made to afford a valuable supply of nutriment, instead of withdrawing it. A manure of this kind is to many plants more serviceable than that furnished by animals. Some remarkable examples are on record of the influence of it upon the growth of vines, which may be here advantageously introduced, as interesting illustrations of the foregoing principles.

191. "Nothing more," says a vine-grower on the banks of the Rhine, "is necessary for the manure of a vineyard, than the *branches which are cut from the vines themselves.* My vineyard has been manured in this way for eight years, without re-

ceiving any other kind of manure; and yet more beautiful and richly-laden vines could scarcely be pointed out. I formerly followed the method usually practised in this district, and was obliged in consequence to purchase manure to a large amount. This is now entirely saved, and my land is in excellent condition. When I see the fatiguing labour used in the manuring of vineyards—horses and men toiling up the mountains with unnecessary materials, I feel inclined to say to all, Come to my vineyard and see how a bountiful Creator has provided that vines should manure themselves, like the trees in a forest, and even better than they! The foliage falls from trees in a forest, only when the leaves are withered, and they lie for years before they decay; but the branches are pruned from the vine about the end of July or the beginning of August, while still fresh and moist. If they are then cut into small pieces and mixed with the earth, they undergo putrefaction so completely, that, as I have learned from experience, at the end of four weeks not the smallest trace of them can be found."

192. The following account from a poorer vine-grower, which is to a similar purpose, is instructive as showing of how much value a little intelligent observation may become. "For the last ten years I have been unable to place dung on my vineyard, because I am poor, and can buy none. But I was very unwilling to allow my vines to decay, as they are my only source of support in my old age; and I often walked very anxiously amongst them, without knowing what I should do. At last my necessities became greater, which made me more attentive; so I remarked that the grass was longer on some spots where the branches of the vine fell than on those on which there were none. So I thought upon the matter, and then said to myself: If these branches can make the grass large, strong, and green, they must also be able to make my plants grow better and become strong and green. I dug, therefore, my vineyard as deep as if I would put dung into it, and cut the branches into pieces, placing them in the holes, and covering them with earth. In a year I had the great satisfaction to see my barren

vineyard become quite beautiful. This plan I continued every year, and now my vines grow splendidly, and remain the whole summer green, even in the greatest heat. All my neighbours wonder very much how my vineyard is so rich, and that I obtain so many grapes from it, and yet they all know that I have put no dung upon it for ten years."

193. Although, therefore, it is probable that all plants and trees in full leaf could grow without any other source of carbonic acid than the atmosphere, an additional supply encourages that productiveness which it is the aim of the cultivator to obtain; and it is in the choice of his materials and the mode of their application that his skill and judgment are shown. The science of Vegetable Physiology has been but too little connected with the arts of the farmer and gardener; and they have consequently been working in the dark, frequently coming, after tedious and unsuccessful trials, to conclusions which might have been drawn immediately from scientific principles. The certainty with which the mode of operation of manures upon vegetation has been now ascertained, should lead to most important improvements in practice, by which the productiveness of land may be much increased.

194. Although carbonic acid and water are the chief sources of nourishment to plants, there is one element of great importance to their active growth,—namely nitrogen,—which is not contained in either of these compounds. It might be thought that, as so large a quantity of it exists in the atmosphere, no difficulty could exist in the introduction of as great an amount of it as might be desirable into the vegetable system. But it would seem that none of the elements of which that system is composed can be introduced into it in a *simple* form. Thus we have seen that the carbon is derived from carbonic acid, and the oxygen and hydrogen from water; and it is found that plants rather increase than diminish the quantity of nitrogen in the atmosphere. Nitrogen is introduced in the form of *ammonia*, the pungent gas which gives strength to hartshorn, smelling salts, &c. and which is liberated by the decomposition of almost all animal substances, in which nitrogen very largely exists. A great quantity of this gas

is thus being constantly set free and diffused through the atmosphere; but still it forms so small a proportion of the whole, that it cannot be shown to exist in the air otherwise than in an indirect manner. Ammonia is very readily absorbed by water; and thus the rain and dew, in descending through the atmosphere, become impregnated with it, although in very small amount. This ingredient can be proved to exist in rain-water; and thus its presence in the atmosphere becomes certain.

195. The quantity of ammonia which is thus supplied to plants appears sufficient for their ordinary growth. If, however, plants be set in powdered charcoal, sheltered from rain or dew, and watered with distilled water (which contains no ammonia) they do not flourish as they have been stated otherwise to do, but soon become stunted in their growth. This fact proves the great importance of the small amount of nitrogen thus introduced. There are many plants, however, to which a much greater supply of ammonia is necessary, on account of the large proportion of nitrogen which enters into some portions of their structure; and such can only be cultivated to advantage when surrounded by additional sources of this material, such as are afforded by decaying *animal* matter of various kinds. For example, corn-grains include a large quantity of starch (which contains but little nitrogen) with a certain amount of gluten, of which nitrogen forms a large proportion; the latter is the most nutritious ingredient of the two, and it should be the object of the farmer to make the proportion of it as great as possible. This may be effectually accomplished by such animal manures as yield a large supply of ammonia. Thus, whilst corn grown in common vegetable mould contains about 66 parts of starch in every hundred, and only $9\frac{1}{2}$ of gluten, that which had been manured with blood or urine was found to contain 45 parts of starch, and 35 of gluten. It is by the use of a rich animal manure termed *guano*, that the barren soil on the coast of Peru is rendered fertile; this guano is collected from several islands in the South Sea, on the surface of which it forms a layer of several feet in thickness; and it consists of the excrements of innumerable sea-fowl which resort

there during the breeding season. It is sufficient to add a small quantity of guano to a soil which consists only of sand and clay, and previously contained not a particle of organic matter, in order to produce the richest crop of maize.

196. Many kinds of soil have the power of absorbing ammonia like carbonic acid, from the atmosphere; and thus add to the supplies which the plant obtains by its roots, so as to diminish the necessity for animal manure. Of this kind is gypsum, the utility of which has long been known, although the cause of its beneficial influence was not suspected. Gypsum powerfully attracts ammonia from the atmosphere, and yields it again to water which may soak through it; so that as much ammonia as would supply the proportion of nitrogen to 100 lbs. of grass is yielded by little more than 4 lbs. of gypsum. The advantage of manuring fields with burned clay, and the fertility of soils containing iron, are to be referred to the same cause. Burned clay has, like gypsum, the power of fixing ammonia from the atmosphere, and of easily yielding it to water; and minerals containing oxide of iron do the same, when separated into fine particles. Powdered charcoal possesses a similar action, and, indeed, surpasses all other substances in its power of condensing ammonia within its pores, absorbing 90 times its volume of this gas. Decayed wood approaches very nearly to charcoal in this power; and vegetable mould, which principally consists of wood in a more advanced state of decay, retains it in a very important degree, so that we perceive its influence on vegetation to be by no means confined to the supply of water and carbonic acid.

197. On this account, vegetable mould is alone amply sufficient for the cultivation of all vegetables which contain but an average proportion of nitrogen; but corn can only be grown to the greatest advantage, when the land is amply manured with those substances which contain the largest proportion of ammonia. This is yielded in the greatest abundance by the excrements, both fluid and solid, of animals, and particularly of man; and in China, where, from the immense population, it is necessary to make the most of every foot of ground, the greatest care is taken

to preserve these, and extraordinary fertility is the result. A similar practice prevails on some parts of the continent of Europe; and it is less successful, only because the mode of collecting the materials allows of the escape of a large proportion of the ammonia before the manure is used.

198. By a judicious system of management, large towns may thus be rendered most important means of increasing the fertility of a country, and therefore of contributing to the supply of wholesome food; instead of bringing together, as at present, so many causes of misery and unhealthfulness.

199. The sources of what may be regarded as the essential ingredients of the food of plants having now been fully considered, (the more fully on account of the practical importance of the subject,) we shall inquire into the influence of certain other materials which particular kinds require for their healthful growth, an increased supply of which tends greatly to their productiveness, and the influence of which ought, therefore, to be fully considered in the tempering of soils or the application of manures. These materials consist of solid particles of various kinds, which are contained in the earthy portion of the soil, and which, being dissolved in the water, are taken up by the roots. Of these, some are imbibed by almost all plants alike; whilst others are retained only by particular kinds, so that they are either not taken up at all by plants of other kinds, or are secreted again into the soil, not being deposited in their tissues.

200. There is considerable variety in this respect among the different tribes of plants; each seeming to grow most advantageously when supplied with a certain kind of mineral matter, but being capable of taking up other forms in place of it, if it should be deficient. Thus the Rhododendron, like most other plants, deposites in its leaves and stem a large quantity of calcareous matter (lime combined with an acid, usually carbonic) when freely supplied with it. When grown in a calcareous soil, the ashes of its leaves have been found to contain $43\frac{1}{4}$ parts in 100 of carbonate of lime, and only $\frac{3}{4}$ of silex or flinty matter; the ashes of the stem of the same plant contained 39 of calcareous earth, and $\frac{1}{2}$ of silex,

But when grown in a soil in which silex predominated, the leaves of a similar plant contained $16\frac{3}{4}$ per cent of earthy matter, and 2 parts of silex; whilst the stem contained 29 parts of calcareous earth, and 19 of silex.

201. It is curious to observe that, whilst calcareous matter seems principally deposited in the softer tissues, silex is found much more abundantly in the stem. This is especially the case in the Grasses, nearly all of which require for their healthy growth a large proportion of silex; and this substance it is, which, being deposited in the slender tissue of the hollow stem, imparts to it a strength that seems disproportionate to the quantity of matter it contains. The silex may be melted by means of the blowpipe, into a bead of nearly the same appearance as glass; and the following curious instance shows the same effect upon a large scale. A melted mass of glassy substance was found on a meadow between Mannheim and Heidelberg in Germany, after a thunder-storm. It was at first supposed to be a meteor; but when chemically examined, it proved to consist of silex combined with potash, in the form in which it exists in grasses; and, upon farther inquiry it was ascertained that a stack of hay had stood upon the spot, of which nothing remained but the ashes, the whole having been ignited by the lightning.

202. Now the various substances which are thus required by plants for their healthy growth, are generally contained in the soil in sufficient amount to supply the majority of plants with the necessary material; and some, when exhausted from the soil, may be supplied again from the water of the district, in which they are dissolved. It is partly by thus renewing what has been withdrawn, that the irrigation or flooding of meadows with water is very serviceable. Even where this water is of ordinary purity, containing scarcely any organic matter, and but very little mineral ingredients, the irrigation of meadows is very serviceable in improving their productiveness. From three to five perfect crops of grass have thus been obtained every year, by covering the fields with river-water, which is conducted over it in spring by numerous small canals; so that the quantity produced in all was

more than four times that which would have been obtained from one not so watered. In the neighbourhood of Edinburgh, the stream which conveys the fluids collected from the sewers of the town into the sea, has been diverted so as to cover much of the low meadow land which surrounds the town on three sides; and the large quantity of organic as well as mineral matter which the fluid contains, is so beneficial to the growth of grass, that the previous produce has been eight or ten times multiplied. This proceeding is very injurious, however, to the health of the town; since the offensiveness of the putrefying matter is very much increased by being diffused through a large quantity of water.

203. The soil may be artificially supplied with the mineral substances required by different kinds of plants, as well as with those which yield carbonic acid or ammonia; and the cultivator is frequently obliged to do this (though in general without understanding the true benefit of the operation) especially when he has forced the growth in other ways. Thus if a meadow be manured only with gypsum (the use of which has been already mentioned,) the crops of grass will be at first greatly increased, but will afterwards diminish; for the potash which the soil contained is soon exhausted by the rapid growth of the grass, and its farther increase is checked. But if the meadow be strewed from time to time with wood-ashes, which contain potash, the grass will thrive as luxuriantly as before. A harvest of grain may be obtained at long intervals on a sandy heath, by strewing it with the ashes of the heath-plants which grow on it, and which gradually collect the alkalies that are conveyed to them by water.

204. It seems a remarkable fact that those plants of the grass tribe, the seeds of which furnish food for man, follow him like the domestic animals. The reason is that none of the corn plants can bear seeds that will yield a large quantity of flour, without a good supply of phosphate of magnesia and ammonia. Hence these plants grow only in a soil which contains these ingredients in addition to the silex and potash already mentioned; and no soil is richer in them, than those where men and animals dwell together since these substances are largely contained in the animal body,

and are set free in their excretions during life and by their general decay after death. Again, this fact explains why bone-earth is a most valuable manure to corn-fields; since it consists almost entirely of these ingredients. The knowledge of it will also guide us in selecting the *kind* of wood of which the ashes will be most valuable; for whilst those of the oak contain but a minute proportion of the phosphate, and those of the pine a quantity not exceeding the sixth part of their weight, those of the beech yield the fifth part; and thus with every 100 lbs. of the ashes of the beech, we supply a field with enough of these ingredients to serve for the growth of more than 15,000 lbs. of corn.

205. It should be the object of the agriculturist, therefore, to ascertain the chemical character of the earthy portion of the soil which he cultivates, and to manure it with such substances as he finds will supply the deficiency for the particular plants which he wishes to grow. There are some soils which contain all the ingredients required for almost any kind of vegetation; and, when these cease to be productive, all that is necessary is to allow them to be fallow during a season or two. The atmosphere then acts upon the mineral particles, and causes that more complete separation amongst them, which is necessary to prepare them for being dissolved in water and taken up by the roots of the plant. In this manner some soils prove extremely fertile, which scarcely contain a particle of vegetable mould, and have received very little animal manure. Thus the land in the neighbourhood of Mount Vesuvius contains clayey earths, with chalk and sand, mixed in such a proportion as to give free access to air and moisture. This soil is produced by the slow decomposition and separation, through the action of the air, of the masses of lava which have at different times issued from the volcano, and which contain a great admixture of mineral matters, without a particle of vegetable mould. Now corn has been grown on this land for thousands of years with scarcely any manure;—the method adopted being simply this. A field is sown once every three years only; and is in the intervals allowed to serve as a sparing pasture for cattle, which feed on the weeds that spontaneously spring up. But the influence of the weather

sets free an additional quantity of the mineral ingredients which the corn requires; the amount of nutriment contained in the seed is sufficient for the development of the young plants; and the soil is of a kind extremely favourable to their subsequent growth.

206. On the other hand, the very fertile land which was found by the first settlers in Virginia has been exhausted by a contrary proceeding. Harvests of wheat and tobacco were obtained for a century from one and the same field without the aid of manure; but now whole districts are converted into unfruitful pasture-land, which, without manure, produces neither wheat nor tobacco. From every acre of this land there must have been removed in the space of one hundred years at least 1200 lbs. of alkalies in leaves, grain, and straw; it became unfruitful, therefore, because it was deprived of every particle of alkali that had been reduced to a state capable of being dissolved; and it would require to lie entirely fallow for a great length of time to regain its fertility. Almost all the cultivated ground in Europe is somewhat in the same condition. That of many of the West India islands has been also exhausted by the avarice of its former possessors, who have left it in a state which renders the cultivation of sugar much less profitable than formerly, since the Canes cannot be grown without a large quantity of manure. If the ashes of the Canes, which, after the juice has been pressed from them, are burned to heat the pans for boiling down the fluid, were to be spread over the fields, the productiveness of the land would probably be much increased.

207. It is not always necessary, however, that a field should lie fallow, in order to render it capable of producing some particular kind of crop, the materials of which had been exhausted; for, if it be sown with some vegetable of an entirely different kind, a profitable crop of this may be raised, whilst the land is renewing itself for the other. The power of doing this depends upon the nature of the ingredient which is deficient. It has been formerly shown that it is not the vegetable portion of the soil which is exhausted by the continued growth of any race of plants in the same spot, this being rather increased than diminished; and therefore any plants which require no other nutriment than this may be made to

grow in a soil which wheat, or some other plant that takes up a large portion of some particular kind of mineral matter, had completely exhausted. Such is the case, for example, with many of the *Leguminous* plants (the tribe including the Pea, Bean, and other similar vegetables,) which absorb so little mineral matter that they may be grown between two crops of corn, with nearly the same advantage for the latter, as if the land had lain fallow between. Hence these are called fallow crops. On the other hand, the injurious properties of many weeds that are apt to show themselves in corn-fields, result from their imbibing a large quantity of the same ingredients as those which the corn requires, so that, in proportion to the vigour of their growth, that of the corn must decrease. Hence it not only conduces to the neatness in the appearance of a corn-field, but also to its productiveness, to keep it free from weeds.

208. Now the principle that a succession of *different* crops may be grown, where *one* could not be repeated without occasional intervals, has gradually superseded the old system of allowing the land to lie for a season, out of every three or four, entirely unproductive; so that the quantity of vegetable substances, nutritious either to man or beast, which is now raised from a given quantity of land is much greater than formerly. This principle has been fully established by experience; but it is still acted on to a very limited degree, because its conditions are not yet fully understood. If there were nothing else to be considered than the kind of mineral substance which each plant draws from the soil, it would not be difficult to say what crops might succeed each other most advantageously, since it would only be necessary to find out the mineral ingredients which each requires, to make those succeed each other which draw least of the same. But there is another very important condition to be attended to.

209. Plants, as already stated (§ 119,) not only draw various substances from the soil, but impart to it a portion of the juices they have formed within themselves. A well-marked instance of this is the oak, which so completely impregnates the soil around its roots with *tannin* (the substance which gives to oak-bark its

peculiar power of converting animal skin into leather) that few trees will grow in the spot from which it has been rooted up; since this agent, even when a very minute quantity of it is dissolved in water, produces an effect like *tanning* upon the delicate tissue of the spongioles, and destroys their peculiar properties. It is probable that every species of forest-tree produces a similar effect; since it is well known that, when a wood composed of one kind has been cleared by the hatchet or by fire, the new growth which soon springs up, is not of the same but of a different species. Again, some of the plants which are known as the rankest weeds, secrete from their roots substances equally injurious to plants around them; thus the Poppy tribe impregnates the soil around with a substance analogous to Opium, which is easily shown by experiments to have as injurious effect upon plants as an over-dose of this powerful medicine has upon animals; and the Spurge tribe exudes an acrid resinous matter.

210. The excretions of all plants seem injurious to themselves as well as to others of the same species grown in the same spot; and in many instances, as in those just quoted, they are injurious to plants of other tribes also. But there are many instances in which they are absolutely beneficial to plants of distinct tribes. Thus most of the Leguminous tribe exude from their roots a matter analogous to gum, as may be easily shown by growing a pea or bean in water, which soon becomes turbid; and this product is beneficial to plants of almost every other tribe. Hence, therefore, the benefit which the farmer derives from taking off a crop of beans between two crops of corn is not restricted to the value of the former; since the succeeding crop of corn is absolutely improved by this proceeding. And, on the other hand, the exhaustion of the soil by rank-growing weeds is not their only evil; since they impart to it some of their own injurious properties.

211. Now, by following out this system, and ascertaining what plants form the most abundant, and at the same time the most nutritious excretions, and what are the others which are most benefited by these,—keeping in view, also, the nature of the mineral ingredients they may respectively require, the agriculturist

may hereafter be able to dispense almost entirely with artificial manure, as he has already done with the fallowing system;—for he will only have to adapt his rotation to the particular soil, and then the excretions of one plant will serve as a manure to the other. Among the most useful for this purpose may be mentioned Lucern, which is remarkable for the extensive ramification of its roots, and the strong development of its leaves, and which requires but a small proportion of inorganic matter. This plant produces an abundant secretion from its roots, which, in the course of several years adds considerably to the quantity of vegetable matter in the soil, whilst its leaves serve as nutritious food for cattle.

212. The subject of the foregoing Chapter has been treated in more detail than may seem consistent with the plan of this work; because it is, of all departments of Vegetable Physiology, the one of most importance to the well-being of man. It can scarcely be doubted that, by improvements in the art of agriculture, the quantity of food for man and beast produced in this country, and the amount of those valuable articles which are cultivated in the various colonies of Great Britain, may be greatly increased. But these improvements cannot be carried into advantageous operation, until correct ideas on the subject have been generally diffused among those who are concerned in the work; for, unless the *principles* on which they are founded are properly understood, it is more than probable that loss instead of gain will result from the attempt to introduce them.

213. These principles may be thus recapitulated.

I. The soil should be of such a character as to afford a steady supply of *moisture* to the roots, and to allow the air to penetrate it freely; if it does not possess these requisites, it should be improved by tempering (§ 176—8.)

II. In order to produce that luxuriant growth of plants which the agriculturist desires, the soil should afford a supply of *carbonic acid* to the roots, either by the decomposition of vegetable mould, or by absorbing the gas from the atmosphere. Its fertility may be increased by the addition of vegetable substances disposed to decay; or by mixing it with charcoal, gypsum, or some other substance which possesses in a high degree the property of absorbing carbonic acid from the atmosphere (§ 179—193.)

III. In order to effect the same object, the soil should be capable of affording a supply of *ammonia* to the roots, either by the decomposition of animal matter contained in it, or by attracting that gas from the atmosphere. The proper supply of this important article of food may be secured, either by the employment of some animal manure which liberates it freely; or by the admixture of some substance (such as gypsum or charcoal) which absorbs it rapidly from the atmosphere. The first method is most desirable when the vegetable substances which it is required to obtain in the greatest quantity, contain much ammonia, as do the seeds of corn (§ 194—8.)

IV. In order to promote the luxuriant growth of any tribe of plants, the soil should be supplied with those mineral ingredients which its tissues naturally contain. If these are originally deficient, they must be added; if they are contained in the soil, but have been for a time exhausted, the land should be allowed to lie fallow, until the action of the weather has farther separated the mineral particles (§ 199—206.)

V. The soil may be improved nearly as much by a crop of a different kind, as by lying fallow; provided *that* crop do not exhaust it of the same mineral ingredient with the one it replaces, and furnish excretions which are beneficial to it (§ 207—211.)

CHAPTER VII.

ON THE STRUCTURE OF LEAVES.

214. The fluid which is so abundantly taken up by the roots of plants, and which is conveyed upwards along the interior of the stem, is very unfit for the nourishment of the structure, and for the supply of the growing parts, until it has been exposed to the influence of the air, by which great changes are effected in its properties. Now this object has to be attained in animals as well as in plants; and we observe two modes of effecting it. In some animals the blood is sent into very delicate external prolongations of the skin, termed *gills;* through the thin membrane of which it may receive the required influence. And, although we usually see an apparatus of this kind existing only in animals which inhabit the water (the air diffused through which is really that which acts on the blood,) yet it is seen in some air-breathing animals also. The usual mode, however, in which the blood is exposed to the influence of the atmosphere in animals living on land, is by the introduction of air into cavities termed *lungs* within the body, constituting the process known as *respiration* or *breathing;* but this requires a series of movements for the constant exchange of the air so introduced, in order that the portions rendered unfit for farther use by the changes that take place in it may be expelled, and a fresh supply admitted. A little consideration will show that to have introduced water in a similar manner, into the interior of the bodies of those animals which inhabit it, would require an immense amount of force, since water is so much less easily moved than air; whilst, on the other hand, to have furnished air-breathing animals with external gills or other similar appendages, would have exposed them to great risk of injury

would have impeded their rapid movements, and would have been attended with many inconveniences.

215. Now in Vegetables, the same object is to be attained, but under different conditions. The nutritious fluid of the plant, like the blood of animals, needs to be exposed to the influence of the air to preserve its power of maintaining life; and this cannot be effected either by the underground roots, nor by the hard woody stems and branches, which expose so small an amount of surface to the atmosphere. Nor can this be effected by the introduction of air into internal cavities in these parts; since this would require a continued series of movements, as in air-breathing animals, which the plant has no means of performing. Again, as the plant is rooted in the earth, and is not adapted to move through the atmosphere, there is no reason why its surface should not be spread out to any extent, for the purpose of exposing the sap to the influence of the air, just as the blood is exposed in the gills of fishes and other aquatic animals to the small quantity of it contained in the water they inhabit. Farther, a very essential condition of the changes which the sap undergoes by coming into contact with air, is the influence of *light*, without which they would be very imperfectly performed.

216. This general view of what is required from the *leaves* will suffice to show how beautifully their structure and situation are adapted to the offices they have to perform. The leaf may be said to consist essentially of an extension of the skin or cuticle of the plant into a flat expanded surface, which is supported by a skeleton prolonged from the wood of the stem or branch. If any leaf be but cursorily examined, it will be seen that from each surface a sort of skin may be torn, which may sometimes be stripped off very cleanly from the tissue beneath;—that the space between these surfaces is occupied by soft green tissue, which the naked eye can often perceive to consist of separate particles loosely united, and which is seen with the magnifying-glass to be composed of distinct cells, usually more closely-packed together near the upper surface than near the lower, where there are many cavities or interspaces among them.

217. The cuticle of the leaves is furnished more abundantly than those of any other parts, with *stomata* (§ 91,) by which watery vapour and gases can pass out, and air can enter; but these are chiefly, and often entirely, confined to the lower surface. The woody skeleton of the leaf forms what is commonly known as the *midrib* and the *veins* proceeding from it. These *veins* or *nerves* (as they are commonly termed) must not be confounded with similar parts in animals, since they do not in the least resemble them. They are principally composed of woody fibre and of spiral vessels and ducts; and they proceed from the neighbouring stem or branch, constituting the greater part of the *footstalk* or *petiole* of the leaf from which they afterwards spread out.

218. This general account of the structure of the leaves of Flowering-plants will suffice to enable us to compare them with the corresponding parts in Cryptogamia. It also enables us to see how beautifully they are adapted,—by the immense amount of surface they present,—by its thinness and delicacy,—by its numerous apertures,—and by its expansion to the light of day, for the purpose they have to perform; the exposure of the crude sap to the air and sun, under the influence of which it is elaborated or digested, so as to become a highly-nutritious fluid.

219. There are few Flowering-plants in which the stem and branches are not, at some part of the year, clothed with these beautiful appendages; and the exceptions are chiefly in those forms—unknown as natives of temperate climates, but common in tropical regions,—in which the stem itself is so altered in structure as to be able to perform the functions of leaves. Most of these are included under the designation of the *Cactus* or *Prickly-Pear* tribe. Their stems, instead of being firm and woody, are comparatively soft and fleshy; their substance is moist, and composed almost entirely of cellular tissue; their surfaces are green, and covered with a distinct cuticle which is furnished with stomata; and their form is often flattened, so as to expose, like leaves, a large surface to the air. It is interesting to observe how completely the deficiency of one organ is here supplied by a modification of another. In almost all the plants of this tribe, there are tufts of prickles

arising from regular points on the surface of the stem; and to these the common designation of the tribe is owing. It will be hereafter shown that these prickles are the *rudiments* of leaves; and that under circumstances different from those in which the plant grows, minute leaves will arise from these very points.

Fig. 36. *a*, leaf-like branches of Butchers' Broom, bearing flowers in their centre; *b*, Xylophylla.

220. A conformation somewhat similar may be observed in some plants of our own country; thus in the common *Butchers' Broom* (*Ruscus aculeatus*,) the branches are flattened into a leaf-like form, and the flowers arise from the middle of their surface. In another foreign genus they are placed around the edges of similar organs.

221. There are, however, some flowering-plants of temperate climates which are destitute not only of leaves but of leaf-like surfaces. These grow by imbibing the juices of other more perfect plants; just as parasitic animals obtain their food by sucking the blood of others. And as the juices which afford them support have already been elaborated or digested by the plant from which they draw them, they have no need of leaves or any similar apparatus for the purpose. Of this kind are the *Orobanche*, or *broom-rape* and the *Cuscuta* or *dodder*. Their branching roots are furnished with suckers by which they affix themselves on the bark of the plants round which they cling, and through which they imbibe their juices.

222. Although there are few instances, then, in which leaves are absent in Flowering-plants, they are comparatively seldom found in Cryptogamia. In Ferns we always meet with them; and their general structure is much the same as that which will be described as characteristic of leaves in general. But, in addition to their other functions, the leaves of Ferns very commonly bear

the fructification upon their under surface ; and hence the name *frond* has been given to them, for the purpose of distinguishing them from the leaves of the Phanerogamia, in which they never bear a part in the production of seed. In some of the Ferns, as the *Osmundia regalis*, or Flowering-Fern (as it has been incorrectly called,) a handsome and well-known species common in England, the fructification is only borne on the edges of particular leaves, which are much less expanded than the rest; these are, therefore, called *fertile fronds;* whilst the other leaves, which here altogether resemble those of Flowering-plants in function, are called *sterile fronds.* In Mosses, we observe a large number of minute and delicate leaflets, having no concern in the fructification, which is entirely distinct; but they have not those peculiarities of structure which distinguish the leaves of higher plants being destitute of a woody skeleton and of stomata; and they seem to have a greater mixture of function, since they not unfrequently send out root-fibres from their under surfaces for the purpose of absorption.

223. We observe in the lower and simpler tribes, as has been heretofore shown, a much greater blending of different functions than in the higher, which possess a special organ for each, and in which they are consequently performed in a more energetic manner. Thus, when we descend below the mosses, we find no distinct leaves;—they become, as it were, blended with the general surface; and all their functions are performed (as in the *Cactus* tribe) by this. Such, it will be remembered, is the case in the Liverworts (§ 32.;) and also in the Lichens and Algæ, in all of which, however, we notice a flat expanded surface, by which the functions of leaves may be in some degree performed. This expanded surface is often of great extent in the Algæ, and possesses a very leaf-like aspect; but, as already stated, it does not perform the functions of leaves alone, but is every where equally adapted for absorbing the fluid that constitutes its nourishment, and in many instances contains the fructification also imbedded in its substance. (§ 41.)

224. The case is different, however, in regard to the *Fungi.*

These plants derive their nourishment from matter which has already been in a state of organization; and the condition in which they receive it is such, that it does not require to be elaborated by exposure to the atmosphere, as it does in all other but the parasitic plants already mentioned, which much resemble the Fungi in habit. Accordingly, the Fungi, the whole energy of whose vegetation seems to be concentrated upon the propagation of the race, do not possess any thing analogous to leaves, and seldom exhibit even such an expanded surface as may be considered to replace them. It is very rare, too, that this surface is *green;* and, as will be hereafter shown, this green colour in leaves is due to certain changes, which, from the condition of the growth just mentioned, the Fungi do not need to perform.

225. We now return to the leaves of Flowering plants; and shall trace in more detail their regular structure, the chief varieties of this, and the functions which they are destined to perform. And in the first place we shall consider their external aspect.

226. The leaf is usually borne upon a *petiole* or foot-stalk; which connects it with the stem; and it is at the bottom of the petiole that the separation from the stem takes place when the leaf falls off. By this it may be known what is really a single leaf, and what is a collection of separate leaves. Not unfrequently a leaf is very compound in its structure, consisting of a number of distinct leaflets, which might be regarded as so many leaves. But if these leaflets all proceed from one foot-stalk, and this drops off altogether at the accustomed period, they are to be considered as only the subordinate parts of a single leaf. Many such instances might be enumerated; but it will suffice at present to refer to the Ferns (§ 23,) in which what appears to be the stem is really but a leaf-stalk; and what seem to be leaves are only leaflets proceeding from it, and forming part of one large leaf.

227. There is not always such a definite distinction between the flat expanded blade and the round and slender petiole, as, from what we observe in common plants, we might suppose to be the case. The petiole is sometimes expanded into a leafy surface, and may even perform all the functions of the true leaves, when

the latter are deficient. Thus, in a British aquatic plant, known by the name of *Arrow-head* (technically Saggitaria sagittifolia) which is common in running streams, we observe what appear to be two kinds of leaves; some elevated above the surface, and formed like the head of an arrow, (whence the name of the plant;) and others flattened, of equal breadth throughout, (technically termed ligulate or strap-shaped,) and not appearing above the water. These last are in reality the flattened petioles, which perform the functions of leaves as long as they remain under water; but as soon as any of them have strength to elevate their summits above its surface, true leaves are developed from them, and the petiole then contracts into a rounded form.

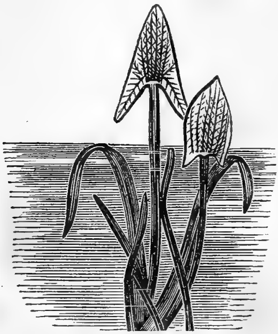


Fig. 37. Sagittaria Sagittifolia, or Arrow-head; showing expanded petioles beneath the water, and true leaves above.

228. A corresponding structure is exhibited by some of the Acacias of New Holland, which are sometimes so completely destitute of true leaves as to be termed "leafless." When this is the case, the petioles are flattened and expanded, and present a leaf-like surface, which is adapted to perform the functions of the true leaves, from which they differ, however, in having the two surfaces alike, and in growing in nearly an upright position, instead of horizontally. The true leaves, (which, like those of other Acacias, are very compound in their character, see Fig. 39,) are only to be found in young plants, or in old ones which have been freely pruned; and it is not uncommon to find many degrees of development, intermediate between those which exhibit the fully expanded leaf with its narrow and cylindrical petiole, and those which have no vestige of the blade, and present nothing but the leafy foot-stalk. In all these, the amount of expansion of the petiole bears a precisely inverse proportion to that of the leaf; the former replacing the latter when it is unfit to perform its functions.

229. The *blade* of the leaf is composed of the expanded veins or nerves proceeding from the petiole, the interstices between which are filled up with cellular tissue, and the whole covered with cuticle. The mode in which these veins are distributed is very characteristic of the principal divisions of the vegetable kingdom. Thus, in the CRYPTOGAMIA, wherever true woody veins exist in the leaves (which is scarcely the case in any but the Ferns,) they are seen to divide and subdivide,—each usually bifurcating, or splitting into two branches like the prongs of a fork, at intervals;—but these subdivisions do not unite again. Hence, as regards their leaves, the Cryptogamia may be characterized as *forked-veined.*

230. In the group of Endogens it may be observed that the veins run in a nearly straight direction, and almost parallel to each other; and that they have but little connexion by the interlacement of their minor subdivisions. The arrangement of these veins, however, differs according to the general form of the leaf. Thus, in the long narrow leaves of the grasses, and of other Endogens, such as the Lily, Iris, &c., the foot-stalk is not continued along the leaf as a great central vein or *midrib*, but divides at once into several veins which run along side by side from one end of the leaf to the other; and as there is very little connexion between these different veins, the leaf may be readily and very straightly torn from one end to the other. In other cases, however, the leaf is broader, and the parallel veins are sent off from a large central midrib, running in the direction of the breadth of the leaf. As these, too, are but little connected with each other, it is easy to tear one of these expanded leaves into a number of narrow ribands, which will then hang from the midrib; and something resembling a compound leaf will thus be produced. As each of these ribands will have its own vein uniting it with the midrib, and is in its natural state scarcely connected with the surrounding parts except by the cuticle which envelopes the whole, the leaf will perform its functions nearly as well when thus subdivided as when entire.

231. It is curious that such a separation should sometimes take

place under the influence of natural causes. The Banana and Plantain of tropical climates have leaves of this kind; and when they grow in situations in which they are much exposed to the wind, its action splits them up in this manner, from which they do not appear to suffer. These plants are sometimes grown in hot-houses in England; and then, being completely sheltered, the expansion of their leaves is preserved entire, which seldom happens in their native habitation. In whichever direction the veins are arranged, the general character of the leaf is the same; and hence the leaves of Endogens are spoken of as *parallel-veined*, by which character they are distinguished from those of the Cryptogamia on one hand, and, as will presently appear, from those of Exogens on the other.

232. The form and mode of subdivision of the system of veins in *Exogens* are extremely irregular; but there is a character common to all, by which the leaves of this group may be distinguished without much difficulty from those of the others. There is usually a midrib, or prolongation of the foot-stalk along the centre of the leaf, from which the smaller veins arise; but sometimes the petiole subdivides at once into several subordinate veins, which run from one extremity of the leaf to the other, nearly parallel with the other, as in Endogens. But the secondary veins of Exogens, however they may be disposed, always give off a vast number of minute branches, which ramify and unite with each other, so as to form a complete net-work; and thus it is, that the leaf of an Exogen can seldom be torn with any regular edge. From this character the Exogens may be described by their leaves as *reticulated-veined;*—the veins forming a *reticulum* or minute net-work.

233. It is in these that we can make the most beautiful skeletons, by removing the soft fleshy portion of the leaves, and preserving only the woody structure. Such skeletons may often be found in the autumn, when the fallen leaves have been exposed to the influence of moisture for some time; and with slight care they may be made to exhibit a very beautiful appearance. They may easily be prepared by soaking in water a leaf possessed of

firm texture, until its softer portion be in a state of decay; if then the latter be washed away by carefully directing a small stream of water against it, the skeleton will be left. Not only do leaves contain such a skeleton; but the leafy parts of flowers, and even the *skins* of such soft fruits as the cherry.

234. Now, with the same distribution of the veins of the leaf, many curious varieties of structure may be produced by a difference in the degree in which the space between them is filled up. One of the simplest of these is where holes are left in the blade of the leaf, in consequence of a deficiency of the fleshy portion. Some plants are particularly liable to this irregularity; which does not exist, however, where they are well supplied with nourishment. A similar, but much more curious variety exists in an aquatic plant of Madagascar, in which the fleshy cellular tissue or *parenchyma* is so little developed between the veins, that the living leaf much resembles in its form one of the skeletons just described.

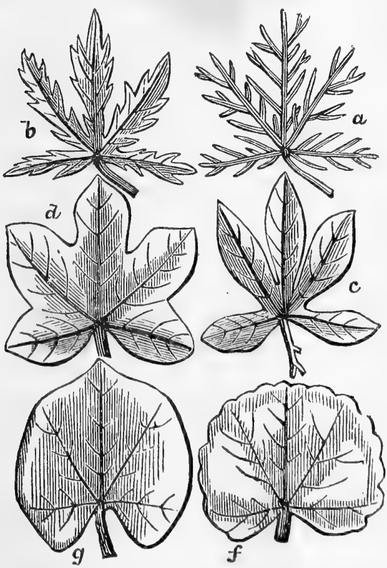


Fig. 38. Different forms of leaves having the same venation; *a*, Water Crowfoot; *b*, Jatropha; *c*, Passion flower; *d*, Sterculia platanifolia; *f*, Dichondra; *g*, Asarabacca.

235. It is by no means uncommon to see the edges of leaves more or less deeply indented, according to the amount of nutriment which the plant is receiving; the distribution of the veins and the general outline of the leaf remaining the same throughout. Thus the *Cocklearia*, or Horse-radish, has the edges of its leaves nearly smooth, when growing in a sufficiently rich soil; but if starved, the blade will

be divided into separate strips like the teeth of a comb, from the deficiency of flesh to fill up the spaces between the veins. In the accompanying figure are represented the outlines of different leaves having the same general distribution of the veins, but a different proportion of the fleshy substances between them.

236. In some plants in which the framework of the leaves is very strong, the ends of this project from the edges of the leaf, when the latter is stunted in its development, forming sharp prickles. This is the case in the Holly; the prickles on the leaves of which will be at once seen, if examined, to be simply the dried and projecting terminations of the veins. On looking at any full-grown Holly, considerable variety will be noticed in the degree in which the leaves have this prickly character; and in general it is seen that the lower ones are the most stunted and rough, whilst the upper ones have the parenchyma of the leaf so much developed as to include these extremities, and thus to render the edges of the leaf quite smooth. Sometimes it has been observed that a Holly, growing in a very luxuriant soil, has had all its leaves in this manner metamorphosed, so as entirely to lose the peculiar aspect of the tree. This is one of the modes in which the repulsive character of some plants is softened down by cultivation. In the *Cactus* tribe, it would seem as if all the nourishment which would naturally form leaves is bestowed upon the stems themselves; and thus the tufts of prickles already noticed are the only indications of their place. These prickles are the woody veins; which are sometimes seen, in specimens grown in hot-houses in this country, to be converted into true though very minute leaves; in consequence, probably, of the greater supply of nourishment they receive under such circumstances, than in the dry and sterile situations they frequent in their native climes.

237. The division of leaves into leaflets may be regarded as taking place upon the same general principle. When a single series of leaflets arises from the midrib, the leaf is said to be *pinnate*, or winged. But sometimes, instead of leaflets arising from the midrib, we find secondary veins, from which, as from smaller midribs, secondary leaflets arise. Such are called *bi-pinnate* leaves.

The division may go yet farther; and the secondary veins may give off their branches before any leafy parts appear on them, and these are of course much smaller and at the same time more numerous. A leaf in which this is the case is termed *tri-pinnate*. Such forms are generally peculiar to different kinds of plants; but there are some in which we find them strangely intermixed, so as to display their real origin and character.

238. Such an example is afforded by the *Gleditsia* or Honey-locust tree of North America, known to English gardeners by the name of the three-thorned Acacia. As in other Acacias, leaves are compound; but the division often proceeds to such different degrees in different parts of the same leaf, that it is difficult to say whether it is to be considered *pinnate*, *bi-pinnate*, or *tri-pinnate*. Of such a leaf, in the accompanying figure, the central stem is the mid-rib; and from it proceed the secondary veins on each side. The first pair of these bears on one side a leaflet which shows indentations marking a tendency to subdivision; and, on the other side a series of secondary leaflets, formed by the complete subdivision of the first. The second pair of veins bears on one side a series of secondary leaflets nearly similar; but two of these are seen to have again subdivided into more minute leaflets; the distribution of the veins in which, however, precisely corresponds with that of the larger ones, so that a skeleton of the whole would exhibit little difference in its several parts. On the other side a portion of another series of secondary leaflets is seen; but towards the extremity they merge again into a larger leaflet. Below these again, we have a complete

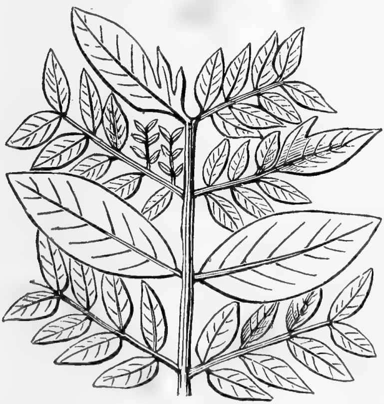


Fig. 39. Leaf of Gleditsia, one of the Acacia tribe, showing curious varieties in the subdivisions of the leaflets.

pair of larger leaflets. If the whole of the leaf had been formed on this last plan, it would have been simply *pinnate.* If on the plan of the lowest division, in which there is a complete series of secondary leaflets on each side, the leaf would have been *bi-pinnate.* And if the whole leaf had been constructed upon the plan of the minutely-subdivided portion of the second division, it would have been *tri-pinnate.*

239. These are some of the most interesting varieties in the form of leaves, depending upon the degree in which the parenchyma or cellular flesh is supplied to fill up the interspaces between the veins. Of those which depend upon the various distribution of the veins themselves it is not intended here to speak; since every plant furnishes materials for observation of these differences. In regard to the *size* of leaves, it may here be mentioned that, whilst in some species they are nearly microscopic, in others, especially of the Palm tribe, single leaves attain the length of from 30 to 40 feet.

240. There are some leaves possessed of the power of developing buds from their edges,—a fact which will hereafter be shown to be important. One of these is the Bog-Orchis (*Malaxis paludosa*) of English marshes; in which these buds may be distinctly seen, though the whole plant is very small. A better example, however, is the *Bryophyllum calycinum*, which is a species inhabiting tropical climates, and known as the *air-plant* or *leaf-plant*, from the circumstance of its having no true stem or roots, but maintaining its life, and even growing and flowering, whilst hung up in a damp and warm atmosphere, without the contact of soil to any part of it. The little buds which develope themselves at the edges of the leaves, may become perfect plants before

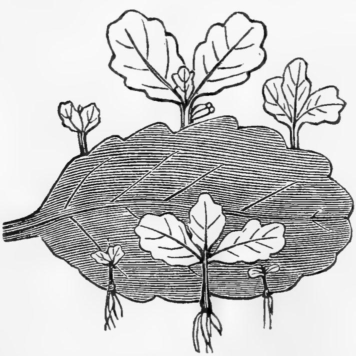


Fig. 40. Leaf of Bryophyllum calycinum bearing buds at its edges.

separating themselves from the parent; but, when they have once formed their own leaves and root-fibres, they are but little connected with it, and may be detached without injury.

241. The usual form of leaves is often remarkably changed; and many of the varieties produced in different plants seem to have for their object to collect water from the atmosphere and convey it to the roots. The large expanded leaves of the *Arum* tribe, for example, have a deep channel down the midrib; and this is continued along the petiole, so that the water collected by the leaf is conveyed to the point of the stem from which it springs. In the common Teazel (*Dipsacus*) of our own fields, and the *Tillandsia*, or wild Pine of South America, there are hollows capable of holding a considerable amount of water at the point of union of the leaf-stalk with the stem.

242. But the most curious contrivances of this kind are those known as *pitchers*. The plants furnished with these curious receptacles are termed Pitcher-plants, and several kinds of them are known. In the *Sarracenia*, which is a native of Canada, these pitchers may be distinctly seen to be formed by the very deep channeling of leaves and leaf-stalks, the edges of which fold towards and meet one another, so as to form a complete vase, the mouth of which is guarded by a sort of hood formed by the top of the leaf. In the *Nepenthes*

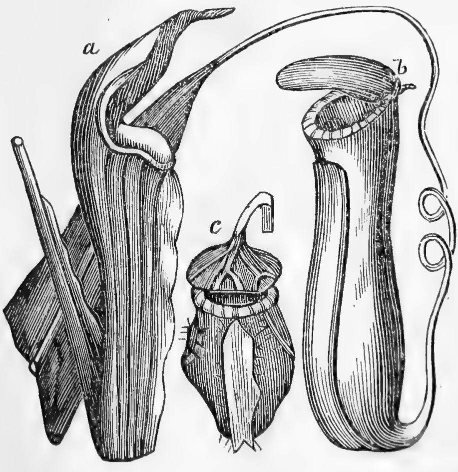


Fig. 41. Different kinds of Pitchers; *a*, pitcher of Sarracenia; *b*, pitcher of Nepenthes; *c*, pitcher of Cephalotus.

or Chinese Pitcher-plant, the pitcher is of more complex and singular construction. The petiole, soon after it arises from the stem, spreads into a broad leafy expansion, which seems to perform the function of the true leaves; it then contracts and forms a round tendril-like cord of several inches in length, and it then expands again, and is hollowed in its interior, so as to form a very capacious and elegant receptacle. The mouth of this is guarded by a separate little leafy cover, which is connected with it by a distinct joint; and this is regarded by botanists as the true leaf. In one more variety, the pitchers of the *Cephalotus utricularis*, or monkey-cups of South America (so named from its being reported that the monkeys quench their thirst with the fluid they contain,) the petiole seems to form the lid; and the pitcher itself is composed of the hollowed leaf which hangs from it by a kind of hinge.

243. In regard to the functions of these curious organs there is some difference of opinion. It seems probable that the pitcher of Sarracenia is a kind of fly trap, which serves to catch insects, the decay of which may furnish materials for its growth. Its interior is beset with long bristly hairs which point downwards; and at the bottom there is poured forth from the plant a honey-like secretion, which is very attractive to insects. They experience little difficulty in reaching it; but when they endeavour to return, they are checked by the downward projection of the hairs, and are caught like a rat in a trap. It has been observed that the plant does not thrive so well in a place from which small insects are excluded; and there is good reason to believe, therefore, (especially since, as we shall presently see, a corresponding instance certainly exists,) that they are in some way beneficial to its growth, probably furnishing by their decomposition when dead a sort of manure which is useful to the plant.

244. In regard to the Nepenthes no very positive statement can be given; and it is certain that, of the fluid which is found in the pitcher in the living plant, a part at least is poured into it from the plant itself, since it has been found to contain fluid while quite immature, before the first opening of the lid. The interior is covered with downy hair; and it is probable that this performs

the same functions as in other cases, attracting moisture from the atmosphere by its numerous points. It has been observed that the lid is closed in dry weather, as if to prevent loss of fluid by evaporation from the interior; but that if the atmosphere be made very damp, and especially if the plants near it in the hot-house be watered, so as to cause a large quantity of watery vapour to surround it, the lid of the pitcher will open, and the quantity of water contained in it will soon show a considerable increase.

245. The most curious, perhaps, of all the pitcher-plants at present known is one which has hitherto only been observed in India, growing in its native forests; and it is called the *Dischidia.* It is a creeping plant, having a long twining stem which is destitute of leaves until near its summit; and this may be a hundred or more feet from the roots, on which, therefore, it can scarcely depend for nourishment by absorption of fluid from the ground. Its supplies of moisture from a tropical atmosphere would be very uncertain if there were no provision for storing up what it occasionally collects; but with such a one it is furnished. The pitcher seems formed of a leaf with its edges rolled towards each other and adherent; and the upper end or mouth, from which it is suspended, is quite open, and adapted to receive whatever moisture may descend from the air, whether in the form of rain or dew. It is accordingly always found to contain a considerable quantity of fluid, in which a number of small black ants are generally seen; these are probably attracted by it, and their decomposition may, as in the case of the Sarracenia, render it yet more nutritious to the plant. But the most curious part of the whole apparatus is a tuft of absorbent fibres, resembling those of the roots, which are prolonged from the nearest part of the branch, or even from the stalk to which the pitcher is attached, and which spread through the cavity. They may be regarded in the light of secondary roots, serving to introduce into the plant the fluid aliment collected in these curious reservoirs, which may be compared to the stomachs of animals.

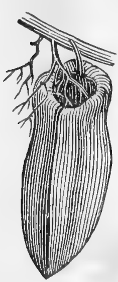


Fig. 42.
Pitcher of Dischidia Rafflesiania; showing the tuft of root-like fibres prolonged into it from the adjoining twig.

246. One more curious modification of the leaf may be noticed;—that which forms the insect-catching trap of the *Dionæa muscipula*, a plant inhabiting the southern part of the United States, and commonly known as *Venus's Fly-trap*. In this plant we find certain of the leaves fringed at their edges with a row of long spines, and endowed with the power of folding the two sides of the leaf towards each other, so as to enclose any thing between them which may have settled upon its surface. When thus folded, the spines cross each other in such a manner as completely to prevent the escape of an insect which may be thus captured. Upon each half of the blade of the leaf, there are three projecting thorns; and it is when either of these receives the slightest touch, that the two sides fold together and form a complete trap, the walls of which seem to press more closely upon the captive the more it struggles. Any unfortunate insect which alights upon the leaf is thus speedily destroyed; and its decay appears to furnish the plant with nutriment beneficial to it. Plants of this kind, which have been kept in hot-houses in this country from which insects were carefully excluded, have been observed to languish; but were restored by placing little bits of meat upon their traps,—the decay of these seeming to answer the same purpose. The petioles of the leaves which form these traps are very much widened and flattened, forming leaf-like organs, which seem to perform the functions of true leaves.

247. Having now noticed the chief varieties of leaves, as regards their external form, we shall proceed to consider their internal structure; and this exhibits a degree of complexity which would scarcely be supposed. The internal structure of the leaf cannot be well examined without a high magnifying power. It is necessary to cut the leaf across with a sharp knife, and then to pare off an excessively thin slice from the cut edge; so that when a section, exhibiting the thickness of the leaf, from one surface to the other, is placed under the microscope, the light may be sent through it. A portion of such a section of the leaf of the Lily, which may be regarded as sufficiently characteristic of leaves in general, is shown in the next figure. The hollow cells of the cuticle

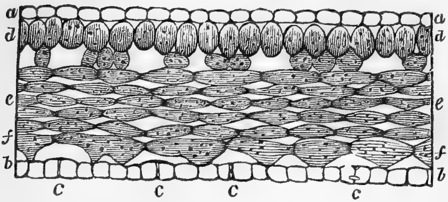


Fig. 43. Section of the leaf of the Lily; *a*, cells composing cuticle of upper surface; *b*, cells of cuticle of lower surface; *c*, *c*, stomata; *d*, upper closely-set layer of parenchyma; *e*, *f*, lower rows of cells more loosely arranged.

covering the upper surface of the leaf are seen above, and those of the under cuticle below. Between these are seen a large number of shaded cells, which represent the coloured parenchyma or fleshy portion of the leaf. These are arranged with considerable regularity, and are packed very closely together beneath the upper surface; and there are scarcely any spaces between them in that part. Below, however, it is seen that the cells are of less regular form, and that they do not come into nearly such close contact, so that there are many spaces amongst them, which, communicating freely with each other, form what are termed the *intercellular* passages and spaces of the leaf.

248. The stomata are chiefly to be found in the lower surface; and they always open into the vacant spaces beneath the cuticle, and not against the cells in contact with it. It is the large proportion of these vacant spaces, which usually contain a considerable quantity of air, that occasions the colour of the under side of the leaf to be usually much lighter than that of the upper. The cells of that part are themselves of a shade fully as deep; but a much smaller number of them lie against the transparent colourless cuticle. This may be easily seen by cutting a thin slice from the under side of the leaf with a sharp knife, in such a manner as to detach a portion of the cuticle with the cells adherent to it; and on magnifying this it will be observed, how small a proportion of it is really rendered green by the coloured tissue in contact with it. The large amount of air which these passages contain, is made evident by putting a leaf in water under the receiver of an air pump; and if the pressure be removed from above, by exhausting the air, a number of minute bubbles will be seen to issue from the pores of

the leaf, which form a portion of the air previously contained in it.

249. Nearly all the leaves which assume the ordinary position, having one surface directed upwards and the other downwards, closely correspond with the one just adduced as an example in their general structure. There are, however, some curious exceptions. Not unfrequently we find the openings of many of the stomata blocked up; especially in plants which inhabit hot and dry situations, and in which, therefore, less superfluous moisture has to be exhaled through them. It is in such that we find the cuticle formed of more than a simple row of cells. The *Oleander* is a very remarkable example of this structure. The upper cuticle consists of three rows of cells filled with air alone. Beneath this we find two layers of green cells packed with extreme regularity and closeness, so as not to leave any passages between them; but between these and the lower cuticle the texture of the parenchyma is very loose. The lower cuticle contains three and sometimes four layers of cells; and its exterior is covered with downy hairs. It contains few or no stomata; but instead of these we find cavities in its substance, opening externally by a small orifice, and closely lined within by similar delicate hairs. Now, as already mentioned, it seems that these hairs act as so many little rootlets; absorbing moisture with which they may be in contact, when the necessities of the plant require it; and nothing can more effectually aid them than the little cavities just mentioned, which are so beautifully adapted to contain such minute quantities of water as the atmosphere may deposite. Thus, the dryness of the soil and climate in which this species naturally exists is compensated by the peculiar structure of its leaves; and it is, accordingly, one of the few plants which will flourish in a sitting-room, the air of which is too dry for the health of most others. Similar cavities have been observed in the Nepenthes and Dionæa.

250. There are many plants, however, whose leaves expose each side equally to the light; their surfaces being upright instead of horizontal. In these, both sides are usually formed alike, and

their colours are the same. Upon examining their interior structure it is found that both sides are equally furnished with intercellular passages; and that the number of stomata above these is nearly equal. This is the case, for example, in the common Iris. But there are some instances in which the general plan of structure is completely reversed,—the stomata being restricted to the upper surface, and the upper part of the parenchyma being much looser in texture than the lower. This is the case, for example, with the Water-Lily, and other plants whose leaves float on the surface of the water. The thick spongy leaf of the Water-Lily contains a large amount of air-channels, which serve to give it buoyancy; but these are all immediately beneath the upper surface, and communicate with the external air through its numerous stomata; whilst in contact with the lower surface,—which, as it lies upon the water, is cut off from the actions that are usually performed by it,—are two rows of closely-packed cells, corresponding to those generally in contact with the upper surface. In all these instances we observe such a beautiful adaptation of the structure of these wonderfully-organized beings to the circumstances in which they are to live and grow, that the intelligent observer can scarcely feel a doubt of the Wisdom and Omnipotence of the Designing hand which contrived it.

CHAPTER VIII.

OF THE FUNCTIONS OF LEAVES.

251. It is in the leaves, as already stated more than once, that those changes are effected, which convert the crude fluid absorbed by the roots (consisting as it does of little else than water in which is dissolved a very minute proportion of the various matters existing in the surrounding soil) into the *proper juice or nutritious sap*,—capable not only of supplying to the different parts of the structure the materials necessary for the maintenance of their healthfulness, the repair of injuries, and the production of entirely new parts,—but also of furnishing the ingredients of those several products, which the various tribes of plants may be said almost to create from the elements around them, and which are so valuable to man as articles of diet, as medicines, or as articles of use in his various manufactures. Many of these will have to be considered hereafter under the head of *Secretions;* but it is interesting to observe here, that,—although almost every tribe of plants forms some substance peculiar to itself, some of which are of a highly poisonous character, whilst others are of the mildest and most wholesome nature,—they all originate in ascending sap, which is of nearly a uniform character in each tribe.

252. In this process of *elaboration*, as this conversion has been termed, several distinct changes are involved. The first is the *concentration* of the fluid by the loss of a considerable proportion of its water, so that the amount of solid matter contained in any quantity of it is much greater than before. This is effected by a process which resembles the perspiration of animals; a large quantity of watery vapour being given off, under favourable

circumstances, from the surface of the leaves as from the pores of the skin of a man.

253. If a glass vessel be placed with its mouth downwards on the surface of a meadow or grass-plot during a sunny afternoon in summer, it will speedily be rendered dim in the interior by the watery vapour which will rise into it, and this will soon accumulate to such a degree as to run down in drops. From an experiment of this kind repeated by Bishop Watson during several successive days, on a meadow which had been cut during a very intense heat of the sun, and after several weeks had been passed without rain it was calculated by him that an acre of grass land transpires in 24 hours not less than 6400 quarts of water. This is probably an exaggerated statement; as the Bishop does not seem to have been aware how completely transpiration is checked during the night; but it will serve to give an idea of the enormous amount of fluid which must be thus disengaged. Any person walking in a meadow on which the sun is shining powerfully, especially in a hot day in summer, when the grass has not long previously been refreshed by rain, may observe a tremulous motion in distant objects, occasioned by the rising of the watery vapour; exactly resembling that which takes place along the sea-shore, when the sun shines strongly on the pebbles that have been left in a moistened state by the retreating tide.

254. It is necessary, however, to distinguish the *evaporation* which is the cause of the latter occurrence, from the peculiar function we are now considering; which as we shall see, is influenced by circumstances that only act during the life of the plant, in such a manner as to prove it to be something of a different character from that which we observe in dead substances. All moist bodies exposed to a tolerably warm and dry atmosphere have a tendency to become dry,—the fluid they contain slowly passing off in the form of vapour. The rapidity with which this takes place will depend upon the amount of heat to which they are exposed, and the degree of dryness of the surrounding air. Every one knows that warmth is of great assistance in drying moistened substances of any kind; and this results from its promoting the conversion

of the water into vapour. It may easily be observed, too, that a damp atmosphere retards the process; and the air sometimes has so large a quantity of vapour suspended in it, that it deposits it as a dew upon dry substances, instead of raising fresh moisture from damp ones.

255. Now the living fabrics of plants are subject, like all other moist substances, to the loss of fluid by evaporation; and this would take place under the conditions just mentioned, from all the parts which have this character, were it not for the protection afforded by the cuticle. This membrane, as formerly stated, covers the whole surface of every plant which is exposed to the air; and, from its dry nature, and the absence of any fluid in its cells, it is not liable to be thus influenced by heat or dryness of the atmosphere, so that it effectually protects from the undue influence of these agents the soft tissues beneath. The difference which results from the presence or absence of this cuticle may be well seen by comparing the long-continued freshness of the leaf of any flowering plant which is kept in the dark (so that its *exhalation*, or transpiration of fluid through the stomata, as presently to be explained, is prevented,) and the rapid shrivelling of the frond of a sea-weed, or of any Flowering-Plant that naturally grows beneath the water, when equally exposed to the influence of a warm and dry atmosphere. And, as already noticed, the cuticle is almost invariably found to be the thickest and firmest in plants which frequent very hot and dry situations.

256. Nevertheless the cuticle does not entirely check evaporation; but this takes place from the surface of a dead plant, or any portion of one, as well as from one in the most active vegetation. The shrivelling of Apples long kept, and the loss of weight of Potatoes, are examples of this slow and gradual change. It may be stated, then, that Plants, like other moist soft substances, are liable to part with some portion of their fluid by evaporation, especially when exposed to a warm and dry atmosphere; but that the amount of this loss is far too small to account for the large quantity of vapour, which, as just stated, may be easily ascertained to pass off at certain times from the surface of the living plant.

257. Now a few simple experiments will show that there is a strong probability that this rapid transpiration takes place through the stomata. If a piece of glass be held near the upper surface of the leaf of a vine actively growing in a hot-house, little effect will be produced upon it; but if it be held near the under surface, the glass will soon be dimmed by the vapour, and in a short time longer this will accumulate so as to form drops. As the upper surface of a vine-leaf is nearly destitute of stomata, whilst the lower is thickly covered with them, the disproportion in these effects is at once explained, if the transpiration really take place through these apertures. Similar experiments on other plants lead to the same general result. Where the stomata are equal in number on the two surfaces, both seem to transpire alike; and when neither possess stomata capable of action, the transpiration is scarcely to be observed. Again, if a plant actively transpiring under the influence of sun-light, be carried into a dark room, its transpiration is immediately and almost entirely checked; and if its stomata be then examined they will be found to have closed. Thus it appears almost unquestionable that the rapid loss of fluid from the whole vegetable surface, but especially from the leaves, which constitutes a most important part of the economy of the living plant, is regulated by the number of stomata which each part contains, and by the degree in which light acts upon them (§ 94.)

258. Still, this kind of transpiration (which, to distinguish it, may be termed *exhalation*) is not altogether different in its character from the common evaporation first described. It will be recollected that the stomata open into large passages channelled out, as it were, in the fleshy substance of the leaf; and that the walls of these are every where composed of a very soft tissue, which is constantly kept moist by the crude sap conveyed so plentifully into the leaves. If, therefore, the atmosphere be admitted into these passages, a very large amount of evaporation must take place from their sides, which resemble, in the want of any protection, the substance of plants habitually living under water; and this evaporation will be the more considerable, as the

surface exposed in these passages is much greater than that of the leaf itself. The *exhalation* of fluid from the living plant, then, may be regarded as a kind of evaporation from its interior, and will be promoted by the warmth and dryness of the air around; but it is entirely controlled by the stomata, which, by admitting or excluding the air, permit or check it, in accordance with the influence of light upon them.

259. Thus, then, we see one important mode in which *light* influences the growing plant. No amount of heat can supply a deficiency of this agent; for, if it be excluded, *exhalation* is entirely prevented, and all the fluid that is transpired has to pass off by the slow process of evaporation only, which is not nearly sufficient for the required concentration of the sap. Moreover, when the exhalation is checked, absorption soon ceases; for the tissues become gorged with fluid, and are capable of containing no more. If a plant, accustomed to grow in open day, be kept for some time in the dark, it becomes unhealthy, and, as it were, dropsical; and will generally die if not restored to its usual condition. This is not, however, the only process performed by the leaves, which is checked by the want of light; and therefore the unhealthiness which results cannot be imputed to it alone.

260. We are now prepared to understand, then, the share which the leaves have in promoting and maintaining the absorption of fluid by the roots. The exhalation which takes place in the leaves has a corresponding effect with the combustion of oil at the top of the wick of a lamp,—occasioning a continual demand for fluid from below. If the flame be extinguished, the oil does not flow over the top of the wick, because the absorption of it ceases also; and so the action of the roots is governed by that of the leaves, the former organs ceasing to absorb the fluid, when it is not drawn off by the latter. This connexion is not only shown by the experiment just mentioned, but by a still more remarkable one, which explains in great degree the cause of the ascent of the sap in the spring, after it has been nearly stationary during the winter. If a vine be growing on the outside of a hothouse, and a single shoot be trained within, in the midst of

winter, the warmth to which the latter is exposed will cause its buds to swell and unfold themselves; whilst those on the outside are quite inactive. A demand for fluid will thus be occasioned along this particular branch; and this will be supplied by that existing in the vessels below. When these are emptied, they will be again supplied from the parts below them; and thus the motion will be propagated to that division of the roots whose fibres are connected with those of the vegetating branch, which will absorb fluid for its support, whilst all the rest are completely at rest. In the spring of the year, when the cheerful rays of the sun call the whole of the buds into activity, the whole of the roots are similarly affected; and that the sap begins to move in the upper branches, before it commences ascending in the trunk, has been shown by experiment,—notches having been cut at intervals, by which the period of its flow could be ascertained in each part.

261. Various experiments have been made at different times to ascertain the quantity of fluid thus exhaled by plants; and the results of many of them are very interesting. Those made by Dr. Woodward 150 years ago have been already noticed (§ 100,) as indicating the large quantity of water absorbed. There is no great difficulty in ascertaining the amount upon a small scale; for if a plant be supplied with a known weight of water, and the weight it has gained during a certain time be deducted from this,—allowance being also made for the evaporation from the surface of the water in which its roots are immersed, the quantity of which may be easily estimated,—the difference must be the proportion exhaled. This differs much in different plants according to the rapidity of their growth.

262. It has been ascertained that the young leaves and shoots of the Wild Cornel exhale twice their own weight of water daily. A common-sized Cabbage in the twelve hours of daylight, was ascertained by Hales, (one of the best experimenters upon this interesting subject) to exhale from 15 to 25 ounces daily, according to the light and warmth to which it was exposed. This quantity, in proportion to the amount of surface exposed by the

leaves, is probably as great as most plants furnish; and is more than is given off from the skin of man in the same time. This has been reckoned to amount in twenty-four hours to about 25 ounces; which, as there is no great difference between day and night, would make $12\frac{1}{2}$ ounces in twelve hours; admitting, therefore, that the surface of his body is about one-fourth less than that of the leaves of the Cabbage, and reckoning the perspiration of the latter at the mean between the greatest and the least, it is still much greater than that of man.

263. The transpiration of a Sun-flower in full growth, during fifteen days and nights, was carefully observed by Hales. This plant was $3\frac{1}{2}$ feet high, weight 3 pounds, and the surface of its leaves was estimated at 5616 square inches,—or about $2\frac{1}{2}$ times that of the human body. The average transpiration during the whole period was found to be 20 ounces per day; but in one warm dry day it was as much as 30 ounces. During a dry warm night, it lost 3 ounces—probably by simple evaporation; when the dew was sensible though small, it neither lost nor gained; and by heavy rain or dew, it gained 2 or 3 ounces. When this amount is compared with that perspired by man, it may be shown that, if their *surfaces* were equal, the man would perspire 50, and the plant 15; but that, for equal *weights*, the plant exhales 17, while the man perspires 1. Experiments upon single leaves, when not too long separated from the plant so as to lose their vitality; yield fully as striking results. Thus a leaf of the Sun-flower weighing $31\frac{1}{2}$ grains absorbed in four hours, by its petiole immersed in water, 25 grains of that fluid; the leaf had increased in weight only $4\frac{1}{2}$ grains; so that $20\frac{1}{2}$ grains had disappeared by exhalation.—Thus a quantity equal in weight to the leaf itself would have been exhaled in about six hours.

264. Experiments of this last kind may be very easily performed by any one who has command of a pair of scales adapted to weigh small substances; and it is well that the student should avail himself of such opportunities of learning how to "put Nature to the question" in matters of this simple character, in order to cultivate habits of accuracy and caution, which are useful in every

condition of life. Let him take several leaves of different plants—such, for example, as the Vine, Oak, Elm, Beech, Lime, Apple, Pear,—weigh them separately, and estimate as nearly as he can the comparative surface presented by each. He would then place their footstalks in glasses or bottles of equal size, into which has been poured a certain weight of water, carefully ascertained to be the same in each; and he would place all these in similar circumstances for a certain time; having also a corresponding glass without a leaf, in order to estimate the amount of fluid lost from the surface of the water by evaporation. By ascertaining how much had been absorbed by each leaf, and the weight each had gained, he would thus be easily enabled to calculate the quantity it must have exhaled; and then, by comparing this with the extent of the surfaces of the different leaves, he would estimate the proportional rapidity of the process in the various species he had chosen,—care having been taken to select, in the first instance, trees in equal stages of growth, and leaves of a similar degree of freshness and development.

265. The watery vapour which is constantly though insensibly given off from the skin of animals, is liable to accumulate in drops, and to form sensible perspiration, when from any cause it exceeds in quantity that which the air can carry away; either in consequence of an increased secretion or separation of it from the blood (as when a person exerts himself in warm weather,) or from the atmosphere being already so loaded with dampness that it cannot contain any additional moisture. In the same manner, some plants exhale so rapidly at sunrise, when the heat of the air is not sufficient to enable it to carry off the disengaged moisture, that the fluid accumulates in drops at the points of the leaves, and has been mistaken for dew. This, however, is not the case; since it has been observed on plants under shelter, as well as on those that are exposed; and it has been noticed also at other parts of the day. A similar accumulation of water in drops has been observed when plants have been electrified; by which process the amount of exhalation appears, for a time at least, to be considerably increased. It is perhaps in this manner that an electric state of the atmosphere hastens the growth of some kinds of plants.

266. If plants are exposed to a light of too great intensity, especially if they possess many stomata, and are not well supplied with water, their tissue becomes dried up by the increased exhalation which then takes place, and which is not sufficiently counterbalanced by absorption, so that their vegetation is materially checked,—a fact of which we see abundant examples in dry sandy soils, and exposed situations. If, on the other hand, the leaves are shaded, and the roots freely supplied with moisture, the growth of the plant is active and luxuriant, but its tissue is soft and altogether destitute of firmness. This, however, is partly due to the imperfect performance of another process shortly to be described as that of *digestion*. Plants of a very fleshy juicy character, termed *succulent*, in which there is usually a great deficiency, or even entire absence, of stomata, require a considerable amount of light to secure for them that regular discharge of moisture which they require; hence when Melons are grown in a frame, as many leaves as possible should be exposed to the influence of the sun's rays, and the accumulation of moisture within should be provided against. There are certain succulent plants which, owing to their deficiency of stomata may be preserved without moisture for many days or even weeks; and as their cuticle is so thick as to resist evaporation, it is often very difficult to kill and dry them for the purpose of placing them in collections. Of this kind are the *Sedums*, or *Stone-crops*, of Britain, which have been known to push considerable shoots when placed under pressure; and many plants of tropical climates.

267. Besides these applications of theory to practice, there are many others which will readily arise from the knowledge of the character of this function, and of the causes on which it is dependent. Thus we learn from it that the operation of transplanting should not be performed in the summer, when the exhalation is most active; since, the roots being always injured in greater or less degree, the process of absorption is imperfectly performed, and cannot supply the loss by exhalation; so that the plant is dried up. This evil may in some degree be guarded against by watering the plant copiously; but it is much better to make the

change either in spring or autumn, when most plants are destitute of leaves, and therefore scarcely exhale at all, and when the function is performed with much inferior energy in those which possess them.

268. Again, we see the reasonableness of the practice, which has been long known as a useful one, of keeping a nosegay, the freshness of which it is desired to preserve, in a dark room; since the check thus put to the exhalation which takes place, not only from the leaves, but also from the leafy surfaces of flowers, prevents the rapid withering which will otherwise occur. Even the light of lamps and candles is to a certain extent effectual in maintaining this function; so that this is to be avoided where, for any particular occasion, flowers which have been picked are to be preserved as nearly as possible in their previous blooming state. Such a plan, however, would prevent the expansion of any buds which the nosegay might include; since this (both in leaf-buds and flower-buds) depends upon the vigour with which the process is performed, and is hastened by light. By artificial light, therefore, it may be possible to cause flowers to bloom earlier than by any other means; for it has been observed that the portions of a row of trees on which a strong light is cast from gas lamps, come into leaf sooner than the rest.

269. The water exhaled by plants is very nearly pure; so that what is furnished by different species varies extremely little either in taste or odour. It has been remarked, however, that fluid thus obtained becomes foul sooner than ordinary water; and this is the case wherever organic matter, even in extremely minute proportion, is diffused through the fluid. The quantity of solid matter contained in 40 ounces of the liquid, exhaled from a vine at the commencement of the summer, has been found to be only two grains; and no more than this was contained in 105 ounces from the same vine at the conclusion of the summer. Even these minute quantities are sufficient to communicate a perceptible taint, when separated by their decay into the gases of which they are composed, and of which the bulk is very much greater.

ABSORPTION OF FLUID BY THE LEAVES.

270. Although the leaves of the higher plants are, without doubt, the special organs of exhalation, they also have the power, like the leafy surfaces of the lower tribes of plants, of supplying fluid nourishment, under peculiar circumstances, when the system requires it. It has been already shown that it is only as we ascend the scale, that we begin to meet with distinct roots for the purpose of absorption;—the same general surface answering both purposes in the simplest tribes. And even where distinct root-fibres are developed, they are often closely connected with the leafy surface; these fibres being sent off from the under side of the leafy expansion of the Marchantia, and often from a similar part in the separate and delicate leaflets of Mosses.

271. It is not to be wondered at, then, that the leaves of higher plants should be capable of supplying in some degree the functions of the roots, when these are absent or imperfect, or unable, from the nature of the soil which surrounds them, to obtain a sufficient supply of fluid nourishment. Not unfrequently the roots, where they exist, serve merely to fix the plant, finding their way into the crevices of the hard dry soil or of the barren rock on which it grows; and then it must be altogether dependent upon the moisture it imbibes through the general surface. In such cases the function of exhalation is but feebly performed; and all the processes of growth are proportionably slow. Plants of this description flourish best near the sea-shore, where there is always a certain amount of moisture in the atmosphere; and especially, too, in tropical regions, where the constant high temperature increases the evaporation from the surface of the water, and at the same time enables the atmosphere to dissolve a greater quantity of watery vapour. It is wonderful to see the precipitous faces of rocks apparently the most barren, studded here and there with plants of the *Cactus* and *Orchis* tribes; the former exciting attention by the brilliancy of their blossoms, and the latter by the strange shapes they often present. In many of the Cacti growing in such situations, the stems contain a considerable amount of

fluid, which, though insipid, is wholesome, and is freely used as a cooling drink in fevers, by the natives of the countries in which these plants abound.

272. Many of the *Orchis* tribe (as well as other plants) grow entirely in the air; spreading themselves over the surface of trees, from which their roots hang freely down like fringes. Such attain their greatest luxuriance in the forests of the tropical parts of South America; and here a constantly moist state of the atmosphere is maintained by the exhalation of the trees upon which they cluster. When grown in hot-houses in this country, they require that the atmosphere should be rendered artificially moist as well as warm; and that their roots should be enabled to spread themselves freely through the air, and should not be confined within pots. The luxuriance which such plants often exhibit, sufficiently proves that the atmosphere contains all the materials, which are necessary for the growth even of the highest plants; and that, if the structure is adapted to imbibe them from it, no other kind of supply is necessary.

273. A fact similar to every one who has bestowed common notice on the processes of vegetation, equally proves that the leaves as well as the roots are capable of absorption. When plants are faded by the intense action of light and heat, and have suffered from deficiency of water, they are observed to revive rapidly when their surfaces are moistened, even if no fluid have been supplied to the roots. More precise experiments lead to the same result. It has been found that leaves placed with one of their surfaces upon water would remain fresh for several months; the absorption through it counterbalancing the transpiration through the other. From a considerable number of experiments on different kinds (though this, again, is a subject which any one may investigate with great ease, and with the certainty of arriving at new and interesting results with a very little trouble,) it seems to be ascertained, that the leaves of trees and shrubs retain their verdure longest, when the lower side is placed in contact with water; whilst the leaves of herbaceous plants absorb most readily by their upper surface, or in an equal degree by both. Thus,

leaves of the White Mulberry, placed with their upper side in water faded on the fifth day; whilst those which absorbed by the lower surface remained fresh nearly six months. This effect, however, was no doubt due in part to the greater degree of obstruction to the loss of fluid by transpiration in the second case than in the first; the stomata being principally situated on the lower surface. But in experiments on other plants in which they are similarly disposed, the contrary result has been observed. Thus, leaves of the Nettle, whose inferior surface only was kept moist, faded at the end of three weeks; whilst others whose upper surface was in contact with water, lived for two months. Lastly, the leaves of the Sun-flower, Kidney-bean, Cabbage, and many other plants were observed to remain fresh for the same length of time, by which ever surface they received their supply of fluid.

274. This arrangement is admirably adapted for obtaining the greatest supply of the moisture contained in the lowest layer of the atmosphere; for when, by the cooling of the earth's surface which takes place on a clear night, this moisture falls in the form of dew, it will manifestly be received on the upper sides of the leaves of plants which are but little raised above the ground; whilst, on the other hand, the leaves of more elevated trees would not benefit by this deposition, being situated above its influence; and these would receive and imbibe the vapour as it afterwards rises from the surface of the moistened earth. We thus learn that, if it be desired to revive drooping or sickly plants or trees by the application of moisture, the mode in which it should be distributed over them will depend upon their size; if they be herbaceous plants, they should be watered from above; and if they be tall shrubs or trees, the water should be thrown up by a syringe from below.

275. The absorbing power of leaves has been shown by other satisfactory experiments. Some plants of *Mercurialis* (Mercury) were placed in water, some of them being immersed by their roots, and the others touching it by a part of their leaves alone, a small shoot of each being kept out, for the purpose of comparison with the rest. After five or six weeks, the shoots of the

plants which were nourished by the leaves differed little in vigour from those which had been supplied by the roots. Experiments upon single leaves, which have already partially faded, are still more striking. Some leaves of *Potamogeton natans*, (Pond-weed,) after being wiped dry, were weighed; and after remaining out of the water for two hours, they were found to have lost from 3½ to 5½ grains each. They were then put in water, and after the lapse of two hours more, were again wiped dry and weighed. It was then found that they had severally gained from 3 to 5 grains each; and this increase (which was also evident from the restoration of their natural freshness and plumpness) could only have taken place by absorption through the cuticle, as the cut ends of their footstalks were defended by soft cement.

276. Other experiments show the remarkable influence of dew in supplying nourishment to plants. Two similar leaves of the *Plantago lanceolata* (Ribwort Plantain,) equally faded, and each weighing 8 grains, were compared; one having its footstalk immersed in water, and the other being exposed to dew. They both weighed 8 grains previously; and on the following morning the first had gained but one grain, whilst the second (after the adherent moisture was wiped off) was found to have gained a grain and a-half. A similar experiment was then tried upon two leaves of *Verbascum* (Mullein,) each of which weighed 13 grains in the first instance. The one whose footstalk was immersed in water gained 2½ grains; whilst the other gained 4 grains. Many other experiments of a similar kind might be related; but these are sufficient to show that leaves whose tissue has been deprived of fluid, have the power of replacing it by absorption from water placed in contact with them, or from a moist atmosphere. This power is probably exercised, however, in the majority of plants, only when their roots cannot from any cause obtain for them an adequate supply; and at other times the leaves are organs of exhalation only.

277. The influence of dew and of a moist atmosphere in maintaining vegetation is often very remarkable in tropical islands, where no rain falls for months together, and where the soil is so

parched by the burning sun as scarcely to yield a particle of fluid to the plants growing upon it. The proximity of the sea occasions the atmosphere of these islands to contain a large quantity of vapour, which, when the temperature of the soil falls at night, is deposited as an abundant dew; and, in consequence, they exhibit a luxuriant vegetation under circumstances which would cause an inland country to appear completely parched. In the present year (1840) the preservation of the young corn during the hot and dry month of April, in many parts of England, was owing to the heavy dews. In consequence of the wetness of the preceding autumn and winter, very little grain had been put into the ground before February; and, as there was little rain from that time, the surface of the ground was not sufficiently moist to cause the rapid germination and growth of the young plants. Towards the middle of April the sun began to shine with great power; and as no rain fell, it was much feared that the young plants, not having length enough of root to penetrate deep into the soil, would be starved for want of nourishment. This was supplied to them, however, in two ways;—partly by the dews, which, in consequence of the clearness of the nights, were heavy; and partly by the action of the powerful sun upon the deeper part of the soil, which had been drenched (as it were) with moisture by the rain of the preceding autumn, so that when it became heated, it sent up a large quantity of vapour, which was probably absorbed both by roots and leaves.

278. This absorption of fluid by the leaves appears to take place chiefly through the membrane of the cuticle, but more particularly by the downy hairs, which seem to act as so many root-fibres. They are chiefly developed, as already stated, upon plants which grow in situations in which they are much exposed to light, and to a dry atmosphere; whilst the same species in damp shady situations will not form any. It has been noticed that they lift up their points and separate from one another at the approach of the evening dew, which collects in minute points around them; and that they fall down again and form a layer of minute cavities on the cuticle, as soon as the heat of the sun begins to be perceived. On comparing the increase in weight when exposed to dew, in

plants thickly furnished with hairs and possessing few or no stomata, with that manifested by plants having a smooth surface and many stomata, it is seen that the former is much the greatest; and that it also surpasses in about the same proportion the weight gained by immersing the footstalk in water. Thus two heads of *Marrubium vulgare* (Common Horehound,) the original weight of which was 15 grains each, were placed, one with its stalk in the water, and the other in a place exposed to dew, for a night; the first was found to have gained 2 grains, and the second 5 grains. Both were exposed to dew during the next night; and on the following morning they each weighed 23 grains, having both gained 8 grains, of which the first had acquired 6 in that night. A withered stem of *Cerastium alpinum* (Alpine Chickweed) weighing 5 grains, gained 6 grains by exposure to dew for two nights.

ON RESPIRATION.

279. The concentration of the crude sap by the loss of its superfluous fluid, and the occasional absorption of what may be necessary to supply the amount insufficiently afforded by the roots, are by no means the only functions of the leaves; nor can they be regarded as the most important. These organs supply also the means of getting rid of a certain superfluous product, to retain which within the system (at least in the form in which it is set free) would be injurious and even destructive; and they serve the equally important purpose of introducing, from the air, the element which chiefly gives firmness and solidity to the vegetable tissue.

280. It is well known that, when an animal is confined in a limited quantity of air, it soon vitiates it, or renders it unwholesome; so that free ventilation, by which the foul air is replaced by that which is fresh, is one of the most important means of the preservation of health. Now this change in the air is effected by the removal of its oxygen, which is the element that chiefly supports the life of all beings; and by the substitution of carbonic acid gas set

free from the lungs of the animal. Thus the blood is purified by the removal of a noxious ingredient, and rendered more capable of maintaining the life of the system by receiving one of the opposite character; and this change is manifested in its aspect as well as in its properties,—the dark purple blood of the veins being converted, by exposure to the action of the air in the lungs, into the bright scarlet fluid of the arteries.

281. If the carbonic acid, which the blood takes up in its passage through the vessels of the body, be not set free in this manner, in consequence of any obstruction to the admission of air into the lungs, or other similar cause, the animal dies. The throwing-off this superfluous ingredient is, indeed, one of the most constant of all the processes of the animal economy; and there is good reason that it should be so, since it is set at liberty by the continual decay to which all parts of the living body are more or less subject (the softer ones, however, much more rapidly than the hard ones,) and which is only prevented from becoming manifest, by the mode in which the decomposed particles are thus separated and carried out of the system, their places being supplied by others newly deposited from the nutritious fluid.

282. Now this process of Respiration is as constant and universal in the Vegetable Kingdom as it is in the Animal; and it is only because a change apparently of a contrary nature sometimes obscures its effects, that it is not generally recognised. In fact, a healthy *plant* placed in a limited quantity of air, and exposed to the usual amount of daylight, will, (so long, at least, as it remains healthy,) add to its purity and will even restore the freshness of that which has been vitiated by an animal. But it is not the less true that there is a *constant* extrication of carbonic acid; for this may be very easily proved to take place, even while carbon is being absorbed. If, for instance, a few small healthy plants be placed under a glass vessel from which all carbonic acid has been previously removed, and allowed to remain there even in sun-light for a few hours, they will be found to have set free a small portion of carbonic acid, which may be detected by shaking the air contained in the vessel with some lime-water, which it will render

turbid. When the same experiment is tried in the shade, or by night, the quantity of carbonic acid found in the air is considerably greater.

283. There are two periods during the life of a plant when this liberation of carbonic acid gas goes on with great energy. One is in the *germination* of the seed; and here we can distinctly trace the object which is gained by the abstraction of the oxygen from the surrounding air, and by the conversion of it into this gas so opposite in its properties. In the seed when approaching maturity, a considerable quantity of starchy matter is laid up for the nourishment of the embryo; and this may remain unaltered for a long series of years, if the seed be not placed in those conditions which excite it to grow. But if it be exposed to warmth, moisture, and air (or any mixture of gases containing oxygen) it will *sprout* or germinate. In this process the starch, which (while it remains such) is unfit for the nourishment of the embryo that is being developed, is converted into sugar, which forms an appropriate food for it. Had sugar been deposited in the first instance, it would have probably undergone fermentation, and would have thus lost its utility, before the time came for its office to be performed; but the deposition of *Starch*, which can remain unchanged for almost any length of time, and which can at any time be converted into sugar, secures these objects in the most effectual manner. Starch differs but little from sugar in chemical composition, except in containing one additional proportion of carbon. When germination commences, oxygen is absorbed by the seed, in the substance of which it combines with the carbon that is to be set free from it; and a large quantity of carbonic acid is then given forth again to the air, whilst, in the same proportion, the starch is converted into sugar.

284. It is in this manner that the nearly tasteless barley is changed into sweet malt; and the change in the air around exhibits to us the function of respiration in its least complex form. Darkness favours it; since, as will presently be shown, a change of contrary character is favoured by light. It is an interesting fact that, after many trials, germination has been found to take

place most readily in an atmosphere consisting of 1 part oxygen, and 3 parts nitrogen; which is nearly the proportion of these ingredients in the air we breathe. If the quantity of oxygen is much increased, the seed loses its carbon too rapidly, and the young plant is feeble; and if the proportion is too small, carbon is not lost in sufficient amount, and the young plant is scarcely capable of being roused into life.

285. The changes which take place in flowering are very similar to those occurring in germination. At the bottom of the flower is usually a fleshy expanded body, into which its different parts are inserted; this is called the *disk* or *receptacle*. Here, too, there seems to be a sort of reservoir of starchy matter for the nourishment of the newly-produced germs; which is converted, as in the other case, into sugar. A part of this is probably absorbed into the interior; but the superfluous portion flows off in the form of honey. During the conversion of the starch into sugar, a large quantity of carbonic acid is substituted for the oxygen, which is absorbed; and this appears to be principally effected by the interior organs of the flower. It has been found that an Arum-flower, whilst in bud, consumed in twenty-four hours 5 or 6 times its bulk of oxygen; during the expansion of the flower, 30 times; and during its withering, 5 times. When the outer leafy parts of the flower were removed, it was found that the oxygen consumed by the interior organs was much greater in proportion. In one instance, the stamens and pistil of an Arum consumed in twenty-four hours 132 times their bulk of oxygen. It has also been observed that double flowers, in which these internal organs are replaced by leafy parts, vitiate the air much less than the single flowers in which the former are perfect.

286. The process of Respiration, then, in plants as in animals, appears essential to the life and health of the system; and, though more energetic at some periods than at others, it is constantly performed. If a plant be surrounded by an atmosphere already vitiated, and be secluded from the influence of light, its respiration will be (like that of an animal in similar circumstances) so much impeded, that its speedy death will follow. But a very

different result occurs if it be exposed to strong or even moderate daylight. The carbonic acid of the air will be decomposed by the *green* parts of the surface of the plant, and the solid carbon will be fixed within its tissues, while the oxygen will be set free, so as to restore the purity of the air. It is in the performance of this function that the leaves, from the extent of the green surface they present, are peculiarly energetic; for in that of respiration they only share with all the rest of the softer portions of the exterior; and in fact the dark surfaces seem to have more to do in it than the light.

287. Now this *fixation* of carbon, as it is termed, which antagonizes so remarkably the effects of the process of respiration may be regarded as in some degree analogous to the function of *digestion* in animals. In the solid food of all animals, whether it be of an animal or vegetable character, carbon is one of the principal ingredients; and vegetables also require this, for the formation of their solid tissues. The proportion which they take in by the roots is but small; and what they require in addition is obtained in this manner from the atmosphere, as they possess no stomachs by which it may be introduced in a solid form into the system. It is, then, chiefly of the water absorbed by the roots, and the carbon thus taken in by the leaves, that the elaborated sap or nutritious juice of the plant consists; and the constant liberation of carbonic acid from the general surface, in which the process of respiration consists, appears more necessary to preserve the healthfulness of the general system, by carrying-off what is in a state of commencing decay, than to change the character of this juice.

288. The proportion of carbonic acid in which a healthy plant will thrive under the influence of strong sun-light, is not less than 7 or 8 per cent: but a much smaller proportion than this would soon be fatal to it if grown in the shade. It is to a peculiar compound formed in the cells of the green surfaces, of which the carbon introduced from the air is an essential ingredient, that the colour is due; and as this fixation can only take place under the influence of sun-light, (artificial light, even the most powerful,

having no influence on it,) plants which grow in dark situations are either in part or entirely destitute of colour. They are then said to be *etiolated* or blanched; and the effect is purposely produced in many instances. If the absorption of carbon from the atmosphere is checked, the fluids have a much more watery character, and do not contain their peculiar principles in nearly so much abundance. Hence many plants, which are rank to the taste and stringy in consistence, when growing in their natural conditions, may be rendered much more palatable by being blanched,—neither the peculiar secretions to which the rankness is due, nor the woody fibres which occasion its toughness, being then formed in the same degree. Thus it is that Celery, Sea-kale, and many other vegetables are blanched,—earth being heaped over their young shoots, so as to keep them from the light. As exhalation will also be checked by the same process, the tissue becomes distended with fluid, and acquires that succulence or juiciness which is so much valued in such vegetables.

289. But though the *bulk* of plants which are undergoing this treatment, may considerably increase, yet the weight of their *solid* contents diminishes; for during the whole period respiration is going on; and, as there is thus a constant loss of carbon, whilst little or none is introduced, it follows that, if the tissues were dried by heat, they would shrink to less than their former amount. This is found to be the case; and it is also true of a seed in the process of sprouting or germinating, which constantly diminishes in the weight of its *solid* contents, up to the time when some of the new-formed leafy surfaces become green, and begin to absorb carbon from the atmosphere.

290. At this period of the growth of the young plant, it may be regarded as having a curious analogy with the tribe of Fungi. Both are supplied with nutriment already organized; for whilst the one has it previously stored up by its parent, the other receives it from the decomposing matter upon which alone it can grow. Both are developed most rapidly and luxuriantly in the absence of light, if well supplied at the same time with warmth and moisture. And the Fungi, like the germinating seed, give out a large

quantity of carbonic acid to the atmosphere, without receiving any carbon from it; since the peculiar character of the aliment they imbibe by their roots renders any additional supply of this ingredient unnecessary. In the Fungi, therefore, we have the process of respiration as distinct and easily understood as in animals,—both classes of beings subsisting upon food already organized, in which there is a large proportion of carbon; and it is a little curious that the tissue of the Fungi should approach more nearly in chemical character to that of animal flesh than does any other vegetable substance; so that, for those whose digestive powers are equal to them, Mushrooms constitute an extremely nutritious food.

291. The process of *digestion* is confined, as before stated, to the leaves and those green surfaces of plants which correspond with them in function; but that of *respiration*, although performed by the leaves more energetically than by any other part (at least during the ordinary processes of growth,) is not restricted to them, but is partially effected by the other surfaces, and even by the roots. The knowledge of this fact is important; since, through ignorance of it, much valuable timber has been destroyed. Several years ago, during alterations in Hyde Park, a considerable depth of soil was added to a part of it in which grew some fine elm-trees; the trunks of these were protected from pressure by circular walls built at a little distance from them; nevertheless the trees languished and died. Now the reason of this was simply, that the roots, being covered with too great a depth of earth, could not exercise their usual function of respiration; to perform which, they seem generally to direct their course as near the surface of the ground, as is consistent with the support they have to afford to the plant.

292. Much discussion has taken place upon the question whether or not vegetation is upon the whole serviceable in purifying the air;—that is, whether plants do altogether give out most carbonic acid or most oxygen to the atmosphere. By Priestley it was maintained that the latter was the *only* effect of vegetation; and that plants and animals are thus constantly effecting changes

in the atmosphere which counterbalance one another. Subsequent experiments seemed to show, however, that the carbonic acid given out during the night might equal or even exceed in amount the oxygen given out by day; but this was probably due to the employment of plants which had become unhealthy by being kept in a limited quantity of air, and which had not been exposed to a fair degree of light. For it has been recently shown by Dr. Daubeny of Oxford, that in fine weather a plant consisting chiefly of leaves and stems, if confined in a capacious vessel, and duly supplied with carbonic acid during sunshine, as fast as it removes it, will go on adding to the proportion of oxygen present so long as it continues healthy;—the slight diminution of oxygen and increase of carbonic acid, which take place during the night, bearing no considerable proportion to the degree in which the contrary effect occurs by day.

293. Thus we see that "the two great organized kingdoms of nature are made to co-operate in the execution of the same design; each ministering to the other, and preserving that due balance in the constitution of the atmosphere, which adapts it to the welfare and activity of every order of beings, and which would soon be destroyed, were the operations of any one of them to be suspended. It is impossible to contemplate so special an adjustment of opposite effects, without admiring this beautiful dispensation of Providence: extending over so vast a scale of being, and demonstrating the unity of plan upon which the whole system of organized creation has been devised."

294. And yet man, in his ignorance, and his thirst for worldly gain, has done his utmost to destroy this beautiful and harmonious plan. It was evidently the intention of the Creator that Animal and Vegetable life should every where exist together; so that the baneful influence which the former is constantly exercising upon the air whose purity is so essential to its maintenance, should be counteracted by the latter. Nothing is more prejudicial, therefore, to the health of a large population, than the close packing which too many of our cities exhibit; hundreds of thousands of men, with manufactories of all kinds, the smoke and vapours of which

are still more injurious than the foul air produced by his own respiration, being crowded together in the smallest possible compass, with scarcely the intervention of an open space on which the light and air of heaven may freely play, and without any opportunity for the growth of any kind of vegetation sufficiently luxuriant to give pleasure to the eye, or sufficiently energetic to answer its natural purpose. For the close confined air of towns is almost as injurious to plants as to animals; the smoke which is constantly hovering above them, prevents their enjoyment of the clear bright sunshine which they require for their health; and the fine dust, that is so constantly floating in the atmosphere, covers over their surfaces, and clogs up their pores.

295. Hence the low stunted dingy vegetation, which the squares and open spaces of some of our large towns exhibit, is of little service; but extensive areas fit for the growth of lofty trees, are so beneficial in such situations, that they have been called *the lungs* of large cities,—so important is the purification of the air which they effect. It is true that they may occasion some degree of dampness in the immediate neighbourhood; but this evil is much more than counterbalanced by the good they effect; so that the cutting down of a tree in the midst of a large town, without some very strong reason, should be regarded as an offence not easily to be atoned for. It is much to be wished that the law of the land required such an open space to be set apart, whenever the population of an extending town or district increases beyond a certain amount.

296. There is good reason to believe that Confervæ and other aquatic plants exercise a similarly important influence, in keeping the water they inhabit in a state fit for the support of animal life; since it appears probable that they absorb the products of the decomposition of that foul matter, by which all ponds and streams are constantly being polluted, and at the same time yield a supply of oxygen to the water. It is a fact well known that fishes are never so healthy in reservoirs destitute of aquatic plants, as in those in which they abound. The lower Cryptogamia appear to flourish better than higher plants would do, when supplied with a

large quantity of carbonic acid, whilst the amount of light they receive is but moderate. In the lake Solfatara in Italy are several floating islands, consisting chiefly of Confervæ and other cellular plants; which are copiously supplied with nutriment by the carbonic acid, that is constantly escaping from the bottom of the lake with a violence which makes the water appear as if boiling.

297. Under favourable circumstances, too, the highest plants are able to continue appropriating a larger proportion of carbon than that commonly existing in the air. The vegetation around the springs in the valley of Gottingen, which abound in carbonic acid, is very rich and luxuriant; appearing several weeks earlier in spring, and continuing much later in autumn, than at other spots of the same district. But it is probable that, taking the average of the whole globe and of all seasons, the quantity of carbonic acid commonly existing in the air, is that which is most adapted to maintain the life of the race of plants at present inhabiting its surface, as well as to interfere as little as possible with the well-being of the animal creation.

298. It is not improbable, however, that, in former epochs of the earth's history, a much larger amount of carbonic acid existed in the atmosphere. At the time of the existence of those vast pine-forests, which, in their decomposed state, supply us with such an enormous amount of that most valuable article of England's wealth—*coal*—an article more really valuable to her than the mines of Peru,—scarcely any land animals seem to have existed; and these were of kinds which are now found to be capable of breathing a comparatively impure air. The great luxuriance of these forests, as indicated by the vast amount of their remains, and by more perfect specimens which have been preserved to us, has led to the opinion that, at the period of their growth, more carbonic acid existed in the atmosphere than at present; and that, in fact, it has from that time been gradually undergoing purification by the processes of vegetable growth; and has at last become fit for the residence of the higher animals.

RETURN OF THE ELABORATED SAP.

299. The crude sap is brought into the leaves by the vessels which are connected with the woody portion of the stem; and these branch out and subdivide in the veins, so as speedily to distribute the fluid over the whole surface. After undergoing the various changes now described, it is collected again by a system of vessels which lie nearer the lower surface, and which communicate with the bark. These are principally of the kind formerly described as *vessels of the latex;* and through these the descending sap, now completely changed in its properties is returned to the stem. This fluid contains the materials of all the products of the vegetable system;—the elements of the organized tissues, the secretions which give solidity and toughness to the wood, those which occasion the delicious odours that so abound among plants, and those which supply so many useful and important products with which the comfort and luxury of man are largely connected. All these are entirely dependent on the action of the leaves; and the action of the leaves is dependent upon the supply of that amount of light and heat, but especially the former, which each species of plant requires.

300. It not unfrequently happens that a plant will *grow* under a considerable change of circumstances; but will not form its peculiar products in any thing like the same perfection as in its natural condition. Thus, Tobacco may be raised in this country, but it is far inferior to that of warmer and more sunny climes; as is also the scent of the Rose, which does not here furnish enough of the very fragrant oil termed Otto of Roses, to make it worth while to cultivate the plant for this purpose, although the oil is imported from the East at an enormous price. On the other hand, the common Lavender is more fragrant in this country than in the South of Europe. In general, plants grown in warmer climates, where the sky is less clouded, form secretions more active in every respect than those of temperate regions;—substances, for example, which are more powerful as medicines, or which have stronger and brighter colours, such as make them useful as dyes.

DEVELOPMENT AND DEATH OF LEAVES.

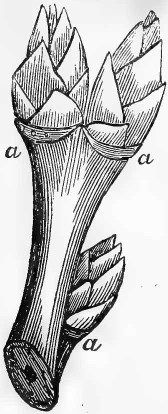


Fig. 44. Leaf-buds about to unfold; *a*, *a*, marks of the attachment of leaves, just above which buds are always developed.

301. When leaves are first produced, they are small, very delicate in texture, pale in colour, and packed very closely together, forming what is called a leaf-bud. Some of the outer ones are of firmer texture and darker colour, and fold over each other like the tiles on the roof of a house, so as to protect the soft and delicate organs within. These are commonly termed *scales*, being often very different from the true leaves in aspect; but there is no real distinction between them; for, on opening the bud, it is easily seen that their inner layers gradually approach the true leaves, in appearance as well as in structure, and at last pass almost imperceptibly into them. The young leaves are most beautifully folded together, in such a manner as to occupy the least possible space; and the peculiar mode in which this is done varies in different tribes of plants. Any one may examine it with the certainty of finding what will greatly interest him, by cutting across the leaf-buds with a sharp knife, when they are swelling, but before they have begun to expand. The outer scales are sometimes covered with a thick down, which may serve as a protection to them against the cold; and sometimes they are coated over with a gluey substance, as in the horse-chestnut, which seems a very efficient guard.

302. The young leaves in most leaf-buds may be easily observed to be arranged around a common centre or axis. When the bud lengthens, the insertions of the leaves, which were at first close together, are separated by the lengthening of the branch which bears them; and they then generally assume something of a spiral or rather a *cork-screw-like* arrangement round it, which is often very apparent. In fact this may be regarded as the regular

mode in which leaves are arranged upon any part of the stem or branches of a tree. Starting from any one leaf, we shall generally find the next leaf not exactly above or below that one, but a little to one side of the perpendicular; the next a little to one side of that;—and so on, until we come directly over the one from which we set off. We shall have thus made a spiral round the stem; and the number of leaves we meet with in its course varies in different species of plants. Sometimes it amounts to twenty or more. Sometimes we only find two; in this case each leaf is nearly on the opposite side of the stem from the other, but higher up or lower down. Leaves are then said to be *alternate.* The point of the stem from which a leaf originates is called a *node;* and the space between two nodes is called an *internode.*

303. Now although it may be considered as the *regular* kind of growth, for a branch to lengthen equally throughout, yet we not unfrequently meet with varieties in the arrangement of leaves, occasioned by the cessation of growth at particular points. Thus, if the internode between any two alternate leaves is not developed, the leaves will be *opposite* to each other. Again, where each spiral turn contains several leaves, if all the internodes between the highest and lowest be undeveloped, these leaves will arise from the same point of the branch, still growing, however, in their proper directions; so that a complete circle of leaves, resembling that of the leafy parts of a regular flower, will be produced; this is called a *whorl* or *verticil.* There are some plants which exhibit the true spiral arrangement, as their regular mode of growth; others in which we constantly find the leaves opposite; and in some they are always verticillate.

304. But there are many species which present differences in the arrangement of the various parts in the same individual, according to the circumstances under which each part has been developed; and it is by such examples that we are able to discern the connexion between the several modes of growth. Thus, in the *Rhododendron*, we find the leaves sometimes opposite, sometimes alternate. In the *Honeysuckle*, the leaves are naturally verticillate; but the whorls are broken up, and the leaves carried

to a distance from one another, by any thing which causes an increased development of the stem, just as when any leaf-bud (which has the young leaves arranged in a series of whorls, one above or within another) is elongated into a branch. On the other hand, in the *Strawberry*, the leaves which are usually alternate, become opposite or whorled at intervals. It is to be remarked that, when leaves are opposite, the several pairs are not in a line with one another above and below; but each is at right angles to the next; so that, if the internode between two pairs were undeveloped, a whorl of four leaves would be produced. Again, when one whorl is developed near another, their leaves do not issue from corresponding points in the stem, but are arranged in such a manner that the leaves of one arise from what seem to be the *intervals* of those of the other, so that the whorls are *alternate* to each other. The knowledge of this fact will be seen to be important, when the structure of the flower is described; as it will then be shown that its several parts are arranged upon the same principle with leaves.

305. It is by the development of leaf-buds into branches bearing leaves, and capable of producing flowers and fruit, that the tree or plant is increased in size. The leaf-bud has also the power of developing roots, if removed from the parent, and may thus form a completely independent structure. It is by separating the buds, and by placing these in circumstances favourable to their growth, that any particular variety of plant may be propagated more certainly than by seeds. As every bud is thus capable of maintaining an independent existence, it may be regarded as in some degree a distinct individual; and thus a tree would not be one being, but a collection of many. This is in part true; still it must be remembered that, while all remaining upon one stem, they are almost entirely dependent upon it for nourishment, and are all liable to be influenced in the same manner, by any circumstances which effect it.

306. Still it is quite possible for some buds to live while others die. Thus if arsenic be introduced into any portion of the sap-wood, it will give such a poisonous character to the fluid, that all

the buds and branches in the line above it will be killed, the others remaining unaffected. It has even occurred that a single bud at the summit of a stem has preserved its life, whilst the vitality of all the others, and of the stem has been in some manner destroyed; and that from this bud have been sent down bundles of root-fibres, between the bark and wood of the dead stem, which, when they have reached the ground, afforded abundant supplies of nutriment to the expanding bud; and this has subsequently grown into a perfect tree, enclosing the original dead stem within its trunk. The original root-fibres are, in such a case, surrounded in the ensuing year by another layer more resembling wood, and this in the next season by another; so that this portion of the structure, like the aerial roots of the Pandanus, may be regarded in the light either of stem or roots.

307. Leaf-buds are always formed from the *cellular* portion of the stem or branches, on which the function of extending the growth of the individual seems especially imposed. They may be distinctly traced, in young branches, to the pith; and where this has dried up, they may be seen to arise from the medullary rays. Sometimes they are stunted in their growth, and instead of being developed into branches, they remain as *thorns;* which are neither more nor less than short pointed branches, containing much dense woody structure (by which they are rendered extremely strong,) and being destitute of leaves. Any one may satisfy himself of this, by looking at the common Black-thorn, in which many intermediate conditions may be seen. Now under cultivation these undeveloped buds may be caused to become fertile branches; and this is another of the modes in which, in Linnæus's phrase, "wild fruits" may be "tamed." (§ 236.) There are no thorns stronger than those of the Acacia tribe, which are sometimes 5 or 6 inches long, formed with great regularity, and strong in proportion. The plants which bear them are often encouraged to grow in the East, for the purpose of forming hedges which serve most effectually to keep out intruders, unless these are covered with some almost impenetrable envelope.

308. The influence of light upon the green colour of the

leaves is remarkably shown, when the buds are unfolding. The stronger the sunshine, the sooner will they assume their characteristic hue; and, on the other hand, in dark dull weather they will remain for days together almost of the same colour as before they expanded. The following is an example of this fact more remarkable than is ever seen in this country. "It frequently happens in America that clouds and rain obscure the atmosphere for several days together; and that during this time the buds of entire forests expand themselves into leaves. These leaves assume a pallid hue until the sun appears; when, within the short period of six hours of a clear sky and bright sunshine, their colour is changed to a beautiful green." One writer mentions a forest on which the sun had not shone for twenty days. "The leaves during this period were expanded to their full size, but were *almost white*. One forenoon, the sun began to shine in full brightness; the colour of the forest absolutely changed so fast that we could perceive its progress. By the middle of the afternoon, the whole of this extensive forest, many miles in length, presented its usual summer dress."

309. The influence of light is also shown in modifying the direction of the stem. Where a plant sends forth a single stem or shoot, it will always direct itself towards the light; and this is especially manifested where the light comes in only one direction, as when a Potatoe, which has begun to grow in a cellar, sends a shoot of several feet in length towards any aperture through which even a small quantity of light finds admission. The reason obviously is, that, in consequence of the loss of fluid from the tissue of the stem, on the side on which the light falls, it is contracted, whilst that of the other side remains turgid with fluid; the stem makes a bend, therefore, until its growing point becomes opposite to the light, and then increases in that direction. Should any obstacle divert it, the same cause will bring it back.

310. The direction of the branches of trees growing in open spaces is less influenced by light; since the rays of the sun exert a much inferior power in this respect, when they are reflected from clouds and other objects, so as to form what is commonly

termed "diffused daylight." It is a curious fact, however, that there seems a tendency in almost every growing tree to send its principal trunk directly upwards. Experiments have been made for the purpose of changing this. For instance, the stem has been bent much out of the perpendicular by means of a rope tied round its summit, and has been kept so for a long period. The plant would then push up that one of the side-shoots which is most nearly in the line of the trunk; and this, increasing in length and diameter in successive years, will gradually present more and more the appearance of a continuation of the lower part of the stem, whilst that which was bent down presents the aspect of a branch.

311. The same means is adopted to repair a natural injury. Thus, the upper half of a large elm tree, which had a long straight trunk, the lower half being without branches, was broken off by a violent gust of wind. From the complete absence of leaves in the trunk that remained, it was not expected to survive; but, being in full sap at the time, the abundant nourishment it contained occasioned the development of buds which were previously inactive, and a great number of small branches soon issued from the stump. Of these, the upper ones have grown most rapidly; and the two highest which were at first nearly horizontal, have gradually changed their direction, so as to follow the line of the upright stem; and it now appears as if the trunk had originally divided, at that point, into two minor ones,—so completely has all appearance of the accident been lost.

312. The leaves of all plants have a very limited term of existence. In temperate climates most trees shed them during the autumn, and pass the winter in a state of complete inactivity. Before they fall off, the leaves usually change colour,—sometimes very decidedly, as does the Beech; and it has been ascertained that at this period they absorb more oxygen, and give out more carbonic acid, which indicates their commencing decay. This absorption of oxygen has been shown by experiment to be the immediate cause of the change of colour; since the green matter of leaves, when acted on by substances which readily yield oxygen,

is found to exhibit it. The separation of the leaf from the stem is probably due to several causes. During the latter part of the summer, some of the vessels become choked up with solid matter, and those which proceed from the interior of the trunk are over-strained by the addition to its diameter which has taken place, so that they are easily ruptured. The tissues of the leaf itself, too, are gradually dried up; and the whole structure loses its vitality, and is cast off as a dead part is from the body of an animal.

313. Trees and shrubs which are spoken of as evergreens, do not really retain their leaves for more than a year; but they are not cast off until a new crop appears, and the exchange does not take place suddenly but gradually, so that the aspect of the tree never undergoes much alteration. In evergreens, the functions of the leaves are carried on, though with great languor, during winter; but at other parts of the year they are less active than those of the species which lose their leaves in autumn. There are some trees of tropical climates which completely lose their leaves two or three times in every year, appearing as bare as in winter; and these are speedily replaced by a new crop. It is probable (though it has not been certainly ascertained) that in such trees, a new woody layer would be formed by every crop of leaves. In very hot and dry summers of this country, trees have been completely stripped of their foliage early in July, and have had strength to put forth a new and apparently vigorous crop of leaves. Such an effort, however, appears very exhausting to the tree, which is seldom so vigorous the next year.

---

314. The facts stated in this chapter respecting the influence of Vegetation on the surrounding air, are very interesting in connexion with a plan which has recently been practised with much advantage, of growing plants under glass cases very nearly closed. They are constructed of almost any form or size;—the experiment will answer with a chamber of a foot in each direction, or in one as large as a common green-house. The plants to be reared are placed in a kind of trough, with a sufficient quantity of light earth and water; and the glass cover is then fitted upon this in such a

manner as not to be quite air-tight, but to allow of extremely little communication between the interior and the surrounding air. The advantage of this system is, that the plants are kept in an atmosphere thoroughly saturated with moisture; and that they can obtain the necessary supply of carbonic acid (which finds its way through the crevices beneath the glass cover) without being also exposed to the impurities which the atmosphere contains. In London and other large towns, the air is loaded with particles of soot and dust, which are so injurious to vegetation, that none but the most hardy plants will flourish there without some protection; yet under this system, the most delicate and beautiful plants may be reared, provided they are sufficiently supplied with light and warmth. Again, many plants are killed by exposure to the sea-air during long voyages; this being loaded with particles of salt. But under this protection, plants have been successfully transported to England from the most distant quarters of the globe, which could only be previously introduced by seeds. By the adoption of this plan, many who take an interest in the cultivation of plants too delicate for our own climate, may indulge their taste at a small expense. A window should be selected with a southern aspect, or nearly so, and a second pair of sashes should be fixed at the distance of a foot or 18 inches within or outside the first, as may be most convenient,—the fitting of the whole being as tight as possible, consistently with the easy movement of the inner sashes. In the space at the bottom, a trough is placed containing moistened earth; and the plants grown in it should be so trained as to expose the surface of their leaves to the light as freely as possible. If a winter warmth is required, the window of a sitting room in which a fire is constantly maintained, should be selected; and this will suffice to grow many plants which naturally inhabit the warmer regions of the globe. This method is particularly adapted for the growth of Ferns.*

* The public are indebted for this important system to Mr. N. B. Ward, of London. The author has that gentleman's authority for saying, that the common notion that the external air should be *completely excluded*, is quite an erroneous one.

CHAPTER IX.

GENERAL REVIEW OF THE NUTRITIVE PROCESSES IN PLANTS.

315. The functions of the several organs concerned in the Nutrition and Growth of the plant having now been separately described, it next becomes desirable to take a general review of the whole, and to trace the connexion between their respective actions, and to point out their bearing on the object of the whole of this beautifully-arranged system. When we look at a well-ordered household, we observe that the actions and duties of each member of it are planned and arranged by the heads of the family, so as to accord with their respective qualifications, and at the same time to conduce to the comfort and happiness of the whole; and the more completely this is accomplished, the greater is the harmony and regularity with which the labours of the whole are performed,—the less is the liability to interruption, arising either from the caprice or incapacity of any of the labourers. And in proportion to the completeness with which this end is gained, do we think highly of the wisdom of those who have studied and executed the means of attaining it.

316. Now the economy* of the vegetable is precisely analogous to that of such a household. The whole structure is composed of a number of different *organs* or members, having different parts to perform in the general scheme; and these parts or *functions* are so beautifully adjusted together, that, in every variety of circumstances in which the being is liable to be placed, they shall

* This word literally signifies *household-law;* and in this sense it is applied in physiology, to designate the regular harmonious system on which the actions of living plants and animals are performed.

still be executed in harmony, and with one common purpose. Thus we have seen that one organ pumps up the required water, another carries it, another uses it in cooking, another gets rid of the waste, another obtains the solid food, another carries the cooked provisions to all parts of the structure, another stores up the superfluity, another builds additions to the edifice, whilst another prepares to send out a colony, furnished with supplies or food, and with every thing requisite to begin life for themselves. Now we have considered the separate parts of the establishment—we have inspected the pump, the conduits, the kitchen, &c.; the general economy of the whole remains to be reviewed. And if we have seen a Wise Design in those, our ideas will be still farther elevated by this mode of viewing the subject.

317. We have seen that the fluid absorbed by plants consists of water, in which are contained carbonic acid and ammonia; and in which are also dissolved the various mineral substances which each species requires for its healthy existence, but which contribute nothing to the formation of those peculiar organic substances that compose the vegetable tissues. The conversion of these elements into the substances intended for the nourishment of the plant begins very low in the stem; and the proportion of them increases as it ascends. The substances at first produced are *gum* and *sugar*, which are the simplest in their chemical nature of all organic compounds; being made up of oxygen and hydrogen in the same proportions as water contains, with the addition of carbon. Being nearer inorganic bodies in their composition, and in the tendency of the latter to the crystalline form, they are also nearer in properties; for they may be preserved for years in a dry state, without any impairment of their characters, since their tendency to spontaneous decomposition is not greater than that of many mineral substances.

318. The crude sap immediately that it has been absorbed, begins to mix with the matter which has been stored up from the previous year, in the tubes and vessels through which it rises; and in proportion as it ascends the stem, it dissolves more and more of this, so as gradually to present in taste, odour, &c., the peculiar

characters of the plant itself. The object of this admixture has been already stated (§ 119,) and it also probably has another. It seems to be a general law of the organized world, that the *raw material* taken in as an aliment by any being, cannot be assimilated (that is, converted into the nutritive matter required to repair, renew, or extend its tissues,) without being mixed with matter previously assimilated. Thus, in animals, the chyle which is taken in from the food in the intestines, and which contains the materials of blood, is not sent to nourish the system until it has been mixed with the blood previously circulating, and acted on by it. In plants this object is effected during the period of active vegetation, by the admixture of a portion of the descending sap with that which has been just absorbed; but as all activity ceases during the winter, the same object is provided for in the autumn, by causing the essential parts of the sap to be deposited in the tissues, so as to be dissolved in the ensuing spring.

319. Although the peculiar characters of the proper juices of the tree are thus communicated to the ascending sap, yet they are possessed by it in but a very slight degree; and it is in consequence of this, that the ascending sap of all trees possesses very nearly the same properties;—as is shown by more than one curious fact. There are some plants which have not the power of forming true roots for themselves, and which obtain their supply of sap from the stems of trees to which they attach themselves. Such is the common Misseltoe. The seeds of this plant are deposited by birds on the exterior of the stems and branches of trees; and the root-fibres which they put out, insinuate themselves through the crevices of the bark, and incorporate themselves with the wood.

320. Now the Misseltoe imbibes the *ascending* sap from the wood of the tree or *stock* on which it grows; and this it converts into a proper juice, adapted to nourish its own structure, by means of its own leaves. The ascending sap of most trees being nearly alike, the Misseltoe seems to grow with almost equal facility on a great variety. It is remarkable, however, that it is very rare on the oak; and it is perhaps this circumstance, which caused the

plant when found in connexion with that tree, to be regarded by the ancient Druids in a religious light. Perhaps it is the *tannin* produced by the oak, of which a small portion will be contained in the ascending sap, and which has been already spoken of as exerting a prejudicial influence on the vegetation of most other species (§ 209,) which is unfavourable to the growth also of the Misseltoe.

321. Now it is a very curious fact, that the law of growth of these root-fibres is different from that which governs other roots. For whilst the latter grow downwards towards the centre of the earth, these grow towards the centre of the bough or stem into which they may be penetrating. This tendency was ascertained by the experiments of the French physiologist Dutrochet, who caused a seed of Misseltoe to germinate when hung by a thread near a large ball of metal; and he found that the radicle always directed itself towards the centre of this ball, near whatever part of the surface it might be placed. By this curious adaptation, the Misseltoe, which, from the want of power to form perfect roots, would otherwise be unable to exist, is endowed with a compensating power;—it being as much a part of its natural habits to grow upon the stem and branches of trees, as it is for other plants to send their roots down into the ground.

322. The fibres of the Misseltoe seem to incorporate themselves completely with those of the stock; and so intimate is the connexion between them, that coloured fluids will pass from the stem into this *natural graft*,—for so it may be termed. It does not appear, however, that any communication exists between the parasite and the bark beneath it, which is always found to be in a dead state around its insertion. But if the part of the branch at which it penetrates be divided with a saw, it will be seen that the two woods are so thoroughly united, that the line of separation between them can scarcely be traced. That the Misseltoe is itself quite deficient in the power of absorbing fluid, has been clearly proved by experiment. If the stem of this plant be cut off and immersed in water, it will absorb little or none of the fluid; whilst, if a portion of the branch with which it is connected

be cut off and immersed in a similar manner, it will absorb nearly as much as if furnished with leaves of its own.

323. A curious fact illustrative of the great difference in the characters of the ascending and descending sap, is that the former is nearly or quite harmless in those plants whose proper juices have the most virulent properties. Thus, the inhabitants of the Canary islands draw off the former, which serves as a refreshing drink, from the interior of the stem of the *Euphorbia canariensis;* a tree of which the descending sap is of a very acrid nature, resembling that of the common Spurge of this country, but much more powerful.

324. The conversion of the water and carbonic acid absorbed by the roots into gum or sugar, involves the setting free a portion of the oxygen contained in those compounds; for as water is composed of oxygen and hydrogen, and carbonic acid of oxygen and carbon, it is evident that, in the production of any substances containing no very large proportion of oxygen combined with carbon and hydrogen, there must be a superfluity of the first of these ingredients. This oxygen is probably conveyed away by the spiral vessels which form the medullary sheath of Exogens, and which are diffused through the woody bundles of the stem of Endogens. These spiral vessels communicate with the leaves; and through them, the oxygen is given off to the atmosphere. By dividing stems under the surface of mercury,* and collecting the minute bubbles of gas which arise from the cut ends of the spiral vessels, it has been shown that they contain a considerably greater proportion of oxygen than exists in the atmosphere.

325. The processes by which the crude sap conveyed to the leaves is converted into the "proper juice" of the plant, have already been described in so much detail, that it is not necessary to do more than briefly recapitulate them here. By Exhalation and Evaporation a great quantity of superfluous water is got rid

* This fluid is used instead of water, when it is desired to collect gases which might be absorbed by water. In the present case it is employed to prevent any carbonic acid that might exist in the vessels, from being undiscovered, through the absorption of it by the water.

of; and the fluid is thus concentrated. By the absorption of carbon under the influence of light,—the process to which the name of *Digestion* may be given,—a large quantity of solid matter is added to it; and the materials are afforded for the increase of the woody structure, which requires this ingredient in a peculiar degree. And by the process of Respiration is removed the product of the slow decay of the whole structure, which would be highly injurious if retained within it.

326. We must remember, however, that, in speaking of these changes, we only state the *evident results* of those more obscure ones which take place in the interior of the plant, and of which the nature is still unknown. In all plants, the functions of Exhalation, Digestion, and Respiration, are performed almost in a similar manner; and the materials upon which they operate are (as already explained) nearly of a similar character; and yet the products are remarkably different. In nearly all of them, however, the material of the tissues themselves is the same. Woody fibre, for example, is found by the chemist to be composed of the same elements, in the same proportions, from whatever tree it is taken, provided it be cleared from those substances which are deposited within it for the purpose of affording it additional strength. But when we look at the immense variety of products which the vegetable kingdom supplies, varying no less in properties than in appearance, we are lost in wonder at the marvellous nature of those processes, in which a difference, undiscoverable by all our most refined means of research, shall be productive of such a number of widely-different results. And at the same time the reflecting mind cannot forget that these results are all of a kind most valuable to Man, furnishing him with the necessaries, the comforts, and the luxuries of life,—support in health, medicine in disease, and the materials of great part of his clothing, his books, and various articles which minister to his mental and moral improvement.

327. These substances may be distinguished under two classes;—the *nutritive products*, adapted to supply the materials of increase to the tissues themselves;—and the *special secretions*,

which are for the most part contained or stored up in them. The former are common to all plants; of the latter different kinds exist in the various tribes.

328. Of the nutritive products, which are carried by the descending sap to all parts of the structure, (as are those of a similar nature contained in the blood of animals,) the principal is *Gum*. This is found in the bark and wood of all plants; and is present in such abundance in several, which are called Gum-trees, as to flow in plenty from the bark when wounded, or when its surface cracks. Of these trees, most belong to the Acacia tribe; and it is in warm climates only that the formation of this product is so abundant as to make the collection of it desirable. Various modifications of this principle exist in different vegetables; but they may all be regarded as combinations of pure gum with other substances. Gum Arabic is one of its simplest forms; this is really brought from Arabia, where it is annually collected in the Acacia forests, at the end of November. A large quantity is imported into this country, on account of its extensive use in calico-printing and other arts. It is a highly nutritious substance to man and animals; and it forms an important article of diet in Arabia and Senegal. Those who are engaged in collecting it live for a time almost entirely upon it; and six ounces have proved sufficient to support an adult for 24 hours. It is on record that a caravan crossing the Desert, their provisions being exhausted, preserved themselves from famine by eating the Gum Arabic which formed part of the merchandize they were transporting. But no animals could continue long to subsist on this ingredient alone; since it contains no nitrogen, which is still more essential to *their* support than to that of plants.

329. Gum is almost the only organic substance that seems to be immediately applied to the nutrition of the plant, when absorbed from without, instead of being first decomposed into water and carbonic acid; for a plant thrives well in a solution of it. This is evidently because it thus supplies an important ingredient in the ascending sap, in which it would otherwise have to be formed. (§ 317.) The gum contained in the elaborated sap

appears to have undergone some change, which renders it more prepared for being converted into an organized tissue. It is this, which, being poured out between the bark and the newest layer of wood, is the viscid substance termed *cambium;* in which the rudiments of the cellular tissue, that is to form part of the new layer of wood, after a time present themselves. Even if this cambium be drawn off from the stem, its particles show a tendency to arrange themselves in a form resembling that of cells and vessels; though no perfect tissues are produced by this kind of coagulation. The interior of young seeds is filled with a glutinous pulpy fluid of a similar description; and partitions gradually appear in this, converting it into a mass of cellular tissue.

330. If a wound be made in the bark, a similar glutinous exudation is thrown out from the cut edges; and by the conversion of this into solid tissue, the wound is gradually healed. If a complete ring be cut away from the bark, this exudation will be much the greatest on the *upper* side,—showing that it comes from the *descending* sap; but it is not altogether confined to that edge since a portion of the descending current, having been carried by the medullary rays into the interior of the stem, is not checked by this interruption to its flow through the bark. Thus we perceive that, although there is not in Plants, as in Animals, a regular continuous circulation of nutritious fluid,—that which has once passed through the system of the latter, being impelled again through its vessels, after having undergone the necessary purification,—Nature has provided for the reparation of their wounds in the most advantageous manner.

331. From this form of Gum it would appear that the materials of cellular tissue are produced; but those of woody fibre are not the same in chemical constitution, containing a larger proportion of carbon. And thus we see why it should be peculiarly necessary for the production of woody fibre, that the leaves should be exposed to the full influence of light, by which alone the proper amount of carbon can be introduced into the system. As already stated, whilst cellular tissue increases in every direction, woody fibres seem to grow almost exclusively downwards. They

may be traced gradually descending from the leaves, in which they always originate, just as the roots make their way through the earth. They pass down in the space between the bark and wood, at the time the cambium is there; and this fluid probably contains the materials for both tissues. If an obstacle intervene,—as, for example, a branch passing off from the stem,—they do not stop in consequence of it, but separate to one side and the other, and re-unite below, just as a bundle of roots would have done. These fibres, being intermixed with the cellular tissue produced by the cambium, compose the new layers of wood and bark, of which a new one is formed every year; and it is in this way that those additions are made to the quantity of solid matter contained in the stem, which the supply of descending sap is principally intended to furnish.

332. The production of new buds is accomplished, as already stated, by the cellular tissue alone; and as they are connected more or less closely with the medullary rays, it is easy to understand how they derive their nutriment from the descending current. Nothing but cellular tissue exists in them, until they have expanded themselves into true leaves, and then they form the materials of woody fibre for themselves. The same is the case with flower-buds, seeds, and other young parts. The substance termed *pectin*, which constitutes the jelly of fruits, is very closely allied to gum, and may be converted into it.

333. Although *Gum* seems to be the chief nutritious product of the assimilation, by the plant, of the substances which formed its aliment, it is not the only one. *Sugar* in many cases appears to have the same office, especially in young and rapidly-growing *parts*. Thus, the starch of seeds is converted into sugar in the first stage of their growth (§ 283.;) and the sugar is dissolved by the water around, and carried up the young stem to the leaves. The starch existing in the disk of flowers, again, is converted into sugar for the nourishment of the young seeds; and it is the superfluous portion of this which flows off in the form of honey. There are particular plants which contain a very large proportion of sugar, just as we have noticed others which abound in gum. Such are

the Sugar-Cane, the Beet-root, and the Maple. The sweet juice which abounds in the Sugar-Cane is exhausted by flowering, and appears, therefore, destined for the development of the set of organs concerned in that process. The same is the case with the Beet-root, and also in the Maple; in the former, the sweet juice does not begin to accumulate in the roots, until the development of the growing parts has ceased for that year; in the latter, the juice which was previously sweet ceases to be so whilst the tree is putting forth its buds, leaves, and blossoms; in both these instances, the use of the sugar in the vegetable economy is clearly seen.

334. Of the importance of Sugar as an article of commerce little need be said. The annual production in different parts of the world is estimated at not far from 20 million hundred-weights, or a million of tons; and this is nearly all obtained from a single kind of plant,—the Sugar-Cane. The soft spongy tissue of this plant, previously to its maturity, contains a large quantity of a sweet juice, which is pressed out from the stems by passing them between rollers. This juice is boiled down into a thick sirup, which crystallizes and deposites the sugar it contains. This is what is commonly known as *brown* sugar; and it has to undergo a subsequent process of refining, in order to convert it into *white.* In Canada and other parts of North America, a good sugar is produced from the Maple, by tapping the stem when the sap begins to arise in the spring; the quantity of sugar obtained, by boiling the sap that flows from one tree during a period of six weeks, is sometimes as much as 30 lbs.

335. It is not unfrequently necessary that a store of nutritive matter, which may be required at some future time, should be provided in the Vegetable system, in such a situation that it shall be out of the general current of the circulation, and at the same time easily brought into it. In animals, the *fat* constitutes a store of this kind. The superfluous nutriment introduced into their system is converted into this substance; which, besides other purposes that it serves, is ready for the support of the body, when from any cause there is a failure of the supply on which the animal usually

depends. In some animals, this production of fat takes place at regular periods; thus Bears, which pass nearly the whole winter in sleep, and take little food during that season, become very plump in the autumn, and are observed to be very lean soon after they have emerged from their winter retreat.

336. Now the *Starch* which is found so abundantly in many plants, and in some part of almost every one, serves the same purpose as fat. It is gum, slightly altered, and enclosed, as it were, in a series of minute bags, which fill the cells of cellular tissue and receive their form. Starch, when removed from the plant, exists in the form of minute granules; each of which, when examined with the microscope, is found to consist of a series of layers of a half-fluid substance, the interior ones being nearly fluid like dissolved gum, and those on the outside being almost as firm as membrane. When put into cold water, they retain their structure, as the outside layer is not acted on by that fluid; but when exposed to a heat of about 160°, this little sac bursts, and its contents are set free and dissolved in the water; and this is why starch, once dissolved in hot water, can never be restored to its original form.

337. Thus, then, we may consider starch as little else than gum divided into minute portions, and stored up out of the way of the nutrient fluid, which would otherwise dissolve it whilst circulating. In all instances, the stores of this substance appear destined for the nourishment of young parts; since they are found in the neighbourhood of these, and are exhausted by their growth. Thus, starch forms a large part of the substance of all seeds; sometimes (as in the Corn grains) being deposited *around* the germ of the young plant; and in other cases (as in the Pea and Bean) being included *within* it, forming the large fleshy cotyledons or seed-leaves, which first come to the surface after the seed has begun to sprout, and which wither in proportion as the young plant developes itself. Starch is found abundantly, again, in the fleshy underground stems destined to nourish young shoots; as are the tubers of the Potatoe, and the rhizoma of the Arrow-roots; and it has been lately pointed out that, if the blossoms be pulled

off the plants before opening, the accumulation of starch will be much greater, in consequence of the exhaustion of the store having been prevented. Starch is also abundant in the fleshy roots which have to furnish nutriment to the young stems, when they first begin to grow, as in the Briony and Elecampane. It is also found in the pith and bark of many Exogens, and in the cellular tissue occupying the centre of the stem of many Endogens (such as the Sago Palm,) where it forms a reservoir of nutriment for the young leaves.

338. The deposite of starch generally continues to increase so long as the plant which forms it is in active vegetation. It then arrives at its greatest amount, and remains the same until the young parts which are to be supplied from it have begun to grow; and then it rapidly diminishes. Thus, it has been stated that a hundred pounds of potatoes contain of starch,

In August	10lbs.	In March	17lbs.
September	14½lbs.	April	13¾lbs.
November	17lbs.	May	10lbs.

339. Although this deposition of starch fulfils a part so evidently important in the vegetable economy, we cannot doubt the wise and benevolent intention of the Creator, in thus providing a store of nutritious and palatable food for man in situations in which he can so easily obtain it; and it is interesting to remark that, from the completely separate form in which it exists, it may be obtained in a state of purity from many vegetables, which, as a whole, are of very poisonous character. An illustration of this fact occurs in the Cassava, which forms a most important article of food in almost all the warmer regions of the globe. This substance is the starch contained in the root of a plant termed *Jatropha Manihot;* and the root also contains a juice so poisonous, that it is employed by some of the savages among whom this plant abounds, to tip their arrows and spears. The root is usually ground or rasped into a sort of coarse meal; and from this, when put under pressure, the juice runs off, leaving the starch nearly pure. The *Tapioca* of Brazil is nearly the same with Cassava.

340. Starch cannot be applied to the nutrition of the tissues however, without undergoing an important change, which reduces

it, in fact, to the condition of sugar or gum. Of this change there are many instances in the progress of vegetation. That which is best known is the conversion of the starch of seeds into sugar, which takes place during germination; and upon this the process of *malting* is founded. The grain of barley contains a large quantity of starch; but, when the embryo is made to sprout, this starch is converted into sugar for its nourishment. Now the germination of the seed is caused by steeping it in water, and then placing it in a warm atmosphere; and this is the first stage of the process of malting. As soon, however, as the growth of the embryo has proceeded far enough for the proper quantity of the starch to be converted into sugar (which is known by the length of the young root and by the appearance of the grain itself,) the germination is checked by the application of a higher degree of heat, which kills the young plant; and the newly-formed sugar can then be employed to give sweetness to water or other fluids. In the same manner, the starch of Potatoes and other tubers, is converted, when required for the nourishment of the growing buds, into sugar, which is absorbed by their vessels; and nearly the same may probably be said of every other instance in which starch is laid up for a purpose of this kind.

341. Now this change of starch into sugar is one of a purely chemical nature; for it can be performed in the laboratory of the chemist, by pouring hot water on the starch, so as to break the vesicles and set free the contained gum; and then treating this with a weak acid for some time; by which the whole is converted into a sugar that scarcely differs from that of other kinds. In the Vegetable economy, however, this change is effected by another means. In the juices of the plants themselves, there is a substance termed *diastase*, very minute quantities of which have the remarkable property of changing starch into sugar. This diastase exists in seeds, and is found in larger quantities near the *eyes* or young buds of the Potatoe, by the vessels of which it is carried through the mass of starch when required. How beautiful an arrangement it is, that a substance possessed of the remarkable property of converting starch into sugar, should be formed wherever

a store of the first of these substances is laid up for the purpose of affording a supply of the latter when required,—and that this *diastase* should be found nowhere else than in the very parts of the vegetable structure in which it will be of use!

342. We see, then, that the form in which nourishment is conveyed to the growing parts of plants is that of *gum* or *sugar*. These two substances are composed of the same elements in nearly the same proportion; and the former may be changed into the latter. They are usually found together in that thick mucilaginous* fluid which lies between the bark and wood in summer, and which is gradually organized, or converted into tissue; and also in that which forms the pulp of the very young seeds which exist in the seed-vessel before the flower has fully expanded. The gumminess of this fluid is at once perceived by its glutinous properties; and that it contains sugar is known by the sweetness of its taste. Gum and Sugar, therefore, are to be considered as the materials out of which the Vegetable tissues are constructed; and Starch must be converted into one of these before it can be applied to a similar purpose.

343. Now the proper juice elaborated by the leaves of one plant may sometimes serve for the nourishment of another. A group of parasites, which, having leaves of their own, can elaborate for themselves the crude sap they obtain from the roots of another tree, has been already described (§ 320,) but there is another which is destitute of leaves as well as of roots, and which is therefore dependent for support on the elaborated sap of the plants, to which its different kinds respectively attach themselves. And as the nature of the proper juice of each species varies much more than does that of the crude sap, these parasites cannot subsist upon the fluids of many different species, but are for the most part restricted to those of a few. Most of them grow upon the roots or underground stems of others; no part of them appearing above the surface (in general at least) except the flower-stalks which are occasionally sent up. They abstract the nutritious fluid from the plants to which they cling, by means of a number of

* Mucilage is the term applied to a solution of gum in water.

little suckers which are formed upon their roots, and which fix themselves to the bark of the stems and roots; and in this manner, they not unfrequently cause the death of the plant, by drawing off its juices.

344. One of the commonest kind is the *Orobanche*, or Broom-rape, so named from the ravages it is thought to commit on the Broom and Gorse of our heaths. The different species of this plant infest different kinds of vegetables; thus the one which infests broom and furze also attacks clover; and in many parts of Flanders, the farmers are altogether deterred from the cultivation of clover by this species, of which the seeds lie dormant in the soil, until it is made to support plants upon which the parasite can grow, and which it then attacks vigorously. Another species of this genus confines itself to certain Composite flowers, as the Centaury and the Scabious; and this occurs on the red Clover and on the Cats-ear; and one species is found exclusively upon the roots of Hemp. The *Cuscuta*, or Dodder, is another plant of the same description, which attaches itself to the stem of the nettle, clover and other plants, round which it coils in a direction contrary to that of the sun. When luxuriant, the Dodder gives a strange appearance to the herbs and bushes on which it grows, covering them, as it were, with a veil of reddish, leafless stalks, studded with blossoms. Their seeds, unlike those of most other parasitic plants, germinate in ordinary soil; but if the seedlings be kept there, they will soon wither and die, from the want of their peculiar nutriment. Some parasitic species derive a part of their aliment, in their adult condition, from true roots spread through the soil; but are still dependent for most of the solid matter they require, upon the supply of ready-elaborated sap, which they obtain by their suckers from the plants upon whose bark they fix them.

345. From these naturally parasitic plants, we may pass to those which are rendered so by artificial means. It will be hereafter explained (Chap. XII.,) that the cultivated *varieties* of plants cannot be propagated with any certainty by seeds, from which we are only sure of obtaining new plants of the same *species*, (§15.) Thus, the seeds of a Golden Pippin or of a Russet, sown in

different soils, will all produce plants bearing Apples of some sort; but these are not likely to bear any greater resemblance to the parent or to each other than all Apple-trees have to their kind; and the character of their fruit will be quite uncertain,—it being little better, if the soil be poor, than that of the Crab, from which all the varieties of Apple have originated.

346. In order to propagate any particular variety of fruit or flower, the cultivator reserves some of the leafy buds of the tree or plant, and places these in circumstances favourable to their growth. In many instances, the leaves or leaf-buds have the power of forming roots for themselves; and this is especially the case when the neighbouring part contains a temporary supply of nourishment for them, such as the tuber of the potatoe imparts to the *eyes*, or buds it contains. Thus, if the young branches of a Vine be cut into as many pieces as there are leaf-buds, and these be properly laid in a favourable soil, and stimulated to growth by heat and moisture, they will soon put out roots and become perfect plants; being at first supported by the nutritious matter contained in the wood to which they adhere, and afterwards by the products of its decay. It is in this way that Sugar-cane is propagated,—the plants that spring from these cuttings being more vigorous, and coming earlier to maturity, than those raised from seed. This method is often employed by the Gardener; who sometimes varies it, by not detaching the bud from the parent stock, but by bending a branch into the earth, and letting it be partly supported by the juices of its parent, until it has put forth roots for itself. This is termed propagating by *layers*.

347. But there are many cases in which it is desirable not to trust to the power which the bud may possess of forming roots for itself; and advantage is then taken of the tendency which the growing parts of plants have to adhere and become united to each other. Such adhesions not unfrequently take place from natural causes. Thus, if two branches, either of the same or of different trees, be lying across each other, in such a position as to rub against one another when moved by the wind, the bark will be worn off from each, and a fluid will be exuded from the wounds which

will be in time converted into solid tissue. This is capable of conveying sap from one branch to the other; for a tree that has been thus united (for the sake of experiment) to two others, and has been then cut off from all communication with the soil, has continued to live, without any other supply than that which it derived through these trees. This natural adhesion of vegetable tissue is well seen in the ivy; the branches of which often interlace and graft together in various places, until the whole forms a rude net-work, enclosing the trunk of the tree on which it has climbed.

348. Now the gardener imitates this process, when he wishes to supply the separated buds of a tree or plant which he desires to propagate rapidly, with nourishment ready to be elaborated by its leaves. He chooses a *stock*, or stem deprived of its own buds, and cuts off its top in a sloping direction, so as to expose a large surface of wood and bark. He cuts the lower end of the young branch, termed the *graft*, in a similar manner, and then fixes them together, taking especial care that the bark and wood of the one should meet and join with the bark and wood of the other. If the operation succeeds, the stock and the graft become so completely united together, as to form in time but one tree, in which all mark of the original separation has disappeared. The stock draws up from the soil the fluid which the leaves of the graft require; these obtain carbon from the air, and elaborate the crude sap into proper juice, a portion of which is supplied by the graft to the stock for the extension of its own tissues, just as if the stem really belonged to it.

349. To effect this object, it is generally necessary to choose as the stock, a plant either of the same species with the graft, or one very closely allied to it; and the less the relationship, the more care and precaution must be taken to secure a union, by bringing the newest layers of bark and wood into contact. It is customary to select for the purpose some less valuable form of the same species; thus the cultivated varieties of Pears and Apples are grafted upon the Wild Pear and Crab. Or a species nearly allied will sometimes answer almost as well, and, from being readily procured, is commonly employed; thus, Peaches and Apricots are grafted on the common Plum. The operation does not always

succeed between two species of different genera; and it fails entirely, if an attempt is made to unite individuals of different families. Thus, for example, Pears answer well upon Pears, nearly as well upon Quinces, less freely upon Apples or Thorns, and not at all upon Plums or Cherries which are of a different family. The Lilac will take upon the Ash, notwithstanding their great apparent difference, because they are of the same natural family; but the Olive, which also belongs to the same family, cannot be profitably grafted upon the Ash, since the vegetation of these is too different to allow them to live long together.

350. From what has been said regarding the readiness of the Misseltoe (which may be considered as a *natural graft*) to grow upon various kinds of trees, and the great similarity of the ascending sap in most of these, it is evident that the cause, which thus restrains the gardener in the choice of his stock, is not merely the difference in the properties of the fluids of the two kinds, but also the difference in the general character of their growth. It is essential that the stock and graft should be naturally in sap at the same time; and this is more likely to be the case in nearly-allied species than in others. However, in very succulent plants, such as the Cacti, of which the fleshy stems are always full of fluid, grafts of very different species succeed very well together; and this exception helps to prove the rule. It is necessary, also, that the rate of growth of the two should be nearly the same; for, if the graft be of more rapid growth than the stock, and more be sent down to the latter than it can convert into tissue, a swelling will be formed above the line of union, like that which takes place when a cord is bound round a stem (§ 144;) and this will increase so as in time to cause the death of both parts, by altogether obstructing the passage of fluid.

351. Not only does the process of grafting enable the gardener to multiply with greater rapidity, and to preserve with more certainty, any valuable kinds of flower or fruit, but, by the judicious selection of a stock, a favourable influence may be produced upon them. Thus, the more delicate kinds of Vines produce larger and finer grapes when worked upon coarser and more robust

kinds; and the Double Yellow Rose, which seldom opens its flowers, and will not grow at all in many situations, blossoms abundantly, and grows freely, when grafted on the common China Rose. Some statements, however, which impute to the stock a much greater influence, are without any foundation in truth. Thus, it has been asserted that Roses became black when grafted on Black Currants; and Oranges crimson if grown upon the Pomegranate:—but this is altogether erroneous, as these species will not unite at all.

352. Errors in regard to the success of the progress have arisen from an occurrence that sometimes takes place,—the formation by the graft of independent roots, which supply it partly or wholly with nourishment, with little or no assistance from the stock. In this way has been explained the fact that the Olive has been made to grow upon the Fig tree (as recorded by Columella, one of the earliest writers upon Agriculture;) for no proper union can take place between them, on account of the wide difference in their character. Mention is made by Pliny of a tree in the garden of Lucullus, which was so grafted as to bear pears, apples, figs, plums, olives, almonds, grapes, &c.; and at the present time the gardeners of Italy sell plants of Jasmines, Roses, Honeysuckles, &c., all growing together from a stock of Orange, or Myrtle, or Pomegranate, on which they say they are grafted. But this is a mere cheat;—the fact being, that the stock has its centre bored out, so as to be made into a hollow cylinder, through which the stems of Jasmines and other flexible plants are easily made to pass, their roots intermingling with those of the stock. After growing for a time, the increase in the diameter of the stems thus enclosed forces them together, and they assume all the appearances of being united. Such plants are of course very short lived.

353. It may be useful here briefly to retrace the mode in which the elaborated sap is prepared and circulated. The roots (or, failing them the general surface of the plant, especially the leaves and young bark,) absorb fluid, which consists of water, usually having some carbonic acid and ammonia diffused through it, and also containing a small proportion of earthy matter, (§ 169.) This fluid is conveyed to the leaves, in part by the attraction which they have for it, and in part by the propelling

force of the roots, (§ 116.) Whilst ascending the stem, it is mixed with some of the fluid previously elaborated, and it undergoes some changes, in which oxygen is set free, and in which the quantity of gum and sugar contained in it is increased. In the leaves, a large quantity of superfluous fluid is parted with, by *exhalation* and simple *evaporation;* and a great deal of additional carbon is obtained by the green surfaces from the carbonic acid of the air, under the influence of sun-light; at the same time a small quantity of carbonic acid is being constantly set free from the whole surface by the process of *respiration*, oxygen being absorbed.

354. These are the principal changes which can be detected by the observer; but there must be others of a much more extraordinary nature, taking place within the vessels of the plant, by which, from the simple elements just enumerated, those peculiar substances are formed, which are to serve for the nutrition of the structure, or are to be laid up for some yet unknown purpose in its economy. Of the mode in which water and carbonic acid are changed into gum or sugar, the chemist is entirely ignorant; and although these are the most simple of all the extraordinary conversions which take place in the assimilation of inorganic matter, he is completely unable to imitate it. There is reason to hope, however, that he will not long remain so; since some animal compounds have been produced by artificial means.

355. A still greater mystery is the process by which the elaborated sap is converted into cellular tissue or any other form of vegetable structure. Some parts of this process have been observed, and will now be described; but of *the cause* of the changes, nothing is known. The young seed, before the flower has expanded, is filled with a sort of sweetish mucilage, which is ready to become organized. The first step consists in the appearance, in what was before a nearly transparent fluid, of a large number of very minute granules. Soon afterwards larger granules appear, round which the smaller ones cluster; and they soon present a regular form, resembling that of pieces of money, being flattened and circular disks. On one surface of each of

these, a delicate membrane is seen to project, just as a watch-glass projects from the face of a watch; and this membrane gradually extends much beyond the original disk, so as to form a kind of bag, in one wall of which that body is included. Still, the membrane is of so delicate a consistence, that it is easily dissolved away by shaking the vessel in which the process is being observed; and it is not until some time afterwards that it acquires any considerable firmness. During the period of the formation of the cell, the space between the membrane and the original disk is filled with fluid; and in this a regular circulation may be seen to take place,—several currents proceeding from the nucleus (or *cytoblast* as it is technically called) and returning to it again.

356. When the cell becomes mature, the original disk is absorbed, and no farther movement of fluid is seen within the cavity; but there are some cells in which it always remains, appearing as a dark spot in their walls; and in these the circulation of fluid generally continues. This circulation may be well seen in the beaded hairs of the *Tradescantia Virginica*, (Virginian Spider-wort,) which consist of several distinct cells; at the bottom of each of these, the disk or *nucleus* may be seen, and several currents may be observed to proceed from it and return to it again. It is a circulation of this kind which has excited much attention in the stem and branches of the *Chara*, (a little cryptogamic aquatic plant) which consist only of large cells laid end to end. The fluid passes down one side of the stem and up the other, turning round at each extremity. If the stem (which is usually composed of a single cell, sometimes many inches long) have a thread tied round its centre, so as to separate the original cell into two, each of these will have a complete circulation of its own. A similar movement of fluid has been seen in the *Frog-bit* (another aquatic plant of this country) and in many others; and it is nearly certain that it takes place in every vegetable cell that exists, during some period of its growth; being only visible for a short time in some, which soon arrive at a condition little subject

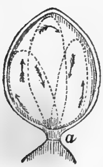


Fig. 45. Currents in the air of Tradescantia.

to change; but continuing during the greater part or the whole of life in others.

357. This movement of fluid in the individual cells, is quite distinct from the general circulation which has been described in the higher plants. It is a part of the process of formation, by which the nutritious fluid that is brought to each part is converted into organized tissue. In the simple Cellular plants, where the same surface performs alike the functions of absorption, exhalation, digestion, and respiration, there is no general circulation of fluid; since each of the cells composing the whole structure imbibes the materials of its nutriment for itself, and converts them into the substance of its own tissue, or employs them in the production of new cells. These seem to be usually developed from the fluid within the parent, in the same manner as the cells of the young seed are produced from the gummy matter it contains, as just now described; and the analogy is the more close, since the membrane lining the seed may be regarded as itself a single large vesicle. The increase in size of any organ is occasioned in part by the enlargement of each individual cell, and in part by the development of new ones, which are formed in some instances between those previously existing, and in other cases (especially in the root) at the extremity only.

358. In the simplest Cellular plants, therefore, there is no necessity for any general circulation of fluid; and no other movement is seen but that which occurs in single cells. But in the more highly-organized tribes, where the parts which receive the different kinds of food from the elements around are at a distance from each other, and from those to which the nutritious fluid must be supplied, a general circulation is required to bring them all into connexion; and this is accordingly found to exist, so that every part of the structure is nourished by a fluid that has been elaborated by a system of organs, of which each is particularly adapted to a single object, whilst the actions of all are directed to a common purpose. This elaborated sap, being supplied to the growing parts of a plant, gives to them all the means of development that they can require; and they then only need the influence of light and heat, to perform their respective actions with vigour.

CHAPTER X.

OF THE SECRETIONS OF PLANTS.

359. We have seen that the elaborated sap contains the materials of the various tissues of the vegetable fabric; and an outline has just been given of what is known of the mode in which they are converted into living structure. The principal uses to man of the various kinds of these structures, will be best stated when the chief groups of plants are described, in the second division of this volume. We have next to consider a class of products, which are not of the same character; for they serve no obvious purpose in the nutrition of the plant itself, and are never converted (so far as can be ascertained) into the materials of its tissues. They usually make their appearance in the elaborated sap; but not unfrequently they are afterwards separated in some degree from it, and stored up (as it were) in a particular portion of the plant. In Animals we find a provision of a similar kind. The blood not only contains the elements of the solid tissues which are to be nourished by it, but also of fluid secretions, which are separated from it by special organs. Hence the term *secretion*, which means a separation, or setting-apart, is derived.

360. In Animals, however, such secretions are usually destined to answer some obvious purpose, either in the system or out of it. Thus the secretion of saliva serves to moisten the food, and that of gastric juice to digest it; and in this process it is one function of the bile to assist. Again, the secretion of milk in the female for the nourishment of the young, that of poison in the venomous serpent for the destruction of its prey, that of the glutinous fluid with which the spider constructs its web, are instances of the

separation of certain ingredients of the blood, which are sent out of the body for particular objects. But secretion in animals has other purposes;—namely to purify the blood from certain ingredients, which, if they accumulated in it, would occasion disease and even death. This is the purpose of the separation of carbonic acid by the lungs; and also, in part, of the secretion of bile, which carries off a large quantity of the superfluous carbon of the system. In the same manner, the secretion of urine carries out the superfluous nitrogen (which exists very largely in this fluid, § 195, 197.)

361. Now in regard to the secretions of plants, it is very remarkable that, whilst in number and variety they much exceed those of animals, the use of them in the Vegetable economy should be much more obscure. In a few instances only are they destined to be sent out of the system; they are usually deposited in some part of it; yet they are not even separated in every instance from the nutritious part of the juices in which they are at first formed. The *Secretions* of plants comprehend all the *peculiar* products which do not form part of their tissues; thus, all the vegetable dyes, the active medical principles, the oils, the resins, &c., and the aromatic or volatile oils, belong to this class of products. Now as the substance of which the tissues of plants are composed is every where almost the same, any varieties which these tissues may present, in colour, taste, &c., must be due to them; and it is from their presence that each plant derives its particular character, either as an article of food, or as furnishing products useful in medicine or the arts. The pure vegetable tissue, and the nutritious gum or starch combined with it, are nearly tasteless; and the alburnum or sap-wood of trees possesses neither toughness nor colour. The former may be rendered uneatable by the disagreeable taste or injurious nature of the secretions diffused through it; the latter is strengthened, and receives its peculiar colour, by the deposition in its cells and tubes, of products which have been separated from the circulating fluid, and which give to the wood a density proportionate to their amount, and to their own power of subsequently hardening.

362. The formation of these secretions is still more dependent on the influence of *light*, than is that of the nutritive materials themselves. Many plants, which, under the rays of a tropical sun, produce secretions of a powerful character, whether as medicines, as aromatics, or as dyes, are almost inert in colder climates, even when the amount of heat artificially given may fully equal that to which they have been accustomed. Thus, the Tobacco of Persia is universally celebrated for its peculiar perfume; and from the Roses of the South alone is it worth while attempting to obtain the powerful essential oil, which is known as Otto or Atar of Roses. This principle is advantageously employed in the growth of vegetables for the table; for, if they are reared under a diminished light, many kinds of plants may be used as food, which naturally contain secretions either unpleasant in taste or injurious in character. Such are the Sea-kale, Lettuce, and Cichory; which are prevented from becoming *rank*, by heaping earth around their young shoots, or by growing the entire plant in a dark situation. The peculiar secretions, too, are not present in young plants, all whose energy seems expended in the extension of their own structure; hence those kinds which are afterwards rank poisons, may be eaten with impunity at an early period. Thus the peasants of Languedoc employ young poppies as food; and cattle do not reject noxious weeds in spring, which their instinct would not permit them to touch in summer.

363. As the special secretions of plants are formed in the elaborated sap, they will not be found in those parts to which it is not afterwards conveyed. They may generally be traced first in the leaves; but in the course of their descent, they are often separated by some particular organ, in which they are concentrated (as it were) to the exclusion of the rest. Thus many of the most powerful medicinal agents are obtained from the bark; some abound most in the roots; other products, especially resins and colouring substances, seem to be chiefly deposited in the wood; fixed oils are generally conveyed to the seeds, where they seem to be deposited for the same purpose as starch,—the nourishment of the embryo; whilst aromatic oils are generally found either in the leaves,

the leafy parts of the flower, or in the coats of the seed or fruit. Not unfrequently certain little bodies, which have received the name of glands, are seen on the surface of the leaves, from which fluids are poured forth for various purposes. Thus the Nettle is covered with glands of this kind, that secrete an acrid fluid, which, being conveyed through a pointed tubular hair mounted upon the gland, produces an irritation in the wound made by the hair, just as does the poison of the tooth of the serpent or the sting of an insect. The little *Dorsera* (Sundew) again, exudes a gluey secretion from the surface of its leaves, which serves to attract and retain Insects, the decay of whose bodies seem to contribute to its healthy existence, as it does to that of the Dionæa (§ 246.)

364. A detailed account of the various secretions of plants would not be adapted to this work; and we shall confine ourselves here to a notice of those which are most serviceable to mankind. Of all these, there is perhaps none more directly important than that denominated *tannin;* although of its use in the economy of the plants that produce it nothing is known. Tannin is the substance, by the chemical agency of which upon animal tissues containing *gelatin* (the material commonly known as glue, which forms a large part of the skin of most animals,) *leather* is produced. Its chemical effect upon gelatin may be shown by steeping some oak-bark, or bruised gall-nuts, in water; and then adding some of this fluid to water in which glue has been dissolved. A quantity of flaky matter will fall down, which is, in fact, leather;—its particles being separate from each other, on account of the liquid form in which the elements were brought together. The process of tanning consists in steeping the skins to be converted into leather in a solution of tannin; this slowly penetrates their substance, converting their gelatin, which would otherwise soon undergo putrefaction, into the compound just mentioned, which is capable of resisting decay. And, as no injury to the texture of the skin is done by this process, it is converted into a substance, which from its pliancy combined with toughness, and durability, is useful for a great variety of purposes.

365. In this country tannin is principally obtained from oak-

bark; but as of late years the supply of that material has not been equal to the demand, it has been necessary to look for some other source from which it may be procured. Several other trees common in this country yield tannin; such are the elm, willow, elder, plum, sycamore, birch, cherry, poplar, hazel, and ash;—but the proportion contained in all, save the first two of these, is not sufficient to render their cultivation for this object a source of profit. Even the common heath has been applied to this purpose; the tannin being extracted from it by boiling. There are, however, many trees of tropical climates, which contain a larger proportion of tannin than that yielded by oak-bark. One of these is a kind of Sensitive-plant (*Acacia Catechu*,) which flourishes abundantly in the mountainous parts of Hindostan, and yields the substance known as *Catechu*, or Terra Japonica (Japanese earth, from its earthy appearance,) which is much valued in medicine from its astringent properties, and which acts very powerfully on gelatin. It is a dry extract, prepared by boiling the heart-wood of the tree, cut into chips, and then evaporating the superfluous water.

366. The *Mangrove* tree, of the East and West Indies, is another form which a large quantity of tanning matter may be obtained. This curious tree grows on the borders of the sea and on the banks of rivers; its stem is supported by a large number of branching roots, which rise out of the water in arches several feet high, closely intertwining with each other; and the branches hang down and send forth similar roots, as in the Banyan (§ 152.) The extract made from its bark is used for tanning in many parts of the West Indies and in Hindostan; and it is said to perform its office more perfectly in six weeks than oak-bark does in ten, producing a leather more firm and durable. In New Holland there is an abundance of a species of Acacia, which is cut down for the purpose of clearing land; and from this it has been ascertained that an extract may be made, fully equal to oak-bark. As, notwithstanding the distance of the colony, it can be supplied very cheaply, so long as there is a superfluity of the Acacias, it will probably take the place in great degree of oak-bark.

367. Another secretion of great importance in the arts, and of

which new and valuable applications are constantly being discovered, is *Caoutchouc*, commonly known as Indian Rubber. It was first brought as a great curiosity from South America about 150 years ago; and for a long time nothing was known of the source from which it was obtained; nor was it applied to any useful purposes, except the rubbing-out of pencil marks, from which it took its name. It is known to be contained abundantly in the juices of many trees growing in tropical climates, as well as, in smaller quantity, in many plants of temperate regions; it seems to form an essential part of the *milky* juices (as they are termed, from their white colour, rather than from their properties,) which are characteristic of several tribes of Vegetables, especially of the *Artocarpeæ* (Bread-fruit tribe,) *Apocyneæ* (Oleander tribe,) and *Euphorbiaceæ* (Spurge tribe) which will be hereafter more particularly described. To the first of these orders belongs the celebrated Palo de Vacca or Cow tree of South America, which yields a copious supply of a rich, bland, and wholesome fluid closely resembling milk. In the plants of the second order, the milk is usually rendered bitter and poisonous by the admixture of other secretions; and in the third it is of a very acrid character. In other orders of plants having milky juices, however, caoutchouc forms but a very small proportion of them; such are the *Papaveraceæ* (Poppy tribe) and *Cichoraceæ* (Cichory tribe;) and here it is replaced by *opium*,—a substance presently to be adverted to. The juices which contain caoutchouc are obtained by making incisions into the bark; and the fluid which runs from them soon thickens, on exposure to the air, into a substance of a pure white colour, having neither taste nor smell. The dark colour which caoutchouc usually presents, is received from the smoke of the fire over which it is dried.

368. The use of Caoutchouc in the arts and manufacture results from two distinct properties;—its high degree of elasticity;—and its complete impenetrability to water. The modes in which its elasticity is made useful are extremely numerous; amongst others may be mentioned, the employment of it to form elastic webs, which are partly woven with threads spun from it, and which

are introduced into braces, saddle-girths, and other bands in which a steady and equable pressure is required. Its impenetrability to fluid has long been known, and was applied by the Indians of South America in the production of waterproof boots; these were made by spreading the juice, when flowing fresh from the tree, over moulds of clay, which could be afterwards broken away from their interior. Similar articles have been made in this country by keeping the juice in bottles from which the air was excluded; by which means it has been brought over in a perfectly fluid state, without losing its power of hardening when exposed to the atmosphere.

369. But of late years, a much more effectual and ready means has presented itself of thus employing to great advantage the valuable properties of Caoutchouc, in the discovery of the power of ether and naphtha* to dissolve it without changing its properties; so that a kind of varnish may be thus formed, from which, when it is spread over any surface, the dissolving fluid (which is extremely volatile) will evaporate, leaving a very thin coating of caoutchouc behind. It is in this manner that the waterproof fabrics are made, which are now so much employed for cloaks, wrappers, &c.; and as these are also air-tight, they may be used for air-cushions, mattrasses, &c. The fabric consists of two layers of cloth, which are varnished, each on one side, and then passed through a pair of rollers with the varnished sides in contact; so that a thin layer of caoutchouc exists between them. Some idea of the great and increasing consumption of this substance, new and useful applications of which are constantly being discovered,† may be formed from the fact that, whilst in 1830 the quantity imported into England was more than 52,000 lbs. (nearly

* This fluid is obtained in England from the tar which passes over with the gas now so universally employed, when coal is heated in closed retorts.

† A patent has lately been obtained for the employment of solid Caoutchouc in saddles and horse-collars. Two objects are here attained by it;—the much increased comfort of the horse by the equal diffusion of pressure over the surface, by which *galling* is prevented;—and the preservation of the padding beneath, by protecting it from being saturated (as it otherwise frequently is) with the perspiration of the animal.

double that imported in the preceding year,) the consumption in the year 1833 was nearly 180,000 lbs.; and there can be little doubt that it has since increased in nearly, if not quite, as rapid a proportion.

370. The large number of *oils* obtainable from plants, may be divided into the fixed or fat oils from which no vapour passes off at the temperature of boiling water; and the volatile or essential oils which give off vapour at or below that temperature. The latter are the sources of all the odours diffused so widely through the vegetable kingdom; and furnish, also, some materials of great importance in the arts of life. The fixed oils are all obtained by pressure from the fruits or seeds of plants, especially those of the Nut kind, all of which contain it in greater or less proportion. That in the greatest request is *olive* oil; which is obtained both from the pulpy part of the fruit, and from the seeds; that drawn from the former source is regarded as the best, being less liable than the other to become rancid. The olive tree was originally a native of Syria, Persia, and other hot countries in Asia; but it has gradually extended itself over the South of Europe and the North of Africa. The cultivation of it has been principally attended to in times of peace, of which it was considered as the symbol. It is extremely profitable to the grower, if properly attended to. The young olive plant bears at two years old; and in six years begins to repay the expense of cultivation, even if the ground beneath it be not made to yield any other crop. It continues to be profitable for a long period, rivalling the oak in longevity, and bearing good crops when the trunk is reduced to a mere shell; so that it is a common proverb where it is cultivated,—"If you want to leave a lasting inheritance to your children's children, plant an olive." Olive oil is very extensively used in the south of Europe, in the preparation of various dishes for the table, for consumption in lamps, for the manufacture of the superior kinds of soap, and for various other purposes. It is used very largely in this country, in spite of a heavy duty; upwards of four millions of gallons having been imported in 1831, of which about half was exported again to other countries.

371. Rape oil is obtained from the seeds of a species of *Brassica*, a plant closely allied to the Cabbage, which is cultivated for that purpose in France and some parts of England. It is much used for burning in lamps; and has the advantage over others, that it remains fluid at a lower temperature. Linseed oil, which is obtained from the seeds of the Flax-plant, is of very general application in the arts; especially in oil-painting and the composition of varnishes, for which it is particularly adapted by its property of drying on exposure to the air. This power may be increased by boiling the oil, which is then termed *drying-oil;* it is in this manner that printers'-ink, which is a sort of paint composed of oil and lampblack, is made to dry rapidly. The seed of the Hemp-plant yields an oil nearly as valuable; and it has lately been found that a large quantity may be extracted from the cotton-seed; so that each of these three plants is valuable to man in two very different ways. The hard cake left after these oils have been pressed out from the seed is used for feeding cattle. Sun-flower and mustard seeds, also, yield a good oil, which is employed in the countries in which these plants abound as a substitute for other seed oils. A large quantity of oil is now obtained on the Continent of Europe, from the seeds of the Poppy. It was commonly supposed, when this oil was first introduced into use, that it must partake of the narcotic properties of the plant; but this was erroneous, for oil, like starch, may often be separated from the peculiar juices of the plant, without being influenced in the slightest degree by their properties. Poppy oil is a very useful one in the composition of varnishes, on account of its freedom from colour, and its drying quality; in the northern parts of France it is much used by soap-boilers. Oil is also obtained in many parts of the Continent, especially Switzerland, from Walnuts and Hazel-nuts; it is much esteemed by varnishers for the same properties as Poppy Oil. The influence of climate on the production of oil, is well shown by the fact that, from these nuts, which in England would scarcely yield enough to repay the labour of extracting, half their weight of oil may be extracted in the South of Europe. Nearly the same may be said of the Beech,

from the kernels of which about 27 per cent. of oil is obtained in some parts of France and Germany.

372. Another important vegetable oil is that known under the name of Palm Oil; it is obtained from the fruit of two species of Palm which grow in several parts of Africa, especially in Senegal. One of these is named *Cocos butyracea*, from the buttery nature of its oil, which is much employed by the natives along the Gold Coast as an article of diet, and which, when fresh, is delicate and wholesome. It is imported into Britain in large quantities, chiefly for the soap-maker and perfumer. The quantity retained for home consumption in 1839, was 276,000 hundred-weight. The oil is contained in the kernels of the nuts, which are not very different from those commonly known as Cocoa-nuts; these last, also, yield a large quantity of oil, which congeals, at the ordinary temperature of the air, into a white fatty substance. In Ceylon, where this fruit is most abundantly produced, its oil is employed by the natives for a great variety of purposes. It makes a most excellent lamp-oil, except from its tendency to congeal by a slight amount of cold; and for this purpose it is employed by the Cingalese, whose greatest consumption of it, however, is for the anointing their bodies. In this country a process has been discovered, by which the oil may be separated into two parts; one resembling fat, which may be applied to the making of candles; whilst the other is as fluid as most other oils, and is particularly adapted for lamps. The oil is also well adapted to the wants of the soap-maker. Its consumption in Britain is much increasing; in the year 1839, nearly 40,000 hundred-weight of the oil was employed in various ways in this country, and upwards of four million pounds of the nuts were imported. The oil known as Ben-oil is of more importance than might be supposed from the small quantity of it introduced into this country. It is produced from a tree, growing in the East Indies, Egypt, and the Levant, which belongs to the same group with the Tamarind. The peculiarity of this oil consists in its very slight tendency to become rancid, and its perfect freedom from smell; on which account it is much used by the perfumers,

to retain the scent of the more fragrant oils. At a low temperature it separates into two parts, the one solid and the other liquid; and the latter is employed by watchmakers, in preference to any other oil, for lubricating their delicate works, on account of its having no action upon the metals.

373. The *essential* or *volatile* oils are mostly obtained from the leaves or flowers of plants; sometimes, however, they exist in the wood and bark, or in seeds. In all instances they possess a powerful scent; and the degree of this depends upon the tendency which the fragrant oil has to diffuse itself. In some of the most odorous flowers this tendency is so great that the oil cannot be procured in a separate form; and their perfume is obtained by causing the flowers to impart it to some fixed oil; for which purpose Ben-oil is preferred where it can be obtained. The volatile oils are not easily obtained by pressure; but are readily driven off by heat; but this must not be so great for the most diffusible as that of boiling water. To communicate the fragrance of flowers to a fixed oil, cotton soaked in it is placed in alternate layers with the flowers whose scent is to be obtained, so as to fill a close vessel, which is then placed in hot water for twenty-four hours; during this time, the fixed oil will have imbibed the rich perfume of the flowers, and it is then separated from the cotton by pressure.

374. The essential oils which are somewhat less volatile may be obtained by distillation, in the same manner as spirits. The substances which yield them are put into a vessel, with water to prevent their being over-heated. When the water is boiled, the oil passes away with the steam; and, when both are condensed, it floats upon the surface of the water. A large number of oils possessing great fragrance and strong taste may thus be obtained from different kinds of plants; and these oils are used in perfumery, in confectionary, and in medicine. The oils of Roses, Lavender, Chamomile, &c. are distilled from the flowers; those of the various plants of the *Mint* kind—Peppermint, Spearmint, Pennyroyal, &c., from the leaves and stems, which contain a number of little receptacles near their surface; that of Sassafras from the wood; that of Cinnamon from the bark; that of Carraway,

Anise, Fennel, and other Umbelliferous plants, from the coats of their seeds, in which they are stored up in little receptacles; that of Lemons from similar little receptacles in the rind of the fruit; and that of Nutmeg from the seed itself. Many of these oils contain Camphor, which may be separated from them by exposure to cold. Sometimes the secretion of volatile oil is so abundant, as to make itself perceptible in the atmosphere around, to other senses besides smell. Thus the Fraxinella gives off so much from its leaves, that the air in its neighbourhood is highly inflammable in warm weather. There are some substances which seem to contain the materials of an essential oil, rather than the oil itself. Thus when water is added to flower of Mustard, an acrid and volatile oil is produced, very irritating to the eyes; yet no evidence of its existence can be obtained without the addition of water, so that the latter probably occasions some change of composition by which the oil is produced. The volatile oil of Bitter Almonds seems to be produced in a similar manner. Perhaps the increased fragrance of our gardens after a shower of rain is due to a similar cause.

375. Into the particular uses of the foregoing oils, this would not be the place to enter; some of them will be noticed in the description of the several orders to which the plants that yield them belong. There are other volatile oils of much more importance in the arts and manufactures, which must next be noticed. One of the best-known of these is Oil of turpentine, (commonly termed Spirit of turpentine) which exists in combination with resin, forming what is commonly known as Turpentine, in all the trees of the Pine and Fir tribe, as well as in some others. The Turpentine is usually contained in special receptacles in the substance of the wood; but sometimes it collects in blisters underneath the bark, which appear during the strong heats of summer. It flows from these as a limpid juice, which thickens on exposure to the atmosphere, when incisions are made into the stem. The common Turpentine is obtained from the Scotch Fir, when growing in the South of Europe, and the Southern part of North America; but it cannot be procured in any large quantity from the same tree when growing in Great Britain. Superior

kinds are drawn from the Pistacia of Scio, and from the Larch in Southern Europe. Turpentine is not itself applied to any important use; but the two substances which it contains,—the volatile oil and the resin,—both serve many purposes. They are separated by distilling the Turpentine with water; which causes the volatile oil to pass over, leaving the resin behind. Oil of Turpentine is extremely useful from its power of dissolving resins, which form the basis of most varnishes; and from its great volatility, it quickly flies off or dries away, leaving a thin coat of the varnishing substance fixed to the surface on which it has been applied. The most extensive use, however, to which it is put, is that of diluting oil colours, so that they will flow freely from the painter's brush. No other known fluid would answer this purpose; for it is the only one which will mix readily with the paint, (diluting its thick oil, as water would dilute a sirup or gummy fluid,) without in the least degree affecting its essential properties,—and which will also dry rapidly.

376. The very important substances known as *tar* and *pitch* are also obtained from trees of the same kind; and they may in fact be regarded as impure turpentines, altered by the heat employed to separate them. A sort of kiln is built up of billets of wood; and round the bottom of this is a channel for drawing off the fluid which runs down whilst the wood is being burned. Tar may be made from trees which no longer yield turpentine, and also from those which have partially decayed on the ground. Pitch is tar deprived of its more volatile part; this may be separated either by distilling off the oil, which is an inferior oil of turpentine, or by burning it; in the last process, the volatile oil, being the most readily set on fire, is burned away, and the resinous part remains. In this manner, two barrels of tar will produce one of pitch; and besides the oil, an acrid passes off, by the distillation of tar, which much resembles that obtained during the burning of wood from charcoal, and hereafter to be mentioned under the name of the *pyroligneous*.

377. Several other Resins are yielded by plants; some of which commonly termed *Gums*, are of service in various arts.

Such is Copal, which is obtained from a species of Sumach; but though the tree will readily grow in North America and in England, it requires the heat of a tropical climate to perfect its juice; and most of this product comes from Africa. Copal is much valued as a varnish, on account of its hardness and transparency; which qualities cause it to be employed for pictures, fine woodwork, and other similar purposes. Mastic is another resin, which is used for similar purposes, and is obtained from a tree termed the Lentisk, nearly similar to that which yields the Chian turpentine. Incisions are made in the trunk and branches during the hottest parts of the summer; and the liquid juice which flows from them, thickens almost immediately that it is exposed to the air, into little drops or tears. Dragons' Blood, so named from its red calour, is a resin which exudes in drops from the stem of several trees growing in the tropical parts of Asia, Africa, and America; it is valued on account of the tinge which it imparts to spirit of wine, and is employed, when thus dissolved, in staining marble and woods. The substance called Benjamin or Gum Benzoin, is also a resin secreted by a tree that grows in the tropical parts of Asia, especially in Siam and Sumatra. This tree grows very rapidly, so that it yields resinous juice when only six years old, its trunk being then about seven or eight inches in diameter. This resin has a very fragrant odour, which probably depends upon its having, mixed with it, a small quantity of essential oil. It is principally used in perfumery, and in the manufacture of pastilles, or incense, which, when burned, diffuse an agreeable odour. Hence the principal consumption of it is in the churches of Roman Catholic and Mohammedan countries; and a much larger proportion of that brought to London is again exported, than is retained in this country. There are many other kinds of resin, of which small quantities are employed for particular purposes; but the foregoing are those most valuable to mankind.

378. Resinous matter, however, exists in other products which are termed *Gum-Resins*, from the quantity of Gum they contain; and this enables them to be partly soluble in water, which pure resins are not in the slightest degree. Some of these are valued on

account of their fragrancy; and have been employed in the incense burned in places of religious worship, from very early times. Thus we find in the earliest records, that the addition of fragrant odours was regarded as rendering the sacrifices offered to the Deity more acceptable; and the same idea seems to prevail in many Christian as well as heathen countries at the present time. Frankincense is one of these substances; it is produced from a kind of Juniper growing in Arabia. Olibanum is another of similar character, also produced by a species of Juniper; and Myrrh is nearly allied to these, but the source of it is uncertain. Gamboge is a gum-resin of very different properties, which is the product of several different kinds of trees growing in Ceylon, Siam, and Cochin China. It flows out in a liquid form when incisions are made in the bark, and is afterwards made solid by the heat of the sun; but it also occasionally exudes from the surface in *tears*. When rubbed with water, it forms a bright yellow fluid, which is much employed in water-colour drawing; the water *dissolves* the gum, whilst the resin remains *suspended* in the form of very minute particles, which may be seen with the microscope. The whole is dissolved in spirit of wine; and this solution is used as a laquer, to heighten the colour of brass-work, by its golden hue. Gamboge is also a powerful medicine, having a violent purgative effect; and with aloes it is the principal active ingredient in the nostrum known under the name of Morison's Pills.*

379. The true *Gums* may next be noticed; these are distinguished from the previous substances, by their being entirely soluble in water, whilst spirit of wine does not act upon them. Their solution in water is a thick adhesive fluid, which is used for many purposes in the arts. It serves to unite substances together in the same manner as glue; and may be used in cases where heat is undesirable. Its chief employment, however, is in calico-printing,

* It is probably to the bad mixture of the ingredients, by which an undue proportion of this active substance has been contained in a particular batch of pills, that some of the deaths which have occurred from their use, are to be attributed; and in other instances they have resulted from the enormous number of pills taken.

being used to stiffen the cloth before the colours are applied, so that they are prevented from running into each other and becoming indistinct. As all trees contain gum in their sap (§ 328.,) it might be obtained in some degree from any; but it naturally exudes in large amount from some kinds, which, therefore yield it most readily when incisions are made in the bark. The kind of gum termed Gum Arabic, which is the one most valued, is obtained from a species of Acacia, which flourishes in almost every part of Arabia and Middle Africa; but it is only in the hottest regions, that the gum is produced in much abundance. When the tree first opens its flowers, the gum begins to exude spontaneously from the bark of the trunk and branches; in the same manner as it is often seen to do from the cherry-tree in this country. In the spring, however, when the weather is very dry, the gum can only be obtained by incisions made in the bark.

380. Gum Senegal is similar to Gum Arabic, being obtained from a kind of Acacia differing very little from that which yields the latter; but it is of inferior quality. Gum Tragacanth, which, is obtained from a low prickly shrub growing in the Levant, is in some respects different from the foregoing. It does not dissolve freely in water ; but forms a thick mucilage with a certain definite proportion of it. If this be mixed with a larger quantity of water, it will separate again after a time and fall to the bottom, leaving very little gum in the water above. This gum is employed in some kinds of calico-printing, in which the chemical action of the dyes on the other gums would injure their qualities. The plant which yields this gum would flourish in England; but it can here only prepare enough of it for its own support, and only possesses a superfluity under the influence of a warmer climate. A large quantity of a gum resembling that of the Acacia, may be obtained from the various species of lichen growing in this country, by the action of hot water. The similarity of *starch* to gum has been already noticed, and some of the sources from which it may be obtained have been pointed out; and it is here, therefore, only desirable to add, that the gum obtained from starch is much used in the arts, especially for the purpose of stiffening different

fabrics, on which account it is employed largely by calico-printers, under the name of British Gum.

381. The next Vegetable secretion to be noticed is Wax; which, though commonly supposed to be formed by the Bee alone, is undoubtedly present in many plants also. It may be seen in the form of minute scales upon the outer surface of the Plum and other stone fruits, forming what is known as the *bloom;* and it is by the existence of a thin coating of it, that the leaves of the Cabbage, Tropæolum (Sturtion,) and other plants are enabled to resist moisture. Wax may be obtained by heat, though in small quantity, from the poplar, alder, and several other plants; but it exists in such abundance in the fruit of a Virginian myrtle, that it has received the name of candle-berry. In the parts of the country where this tree abounds, it is quite worth while to collect the berries for the wax they yield, which, when made into candles, burns with peculiar brightness and freedom from smoke, at the same time giving off a fragrant odour. Another wax-bearing tree exists in South Africa; and the substance yielded by its berries, which is made into candles by the Dutch, is greedily eaten by the Hottentots. In South America there is a kind of palm, the leaves of which have their surface covered with minute scales of wax, which separate when they are dried in the shade; and of this wax, mixed with a small proportion of tallow to avoid brittleness, excellent candles may be made. The leaves are so little permeable to moisture, that they may be used as coverings for houses; and they have been known to sustain the vicissitudes of weather for twenty years in such situations, without requiring to be renewed. The pith and the fruit of this palm also furnish a nutritious food for man and cattle; and the wood is useful in building houses, making fences, &c.; so that it is a very important tree in the district in which it abounds. Another species of Wax Palm is found in the more elevated parts of South America; growing on the mountain ranges, to the prodigious height of a hundred and sixty feet. The wax here exists in the form of a kind of varnish covering the trunk.

382. A substance nearly resembling *Tallow* is yielded by a

tree named the *Croton sebiferum* which grows abundantly in China, and is described as being the largest, the most useful and the most widely diffused, of any of the plants of that country. It imitates the oak in the height of the stem and the spread of its branches. The seed-vessels are hard brownish husks, not unlike those of chestnuts; and each of them contains three round white kernels, about the size and shape of hazel-nuts, having small stones in their interior, around which the fatty matter exists. From the kernel of the stone, an oil fit for burning in lamps may be pressed. Almost all the candles burnt in the southern provinces of China are made from this vegetable tallow, there being very few sheep in that part of the country; but it does not burn so well as animal fat. A tree abounds on the Malabar coast of India, termed the Piney, which bears a pulpy fruit that yields a large quantity of very solid tallow, almost approching wax in firmness, and very superior for the manufacture of candles to animal fat. It is not applied to that use by the natives, however, who (on account of the heat of the climate which prevents the employment of common tallow candles,) are accustomed to burn lamps only, which are fed with vegetable oil. This vegetable tallow might probably be imported in great abundance and at a low rate into this country.

383. The last inflamable substance secreted by plants which will here be noticed, is *Camphor*, which is much used in the composition of varnishes, besides its employment in medicine. Although chiefly obtained from a species of Laurel growing in the East Indies (where it attains the size of an oak) it exists in numerous plants, especially those yielding aromatic oils. Camphor differs in some degree in its properties, according to the way in which it is obtained. In general, pieces of the roots are put into an iron vessel, within the cover of which (fitted closely down) are cords of rice straw. When the lower part is heated, the camphor is raised into a vapour, and condenses again on the straw above. In old trees, however, the camphor is sometimes found, on splitting the trunk, to exist in a very pure state, in the form of small concretions or tears, in the interior. This camphor under-

goes little loss by exposure to the air; whilst that obtained by heat very rapidly evaporates. Besides the uses of this substance already noticed, it should be mentioned that camphor is valuable as a preservative of specimens of Natural History against the depredations of insects; and the most effectual way of applying it, is to have the cases made of the wood of the Camphor tree, which is of a white colour, easy to work, and durable.

384. Opium is the next vegetable secretion which we shall here notice; and this rather on account of its importance in medicine, than because of the large quantity produced, which is mostly employed in a manner injurious rather than beneficial to mankind. Opium is contained, in small amount, in the milky juices of many plants; but especially in those of the *Papaveraceæ*, or Poppy tribe. The species which yields it most abundantly is the White Poppy (*P. somniferum;*) but this does not produce it in any large amount in temperate climates, and is cultivated in Europe chiefly for the oil yielded by its seeds (§ 371.) The juice is obtained by making incisions in the capsules or seed-vessels (commonly termed *heads*) whilst they are quite green; and that which hardens upon them is scraped off. Many kinds of opium are known to the importers of drugs; but their difference only results from the varieties of climate in which they are grown, and from the mode in which the juice is obtained and prepared. Some kinds are very much adulterated. More opium is now raised in Hindostan than in any other country; and the principal demand for it has been in China. Opium is a substance of very compound nature. A large proportion of it consists of a gum soluble in water; there is also, however, a small quantity of resin and of caoutchouc. The ingredients which act so powerfully on the animal body, however, constitute but a very small proportion of the whole. The most important of these are two substances of an alkaline character (being capable of uniting with acids to form a salt) which are named Morphia and Narcotine. The properties of the first of these are directly sedative; that is, it causes sleep or the relief of pain, without any previous excitement. The first effect of Narcotine, on the other hand, is to

stimulate. These alkalies exist in the opium in combination with a peculiar vegetable acid termed the *meconic;* and they are separated by chemical processes, since, in order that their medicinal effects may be most advantageously produced, it is desirable to administer them separately.

385. The chief consumption of opium, however, is unfortunately not for the purpose of curing disease, or of relieving pain, but for the production of a species of intoxication, the constant indulgence in which has a great tendency to degrade the mind and to enfeeble the body. The quantity necessary to produce the desired effect increases with habit; so that the confirmed opium-eater often takes as his single dose, repeated many times through the day, a quantity sufficient to poison any one unaccustomed to its use. The practice of taking opium often commences with the occasional use of it for the purpose of allaying or procuring sleep; and those who are obliged to have occasional recourse to it for this purpose, should be on their guard against taking it more frequently than is absolutely necessary. For such persons, morphia is the most desirable medicine; since it produces more completely the effects they desire, without that excitement to the nervous system which leads to the employment of it as a source of pleasure. The quantity of this drug annually consumed in England may be stated at about 35,000 lbs.; whilst that which has been introduced into China, in spite of the laws which prohibit it, has for some years averaged more than 3½ *millions* of pounds, the value of which considerably exceeded that of the tea exported. The quantity seized by the Chinese government in March, 1839,, was upwards of three million pounds.

386. We shall next notice some of the principal colouring matters secreted by plants. On these are dependent the varied hues so beautifully and abundantly distributed through the vegetable kingdom; of which some at once delight the eye of man, whilst gazing upon the garden, the meadow, or the forest; whilst others, extracted from the interior, even of plants of the dullest aspect, contribute to his comfort and luxury in various ways. The colouring secretion most universally diffused through plants, is that

termed *chromule*, on which the colour of all green parts depends. It is found in little grains, which adhere to the inside of the cells beneath the cuticle; and the formation of it is due, as formerly stated (§ 288,) to the influence of light in fixing carbon from the atmosphere. The brightness of this green colour soon disappears after the death of the part; and it is not unfrequently seen to alter its hue, whilst vital actions are going on in it. Thus the leaves of many trees, as the Lombardy Poplar, change to yellow in autumn, long before their fall; whilst others, as the Beyberry, Sumach, &c., turn to red. This alteration is due to an increased absorption of oxygen, which is no longer given out by day; and the chromule may be artificially converted, by the action of acids, first into a yellow and then into a red. The red colour of many flowers possesses the same properties as that of leaves when thus altered; and this fact will possess a higher degree of interest, when it is shown, as it hereafter will be (Chap. XII.,) that the leafy parts of flowers have the same general structure as leaves, and often differ very little from them. It is farther probable that all the colours of flowers are caused by the presence of chromule, altered by various chemical means; in all instances it may be seen that these colours exist in the same parts,—namely, minute globules contained within the cells. It has been observed that the colours of many flowers may be greatly changed by cultivation; in some species, as the Dahlia and Poppy, great varieties occur without any obvious cause,—the seeds of the same parent, raised in the same soil, producing flowers of extremely different hues; whilst in other cases, the hue is manifestly influenced to a great degree by the nature of the soil. It has been ascertained, however, that these varieties are not beyond the control of general principles. The colours of flowers may be arranged in two series, as under.

Green.

Blue series.	Greenish-blue	Yellow-green	Yellow series.
	Blue	Yellow	
	Violet-blue	Orange-Yellow	
	Violet	Orange	
	Violet-red	Orange-red	

Red.

Flowers belonging to the yellow series may pass into red or white with all intermediate shades, but never into complete blue;—this is the case with the Dahlia, the original colour of which was yellow, and with the garden Ranunculus, which presents every gradation from red to green. On the other hand, the Hyacinth passes through all the gradations in the blue series, from green, through blue, to red; but never becomes yellow.

387. The colouring matter of rapidly-growing parts has seldom sufficient permanence, when removed from the plant to render it valuable for the purpose of staining cloth, &c.; and the substances used for this purpose in the arts of the dyer, calico-printer, &c.; are chiefly obtained from the heart-wood, roots, or bark; sometimes, however, from the softer parts, as the leaves and fruit. The principal dyes, by the combination of which all varieties of shade may be produced, are blue, violet, red, yellow, fawn, and black, and substances yielding all these are produced in abundance by different tribes of plants.

388. Of all the *blue* dyes, *Indigo* is the most important. This is obtained from the juices of several different species of plants, of which some grow in almost all parts of the torrid zone. These plants are raised from seed, and are of very rapid growth,—being ready for cutting at the end of two months. A subsequent growth from the same roots is again ready for the sickle in six or eight weeks; and more may be subsequently obtained. In India, it is not considered advantageous to obtain more than four crops from the same seed, as the produce of each is less than that of the preceding; but in Egypt, the seed is sown only once in seven years, and two crops are obtained in each year. The indigo, which seems to be nothing else than the *chromule* of the plant, is usually extracted by fermentation. The plants are laid in a vat, and covered with water; and in about 18 hours they begin to swell, and to give off a large quantity of gas,—the water at the same time acquiring a green tinge. This process is allowed to go on, until the colouring-matter of the vegetable tissue has been entirely yielded to the water; but if it continue too long, so that any putrefaction take place, the dye is destroyed. The fluid is then drawn off into

another vat, where it is violently agitated, for the purpose of separating the pulp from the water. The former consists of little grains, which, during the process, turn from green to blue by attracting oxygen from the air; and, by farther processes, it is dried into a solid mass, constituting the indigo of commerce. Nearly all the indigo imported into Britain is produced in the East Indies; its amount averages about *seven millions* of pounds every year, of which, however, more than half is exported again, chiefly to the North of Europe and Italy. Owing to the great variation in the productiveness of the crops, the price of Indigo is almost constantly changing. In the season 1824–5, it was nearly 11*s.* 6*d.* a pound; whilst in the season 1829–30, owing to an over-abundant supply, it was only 4*s.* 4*d.* At the former rate, the value of the average quantity annually imported would be about *four millions sterling:* and at the latter, scarcely above *one and a half.*

389. This valuable dye has so strong an attraction for almost every kind of fibrous texture, whether animal (as woollen or silk,) or vegetable (as linen or cotton,) that it will impart to it a permanent colour without the assistance of a mordant.* In order to apply it, however, it must be *dissolved* in water; and this can only be accomplished by a change in its chemical nature, which restores it to its original yellow-green colour; the stuffs, after being dyed, change again to blue by exposure to the air. This process appears to injure, in some degree, the durability of the colour; and it is preferable to apply the dye when first separated from the plant. The brilliant blue cloths of Africa and China, which are superior to those of any other part of the globe, are produced in this manner.

390. The juices of several plants, growing in the different countries of the East, are used by the natives of those countries in the same manner as Indigo, and might probably furnish a good substitute for it, if prepared with sufficient care. The use of Indigo as a

* Mordants are substances used in dying and calico-printing, to hold together the particles of the texture dyed, and those of the dyeing material, when these have not a sufficient attraction for each other. If not so united, many colours would be washed off as readily as they are laid on.

dye, on a large scale, is comparatively recent. It was not until long after the discovery of America that it was commonly employed in England; and the use of it was forbidden by the governments of some European countries, from the fear that it would supercede the use of *Woad*, which was then very extensively cultivated. This dye was known to the Ancient Britons, who stained their bodies with it; and it was the principal blue dye, until the introduction of indigo. Its colour is much less lively than that of indigo, but it is more durable; hence it is commonly employed in union with that and other dyes, but seldom now by itself. Woad (*Isatis Sativa*) is cultivated in many parts of Europe; and is grown in considerable amount in Lancashire. Its stem is about three or four feet high, and about half an inch in diameter; it divides into many branches, which are loaded with leaves. It is cut down with a scythe when the flowers are about to appear; and afterwards at intervals of about six weeks;—three or four crops being usually obtained in one year. The plants are first washed; and then dried in the sun, without which they will begin to putrefy, their green colour turning black. They are then conveyed to a mill, where they are ground into a paste. This paste is afterwards subjected to several processes for the purpose of drying it. It is finally used nearly in the same manner as indigo; with which, indeed, its colouring matter, if extracted in the same manner, is found to be nearly identical.

391. A *Violet* hue is easily given to cloth, by mixing blue and red dyes in any required proportion; but there are some plants which yield a violet or purple dye, without any admixture. The chief of these is *Logwood*, the produce of a tree growing in the bays of Campeachy and Honduras,—the native country of the Mahogany. When Logwood was first introduced into this country as a dye, the use of it was forbidden by Government on account of its "deceitful" character; the colour it communicated being fair to the eye, but speedily departing. The art of fixing it by mordants, however, being afterwards discovered, this substance came into general use; and it is now imported largely from

Jamaica, as well as from its original country. The part which yields this dye is the heart-wood; this is hard and heavy, in consequence of the amount of secreted matter contained in it; and it yields its colour readily to water, when this is boiled upon its chips. The deep violet or purple hue of the fluid first changes to a yellowish tint, and finally becomes black; but this change may be prevented by the use of proper mordants. The chief use of this substance, however, is in dyeing black, and producing all shades of gray. The quantity imported into Britian in 1839 was 23,000 tons, the value of which was above £180,000.

392. The principal *Red* dye obtained from the vegtable kingdom is *Madder*, the produce of the *Rubia tinctoria*, a plant which grows naturally in the Levant, and is cultivated with success in the South of Europe; its cultivation does not answer in England. The colouring-matter is obtained from the roots, and is not sufficiently formed until the third year; the roots are taken up in the autumn, after the leaves have fallen off. They are then carefully cleaned, dried, and reduced to powder. A great variety of colours, varying from lilac to black, and from pink to deep red, may be produced by the application of different mordants to the stuff, before it is placed in the madder. These are partly due to the intermixture in this substance, of two distinct colouring principles, a fawn and a red. The latter if separated from the other, is much more brilliant; and various processes have been devised for the purpose. The best of these requires that undried roots should be employed; and these are largely imported into this country for the purpose. The quantity of madder employed in Britain in 1838 was upwards of five thousand tons; and of the roots, more than four thousand. The value of these would be together £600,000.

393. Another valuable Red dye, is obtained from the wood of the *Cæsalpinia crista*,* commonly known as *Brazil* wood. Though abundant in that part of South America, the tree is a

* An allied species of this tree, the *C. pluviosa*, also a native of Brazil, is remarkable for a constant flow of water from the points of leaves, which falls down in drops, like a shower of rain.

native of other parts of the world; and it was known under its present common name before the discovery of that country. And in fact, the portion of that continent which bears the name of Brazil, was so named in consequence of the numbers of these trees which were found growing there. As in the case of Logwood, it is only the *duramen* (§ 131.) of this tree which is of any service; the remainder being colourless. The colour obtained from this wood is brilliant; but is not so permanent as that of many other substances. It is generally used to heighten the effect of other dyes. Red ink is commonly made by boiling this wood in beer, wine, or vinegar, to which alum has been added. Of late years the consumption of this wood in Britain has much diminished; whilst that of another kind, termed Peach-Wood, or Nicaragua-wood (so named from the Gulf of Nicaragua, whence it was first imported into England) has greatly increased, so as to be now nearly double the first. The colour obtained from it, is brighter and more delicate than that yielded by Brazil-Wood.

394. Another red dye, now largely employed in England, is obtained from a Lichen, commonly termed *Orchilla*, which abounds in the Canary and Cape de Verd Islands, and which is sometimes found (though of inferior quality) on the rocks of Guernsey and the Isle of Portland. The plant is usually imported without any preparation; and it is afterwards dried and reduced to powder, and altered in its character by chemical processes, the result of which is a deep red powder known as *Archil* or *cudbear*, the infusion of which is of a crimson colour bordering on violet. It is seldom used by itself, as its colour is not permanent; but it is chiefly employed to give a brightness to the hues of stuffs dyed with other substances. Several other red dyes might be enumerated, which are used in small quantities for particular purposes. Among the most important of these is *Alkanet*, which is obtained from the roots of the *Anchusa tinctora*, a native of the Levant and the warmer parts of Europe, but grown also in England. This colouring principle is not soluble in water; but it gives a deep red colour to oils, wax, and unctuous substances. It is consequently used chiefly to colour oils, ointments, lip-salves, &c;

and it is sometimes applied to the staining of wood, when dissolved in oil. Notwithstanding the apparent insignificance of these purposes, above 50,000 lbs. of it are annually imported into this country for home use, besides what is raised in Britain.

395. Many good *Yellow* dyes may be obtained from plants; and the most important of all those used in Britain is procured from a plant of native growth,—*Weld* or *Wold*, or (as it is sometimes called) dyer's weed. This grows spontaneously in many parts of the country on uncultivated wastes, and is a very hardy plant, preserving its verdure through frost and drought. It is nearly allied to the mignionette; but is a much taller plant, attaining the height of three feet before blooming. It takes two years to come to maturity, and is gathered whilst the seed is ripening. The plants are dried, and then transferred to the dyer, who at once extracts the colour by boiling; there is reason to believe, however, that the seeds contain the really important part, and that, if they be saved, the trouble which arises from the bulk of the whole plant, may be avoided. The colour is also separated, in the form of a yellow powder, for the use of the paper-stainers who employ much of it. A much larger quantity of weld is used in England than is supplied by cultivation, and it is consequently imported from abroad. This is much to be regretted; as there is good reason to believe that it will thrive and yield a handsome profit on lands so poor as not to be profitably cultivated in any other way.

396. Another very excellent yellow dye is obtained from the bark of the *Quercus tinctoria*, or Quercitron, a species of Oak common in America, the timber of which is employed largely in building. This bark is employed in the United States for tanning; and its colour being considered a defect, this is removed by a chemical process. More than a thousand tons of it, however, are annually imported into Britain: and it is here much valued on account of the number of different shades of colour which it may be made to produce, as well as on account of its superior durability. A much greater demand exists, however, for the dye termed *Fustic*, which is extracted from the wood of a species of

Mulberry tree that grows spontaneously in Brazil and the West Indies. It does not yield above one-fourth the amount of colouring matter obtained from quercitron, and its colour is not so lively; but it is more efficient in combination with some other dyes, and is used with indigo to dye Saxon green, and with salts of iron for drab.

397. *Arnatto* is another dye of a reddish yellow, employed for particular purposes; it is obtained from the crimson pulp lying between the husk and the seeds of the Arnatto tree, which is a native of both the East and West Indies. It is brought to this country in cakes, which are made by boiling down the pulp; and these are of a brownish red, giving a bright orange, when dissolved in water with the addition of an alkali. Its hue is not permanent, however; and it is seldom employed by itself, except for giving colour to cheese, for which it is valued on account of the ready communication of its colour without imparting any unpleasant flavour or unwholesome quality. One of the most beautiful yellow colouring substances is that known as *Saffron;* but it is too expensive to be much employed by dyers. Its chief use is in medicinal and culinary preparations, to which it imparts its brilliant hue and agreeable flavour. Saffron is the product of a kind of Crocus, which is cultivated in England, as well as in France and Spain. This plant flowers in October, and the flowers are gathered, even before they are full-blown. The *stigmata,* or points of the pistils (§ 434.,) of these flowers, are then picked off; and the rest of the flower is thrown by as useless. These little bodies, constituting the Saffron, are next very carefully dried, and pressed between paper. Its high price results from the very small amount of it produced, even on good land; even when the roots are planted thickly, the average quantity for the whole three years (beyond which they should not be allowed to remain in the ground,) being not above 26 lbs. per acre. *Turmeric* is sometimes used as a substitute for Saffron, the colour it produces being very bright, though deficient in durability. This dye is procured from the roots of an East Indian plant named *Curcuma longa,* which has also been cultivated in the West Indian Islands

with success. These roots are not unlike ginger, either in figure or size; and the dye brought to this country consists simply of the roots, either whole or reduced to powder. It is sometimes used to give brilliancy to other hues, and is employed as an ingredient in yellow varnishes. Several other plants affording yellow dyes might be enumerated; but the foregoing are the chief. It may be mentioned, however, that the clothiers of some parts of Lancashire and Yorkshire make use of common *Heath* for their yellow and orange dyes; this, with a proper mordant, is said to produce on woollen cloth a more beautiful colour than either weld or quercitron; but it is not so permanent.

398. Almost all vegetables contain more or less colouring matter, capable of affording *fawn* or brownish hues, inclining to yellow, red or green. The dye chiefly employed for this purpose, however, is obtained from the Sumach, a native of the south of Europe and of Syria. The shoots of this plant are cut down every year close to the root; and after being dried, they are reduced to powder by means of a mill. An infusion of this powder yields a greenish fawn colour, which may be altered by mordants. The principal use of Sumach, however, is in dyeing black, in the manner presently to be described. The colouring matter of the husks of walnuts forms an excellent dye for wool; and it is much esteemed among the French dyers, for the agreeable and durable hues it affords without the assistance of mordants. In order to obtain this colouring matter, the husks are kept in water for a year or two; after which they give out much more of it than when fresh. The *Henna*-juice, which is employed by the ladies of the East for the purpose of staining their nails, is a very permanent brown dye; the colour not disappearing until the substance of the nails is changed by growth. It is also employed for dyeing ordinary stuffs; but it has not been introduced into this country.

399. The vegetable kingdom affords several substances which are capable of themselves producing a permanent black dye; but a much larger amount of such materials is required than could thus be obtained; and the black colour of our cloths and stuffs is procured by a chemical process, of which the vegetable kingdom

furnishes one important ingredient. This process consists in adding *gallic acid* to a solution of iron; by which an insoluble bluish black substance, the gallate of iron, is immediately formed. If a cloth therefore, previously steeped in a solution of iron, be immersed in an infusion of any vegetable matter containing gallic acid, a black dye will be communicated to it. Almost all vegetable substances having an astringent taste contain gallic acid; but especially the Oak tribe. It is from the abundance of this acid in the Gall-nut (which is an excrescence resulting from a kind of inflammation, excited by a wound of the soft tissue of the leaves or young shoots by the gall-fly,) that it takes its name. Gall-nuts are not, however, formed upon the Oak of this country:* but upon a smaller species which grows wild in the countries bordering on the Mediterranean. They are usually pounded and then boiled in water, in which the cloth is steeped; and this is afterwards placed in the solution of iron (commonly termed copperas.) The colour thus communicated is not a deep black, but rather a dark blue. It is improved by logwood, which is boiled with the copperas; and the stuff should have been previously dyed of a deep blue with indigo. A similar process is employed in the manufacture of common black writing-ink, which essentially consists of gallate of iron suspended in water by means of a small quantity of gum; and logwood is here also added to improve the colour. Galls are imported from the East Indies, as well as from Turkey; but of late years they have been in less demand, in consequence of the introduction of another source, from which gallic acid may be obtained at a much cheaper rate. This is in the cups of acorns of the Velani Oak, a species which grows abundantly in Greece, and in the maritime parts of Asia Minor. These cups, which do not contain gallic acid in the same proportion as gall-nuts, are known in commerce by the name of Valonia; and in consequence of their cheapness (being only about one-fifth the price of galls) the consumption of them is very great. During the year 1830, the quantity of gall-nuts employed in England was 2,297 cwt; whilst that of Valonia was 86,538 cwt. Many other

* The Oak Apples, however, are similar formations.

astringent substances may be used as black dyes with iron; and a good deal of the Sumach imported into Britain is used for this purpose, as are also walnut husks in France; the shells of chestnuts, too, have been employed, although not profitably. In India, the juice of the fruit of the Myrobalans, which is not unlike a plum, is used for dyeing black with iron; and when the pulpy portion is freed from the stone, which is useless, it contains more gallic acid than an equal weight of galls, and might be made a profitable article of commerce.

400. From gallic acid we may naturally proceed to speak of the other acids which are produced by Vegetables. These are all, like the foregoing substances, formed by the plant itself, from the elementary bodies it receives as food; and thus they may be regarded as true products of vegetable secretion, and not as merely separated by the plant from the surrounding soil. In this last light we must regard the earths and alkalies obtained from plants, and not as products of their secreting processes. The acid which is employed in largest quantity is the *Tartaric.* This is obtained from the crust that is deposited by wine, when kept a long time; the amount of which depends chiefly upon the degree of acidity in the wine. The crust which goes by the name of Argol, chiefly consists of tartaric acid in combination with potash, forming what is commonly known as *Cream of Tartar;* and this requires to be purified from its colouring matter and other impurities, before it can be employed in the arts. The acid is easily obtained in a separate form by chemical processes; and it is employed for many purposes which cannot be answered by the cream of tartar. Its chief use is in many processes of dyeing and calico-printing.

401. Another vegetable acid much used in the arts is the *Oxalic,* which is well known as a violent poison. From the resemblance of its crystals, in size and general form, to those of Epsom salts, it has not unfrequently been administered by mistake, with the most dreadful consequences. This acid is found united with potash in the leaves of the Wood-sorrel and common Sorrel; and the oxalate of potash is prepared from their leaves in large quantities, in Switzerland and the neighbouring countries, where

these plants grow abundantly. Its long needle-like crystals may be seen lying amongst their tissues, if a thin section of the stem or leaf-stalks be placed under the microscope. The salt is known as Salt of Sorrel; but it is sometimes sold under the name of Salt of Lemons, to which title it has no right whatever. The acid may be separated from it, as in the former instance; and it is employed for many purposes by the dyer and calico-printer; as well as for removing the stains of ink, iron-moulds, &c. which it does without injuring the texture of the stuff.

402. The acid which gives sharpness to the juices of lemons, oranges, limes, and a variety of other fruits, and is known under the name of Citric acid, is likewise one which has many important uses, besides that of imparting a peculiarly refreshing character to these juices. It is largely employed by calico-printers, who now usually import their own lemon-juice, and concentrate it for themselves. At one time, the citric acid, which is not combined in the juice with any earth or alkali, was obtained by chemical processes in separate crystals; but it is now found that the impurities of the juice do not interfere with its use in calico-printing; and it is employed for this purpose almost in its original state. For other purposes, however, pure citric acid is required; and this is partly made in Sicily, where the Lemons are abundantly produced, and from which island, with the neighbouring continent of Italy, the greater part of the juice consumed in Britain is imported. Pure citric acid is used in the preparation of the best morrocco Leather; for improving a beautiful scarlet dye produced by a preparation of tin; and for altering the hue of some colours which are exclusively used in the dyeing of silk. Besides its use in the arts, Lemon-juice is very largely used in the navy for the purpose of preventing the complaint termed scurvy which is very apt to be brought on by the continued use of salt meat. During long voyages, a regular allowance is made to each man, which he is required to use as a medicine. This, however, has been now rendered less necessary than formerly, since the art of preserving meats in a fresh state has been brought into gene-

ral use. Citric acid exists in many of our commonest fruits,—such as the cranberry, cherry, red whortleberry, and the hip of the wild-briar; whilst in the red gooseberry, the currant, the bilberry, the black cherry, the wood strawberry, and the raspberry, it is mixed with an equal proportion of *malic* acid, which exists alone in apples, pears, and other fruits. It is interesting to notice the uses of the acids in these situations. It has been formerly stated that gum or starch, when acted on by a vegetable acid with a moderate degree of heat, is converted into sugar; and this is exactly what takes place in fruits during ripening,—which process consists in the conversion of the starch of the hard unripe fruit into sugar, without any diminution in the amount of acid, which is sometimes indeed really increased, whilst its taste is concealed by the sugar.

403. One more vegetable acid may be mentioned; though it probably does not exist as such in the substance from which it is obtained, but is formed by the heat employed to set it free. This is *pyroligneous* acid, formerly called acid spirit of wood, which is procured by subjecting wood in closed iron retorts to a strong red-heat; the vapour that is given off partly consists of this acid, mixed with tarry matter, which is separated by a second distillation. This acid, which in some degree resembles very strong vinegar, is used by the dyer and calico-printer; and it is also employed for making pickles and other culinary preparations, in which an acid of great strength is required. The impure acid has been found to possess, in a remarkable degree, the power of checking the putrefaction of animal substances, even when applied in very small quantity; this is due, however, not to the acid, but to a certain ingredient in the tarry matter which is mixed up with it, and which, when separated under the name of *creosote*, is now well known as a valuable medicine, especially for the relief of tooth-ache. The discovery of the influence of this substance in controlling putrefaction would be of great value if it were not that by no subsequent process of cooking can the tarry flavour communicated by it to the meat be got rid of.

---

404. Having thus passed in review some of the most impor-

tant products afforded by the secreting processes of plants for man's use and benefit, and having been obliged to confess our almost entire ignorance of the processes they serve in the vegetable economy, we might proceed to the next division of our subject; but it would be wrong not to pause here for a moment, to contemplate the important inferences which may be drawn from the foregoing details, in regard to the Power, Wisdom, and Goodness of the Almighty Designer. His power is scarcely any where more remarkably displayed, than in the immense variety of products which are elaborated out of the three simple elements—oxygen, hydrogen and carbon, by processes, which, as far as we can understand them, appear to be of the most simple description. His Wisdom is strikingly evinced in the diffusion of these products over the whole globe; so that there is scarcely a country which does not naturally contain those which may be most useful to its inhabitants. And his Goodness is peculiarly manifested in the adaptation of these products—the formation of which (we can scarcely doubt, although we cannot understand,) must have an object as regards the plants themselves—to the use of Man, in ministering to those various wants, which have sprung out of his condition as a rational being, endowed with higher faculties and more varied powers of enjoyment than those of the beasts which perish, and yet dependent for the most favourable use of these, upon the judicious employment of the means with which a bountiful Providence has abundantly supplied him. The nourishment of man's body in health, his restoration in disease, the clothing that covers him, the varied hues which he can communicate to this, the colours which delight his eye in the verdant lanscape, or in the skilfully painted picture, the odours which refresh his senses, the timber of which his habitations, his manufactories, his ships, are partly or wholly constructed,—these are but a few of the provisions which the benevolence of the Creator has made for his comfort, in the organization of the Vegetable World. Who, then, shall say that it is less fertile in the evidences of a Designing Providence, than the Animal Creation?

CHAPTER XI.

OF THE PRODUCTION OF LIGHT, HEAT AND ELECTRICITY BY PLANTS.—MOTIONS OF PLANTS.

405. It has been already stated that, by the operation of these agents upon the Vegetable system, are chiefly maintained those changes which make up the *life* of each being. (§ 9.) If Light be withdrawn, several of the most important of these are speedily checked. If Heat be suspended, all of them directly cease. With regard to the influence of Electricity, less is known, and nothing can be positively stated. But Light, Heat, and Electricity are sometimes produced by plants, as well as required by them as conditions of their growth.

406. There are few instances in which *Light* is evolved from living Plants; but these few are very curious. Many flowers, especially those of an orange colour, such as the Sun-flower, Marigold, Nasturtium, &c. have been seen to disengage light in serene and warm summer evenings, sometimes in the form of sparks, sometimes with a steadier but more feeble glow. Light is also emitted by certain species of Fungi, especially those which grow in moist and warm places, where light is entirely excluded, as in the depths of mines. The light is perceived in all parts of the plant; but chiefly in the young white shoots. It ceases if the plant be deprived of oxygen, either by being placed in a vessel from which the air has been exhausted, or in some other gas; and it re-appears when the plant is restored to air. No luminousness is perceived after the death of the plant. It would seem probable, therefore, that this extrication of light is in part connected with that conversion of oxygen into carbonic acid, which, as already mentioned, takes place very rapidly in flowers and in the whole substance of the Fungi (§ 290,) and which may be regarded as a sort of slow combustion. An evolution of light has also been observed to take place from dead and decaying wood of various kinds, particularly that of roots; and also from Fungi whilst decomposing. This corresponds with the luminousness of certain animal bodies after death.

407. It is well known that the higher Animals alone possess the power of keeping the temperature of their bodies up to a certain fixed standard; and that in the lower tribes the heat of the body varies with that of the atmosphere, being frequently but a very little above it; so that these, giving to the touch a sensation of cold, are termed cold-blooded animals. Still, they have *some* power of generating or producing heat, which is shown by their power of resisting the influence of extreme cold for a long time. In regard to Plants, much doubt has been entertained at different times, whether they could be said to have a *proper heat* or not; or whether their temperature is not entirely dependent upon that of the atmosphere. But this doubt has resulted from a very limited view of the processes of the Vegetable Economy, against which it is desirable to guard the young reader.

408. It will be stated, under the head of Animal Physiology, that the production of heat is entirely dependent upon the conversion of Oxygen into carbonic acid, by its union with the carbon thrown off in respiration; and just as the rapid combustion of charcoal in oxygen gives out a great degree of heat, so does the slower process of union, in which the respiration of human beings really consists, disengage heat more gently. Now in Plants this process of respiration takes place so slowly (in comparison with animals,) and from a surface so openly exposed to the atmosphere, that it could scarcely be expected that there should be any sensible elevation of the temperature of the part from this source; especially when it is considered that a constant loss of heat is taking place by evaporation.*

409. Some recent experiments, however, made with an apparatus that would indicate extremely slight changes of temperature, have proved that the process of respiration in plants *is* accompanied by a disengagement of heat; but in order to establish this, it was

* This fact is readily understood by pouring a little water, a little spirit of wine, and a little ether, one after another, upon the back of the hand. Although they may have been all of the same temperature, the hand is cooled least by the water, more by the spirit, and most by the ether,—in proportion, in fact, to the rapidity with which these fluids respectively pass off in vapour.

necessary to compare the temperature of a living plant with that of a dead one having the same proportion of moisture at its surface; since in this way only could the true effect of respiration in producing heat be known, whilst the evaporation was continually preventing the manifestation of it, by cooling the surface. In this manner it was found that the heat of the surfaces of plants is raised by respiration from 1 to 2½ degrees above what it would otherwise be.

410. It has long been observed that the interior of large trunks possesses a temperature more uniform than that of the surrounding air; being cooler than the atmosphere in summer, and warmer in the winter. There are at least two causes of this occurrence. Wood is a slow conductor of heat; thus, if a piece of stick and a rod of iron of equal sizes have one end heated in the fire, the farther end of the stick will be nearly cold, whilst that of the iron is too hot to be handled. Farther, the conducting power of wood is still less *across* the grain (or through the stem) than *with* the grain (or along the stem;) so that changes in the external air will not readily affect the centre of a large trunk; and, accordingly, it is found that, the larger the trunk on which the observation is made, the greater is the difference between its state and that of the air. The other reason is, that some motion of the sap takes place even in winter; and the fluid taken up by the roots principally comes from a depth in the ground, at which, from the bad-conducting power of the soil, the temperature is nearly uniform throughout the year.

411. The evolution of heat by Plants is most evident at those periods of their existence, in which an extraordinary quantity of carbonic acid is formed and given off. This is the case during the germination or shooting-forth of seeds; and though the heat produced by a single seed is too soon carried off by surrounding bodies to be perceptible, it accumulates to a high degree when a number are brought together, as in the process of *malting* (§ 283,4.,) in which the thermometer has been seen to rise to 110°. The same may be said of that other period of vegetation, in which an extraordinary amount of carbonic acid is evolved,—that of flowering (§ 285.) It is evident that, from the little *substance* of the

parts thus heated, and the large amount of *surface* they expose to the air, the heat will be carried off by the atmosphere almost as rapidly as it is produced. Still in some flowers, a considerable amount of heat can be proved by the thermometer to be disengaged; thus, a Geranium has been found to possess a heat of 87°, when the air around was at 81°.

412. As in the case of seeds, however, the production of heat is most sensible, when a number of flowers are crowded together; and this is still more the case when they are enclosed in any general covering, as are those of the Arum family. In these, the flowers are small, and are very closely set upon a stalk, which is called a *spadix;* and the whole cluster is surrounded by a large leafy sheath called a *spathe.* It is in these flowers that the size of the fleshy disk is the most considerable, and the quantity of carbon to be united with oxygen is therefore the greatest; and the combination of this cause with the other, occasions the temperature of the clusters to be raised very high. A thermometer placed in the centre of five spadixes has been seen to rise to 111°, and one in the centre of twelve to 121°,—while the temperature of the external air was only 66.° The increase of temperature commences with the opening of the flower; and it is greatest at the time of the shedding of the pollen (Chap. XII.)

413. That the development of heat in these cases is owing to the conversion of carbon into carbonic acid, is proved by two kinds of experiments. In one, the cluster of flowers was placed in pure oxygen, by which this change was performed much more rapidly than in common air; and the heat given out was much greater than that evolved by a flower-stem at the same stage in common air. On the other hand, a spadix being put into nitrogen (the gas which forms the greatest part of common air, and seems to have for its object to dilute the oxygen, which by itself would be too powerful for the support of animal and vegetable life,) the formation of carbonic acid was altogether checked, and no heat was given off, although the opening of the flower, and the shedding of the pollen took place to all appearance as usual.

414. So little has been satisfactorily ascertained regarding the connexion of *Electricity* with the processes of Vegetable growth, that it seems undesirable here to dwell upon the manifestations of this agent which sometimes occur. It may be stated, however, that, whilst on the one hand, the condition of the atmosphere in regard to Electricity has evidently a striking influence on the rapidity of their growth (some plants having been known to increase in the most extraordinary manner during thundery weather,) the electricity developed by the changes which take place in the economy of plants has probably a very powerful influence on the condition of the atmosphere. It is well known that by all chemical changes, such as occur in every process of vegetation,—from the absorption of the crude sap, to its final conversion into the substances which are to remain fixed or permanent through a long series of years,—electricity is produced. Farther, the mere evaporation of water from the surface of the leaves will do the same; and thus a constant series of changes in the electric state of plants will occur, which will communicate themselves to the atmosphere.

415. The general electric state of plants is found to be that termed *negative;* and if any circumstances cause the atmosphere to be *positively* electrified through a considerable space, some great commotion of the elements is not unlikely to take place. Hence, the dreadful hurricanes, which occasionally devastate the West Indian islands, may be in some degree accounted for. The evaporation of the water from the surface of the surrounding ocean tends to make the air above it positively electrical; and, this, too, at the very time when the brilliant light and genial warmth of the sun is causing the vegetation of the land to possess an opposite condition. "How wonderful," it has been remarked, "are the operations of nature. The silent and peaceful growth of a vegetation whose splendour fascinates the eye, developes an agency, which, opposed to that produced by the rapid but unobserved evaporation from the surface of the surrounding ocean, tends to load the atmosphere with conflicting elements, from the depth of whose strife issues thunder proclaiming the approach of the hurricane and tornado."

OF THE MOTIONS OF PLANTS.

416. The gradual movements of the parts of plants, which occur as a part of the natural changes involved in their growth,—such as the extension of their roots beneath the ground, and the elevation of their leaves and flowers by the upward extension of their stems and branches,—have been already noticed, and the causes which influence them have been assigned, as far as our knowledge of them extends (§ 107, 309.) A curious experiment has been recently performed, which proves in a remarkable manner the influence of light on the direction of the growth of these parts. Some seeds of Cabbages, Mustard, and Kidneybeans, were placed in Moss; and were so arranged, that the only light they could receive was from a mirror, which threw the solar rays upon them from below upwards; the natural direction of their growth was in this manner completely changed,—the stem being sent downwards, and the roots upwards.

417. We have here to notice, however, another set of movements displayed by Plants, in which an evident change of place occurs whilst they are being observed for a short time. One of these is known as the *sleep* of plants, from the circumstance of its generally occurring in the evening. This consists sometimes in the folding-together of the leaves, in other cases in their drooping, and occasionally in their clasping the stem; it is most displayed in Leguminous plants having pinnate leaves (§ 238;) and in them the lateral leaflets commonly fold together, whilst the leaf-stalks are bent downwards on the stem. Many flowers, also, exhibit a regular movement of the same description;—closing together at night, and unfolding in the morning. There are a few species, however, which unfold at night and close during the day. There are some, too, which close during the day, when the sky is overcast and a storm is threatened. These changes seem almost entirely dependent upon the degree of light to which the plant is exposed; for they may be made to take place at the contrary periods, by keeping the plants in a darkened room during the day, and placing them at night in strong lamplight. It is usually some little time, however, before they become accustomed to the

change; and their movements are at first irregular. The mode in which light produces these movements has not yet been ascertained; but it can scarcely be doubted that it is by its influence on the exhalation of fluid from the soft tissues, on one side of the bending part more than on the other. Supposing that the part were otherwise bent, the influence of light upon the cells of the convex side would cause them to contract, and thus straighten it,—a change which we shall presently see to be elsewhere effected by another cause acting in like manner. Whilst, if the part were straight in the dark, so that the leaves were erect, and the flowers expanded, the influence of light acting more on one side than on the other would cause it to bend.

418. The influence of water, or of varying degrees of moisture in the atmosphere, seems often to produce movements in the living plant, as well as in dead portions of its tissues. It is in this way that the closure and unclosure of the Rose of Jericho and the Lycopodium of Peru are occasioned,—the one by drought, the other by the contact of fluid. This is easily accounted for by supposing that the cells on one side are larger and have thinner walls than those on the other; and these will, therefore, be most easily distended when placed in water, and will soonest lose their fluid in drying. The beards of the Geranium and Wild Oats curl up in dry weather and straighten in damp; those of most other plants perform the contrary movement. Such parts of plants are often used in the construction of *hygrometers*, to indicate the amount of dryness in the atmosphere, to detect dampness in beds, &c.

419. Some of the most interesting among the vegetable movements are those concerned in the deposition of the seed. The Balsam termed *Impatiens noli-me-tangere* has a seed-pod or capsule formed by two halves or valves, which when the seed is ripe, suddenly separate from one another and curl inwards scattering the seed to some distance. Now an examination of the tissue of these valves shows that their outer part consists of much larger cells than the inner, and that the fluid contained in it is the densest. By the laws of *Endosmose* (§ 118,) therefore, the fluids contained in the tissue of the interior will have a tendency to pass towards the outside, and will distend its vesicles still

more. This distention of the outside layer will manifestly give the valves a tendency to curl inwards; just as when two thin plates of metal, which expand unequally by heat, are soldered together, and, heat being applied, the compound plate bends towards the side which expands least. This tendency continues to increase up to the time when the seed is ripe; and it is then so powerful as to cause the separation of the valves from each other, and to occasion the rolling inwards of each. Now it has been found that, if the valves be placed in a fluid more dense than that which the valves contain, such as sirup or gum-water, the fluid will be drawn off from their cells according to the same law of Endosmose; and the cells on the exterior will be emptied soonest, on account of their being larger and fuller than the other; so that the valves become straight, and even curl outwards. But if they be put into water, the Endosmose, still taking place towards the side on which the fluid is densest,—namely the interior of the cells,—will distend them still more, and will cause the valves to curl inwards more powerfully than at first. Another instance of movement with the same object, which may be explained in a similar manner, is that of the seed-vessel of the common Squirting-Cucumber (*Momordica Elaterium.*) This when ripe, very readily separates from its stalk; and its pulpy contents are violently forced out from the aperture thus left. The pulpy matter surrounding the seeds occupies the centre of the fruit, and by its own increase in amount, distends the cavity; the elasticity of the walls, therefore, occasions their violent contraction, when an aperture is formed in any way, by which the distention is relieved.

420. Such explanations, however, will by no means account for all the evident movements of plants; and it is necessary to suppose their living tissues to be endowed with a property termed *contractility*, by which they are enabled to contract upon the application of a stimulus, just as do the muscular fibres of animals. The vegetable kingdom affords many examples of this kind of contraction. Thus, if the leaves of the common Wild-Lettuce be touched, when the plant is in flower, the part will be covered

with milky juice, which is forced out through the stomata by the contraction of the cells or vessels beneath. Again, in the flower of the Berberry, if the base of the stamen be touched with the point of a pin, the filament or stalk will bend over, so as to strike its top against the style or central pillar of the flower. This movement will hereafter be seen to be connected with the process of *fertilization;* and it must be frequently caused by the contact of insects, which thus assist in that function. There is a curious New Holland plant, named Stylidium, sometimes cultivated in green-houses in this country, which has a tall column rising from the centre of its flower, and consisting of the stamens and style united; this usually hangs down over one side of the flower, but if it be touched ever so lightly, it starts up with a jerk, and rapidly swings over to the opposite side.

421. One of the most interesting of all the vegetable movements, however, is that displayed by the *Sensitive plant* (Mimosa pudica.) This is a Leguminous plant of the Acacia kind, which has its leaves very much subdivided into leaflets. When spread out in sunshine, they present no peculiarity of appearance; but at night they fold together as in sleep, more completely perhaps than the leaves of any other plants. If, when expanded, one of the leaflets be slightly touched, it will close towards its fellow; the neighbouring leaflets will presently do the same; the vein upon which these are set will bend downwards, and meet the one on the opposite side of the midrib; the midrib itself will afterwards bend down upon the stem; and, if the plant be in a very irritable condition (from its functions being in a state of great activity) the other leaves are sometimes affected in a similar manner. The explanation of this very curious phenomenon requires that the structure of the parts concerned in it should be explained. It is evident that the cause of the movement must be in some way propagated from the part touched, to the parts where the change actually takes place,—namely the points where the leaflets join the veins, the veins come from the midrib, and the midrib, from the stem. At every one of these points, there is a little swelling or *intumescence*, formed of very spongy cellular tissue, and containing a great deal of fluid in its cells. If the *under* side of the

intumescence at the foot of the leaf-stalk be touched, its vesticles being very irritable, contract and force out the fluid they contain; and this necessarily pulls down or depresses the leaf-stalk and all that it carries. If, on the other hand, any thing distend the cells on the upper side of the intumescence, the leaf-stalk is pushed down, as it were, in a similar manner. The intumescence at the origin of each vein, and at the base of each leaflet, seems to possess the same properties in a degree proportional to its size, and they are all connected together by the vessels and woody tubes of the midrib and veins. Now, when the tissue of any of the leaflets be touched, it appears to contract in the same manner as does that of the Wild-Lettuce; but instead of squeezing out its fluid upon the surface, it forces it through the vessels into the upper side of the intumescences at the base of itself and its fellow, and these leaflets are thus caused to fold down and meet each other. The fluid forced out from the under side of their intumescences is probably carried to the upper side of those at a little distance; and thus the neighbouring leaflets also are depressed. The depression of the veins upon the midrib, and of the midrib or footstalk itself upon the stem, will follow in like manner; the extent to which the movement is propagated, being dependent on the amount of fluid expelled from the lower side of the intumescence, in the parts where it has already taken place.

422. Various other stimulants, besides the touch of a hard body, will produce similar effects. Thus, if electric sparks be communicated to the lower side of the intumescence, or the rays of the sun be concentrated on it with a burning-glass, a similar contraction of its vesicles, and depression of the leaf, will follow. In this, as in the foregoing instance, the leaves return after a time to their usual condition. Several species of the Acacia tribe, growing in warm climates, exhibit corresponding changes in a less degree. The closure of the fly-trap of the Dionæa (§ 246.) may be probably explained on similar principles; the part here irritated is the tissue at the base of the three thorns on each side of the leaf, one of which must be touched in order to excite the movement.

CHAPTER XII.

OF THE REPRODUCTION OF PLANTS.

423. The limits which have been set by the Creator to the duration of the life of each being that exists at any one time on the surface of the globe, would cause the earth to be speedily unpeopled, were not a compensation provided in the faculty of Reproduction,—or of the formation of a new being similar to itself,—possessed by every kind of Plant and Animal. This power of creating (as it were) a living structure, with all its wondrous mechanism,—possessed, too, in Animals of the faculties of sensation and thought, and in Man the residence of an immortal spirit,—seems at first sight more extraordinary and mysterious than any which we elsewhere witness. Yet it is not perhaps so in reality. The processes which are constantly taking place during the life of each being, and which are necessary to the maintenance of its own existence, are no less wonderful, and no less removed from any thing which we witness in the world of dead matter. When the Tree unfolds its leaves with the returning warmth of spring, there is as much to interest and astonish, in the beautiful structure and important uses of these parts, as there is in the expansion of its more gay and variegated blossoms; and when it puts forth new buds, which by their extension prolong its branches over a part of the ground previously unshaded by its foliage, the process is in itself as wonderful as the formation of the seed that is to propagate its race in some distant spot. Thus it is that scientific knowledge heightens our interest in Nature, by showing that, in those things which seem most common, there are as many sources of interest and instruction, as in that

which, from its apparently mysterious character, is usually regarded with more curiosity.

424. In the lowest plants, the process of reproduction is as simple as that of their growth. Each single cell of the *Red Snow* (§ 48. Fig. 8.) for example, produces within itself a number of little particles; which, at a certain period, are set free by the bursting of the parent-cell which encloses them. These granules then gradually enlarge,—deriving their nourishment from the air and moisture around; and in time they acquire the size of the parent plant, and in their turn produce a new family within themselves, which at the proper time they set free. A similar process takes place in the Yeast-Plant (§ 56. Fig. 10.) In the *Confervæ* (§ 41. Fig. 6.,)—in which a number of cells are united together, end to end, in each filament,—the several cells in like manner set free from their interior the little green particles which serve to propagate their kind; but the parent cells do not lose their own lives in thus sending a new generation into the world; for, instead of bursting, they allow the granules to pass out by a small aperture which forms in their walls. The growth of these particles within the parent cell may be distinctly traced: at first they are seen adhering to its inner wall; then they separate themselves from it, and float in the fluid it contains; then they are seen to move while yet within the cell; and after they have passed out, they continue their motion, even in an increased degree, for some time. At last they attach themselves to some fixed object, and their development into new plants then begins. The particle gradually enlarges and forms a cell containing fluid; this cell takes an oval form, and a partition then appears across it, dividing it into two; one of these is elongated in the same manner, and is again subdivided; so that at last a complete filament, consisting of many cells, is produced;—this, in its turn, sends out reproductive particles from its cells, which go through the same processes. The curious movement of these granules (which any one possessing an ordinary microscope may observe for himself, by watching the reproductive processes in the common Confervæ of our streams) has given rise to the notion that they were to be regarded as

animalcules at this stage of their existence;—a notion which is only mentioned here to point out its absurdity; since, whatever may be the cause of these movements (which is still obscure,) they do not afford any evidence of being guided by Sensation and will, of which no real animal can be entirely destitute.

425. In all these cases, the process of Reproduction is performed in a manner as simple as that, which any of the functions of Vegetable Life present to us. There is nothing more wonderful in the fact that a cell should produce the rudiments or germs of new cells, in its interior, than that it should develope additional cells which are to form parts of its own structure, (as in the Yeast-plant § 56, and higher plants in general,) from its outside. Each may be regarded as a Law of Nature;—which is only saying that it is the mode in which the Creator operates. Now we shall find that, in higher plants, the essential part of the reproductive process is really the same—following the same general laws; and it is one of the most interesting results of scientific research, to see that things which *appear* widely different, may often prove to be closely connected. We may hence learn a lesson, too, which is very useful in the ordinary concerns of life,—not to judge too hastily by *appearances.* Nothing could *seem* more unlike than the production of the seed of some noble tree, from the elegant flower, with all its complex apparatus of parts,—and the propagation of the humble kinds of vegetation we have been considering, by the simple conrtrivances just described. And yet it will be seen that, although in the former there is much of an *additional* character, subservient to particular purposes, yet that the mode in which the germ is at first produced is *essentially* the same.

426. The first stage of this increasing complexity is seen in the higher Sea-weeds; in which, of the large number of cells that the whole plant contains, only a small part are appropriated to this function. Sometimes these reproductive cells are spread over the whole surface of their leaf-like expansion; but sometimes they are restricted to the extremities of the plant. In the common Bladder-wrack (*Fucus vesiculosus,*) which abounds on most of

the shores of Britain, a swelling may be seen at the end of each of its divisions, which is distinguished from the rest by its yellow colour, when the fructification which it contains is mature. In this swelling a number of pores or minute apertures may be distinguished; and if the substance be cut across, it will be found that, beneath each of these pores, there lies a cell larger than the rest, and partly separated from it. This cell, when the fructification is ripe, passes out through the pore, and soon after bursts, setting free the minute particles it contains; and these, like the granules of the Red Snow or the Confervæ, develope themselves into new cells, by the multiplication of which a new plant similar to the parent is gradually reproduced. Now this cell, thrown off from the rest of the structure, and containing reproductive particles, which it afterwards sets free, corresponds with what in the higher Cryptogamia are called *spores*. These spores take the place of *seeds* in this division of the Vegetable kingdom. We shall hereafter (§ 431, 440, &c,) trace the differences in their structure.

427. The processes of Reproduction in the *Lichens* and *Fungi* appear to be as simple as those just described. Cells are seen in certain parts of the structure, which differ from those composing its own tissue, and which are destined to be cast forth from it, when the reproductive particles it contains are mature. The immense number of these reproductive cells or spores which are contained in the different plants of the Fungus tribe, has been already noticed; and the various organs which contain them will be hereafter described. One of the highest forms of this group is the common Mushroom, in which there is a very distinct separation of the fructifying from the nutritive system. The spores are contained in a number of little tubes, which are arranged side by side in the membrane forming the *cap* of the Mushroom, and in the thin plates (commonly known as the *gills*) which spread from the centre on the under side of this; whilst between this part and the roots is a distinct stem. The whole energy of the Fungi seems directed towards the propagation of their race; and the duration of life in individuals is usually very transient. In Lichens, on the other hand, each individual fre-

quently exists for many years, and its powers of propagation are much inferior. Indeed some Lichens do not form any distinct spores; but multiply themselves by little bud-like bodies, which they form in hollows of their surface. In the common Cup-Moss, for example, (which is really a Lichen,) these little bodies may be seen in the form of a fine greenish powder, in the hollows of the cups; and from these, when they are removed from the parent plant, new individuals will spring.

428. In the *Liverworts* we find a similar provision, as already noticed (§ 32.;) but here there is a distinct set of organs of fructification raised above the general level of the plant, as shown in Fig. 4. The little bodies forming as it were the spokes of the wheel, are cases containing spores or reproductive cells; and these are scattered, when mature, by a set of elastic spiral filaments which lie among them. When it begins to develope itself, the spore does not altogether burst and emit the granules it contains, as in the Algæ; but its outer coat only ruptures, and a long tube projects from its interior, within which new cells are seen to grow, taking their origin from the granules or minute germs which the spore contained. These cells gradually increase into a leafy expansion, from the lower part of which root-fibres proceed; and this in time acquires the appearance of the original plant, and forms its own organs of fructification.

429. The organs of fructification in the *Mosses* (§ 27.) are extremely beautiful and delicately-formed; but as the essential nature only of their reproduction is here to be explained, the description of these peculiarities must be deferred. We here find a complex provision for the development and dispersion of *spores*, which in themselves resemble those of the Marchantia. The little urns, mounted upon long stalks, which are peculiar to this group, are furnished with lids, that drop off when the spores within them are mature; these spores having been developed around a central pillar termed the columella. The subsequent changes which take place in the spore nearly correspond with those described in the last section; the principal difference being, that a number of tubes are put forth instead of a single one. Each of these tubes can be perceived to contain some

of the little granules which the cell produces within it; and every one of these is capable of itself forming a perfect plant, as has been ascertained by cutting the tubes into several pieces. In general, however, all these go to form one young Moss,—the cells which they produce uniting together at an early period; and thus the process is rendered much shorter than if the whole plant had to be developed from a single cell.

430. In the *Ferns*, again, we meet with another form of the same process. The spore-cases are here developed on the backs or at the edges of the leaves, and differ in form from those of the Mosses; but the spores which they contain could not be distinguished from theirs. If a Fern-leaf whose fructification has come to maturity (as may be known by the brownish tinge of the yellow or orange spots or ridges on its leaves) be placed with its underside upon a piece of white paper, this will be found in a day or two covered with a very fine brown dust. These are the spores which are scattered by the bursting of their cases. The process of development of these spores presents several points of interest. In its first stages it closely resembles that of the Marchantia. The outer coat of the spore ruptures, and the inner one projects into a long tube; within which, as well as within the original cavity, new cells are formed from the germs included within it. The first tendency of these newly-formed cells is to grow together, and to increase into leaf-like expansion, very much resembling that of the Marchantia. In the middle of this (which has received the name of primary frond,) a knot or protuberance gradually makes its appearance; and this is afterwards prolonged above into a sort of stem, and below into a root. From this stem, the true leaves or fronds are afterwards developed, unrolling themselves after the manner formerly described (§ 25;) and, when these make their appearance, the primary frond decays away, leaving no traces of its existence. In this very curious process, we see that the Fern passes, as it were, through the stage which is permanent in the Marchantia; but that when it attains a higher form, the organ, which was only for a time subservient to its existence, decays away. Many instances of a similar kind present themselves in the Animal kingdom. Thus

the Frog comes forth from the egg in a state resembling that of a Fish, breathing by gills instead of by lungs, possessing a long tail by which it moves itself in the water, and destitute of legs. Subsequently legs are produced, which render its tail unnecessary; and lungs are developed, which perform its respiration more effectually than gills; and these two sets of organs, though they permanently exist in Fishes, disappear in the Frogs, as soon as they have served their temporary purpose. Corresponding changes, hardly less striking than this, take place during the development of every one of the higher animals; and in every instance we see that, when a higher form is attained, the parts which had their uses in an inferior condition of existence, are cast off as cumbrous and unnecessary. How beautifully does this principle apply to the history of the development of the human soul! At first it is entirely dependent for its activity on the impressions which it receives through the bodily frame with which it is connected. The calls of hunger, the presence of unaccustomed objects, strong impressions upon its senses, first excite its attention; and all its subsequent acquisition of knowledge depends upon similar influences. Perfect in their kind as are the organs of sensation by which these impressions are communicated, there are still bounds to their operation. All that their highest exercise, with the aids derived from the most refined ingenuity, can effect in this life, serves but to give to the philosophic mind a glimpse of the wonders of Creation; and there can scarcely be to such a mind a more powerful *natural** argument in favour of a future state, than that which rests upon the vast amount of knowledge of which the sources are presented to man, and the insatiable desire for it which he possesses, compared with his very limited power of satisfying that desire within the short duration of an ordinary life. All analogy, then, leads to the conclusion, that with the mortal body, the soul shall cast away those instruments which are adapted only to the present material finite state of existence, and shall be endowed with

* By this is meant an argument drawn from the Natural World, as distinct from the Revealed Word of God.

more direct means of becoming acquainted with those glorious truths which here it only sees "as through a glass, darkly."

431. To return from this digression.—In reviewing the processes of Reproduction in Cryptogamia, we perceive that they are every where essentially the same. The spore, or reproductive cell contains a number of granules, each of which is capable of producing a new cell, at the expense of the fluid which its parent contains; and these new cells are able, either together or separately, to develope themselves into plants similar to their parents, without any other influences than those which they receive from the light, air, and moisture, which surround them. Now we shall find that the real essential difference between the Phanerogamic and the Cryptogamic (the flowering and the flowerless) plant, consists in this,—that the former possesses a series of organs fitted to receive and cherish the germ, and to assist in its early development, of which the latter is destitute; and that the presence or absence of those parts which are ordinarily known as constituting the flower, is of no primary importance. These parts are often absent, without the process of Reproduction being thereby affected; and, on the other hand, there are many flowers, which appear perfect to the uninstructed eye, but which are totally destitute of fertility.

432. The parts of a flower essentially concerned in the reproductive process are the *stamens* and *pistil.* The stamens are a number of little bodies, having yellow heads mounted on long stalks, which are seen *around* but not *in* the centre of the flower. These stalks are called *filaments;* whilst the heads are called the *anthers.* Each head is usually seen to be more or less completely divided into two parts, which are termed anther-lobes. These are commonly united together; as in Fig. 46. *a, b, c, d;* but sometimes they are separated, as at *e;* and occasionally only a single lobe is present, as at *f.* Within the

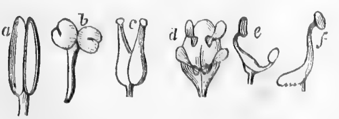


Fig. 46. Different forms of stamens; *a*, lily; *b*, lemna; *c* potatoe; *d*, berberry; *e*, ginger; *f*, sage.

stamens are produced a number of minute yellow bodies, usually of a globular form, which together constitute the fine dust known as the *pollen* or *farina* of the flower. Each grain of pollen, when examined with the microscope, is seen to consist of a cell exactly analogous to that which constitutes a spore. It has two or more coats, which enclose a fluid; and in this a large number of extremely minute granules may be seen with a good microscope. These granules are probably the germs of new cells; being analogous to those which are sent forth from the Red Snow, the Confervæ, and the Yeast Fungi. They may be seen to move within the parent cell, or pollen-grain, previously to the time when its walls become too thick to allow of their being observed through them; and, when the contents of the pollen-grain are mixed with water, they are seen to be constantly performing a sort of vibratory motion.

433. The anthers, or receptacles of pollen, which evidently correspond with the capsules or spore-cases of the Cryptogamia, burst when their contents are mature, and scatter the grains forth. They have various ways of opening; sometimes they split along their length, as at *a*, Fig. 46; sometimes transversely, as at *b*; sometimes by little openings at their extremity, termed *pores*, as at *c*; and sometimes by valves, as at *d*. These different methods are characteristic of different tribes of Flowering-plants.

434. Now the portion of the reproductive system in the Phanerogamia, to which nothing analogous exists in the lower tribes, is that which is denominated the *ovarium* or seed-vessel, which occupies the centre of the flower, being sometimes situated above and sometimes below the point at which the leafy parts of the flower arise from the axis which bears them. This ovarium is the part in which are formed the *ovules* or young seeds; and these, after being fertilized in the manner presently to be described, ripen into the perfect seeds. Sometimes it consists of several evident divisions; in other instances, these are united together, more or less closely; and all mark of a

Fig. 47. Pistil of *Coriaria myrtifolia*, showing distinct carpels and styles.

division may even disappear. The adjoining figure represents the centre of a flower in which the several parts of the ovarium remain separated; three only are seen, the others being concealed by them. These separate parts are termed *carpels.* Each carpel is surmounted by a sort of pillar, termed the *style;* which usually expands at its summit into a fleshy surface, called the *stigma.* When the carpels adhere closely together, their styles also frequently unite, so as to form a single pillar, which sometimes however divides again into several branches at the top. The ovarium with its style and stigma, is then called the *pistil;* and sometimes each separate carpel with its own style and stigma receives the same appellation. An excellent illustration of an ovarium consisting of many carpels, appearing externally single, but each really separate from the rest, is the Orange; the rind of this fruit is formed by the external part of the flower which wraps over the ovarium, whilst the juicy part is the ovarium itself, composed of a number of carpels adhering together, but not so closely united as to prevent their being torn apart. The position of the pips or seeds of the Orange will give a good idea of the manner in which they are usually situated within the carpels, especially when they are few in number. Sometimes, however, they are attached to the whole length of the carpel, from one end to the other, as is seen in the common Pea, of which each pod is a separate carpel.

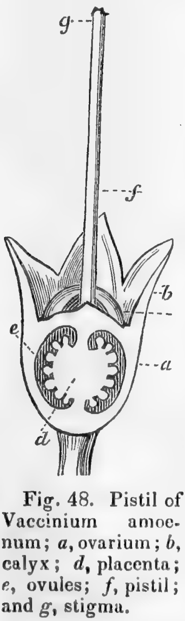


Fig. 48. Pistil of Vaccinium amoenum; *a*, ovarium; *b*, calyx; *d*, placenta; *e*, ovules; *f*, pistil; and *g*, stigma.

The portion of the carpel from which ovules arise, is usually thick and fleshy, and is termed the placenta. The section of the pistil of the *Whortleberry*, in the last page, will give an idea of the arrangement of the parts in an ovarium whose carpels and styles have united. The ovarium *a*, of this flower is wrapped over, like that of the orange, by the leafy portion of the flower itself; which is seen to rise beyond it at *b*. The centre of the ovarium is occupied by a thick fleshy placenta, formed by the union of that of the several carpels; and on this the ovules are clustered. Above is seen the single style with its stigma. Another variety of the same kind of structure is shown in Fig. 49; here the ovarium, *b*, is in like manner enveloped by the outer part of the flower, *a*; and the partitions between the carpels have entirely disappeared, so that only one central pillar is left, around which the ovules are clustered. There is another common form of the ovarium of which that of the common Heartsease, Fig. 50, may be taken as an example: in this the partitions have disappeared; but the placentæ of the several carpels, instead of remaining clustered together, are attached separately to the walls of the ovarium, as at *a*.

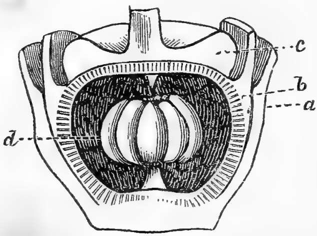


Fig. 49. Ovarium of Thamnea uniflora; *a*, calyx; *b*, ovarium; *c*, disk; *d*, ovules.

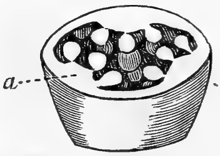


Fig. 50. Ovarium of Viola tricolour; *a*, placenta.

435. These two sets of organs are by no means constantly united, however, in the same flower. The *staminiferous* or stamen-bearing flowers are frequently distinct from those which are *pistilliferous* or bear pistils. When they occur on some other part of the same plant, it is said to be monœcious (single-housed;) if on a different plant, it is dïœcious (or double-housed.) Sometimes the same collection of flowers contains some perfect ones, with others staminiferous, and others pistilliferous only. There is reason to believe that, when either set of organs is not developed the

rudiments of it really exist; for these parts are frequently made to appear by cultivation.

436. If the ovarium be cut into, previously to the opening of the flower, it will usually be found to contain a great number of the ovules or young seeds. These are at that period quite soft; and their interior is filled up with a kind of pulp, which is enclosed in two or more envelopes. These seed-coats do not entirely cover the central envelope, but leave a small opening, which is called the foramen. This opening may be easily detected in the perfect seed, although it has there nearly closed up, by soaking it in water, and then pressing out the fluid that has been absorbed, which will be seen to issue from this little orifice. The foramen, as will presently appear, has a very important purpose in the fertilization of the seed; which, at the period now described, contains no trace of the germ of the new plant.

437. This germ appears to be conveyed into it from the pollen in the following curious manner. The little grains or cells, when set free from the anthers, fall upon the stigma of the pistil. In general the anthers are situated above the stigma,—the stamens being longer than the pistil in flowers that are erect or upright, and shorter in those which hang down; but sometimes a special provision is necessary for the conveyance of the pollen to the stigma, especially in monœcious or dïœcious plants. This function is often accomplished by insects, which in going from flower to flower in search of honey, cover over their bodies with pollen-dust, and rub them accidentally against the pistils of other flowers. When the pollen falls on the stigma, it is caused to adhere to it by a honey-like secretion from its surface; and after a short time it undergoes a remarkable change which closely resembles that already described in the spore of the Cryptogamia.

438. The outer coat of the pollen-cell appears to burst at one or two points, and to allow the inner coat to pass out through it in the form of a tube. This tube insinuates itself between the cells of the stigma, and passes down between the long and loosely-arranged cells of the style. It gradually extends, until

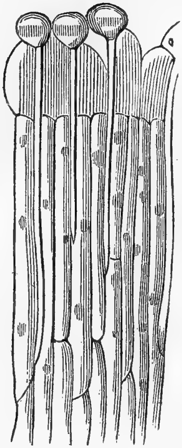


Fig. 51.
Section of the top of the style of Snap-dragon; showing the passage of the pollen-tubes between its cells.

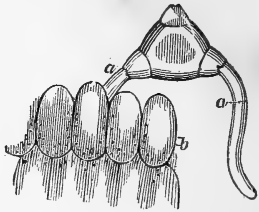


Fig. 52. Pollen-grain, of Œnothera biennis, sending its tubes *a*, *a*, between the cells, *b*, of the stigma.

it reaches the ovarium itself, even when the style is several inches long. The pollen-grains are not always globular, but are sometimes triangular, and emit a pollen-tube at each corner, as in the accompanying figure; such are analogous to the spores of Mosses, which put forth several tubes. The tubes, when they arrive at the ovarium, direct themselves towards its different chambers, and have been seen to enter the apertures in the several ovules, which are at that time directed towards the part of the base of the style, from which the pollen-tubes project themselves. Sometimes a considerable change in the position of the ovule is necessary, in order that the foramen should be applied to the right portion of the wall of the ovary; but this change always takes place just as the pollen-tubes are passing down the style. The granules which the pollen-grain originally contained, are seen to pass down the tube; and some of them are conveyed, by it into each ovule. Whilst yet within the tube, they are seen to develope themselves into new cells; and these cells are the rudiment of the future plant.

439. The germs are thus conveyed into a sort of receptacle where they are supplied with nourishment that has been previously prepared and stored up for their use by the parent

structure; and they are thus greatly assisted in their early development. The pulpy matter contained in the ovules consists of starch and sugar; and these nutritious substances are absorbed by the cells of the embryo, which increase at their expense. The first increase of these cells does not so much tend, however, to form those parts which are afterwards to be developed into the stem, root, and leaves; as to produce those temporary structures, termed *cotyledons* or seed-leaves (§ 21,) which are destined like the primary frond of the Ferns, to assist for a time in the development of the permanent structure, and then to wither and decay. Hence, at the time of the ripening of the seed, the cotyledon (which is sometimes double, sometimes single—see § 440–2) forms the greatest part of the embryo or young plant. Besides this, the seed contains a considerable quantity of starch, destined for the nourishment of the young plant, when it is beginning to sprout, and whilst yet unable to take in food for itself. This starch is sometimes absorbed into the tissue of the cotyledons, rendering them thick and fleshy, as in the Pea or Bean; and then these, with the small germ to which they belong, form the entire contents of the seed. In other instances, however, the cotyledons are thin leafy organs, and occupy, with the germ, but a small part of the seed; the remainder then consists of a separate store, which closely resembles the yolk-bag of the egg, and is termed the *albumen*. This is the case in the seeds of all Mono-cotyledonous plants, and also in some Dicotyledons, as the Ash and Horse-chestnut.

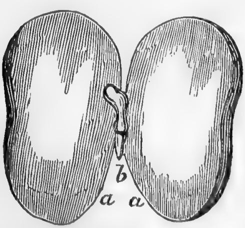


Fig. 53.
Seed of the Bean, with its cotyledons, *a*, *a*, separated; *b*, germ.

440. The structure of the seed of the two principal divisions of the Phanerogamia is shown in the adjoining figures. In Fig. 53, is seen that of the Bean, a *Dicotyledon*, after the seed-coats have been stripped off, and the cotyledons separated. The two large fleshy lobes, *a*, *a*, are the cotyledons, into which the whole of the starch originally contained in the ovule has

been absorbed. Between these is the real germ; the upper extremity of which, termed the *plumula*, subsequently developes itself into the stem, and puts forth leaves; whilst the lower part, which is always directed towards the foramen, becomes the root. The plumula sometimes presents the appearance of the plant in miniature; its leaves and buds being quite discernible, though on a very small scale. The subsequent development of the germ contained in the seed into the perfect plant, is that which in its early stage is known as *germination*. Of the causes which excite it, we shall presently speak. When a seed like that of the Bean begins to germinate, it first swells and bursts its seed-coats; the plumula then extends upwards, bringing the cotyledons just above the surface of the ground; whilst the radicle penetrates it in the opposite direction. In some plants, however, the cotyledons remain under ground, as in the Oak; and there are a few in which they are entirely absent. The cotyledons, when exposed to the light, become green; and perform for a time (though imperfectly) the functions of leaves, at the same time yielding to the young plant the nourishment they contain. By the time this is exhausted, the true leaves and roots are sufficiently developed for the support of the structure; and the cotyledons, being then no longer required, decay away. Thus it is seen that, in all the essential points, the history of the young Phanerogamic plant corresponds exactly with that of the young Fern;—the chief difference consisting in this;—that the development of the former, up to the time when its cotyledon or primary frond ceased to support it, is assisted by the nourishment prepared for it by the parent; whilst the latter has no such assistance, but obtains its nourishment from the surrounding air and moisture.

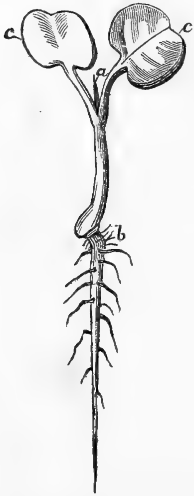


Fig. 54.
Germination of Dicotyledonous seed; *a*, plumula; *b*, radicle, *c*, *c*, cotyledons.

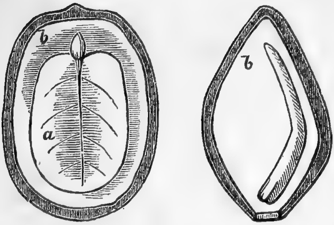


Fig. 55.
Seed of the Marvel of Peru.

441. The adjoining representation of the seed of the Marvel of Peru affords an example of a dicotyledonous seed possessing leafy cotyledons and a separate albumen; in these, the process of germination is the same, except that the cotyledons only perform the functions of temporary leaves, the nutritious part of the seed being retained within its coats, until it is exhausted by the young plant.

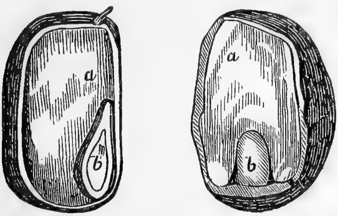


Fig. 56. Sections of Seed of Onion; *a*, *a*, albumen; *b*, *b*, embryo.

442. In the seeds of the *Monocotyledons*, the structure of which is illustrated by the accompanying figure of that of the Onion or Lily, the albumen is always separate; and the embryo, which occupies but a small proportion of the whole mass, cannot always be readily distinguished in the midst of it, until germination commences. The cotyledon at first completely sheathes the plumula, which afterwards pierces it, and unrolls its first true leaf.

443. Now it is an interesting fact, that the division of the Phanerogamia, founded upon the structure of the seed, exactly corresponds with that formed according to the structure of the stem;—that is, all Exogens are Dicotyledonous (with only a few apparent exceptions;) and all Endogens are Monocotyledonous. Moreover, all the Acrogens, which have no regular method of adding to the diameter of their stem, are destitute of the power of forming true seeds,—the germs being, as it were, at once cast upon the world, instead of being reared and cherished by parental care. It has formerly been pointed out that Exogens, Endogens, and Acrogens differ also in the distribution of the veins in their leaves (§ 229—32;) and it may here be mentioned that they differ

also in the number of parts of which the flower is usually composed. Thus, in Exogens, the regular number of stamens is either four or five, or a multiple of one of these numbers; and that of the carpels is similar; whilst in Endogens the number of the same parts is three, or a multiple of it. The number of the external or leafy parts of the flower follows the same laws, as will be hereafter explained.

444. The conditions requisite for the germination of the seed, are warmth, moisture, and the presence of oxygen. The process is also favoured by darkness. The influence of each of these agents will be readily understood. No vital action can go on without a certain amount of *heat;* and where this is not produced within the being, it must be derived from without. The germination of the seed is as much dependent upon warmth, therefore, as the hatching of the egg of a bird; though the amount it requires is not nearly so great. *Moisture* is also evidently required, for the conversion into a fluid state of the dry nutriment which has been previously stored up in the seed; and no change can commence until this be supplied. The presence of *oxygen* is necessary, because the conversion of starch into sugar requires (as formerly stated § 283,) that some of the carbon of the former should be set free; and this can only be accomplished by the union of it with oxygen, so as to form carbonic acid. This process is favoured by darkness, because light has a tendency to produce the contrary change—the *fixation* of the carbon within the structure (§ 286.)

445. It is interesting to observe how all these conditions are supplied, in the ordinary course of Nature, by the soil in which the seed is dropped. If it be sown during the spring or summer, it speedily begins to germinate; but if it is deposited in the autumn, it remains almost unchanged, until the winter has passed, and the returning warmth of the air and earth arouses it into activity. It is seldom that the soil is so completely destitute of moisture, for any long time together, as not to be able to excite seeds to germinate; but their sprouting is well known to be favoured by damp weather; and if seeds, through being put into

the ground during a drought, remain undeveloped, they are brought forwards very rapidly by a genial shower. A porous soil is to be preferred on account of the free admission of air which it gives to a germinating seed, as well as for the other processes of vegetation (§ 178, 9.) A stiff clay soil prevents this necessary contact; and thus impedes germination. So complete a check, indeed, may be thus produced, that it has been proposed to bury seeds in clay rammed hard, when it is desired to convey them from one part of the world to another through very hot climates; the high temperature of which might destroy their vitality, if its influence were not partly prevented by the bad-conducting power of the mass in which they are thus enclosed. If seeds be buried very deep, even in a light soil, the contact of oxygen will be sufficiently impeded to prevent their germination; and the bringing such seeds nearer to the surface will then have as much influence in causing them to sprout, as the supply of either of the agents just mentioned, which might have been previously deficient.

446. The seeds of most plants are endowed with a remarkable power of preserving their vitality for an almost unlimited time, if they are placed in circumstances which neither call their properties into active exercise, nor occasion the decay of their structure. The conditions most favourable for this preservation will evidently be a low or moderate temperature, dryness of the surrounding medium, and the absence of oxygen. If all these be supplied in the most favourable manner, there seems no limit to the period during which seeds may retain their vitality,—that is, their power of performing their vital operations, when placed in the proper circumstances. And even if moisture or oxygen be not entirely excluded, the same effect may result, provided that the temperature be low and uniform. Thus the seeds of most plants may be kept for several years, freely exposed to the air, provided they are not exposed to dampness, which will either cause them to germinate or to decay. Some of those which had been kept in seed-vessels of plants preserved in the herbarium of Tournefort, a French Botanist, were found to retain their fertility after the lapse of nearly a century.

447. Instances are of no unfrequent occurrence, in which ground, that has been turned up, spontaneously produces plants different from any in their neighbourhood. There is no doubt that in some of these cases, the seed is conveyed by the wind, and becomes developed only in spots which afford it congenial soil, as was formerly mentioned in regard to the spores of the Fungi (§ 50.) Thus, it is commonly observed that clover is ready to spring up on soils which have been rendered alkaline by the strewing of wood-ashes or the burning of weeds, or which have had the surface broken and mixed with lime. But there are many authentic facts which can only be explained upon the supposition that the seeds of the newly-appearing plants have lain for a long period imbedded in the soil, at such a distance from the surface as to prevent the recess of air and moisture; and that, retaining their vitality under these conditions, they have been excited to germination by exposure to the atmosphere. The following possesses considerable interest.

448. To the westward of Stirling, there is a large peat-bog, a great part of which has been flooded away, by raising water from the river Teith, and discharging it into the Forth,—the object of this process being to lay bare the under-soil of clay, which is then cultivated. The clergyman of the parish was on one occasion standing by, while the workmen were forming a ditch in this clay, in a part which had been covered with fourteen feet of peat earth; observing some seeds in the clay which was thrown out of this ditch, he took them up and sowed them; they germinated, and produced a species of Chrysanthemum. A very long period of years must have probably elapsed, whilst the seeds were getting their covering of clay; and of the time necessary to produce 14 feet of peat-earth above this, it is scarcely possible to form an idea, but it must have been (in the natural course of things) extremely great.

449. The following circumstance, which occurred about 30 years ago in the State of Maine, in North America, is, perhaps, still more remarkable. Some well-diggers, when sinking a well, at the distance of about 40 miles from the sea, struck, at the depth of about 20 feet, a layer of sand; this strongly excited curiosity and

interest from the circumstance that no similar sand was to be found any where in the neighbourhood, or any where nearer than the sea-beach. As it was drawn up from the well, it was placed in a pile by itself; an unwillingness having been felt to mix it with the stones and gravel which were also drawn up. But when the work was about to be finished, and the pile of stones and gravel to be removed, it was found necessary to remove also the sand-heap. This, therefore, was scattered about the spot on which it had been formed, and was for some time scarcely remembered. In a year or two, however, it was perceived that a great number of small trees had sprung from the ground over which the sand had been strewn. These trees became, in their turn objects of strong interest; and care was taken that no injury should come to them. At length it was ascertained that they were Beach-Plumb trees; and they actually bore the Beach-Plumb, which had never before been seen, except immediately upon the sea-shore. Theset rees must, therefore, haves prung up from seeds which had existed in the stratum of sea-sand pierced by the well-diggers; and until this was dispersed, in such a manner as to expose them to the air, they remained inactive. "By what convulsion of the elements," adds the narrator, "they had been thrown there, or how long they had quietly slept beneath the surface of the earth, must be determined by those who know very much more than I do."

450. The following is an example of the same general fact, which is interesting from its connexion with historical events. In the year 1715, during the rebellion in Scotland, a camp was formed in the King's Park (a piece of ground belonging to the castle) at Stirling. Wherever the ground was broken, broom sprang up, although none had ever been known to grow there. The plant was subsequently destroyed; but in 1745, a similar growth appeared, after the ground had been again broken up for a like purpose. Some time afterwards, the Park was ploughed up, and the broom became generally spread over it. The same thing happened in a field in the neighbourhood, from the whole surface of which about nine inches of soil had been removed. The broom-seeds could not have been conveyed by the wind,

although the plant is a common one in the neighbourhood, because they are heavy and without wings (§ 471.;) and the form of the ground is such that no stream of water could have transported them, or have covered them afterwards with soil. Such an effect must have resulted from the operation of causes continued through a long period of time.

451. Perhaps the most remarkable instance on record, as presenting satisfactory proof of the lapse of at least 1600 or 1700 years, is one related by Dr. Lindley. "I have now before me," he says "three plants of Raspberries, which have been raised in the gardens of the Horticultural Society, from seeds taken from the stomach of a man, whose skeleton was found 30 feet below the surface of the earth, at the bottom of a barrow,* which was opened near Dorchester. He had been buried with some coins of the emperor Hadrian." Corn-grains enclosed in the bandages which envelope the mummies, are said to have occasionally germinated, though most of them seem to have lost their vitality. There is nothing improbable in the fact; but as the Arabs, from whom the mummies are commonly obtained, are in the habit of previously unrolling them in search of coins, &c. it is not always certain that the seeds which have sprouted were really at first enclosed with the mummies.

452. When a plant is raised from seed, it will always bear a strong likeness to its parent; and if the species be one which has little tendency to variation, it will resemble it very closely. But there are many species, which have a great disposition to present deviations from what may be considered their original form (§ 13–16;) and thus, from the seeds of the same parent it is often possible to produce, by a difference of treatment, a number of plants differing considerably from one another. Whatever such

* These *barrows*, as they are termed, are large mounds of earth, which are very common on the downs along the south coast of England. They are evidently artificial, not natural; and when dug into, are usually found to contain human remains, with pottery; weapons, &c. Hence they are evidently burial-places; and as a large number of them are generally found together, they seem to have been erected on fields of battle, to contain the bodies of the slain.

differences may be, however, these plants are all regarded as belonging to the same species, since they are descended from a common stock; and by such experiments, it is often possible to show that plants which have been considered as distinct species, have no real title to be so classed (§ 16.)

453. It is often possible, however, to produce seeds capable of giving origin to plants that shall combine the characters of two different races. This is done by placing the pollen of one species upon the stigma of another; so that the germ, furnished by one, shall be nursed (as it were) by the other. It is not difficult to understand how the germ thus influenced, should be subsequently developed into a form differing from that of its own parent; for the germs of Cryptogamia, which are not received into any ovule, but are dependent upon the elements alone for their support, are often developed (especially among the lower tribes) into forms very different from that which they would naturally present. Thus a *Mucor*, a sort of Fungus concerned in the production of mouldiness, has been seen growing in water in a form so like that of a Conferva, that it was only recognised as a Fungus when it lifted up its fructification above the fluid.

454. The plant developed from a seed produced by the agency of two races, is termed a *hybrid*. It is necessary, in order that the seeds thus formed should be fertile, that the parent species should be nearly allied to each other; and it is very seldom that a hybrid can be produced when they do not belong to the same genus. Now, if the hybrid bear flowers, and its stigma be fertilized with its own pollen, it may produce seeds that can be raised into plants like itself; and these may flower and produce a third generation in like manner. But there is no instance in which a hybrid race, which has thus originated in the intermixture of two species really distinct, has ever been continued without intermixture beyond the fourth or fifth generation. The plant, when not fertile by itself, may bear seed, if its stigma be sprinkled with the pollen of one of its parent species; and its pollen may be fertile when placed on the stigma of either of these. In this manner, a race intermediate between the hybrid and one of the parent

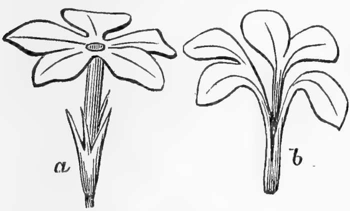
species is produced; and this is continued longer, just in proportion as it is caused to approach the pure breed, by a successive intermixture of this kind. The end of all hybrid races, produced between species really distinct, appears to be, therefore, that—either the race becomes soon extinct, which it will do if kept separate,—or it merges into one of the parent races, if continued by intermixture with either of them. This principle affords a valuable test for determining what really are, and what are not, distinct species; for if a hybrid race can be produced between them, which continues to be fertile of itself, the probability is strong that they are only varieties. Cultivators of flowers are constantly in the habit of producing such new races between the different varieties of many plants,—for instance, the South American *Amaryllis* and the *Calceolaria;* both these species are very much disposed to spontaneous variation; and, by selecting the most beautiful of the new races that spontaneously originate from their seeds, and causing these to produce hybrids, a still larger amount of variety, both in form and colour may be obtained. These hybrids are of equal fertility with their parents, since the latter are not separated by any really essential difference.

---

455. Having now considered the general structure and offices of those organs of Phanerogamia, which are most interesting to the Physiologist, from their connexion with the important function of Reproduction, we shall notice those parts of the flower which are less essential to this object, but which commonly excite more interest, on account of the varied and beautiful forms and colours they present;—namely, its external leafy portion. This may be altogether termed the *perianth*, or floral envelope; the *essential* portion of the flower being, as before explained, the stamens and pistil occupying its centre, which are sometimes destitute of any protection. The perianth may be regarded, as consisting, in its most regular form, of two circles (arranged like the whorls or verticils of leaves) of leafy organs; of which the outer circle is

generally green, and the inner one coloured.* Of this outer circle, the leaves or *sepals* not unfrequently grow together, or adhere, at their edges; so that a sort of cup is formed; hence the whole is termed the *calyx* (cup.) The inner whorl is termed the *corolla*, and its divisions are called *petals;* they not unfrequently grow together in the same manner (as in the *Campanula* or Harebell) forming a second cup within the calyx.

456. When the calyx seems formed of but one piece, in consequence of the adhesion of its leafy portions, it is said to be *monosepalous* (possessing but a single sepal;) and when the petals have united in a similar manner, the corolla is said to be *monopetalous.* Though these terms are not strictly correct (since there are really as many sepals and petals in the one case as in the other,) they are convenient, and are often employed in describing plants. The real nature of such a calyx or corolla is shown by varieties, or monstrosities, like that delineated in the adjoining figure; here the regular form of a monopetalous corolla, (in which the petals have grown together to form a tube, and are only separate at the top) is shown at *a;* whilst *b* shows the separate condition of the petals which is occasionally seen as the consequence of a want of adhesion between their edges. Different kinds of flowers, too, exhibit every variety between the completely-separate and the completely-adherent condition of the sepals and petals; and these differences are often very useful in distinguishing them from each other.



Fig, 57. *a*, monopetalous corolla; *b*, monstrous form of the same.

457. Outside the calyx is not unfrequently to be found another whorl of leafy bodies, more resembling in their aspect the ordinary leaves of the plant; these are called *bracts*, and are well seen in

* In Botanical language, the term *coloured* always means that the part is *not green*, green being regarded as no colour in Plants. A *white* flower is spoken of as coloured.

the Strawberry, where they surround and alternate with the sepals of the calyx. When no complete circle of them is seen, one or two are often present, and then they are generally larger. They do not always immediately surround the flower; but are often to be found at the bottom of the flower-stalk. These bracts may be regarded as establishing the transition of form and structure between the common leaves of the plant, and those modified or metamorphosed leaves which form the perianth. Sometimes they can scarcely be distinguished from the former; whilst in other cases, they are brightly coloured, and more closely resemble the latter; and, in the *Hydrangea* and some other plants, they really constitute the most showy portion of the flower, being very large and brilliant, whilst the flower they enclose is so small as to be almost overlooked. In many instances, the bracts form so gradual a transition between the true leaves and the parts of the flower, that it is very difficult to say where the former end and the latter begins. This is the case in the double Pæony,—a plant now very common in gardens. Its lower leaves are very complex in their structure, being divided into a great number of segments (§ 235;) in tracing them up the stem, they are found to become simpler and simpler in their character as they approach the flower, and also to diminish in size; and at the same time their spiral arrangement round the stem becomes more evident, the intervals between them being diminished. In this manner, they may be at last traced into the outermost whorl of the leafy parts composing the flower; and it is quite impossible to specify the exact place at which the true leaves may be said to end, or the calyx to commence.

458. From this it would appear that there is no *essential* difference between the sepals of the calyx and regular leaves; and examination of their structure bears out the conclusion. If we take an example from a plant in which the sepals are distinct from each other, and green, we should find it difficult to assign any important characters in which they differ from leaves. They possess two layers of cuticle, furnished with stomata; having green cellular tissue or parenchyma between them, supported by veins consisting of woody fibre and vessels. There are many cases, however, in

which the calyx is brightly coloured, equalling the corolla in beauty, and even surpassing it in brilliancy. In the Lilies and Tulips, we find the perianth composed of six coloured parts, which seem to spring at once from the flower-stalk, without bracts or calyx. But, if they be examined, it will be found that three of these arise lower down than the others, and therefore partly enclose them; so that these three are to be regarded (in spite of their colour) as sepals of the calyx; and it may often be observed that, though coloured in their interior, they are greenish outside, especially along their middle. In the Fuchsia, a plant which is now becoming naturalized in our gardens, though formerly considered a rare exotic, the calyx is even more brightly coloured than the corolla. This change of colour, however, by no means disproves what has been said of the analogy between sepals and leaves; since, as formerly noticed, leaves themselves occasionally undergo similar changes, and the colouring principle seems to consist in all cases of nearly the same substance, in different states of chemical combination (§ 386.) Farther, the calyx not unfrequently returns to the form of true leaves, in flowers in which its regular appearance is very different; such irregular formations, which are termed monstrosities, are in this, as in many other instances, very instructive to the physiologist, in leading him to the knowledge of the true character of organs, of which the external form may have been greatly changed.

459. Similar remarks may be made upon the real nature of the petals of the corolla. They are almost always coloured; but they still preserve their leafy structure, having cuticle, stomata, parenchyma, and veins. It has been seen that, in the Tulip and Lily tribe, there is no essential difference between the sepals and petals; what is true of the former, therefore, must be also true of the latter. Farther, in the Pæony, the transition from the form of the sepal to that of the petal, is as gradual as that from the ordinary leaf to the sepal. If we trace the portions of the perianth from without inwards, we may observe that the green leafy sepals are slowly changed,—in the first place by having their points and edges turned from green to pink, and becoming more delicate in

their structure;—next the inner side is seen to be completely coloured, while the back is still greenish in its centre;—and finally the whole is converted into an ordinary petal. But even where the appearance of the petals is the farthest removed from that of ordinary leaves, it is very common to find monstrosities which show that there is no essential difference. The common Wood-Anemone, for example, not unfrequently presents several varieties in the character of the sepals and petals, intermediate between what may be regarded as natural to them, and that of the ordinary leaves. Thus, the calyx may be converted into a whorl of true leaves, whilst the white petals have become green and resemble the ordinary sepals; or the metamorphosis may have proceeded farther, and the petals as well as the sepals may have been converted into ordinary leaves.

460. The structure, appearance, and functions of the stamens are so different from those of the parts of the perianth, that it would scarcely appear probable that *they* too are transformed leaves; and yet this will prove to be the case. There are many flowers in which the transition from the form of the petal to that of the stamen, is as gradual as those already described. This is the case, for example, in the Pæony; and it is still more evident in the common White Water Lily, the principal stages of transformation in which are represented in the adjoining figure. The petal is first thickened near its point, by a deposite of yellow substance, which, when examined, is found to be pollen. This thickened part gains upon the expanded portion of the petal, which becomes contracted in a corresponding degree, as we advance nearer the centre of the flower; until we arrive at the regular form of the stamen, in which we observe that the two thickened parts have met as anther-lobes, and that the leafy portion of the petal is contracted

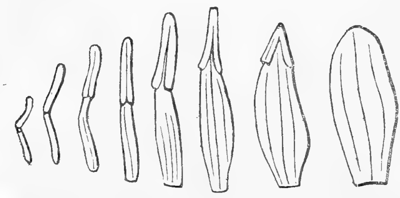


Fig. 58. Stages of transformation of petals of White Water Lily into stamens.

into the filament supporting them. The inner rows of stamens (of which there are several) are still more contracted, not being fully developed; and here we lose all trace of the leafy appearance.

461. Although the usual appearance of the stamens is such as was formerly described, there are several flowers in which they ordinarily have very broad expanded filaments; and these organs are subject to the same kind of transformation into the leafy character as are the portions of the calyx and corolla. The transformation of stamens into petals, in fact, is extremely common; it being generally in this manner that *double* flowers are produced from single ones. In the wild Rose, for example, we find but a single row of petals, surrounding a very large number of stamens; whilst in the cultivated Rose of gardens, there are several rows of petals, and the number of stamens has proportionally diminished. The Rose is a flower which is very liable to produce monstrosities or irregular growths; and it is not uncommon to find this transformation more complete,—the stamens, as well as the petals and sepals, being converted into true leaves, so that the flower is entirely green. The same is often the case with the Wood-Anemone. No farther evidence, then, is required to prove that the *elements* of the leaf and the stamen must be the same (although their fully-developed forms are so different;) and that that these elements may be developed into one form or the other according to circumstances, with which we are as yet only in part acquainted.

462. We now come to the Pistil, which occupies, as formerly stated, the centre of the flower. In considering its real nature, it is always necessary to regard it as made up of a number of separate *carpels* (§ 434,) whether or not they can be completely distinguished;—just as the monosepalous calyx and the monopetalous corolla are considered as formed by the adhesion of their several constituent portions. We have to examine then, what is the real character of each carpel; and this is sometimes manifested to us in a remarkable manner. When the carpels are distinct, and are fully developed, they not unfrequently present a very leafy appearance. Thus, the pod

Fig. 59.

of the Pea, when opened, is seen not to differ essentially from what a leaf with its two edges rolled together would be; the prolongation of the stalk corresponds with the midrib, and the two valves of the pod are the two lobes of the leaf. Instances occasionally present themselves in which this is seen more decidedly, from the want of devolopment of the ovules, and the non-closure of the pod, so that its leafy aspect is less departed from. There are little projections, however, from the thickened edges of this *carpellary leaf*, which show where the ovules should have been. A still more interesting monstrosity is almost constantly presented by the double cherry. The centre of the flower is occupied by a small leaf in place of the usual carpel. This leaf (Fig. 60; *a*) has the two edges folded towards each other, and the midrib is greatly prolonged, having a little dilatation at its summit. If this be compared with the carpel of the cherry, seen at *c*, no doubt can be entertained that the two sides of the leaf answer to the walls of the ovary, the prolonged midrib to the style, and its dilated extremity to the stigma. In some instances the flower contains two such leaves; and they are then always seen to present their hollowed faces towards each other, in the manner seen at *b*. This

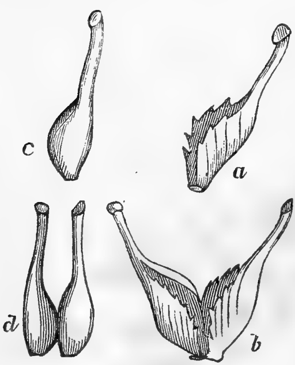


Fig. 60.

precisely corresponds with the position of the true carpels, shown at *d;* in which the *suture*, or line of junction of the two edges, of each carpel is opposite to that of the other. If any farther proof were required, of the carpel being a transformed leaf, it is afforded by the fact that, in Roses, Anemonies, Ranunculuses, and other such flowers, which are liable to have their stamens converted into petals, or into true leaves, the carpels not unfrequently undergo the same changes, so that the whole flower is metamorphosed into a bunch of leaves, which are still arranged, however, on exactly the same plan with the parts of the real flower.

463. The usual arrangement of these parts corresponds precisely with what was formerly stated of the disposition of the leaves (§ 185.) When the spiral, which may be regarded as their regular mode of arrangement, is converted into a whorl or verticle, by the non-development of the intervening part of the axis, and two or more of these whorls succeed one another, their several leaves do not correspond in the direction in which they issue from the stem, but are so placed that the leaves of each are above or below the intervals between the leaves of the other. When this is the case, the whorls are said to alternate with each other. Now the regular flower may be considered as made up of five such whorls, arising from nearly the same part of the axis; and they are disposed alternately with each other. Thus the sepals of the calyx *alternate* with the bracts; the petals of the corolla alternate with the sepals, and are *opposite* to the bracts; the stamens alternate with the petals, and are opposite to the sepals; and the carpels alternate with the stamens and are opposite to the petals.

464. This very simple law, regulating the position of the parts of the flower, is apparently subject, however, to many exceptions; but these all arise from the interference of other causes. For example, the number of parts may be so much increased, that they cannot be all arranged in one whorl, and they then form additional verticils; which, however, still follow the same principle of arrangement. For example,

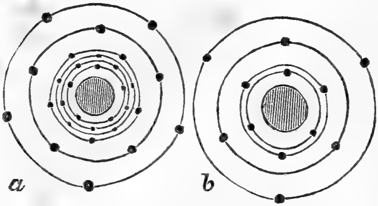


Fig. 61.
Plans of flowers; *a*, Cherry; *b*, Squill.

the adjoining figure shows a plant (*a*) of the flower of a Cherry; in the outer circle are marked the places of the five sepals, and in the next those of the five petals which alternate with them. Within these, however, we find no less than twenty stamens; but these may be regarded as composing four whorls with five in each, apparently blended together, however, by the closeness of their origin. The other diagram (*b*) is the plan of the flower of a Squill, in which, as in other Endogens, the parts are disposed in *threes* not in fives. The outer circle has three dots indicating the places of the three sepals; and on the inner one the petals are indicated in like manner, and are seen to alternate with the former; the stamens are six in number, and distinctly form two rows, of which the outer one is opposite to the whorl of the calyx, and the inner one to that of the corolla; and with this, again, the carpels would alternate.

465. An apparent irregularity, however, is more frequently produced by the absence of some of the parts. Thus, in the Primrose, there are five sepals, five petals, and five stamens; but the stamens are opposite to the petals, instead of alternating with them (Fig. 62; *a*.) Now the explanation which the Botanist would offer of this irregularity, is,—that there must be a row of stamens intermediate between the petals and the stamens, which from some cause have not been developed. And this is found to be really the case; for in the Samolus, a plant otherwise formed upon the same plan as the primrose, five little scales, which are partly-developed stamens, appear in the situation of the absent

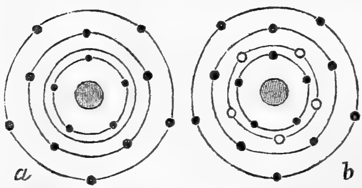


Fig. 62.
Plans of flowers; *a*, Primrose; *b*, Samolus.

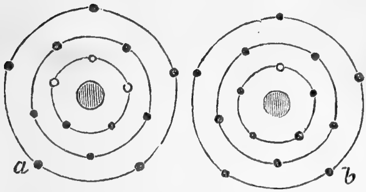


Fig 63. *a*, plan of flower of Sage; *b*, development of stamens in allied genus.

row. In the Sage, again, we find a calyx of five sepals, and a corolla of five petals; but only two stamens are seen within (Fig. 63; *a*.) Now, upon looking attentively at the inside of the tube of the corolla, two little scales are often to be seen growing in the place where two of the deficient stamens should have been,—that is, alternating with the petals; these two scales are often developed as perfect stamens, in flowers which are otherwise constructed exactly like the Sage (*b*); and even the fifth makes its appearance in some instances, exactly where it should regularly be found. Such deficiencies are often to be noticed; thus in the genus Bauhinia, which has, properly ten stamens arranged in two whorls, there are some species in which only three, or even but one, perfect stamen is developed. Deficiency in the number of Carpels in the pistil is even more common; and it is in fact rare to find a flower which presents a structure that may be considered perfectly regular, as well in its form as in the number of its parts. Without forming some such standard, however, it would be impossible to obtain a definite idea of the nature of the deviations, of which some of the principal kinds will have to be considered hereafter.

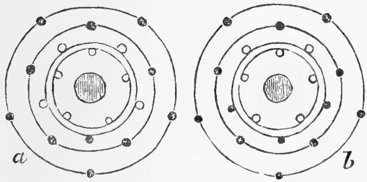


Fig. 64. Plans of Flowers of Bauhinia.

466. One of the commonest of these deviations is that in which the calyx appears to arise, not, as is usual, below the ovarium, but above it. In this case it will be found that the real position of the parts is the same; but that the perianth wraps round or encloses the ovarium and spreads itself out only when freed from it. The stamens too, not unfrequently seem to arise from the

corolla, instead of from the axis of the flower; but this effect is produced in a similar manner—namely, by their adhesion at their lower part to the inner side of the petals. The stamens, again, sometimes adhere to each other, so as to form a complete tube, surrounding the pistil.

468. In the foregoing instances, the *symmetry* of the flower is not destroyed; that is, it may be divided into two similar halves by a line crossing it in any direction. But there are many irregularities resulting from the unequal development of the different parts of the same whorl, and from the adhesion of these parts to each other in various ways; so that the whole form of the flower sometimes appears completely changed, and there is only one direction in which it can be divided into two equal halves. This is the case in the flower of the Pea or Bean, for example; in which, as in other plants of the Papilionaceous group (so named from the resemblance of the flower to a Papilio or Butterfly,) there is one broad petal standing erect, two separate ones termed the wings, which are prolonged from its base, and two others united together, forming what is termed the keel, which is enclosed between the last.

468. The flower is usually placed at the end of the flower-stem, or of its subdivision of it; and the tendency in this stem to lengthen, appears to be checked by the development of a flower-bud. It commonly swells out at the insertion of the perianth, forming what is called the *disk* or *receptacle;* and in this, as formerly stated, nourishment is frequently laid up, in the form of starch, for the development of the young ovules (§ 285.) This receptacle sometimes grows upwards between the carpels, and even encloses them. In other cases, it extends so much as to separate the carpels from one another; this is the case in the Strawberry, of which the fruit is the swollen receptacle, whilst the little bodies scattered over its surface (commonly termed seeds) are in reality the carpels. Sometimes, however, it happens that the flower-stem continues to grow between the points from which the solids proceed; and they are then separated, from each other, just as are leaves in like circumstances (§ 304.) The spiral line, in which

the different parts of the flowers are inserted round the axis, then becomes very evident. This is the case not unfrequently in the Double Tulip; and as the parts of the flower are generally at the same time more or less changed into the leafy character, the resemblance of the whole flower to a leaf-bud or undeveloped branch then becomes very obvious. Sometimes after giving off the whorls of the perianth, the flower-stalk is prolonged through their centre, and bears another bud at its extremity; this is by no means uncommon in Roses. It is well known to Gardeners that, by a still farther change, flower-buds may be actually converted into leaf-buds, and developed into true leaf-bearing branches; a fact which sufficiently proves that every part of the flower is formed out of the same elements with leaves, and that the development of either may take place according to circumstances. Hence we know why a difference in the amount of nutrition which the plant receives, should influence its tendency to the production of flowers and fruit. It has been stated that, in each of the parts of the flower, there is a tendency to revert to the leafy form; and this is especially the case with the stamens, which are often converted into petals (thus changing a *single* flower into a *double* one) when the plant is transferred from the poor soil in which it may be naturally growing, into the rich mould of a garden. Now if a plant be over-supplied with nourishment, it will *run to leaf*, as it is termed,—that is, it will develope too many leaf-buds, and will not put forth flowers; so that, in order to make it bear fruit, it is necessary to diminish its quantity of sap; one method of effecting which, is to dig a trench at a certain distance round the bottom of the trunk, so as to cut off part of the supply it receives from the roots.

469. It might be objected to the statements here made, that the pollen and the ovules are so different from any thing which the leaf naturally produces, that no analogy can be imagined between organs bearing these, and the ordinary leaves. But, if the structure of the pollen-grain be considered, it will be perceived to correspond precisely with that of other cells of cellular tissue; differing chiefly in its power of separating itself from the rest, and of sending forth little granules which are to form new

plants, instead of adding to the number of cells in the parent structure. Every cell of the Confervæ, it will be recollected (§ 424,) may be regarded as essentially a pollen-grain; and therefore the difference cannot be really so great as it appears. Farther, in regard to the ovules, the fact heretofore mentioned (§ 240,) that certain leaves have the power of producing little buds from their edges, becomes of great interest; for, if the ovules could be regarded as at all analogous to buds, it is evident that their situation on the edges of the carpellary leaf would quite correspond with that of the buds of the *Bryum*, or of the Bog Orchis. And it has been proved by the occurrence of some curious monstrosities, that this is a real analogy; for a seed-vessel has been known to bear a set of little buds at the edges of its carpellary leaves, arranged just as the ovules should have been.

470. We have in the last place to consider the structure of the Fruit, which is the mature or ripened ovary containing fertilized seeds. This frequently differs remarkably from the ovary which the centre of the flower contained, both in its external appearance, and in the arrangement of its interior. For example, the Cherry, Plum, Almond, or other stone fruit, is formed by a remarkable change in the substance of the carpellary leaf; the internal surface of this becomes hardened into the stone, whilst the external remains as a thin cuticle or skin; and the pulp of the fruit is formed by the increase of the parenchyma or fleshy tissue of the leaf. Here each carpel originally contained several ovules, but only one of them is usually developed. In the ovary of the Chestnut, there are originally seven carpels or cells with two ovules in each, whilst the ripe fruit consists of but one cell and one seed; so that no fewer than six cells and thirteen ovules are suppressed, in order to enable a single ovule to grow and be matured. It is not uncommon, however, to find two or even three chestnuts within a single shell, separated by slight partitions. The fruit of the Orange, as formerly mentioned, consists of the carpels, surrounded by the calyx which is adherent to their exterior, and having the space between their inner wall and the seeds they contain, filled up with a very succulent cellular tissue. On the other hand, in the

Apple, the carpels lie in the centre of the fruit, and their walls are somewhat horny; the fleshy substance of the fruit is formed by the calyx, which is adherent to the exterior of the ovary; and the parenchyma between its two surfaces swells out in ripening, in the same manner as does that of the carpellary leaf of the Plum. In the Medlar, the carpels have a hard or bony covering, and they lie separately in the midst of the pulpy envelope, which they acquire in like manner from the calyx. In the Strawberry, as formerly mentioned, the carpels are separated from each other by the receptacle, the expansion of which forms the fleshy part of the fruit. In the Raspberry, on the other hand, the receptacle is the white fleshy stalk which occupies the centre of the fruit; and the pulpy portion consists of the carpels enclosing seeds. The pods of the Pea, Laburnum and other Leguminous plants, again, are single carpels, which sometimes grow to a great length, and contain many seeds. A great many more varieties might be enumerated; but the mention of these will serve to give an idea of the mode in which the very curious transformation of the ovary into the fruit takes place.

471. When the seeds are ripe and ready to be dispersed, the carpel usually splits either along the suture, or in the opposite direction, in order to set them free. There are many curious provisions for their dispersion to a great distance from the parent. Some of these, depending on the movements of the capsule, have already been explained. Many seeds are *winged*, that is, are furnished with a little expansion on each side, filled to catch the wind; and thus they are wafted to places far distant from those in which they were produced. A very common provision is that of which the Dandelion seed is an example. This, as is well known, is furnished with a very light downy appendage, by which it is floated along with the slightest breath of air. Other seeds, again, are conveyed by the waters of streams and rivers, into which they fall; and take root when left by the current upon a congenial soil. Some are even capable of resisting the influence of the waters of the sea; and in this manner it is that the coral islands, which are gradually appearing above the surface of the

Pacific Ocean, are speedily covered with a crop of luxuriant vegetation. Birds, too, are very important agents in diffusing the various species of plants; some of which are scarcely dispersed in any other way. They carry off the whole fruit to a convenient place, and drop the stone when they have eaten the pulp; or they eat the whole, and the seed, being undigested on account of the hardness of its coats, falls into the ground when voided by them. Some seeds will not readily germinate until they have undergone this process. When it is considered that from a single seed, as many as 30,000 or 40,000 of some species may be produced in a single year, it will be perceived how abundantly the Creator has provided for the continuance of their race, and how unlikely is their extinction without some great convulsion of Nature.

472. The Reproductive System of Vegetable, then, counteracts in its operation the effects which would otherwise speedily result from the law, which the Creator has impressed on all organized structures;—that law of limited duration, which renders their death and decay as complete a portion of the series of actions they exhibit, as the wonderful phenomena in which they are concerned during life. By this counterpoise, all limit to the continuance of *races* is removed, except such as is interposed by some causes beyond. The records of the history of the Earth, which are brought to light by an examination of the rocks that appear at its surface, afford abundant evidence that vast convulsions must have formerly occurred, involving the Vegetable as well as the Animal kingdom; and that, at each of these, many races of Plants were utterly destroyed, so that there is now probably not a single species remaining, of those which first covered the dry land with verdure, when it was lifted from the depths of the ocean by Almighty Power. Such a convulsion will again occur. A time is foretold when "the elements shall melt with fervent heat, and the earth also and the works that are therein shall be burned up." But the soul of man will survive this general conflagration, and his faculties receive that full development of which it is of such vast importance that he should here become prepared.

CONCLUSION.

The Author is not without hope, that the interest excited by this Treatise in the minds of some of his readers, may lead them to desire farther information on the subject, and to make it a regular object of pursuit. Several works of great value to such inquirers exist in our own language; among which may be specified Dr. Lindley's "Introduction to Botany," and his Treatise on the subject in the "Library of Useful Knowledge;" Professor Henslow's "Treatise on Botany" in Lardner's Cyclopædia; and Dr. W. B. Carpenter's "Principles of General and Comparative Physiology." The general plan of the following Treatise is more formed upon that of the *last* of these Volumes, than upon any other; but to all of them the Author has to acknowledge his obligations, for the valuable materials which he has freely drawn from them. To those acquainted with the French and German languages, the "Organographie and Physiologie Végétale" of Professor De Candolle, and the "Physiologie der Pflanzen" of Professor Meyen, may be recommended as the most comprehensive works on the subject. In the Sixth Chapter, the Author has embodied a summary of the inquiries on the food of plants, recently made by the eminent German Chemist, Liebig; whose Treatise on the "Application of Organic Chemistry to Agriculture and Physiology" (translated into English) he regards as one of the most important contributions hitherto made by Science to the Arts. Dr. Lindley's recent Treatise on the "Science of Horticulture" may also be recommended to those who feel a desire for additional information on that department of the subject.

In Schools and Families in which this Treatise is employed as a Class-Book, Carpenter and Westley's series of coloured paintings on glass may be exhibited with very advantageous effect, by means of the Magic Lantern, which is also very serviceable for Zoological and Astronomical illustration.

DETENTION TW

IBIT