THE PLANT,

An Illustration

OF THE

ORGANIC LIFE OF THE ANIMAL.

BY

HARLAND COULTAS,

AUTHOR OF "THE PRINCIPLES OF BOTANY AS EXEMPLIFIED IN THE CRYPTOGAMIA," ETC., ETC.

PHILADELPHIA:
PERRY AND ERETY, PUBLISHERS,
S. W. CORNER FOURTH AND RACE STS.
1855.

PRINTED BY HENRY B. ASHMEAD,
GEORGE ST. AB. ELEVENTH.

TO

SAMUEL JACKSON, M. D.,

PROFESSOR OF THE INSTITUTES OF MEDICINE IN THE UNIVERSITY OF PENNSYLVANIA.

DEAR SIR,—

Knowing the enlarged and liberal views which you take of medical education, and your willingness to encourage your students in all inquiries tending to render them skilled and accomplished in their profession,—allow me to lay before you this humble attempt to show the uniformity of the organic laws in plants and animals.

I remain,

With sentiments of respect,

Yours truly,

HARLAND COULTAS.

CONTENTS.

PART II.

NUTRITION IN PLANTS AND ANIMALS.

CHAPTER V.

CHAPTER VI.

PART III.

REPRODUCTION IN PLANTS AND ANIMALS.

CHAPTER VII.

CHAPTER VIII.

PART IV.

ON THE GEOGRAPHICAL DISTRIBUTION OF PLANTS AND ANIMALS.

CHAPTER IX.

CHAPTER X.

PREFACE.

The two volumes on Cryptogamous and Phanerogamous plants already published by the author, were written with an "especial reference to the wants of medical students and physicians." Botany has not yet obtained that position to which it is deservedly entitled, as a preparatory study to the organography and physiology of animals. It is still excluded from the most important medical schools; and this state of things will continue despite of all the efforts of botanists, so long as the plant is regarded as if it were isolated from the rest of organic nature.

The functions of animal life appear to be gradually superadded to those which are strictly vegetative. As we pass from the plant through the coral and sponge to the higher order of animals, bones, blood-vessels and nerves, gradually appear; the organs of the senses become more perfect, and the motions more complicated, until at length in man, the nervo-muscular system, which has thus been gradually superadded to the vegetative, manifests itself most perfectly in all that infinite variety of movement and sensation peculiar to rational beings. On the other hand, as we descend from man to animals still lower in the scale of creation, in proportion as the functions of animal life are suppressed, the vegetative life of the organism gradually predominates, until life becomes wholly vegetative.

Life in plants is therefore limited to the two functions of nutrition and reproduction ; and nutrition and reproduction in animals are necessarily illustrated by the flowers and forest trees with which the earth is beautified and adorned. Such appears to me to be the way in which organic nature ought to be regarded, such the relative positions of the vegetable and animal creation.

Few, we believe, recognize as they ought to do, the benefits which have already resulted to animal physiology and the science of medicine, from the study of a few humble plants. The great cell-doctrine of physiology, which is now admitted to be the basis of all sound scientific investigations into the phenomena of organized beings, originated in the study of vegetable matter. M. Mirbel, in a most admirable memoir on the development of Marchantia polymorpha, a little acotyledonous plant belonging to the family of the Hepaticæ, was the first to show the cellular origin of every other form of vegetable tissue. He proved that the fibre cells of plants are only attenuated utricles, and that the different varieties of vasiform tissue and ducts, by which the interior of the plant is aerated, originate in a row of utricles ; these gradually elongate, and the various secondary deposits characteristic of the different forms of spiral vessels, appear on their internal surface ; the septa or partition walls between the several cellules are then absorbed, and the transformation of the utricles into vessels is completed. These observations were confirmed by the researches of Schleiden and other distinguished botanists, and thus a flood of light was thrown on the organization of plants.

But how do the cells of plants and animals originate? How do they multiply and extend themselves so as to produce the growth or enlargement of the organs? These are difficult but interesting questions, and botanical researches have enabled us to reply to them satisfactorily.

A German naturalist, Mohl, selected for observation one of the fresh water algæ, which had been previously figured and described as Conferva glomerata. This simple, thread-like plant was placed beneath the microscope, and the development of the row of utricles of which its entire organization consists, watched. Very soon, Mohl observed that the interior face of the cavity of one of the utricles presented towards its middle part a fold, which increased almost imperceptibly until it ended by forming a complete wall dividing the cavity of the utricle into two parts. Each of these then dilated itself into a new utricle. Thus in the place of one cell there were two cells, which again divided in the same way, and so on. It is in this way that a single cell gives rise to a row of connected cells, when the division takes place in one direction, and to a plane or solid mass when it takes place in two or more directions. There are other modes of increase which we shall notice in the ensuing pages; suffice it for the present to say, that their discovery originated in the investigation of cryptogamous plants of extreme simplicity of organization.

Up to this period it was believed by the most eminent physiologists, that animal and vegetable tissues differed widely in their development, and that cells existed only in plants. Such was the condition of things in 1838, when Schwann, taking up the beautiful investigations that Schleiden had just published upon the structure and growth of vegetable cells, came to the conclusion that animal tissue consisted equally of cells, and that whatever may be the character of the tissues, whether they assume the form of muscle, bone, or blood-vessels, all originate in cells, of which they are but modifications.

Let it be remembered that these grand discoveries, which have given such an impulse to animal physiology within the last twenty years, originated in botanical investigations. After such fruits have been reaped, the study of the physiology of plants ought to be encouraged. Where would have been our knowledge of the histology of animals, but for the botanical researches of Mohl, Schleiden, Mirbel and other distinguished physiologists? Incalculable, then, has been the amount of good which has resulted to animal physiology, from the study of the simple and beautiful organization of plants, and in the face of these facts, there is no excuse for the coldness and neglect with which this department of Natural History still continues to be treated. It is not the mere collecting of species, the technical description of their several peculiarities, and their proper classification and arrangement which is here advocated, so much as the study of their vital phenomena and the laws of their development. No extensive acquaintance, either with rare exotics or the choicer native species, is at all necessary for such researches, for these laws may be studied in the commonest weeds growing around our dwellings.

The views on vegetable respiration in this work are not my own peculiarities; for they were held by Dr. Gilbert Burnett, an eminent English physician and physiologist. I have also been very favorably impressed with the opinions advanced by

Dr. Draper, in reference to the exciting causes of the motion of the nutritive fluids in the organism of plants and animals, notwithstanding the attempts which have been made to controvert them. Let it be considered that there is the same successive degrees of attenuation in the conduits of both the sap and blood, resulting from lateral ramifications; the same beautiful anastomoses amongst the capillaries in which these conduits finally terminate. By these means the nutritive fluids are diffused in all directions, and brought into immediate communication with the cellular tissue of the organs. Let the structure of any exogenous leaf be examined even superficially, without the microscope. The successive attenuations of the fibrous system by lateral ramifications into a network of capillaries, which develop horizontally in a series of closely approximated planes, through the parenchyma of the leaf, show that the same laws predominate in the distribution and elaboration of fluids in vegetable as in animal matter. At least it is not unphilosophical to infer some analogy, if not absolute identity of function, where there is so manifest a similarity in organic structure.

I cannot conclude my Preface without acknowledging my obligations to my numerous friends and patrons through whose assistance I have been enabled to produce this volume.

In the preparation of Part I. an excellent Chevalier microscope was employed. This instrument was kindly lent me by Dr. Francis Lewis. It gives me pleasure also to mention the services of Dr. Samuel Jackson, Dr. Samuel Lewis, Dr. Francis West, Dr. S. Tucker, the Hon. W. D. Kelly, and Professor Saunders of the French Collegiate Institute, West Philadelphia.

INTRODUCTION.

GENERAL CONSIDERATIONS ON ANIMAL AND VEGETABLE LIFE.

If we cast a glance at the immense quantity of animals and plants which live on the surface of our globe, we are at first struck with the variety of forms under which they present themselves, with their colors so diversified and sometimes so brilliant, and with the collossal proportions of some, as compared with the diminutiveness of others. But when, after this superficial examination, we study them more attentively; when we examine with care the structure of each being, we at once see the perfection which exists in its organs, and how well they are adapted to its peculiar habits and mode of life—from the enormous whale, which requires an ocean to swim in, to those minute and myriad forms which find ample room for all their evolutions in a single drop of its waters; from the lofty tree which has stood for centuries, an ornament in the midst of the landscape, to the lowly flower which attracts us by its beauty and fragrance—all form a collection of objects whose framework is constructed in the most admirable manner, and whose vital manifestations are in the highest degree instructive and interesting.

At first sight, nothing would seem to be more widely different from each other, than an animal and a plant. How different is the tree from the bird singing on its branches, or the traveller resting beneath its shade. In the one instance, the organism is immovably fixed to the soil which gave it birth, and has neither the faculty of moving itself, nor that of manifesting pleasure or pain. The hatchet penetrates its tissues, and it falls without any external signs of suffering. But in the other cases, the organic beings are far more highly complicated. They are endowed with the power of moving from place to place, have a will and desires, senses to apprise them of the character and qualities of external bodies, and introduce food into their interior, where a special cavity is provided for its elaboration before it is employed in the nutrition of their organism. Plants have no such special receptacle in their interior. They live, as it were, in the midst of their food. It is furnished to them by nature in a condition fit for assimilation and circulation. They draw it at once from the earth by their roots, and from the atmosphere by their leaves. They therefore possess no special organs for its preparation. It would seem impossible that there could be anything in common between bodies so strikingly dissimilar in their organization and habits.

But if we consider the vital phenomena manifested by animals and plants, we shall very soon see that there is abundant reason for believing that the difference between these organic productions of nature is not so great as we at first thought.

In the first place, both the animal and plant spring invariably from a being perfectly similar to themselves, to which they adhere during a space of time more or less long, and from which they are finally separated at a determinate epoch, under the form of an egg or a seed, which, under envelopes more or less resisting, encloses a germ. In this germ, all the organs of the adult animal and plant exist in a rudimentary undeveloped condition. Germination, or the act by which these organs disengage themselves from their envelopes, does not increase their number, but only augments their size or modifies their form. The seed contains the plant, and the egg the animal. Thus, they are alike at the commencement of their being. In the second place, the organs of plants and animals,—the root, stem, and leaves of the former, the bones, muscles, and limbs of the latter,—will not grow without a plentiful supply of food and air. In both instances it is absolutely necessary that the nutritive aliment should be introduced into the interior of the plant or the animal, and be distributed to all the parts of their organization. Now the absorption, circulation, and assimilation of food and air, by animals and plants, is *in principle* precisely the same process. Abundant proof of this position will be given in the succeeding pages.

Well-marked and obvious distinctions between animals and plants exist only in the more highly organized forms of animal and vegetable life. As we descend to beings of a lower rank in creation, these distinctions become gradually effaced, and we see successively disappear the most important organs of animal life. The organs of the senses become rudimentary, bones, blood vessels, and nerves totally disappear, and in proportion as the powers of animal life are suppressed, those which are truly vegetative gain the ascendancy. Thus, the lower orders of the cold-blooded vertebrata, whose bodily temperature is regulated by that of the medium in which they live, become torpid and inactive in common with plants in winter. So also many vertebrated and crustaceous animals change their epidermal appendages. The serpent casts its skin, the bird its feathers, crabs and lobsters their claws, just as the leaves and bark fall from the branches and stems of trees. Moreover, the exercise of the reproductive function which in man is not limited to any particular time, is periodical in inferior animals, precisely as plants flower and fruit at certain seasons of the year. At length, in the lowest orders of the animal creation, the animal and plant approach each other so closely that it is hardly possible to draw any line of demarcation between them.

This is the case, for example, with that order of animals which have been very properly called by naturalists, zoophytes, of which the coral and the sponge are familiar examples. These creatures, which show undoubted signs of animality, present also at the same time many striking

Fig. 1.

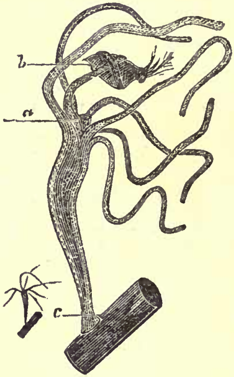


Fig. 1. Hydra, or polype attached to a piece of stick, with its arms extended in quest of prey. *a.* The mouth of the animal, surrounded by the tentacula. *b.* The tendril-like grasp of an aquatic insect. *c.* Foot or base of the animal with its suctorial disc. The figure shows also the natural size of the animal.

indications of a vegetable nature. They are not only fixed to the ground like plants, but they have also a plant-like method of growing and propagating.

It is extremely difficult to convey any general idea of a zoophyte, because there is no order of creatures of which the different individuals bear so little resemblance to each other. The organization of the corallines, flustras, sertularias, and other orders of marine zoophytes may, however, be illustrated by that of the Hydra, or common fresh-water polype. These animals, which resemble little pieces of jelly, are found in ponds or slowly running streams, attached to the under surface of the leaves of aquatic plants, or to any floating substance, such as a stick or a straw. They are remarkable for the extreme simplicity of their organization, which consists of nothing but a digestive cavity or stomach, surrounded by a fringe of long thread-like arms or movable tentacula, by means of which the animal procures its food—generally some minute insect or worm, which it seizes with a tendril-like grasp and instantly conveys into its stomach by a contractile effort. The contractility of the tentacula of the Hydra is truly wonderful. When the animal is hungry and in search of prey, the tentacula are extended to a distance of not less than six or seven feet from the mouth of the stomach; but when the digestive cavity is filled with food and the wants of the animal are appeased, they are so contracted as to appear only like tubercles around its entrance.

The different species of corallines, flustras, and sertularias, usually found attached to, or more frequently intermingled with, the sea-weed cast upon our shores, consist of an association of polypes having individually a similar organization to the Hydra, but united together about a common axis of growth like the buds and branches of a plant. It is interesting to trace the analogies between the members of the animal and vegetable kingdom in the lower orders of animated nature. The sertularian polypes

Fig. 2.

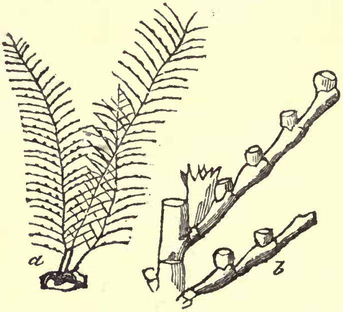


Fig. 2. *a.* Sertularia or compound polype. *b.* Magnified view of a portion of its branches, showing the polype buds.

with their common stalk bearing numerous individuals, have in every instance been produced by continuous growth from a single individual. Here we have a repetition of similar parts precisely as in plants. There can be no mistake as to the vegetative nature of these actions. Each of these associated polypes has an independent vitality of its own, and yet all depend on the general life diffused through the entire community. They individually capture and digest their prey like the Hydra, and yet the products of their individual digestion are applied not only to their own support but to that of the genèral axis; for the stomachs of the several polypes, communicate with each other by means of a tube which proceeds from the base of each into the common digestive cavity of the stem. Some of these polype buds periodically die and are cast off like the leaves of a tree; whilst others, retaining their vitality, spontaneously detach themselves and evolve into similar fabrics elsewhere.

It is, however, amongst the algæ that vegetable and animal life appear to be the most completely blended together. It is well known to naturalists that the spores of some of our common fresh water algæ, as for instance, conferva glomerata and prolifera rivularis, when first discharged into the water, move about by means of certain ciliary appendages during a certain period of their life. At this stage of development they were observed by Ehrenberg, and were actually figured by him as infusoria. After awhile, however, their ciliæ are absorbed, their motions cease, they become attached to some substance in the stream, and develop into plants fixed and immovable except from the influence of the current. It would appear from this, that these simple unicellular organisms are animals during the first period of their life and vegetables towards its close.

All organized matter, whether animal or vegetable, consists of cells, and life is only known to us as manifested through their agency. Not only may every animal and plant be traced to a simple cell, but organic nature is evidently only a series of forms which exhibit the successive stages of its development. The animal and plant seem to be blended together in this the primitive form of all organized being. It is here that the last signs of animality disappear, after which, life becomes wholly vegetative.

It is not then among vegetables and animals the most highly organized, that we find the most striking analogies between the animal and vegetable kingdoms, but it is those which possess the greatest amount of structural simplicity, that approximate the most closely to an identity of function.

The assemblage of organized beings denominated animals and plants, may be collectively represented, in reference to their mutual relationship, by two cones, one of which is inverted on the other, so that their summits are brought into mutual contact. For there is a point of departure common to both of these grand divisions of living nature,—THE ORGANIC CELL,—which animated, commences the animal series, and remaining immovable, serves as the basis of the vegetable creation. This organic cell may be imagined to be situated at the apex of the cones, the lower cone representing the vegetable and the upper one the animal creation. Plants and animals increase in organic simplicity and the analogies between them multiply and become more striking in proportion to their approach to this point; while, on the contrary, the differences which separate them increase and their organization becomes more complicated, as they elongate from it.

All that variety of form which marks the external organs both of plants and animals, is clearly traceable to the same organic laws. Thus, the same organ which attains a high degree of development in one plant or animal, is for certain physiological reasons in another, either suppressed altogether or reduced to a rudimentary condition. But these changes take place almost imperceptibly. We never see an important organ disappear all at once in any of the classes of the animal and vegetable kingdom. It is by degrees that the organ loses in succession the several parts which complicated it; these become rudimentary, and the organ is finally reduced to the utmost degree of structural simplicity, those parts alone remaining which are absolutely essential to enable it to perform its function. What are called varieties by naturalists are, in fact, only different phases in the organic development of the same specific form; and a truly scientific classification can only be achieved in proportion to the accuracy of our perceptions of the natural relationship subsisting among the organs thus modified.

The anterior organs of the different order of vertebrated animals, for instance, are organically modified to the degree of their intelligence, their powers of locomotion, and their peculiar habits. In some quadrupeds they are adapted for the prehension of food and for locomotion; in the bird they are organized for flight; in the fish, for balancing the body and assisting its progress through the water. The twisted arm of the tortoise can be applied to no other purpose than that of creeping, and the enormous hand of the mole can be used only for burrowing. Yet the anterior members in the different orders of the vertebrata consist essentially of the same parts as those which exist in the same members in man. We find in each the same bones, muscles, nerves, and vessels. Yet how different their appearance! how varied their functions! All these ends are attained by a modification in the development of the different parts, one bone being largely developed, a contiguous one less so, some being evolved to a maximum, whilst others are left rudimentary.

We have a manifestation of the same organic law in the vegetable world. Thus the leaves of plants are variously modified so as to be rendered subservient to the exercise of the different vegetative functions. The different organs appended to the vegetable axis and designated as scales, stipules, bracts, sepals, petals, stamens, and pistils, are only a series of leaves in a state of progressive or retrograde development, which have assumed this peculiarity of form in consequence of the peculiar and distinct functions assigned them. A fully developed leaf consists of two parts, a little stalk or support called a petiole, and a flat expanded portion called the blade or limb. In the scale, stipule, and bract, the petiole and lamina of the leaf are reduced to rudimentary condition; in the sepal the former is wholly suppressed and the latter more or less developed. In the petal both lamina and petiole are sometimes present, as in the pink and wall-flower. The petals of these flowers which are broad and expanded at their summit gradually taper into a narrow stalk or petiole, which in this instance is called an *unguis*, or claw. In the stamen, the petiole is represented by the filament, the lamina by the anther, whilst the reproductive matter called pollen, which is contained in the anther-cells, is only a peculiar transformation of the parenchyma of the leaf. In the pistil, there appears to be the greatest departure from the primitive type; yet it is not difficult to trace it even in this instance. The pistil is nothing but a folded leaf, the margins of which have united to form a placenta or point of attachment for the ovules, or young germs, which develop along its edge. Other instances might be brought forward illustrative of the fact that the same laws of development and adaptation, govern the organization of both plants and animals.

It is only by viewing nature as a whole that any part of nature can be properly understood. It is to the study of comparative anatomy and physiology, that we are indebted for our knowledge of this identity and unity of organization. The organism of one species has been compared with that of another, and the transitious forms of the several organs have been traced, so that organs are now recognized as the same which were formerly thought to be altogether different. It is to the contributions which they mutually afford each other that we are indebted for the advance of the physical sciences, and the same principle applies to natural history. Almost every part of the human frame has its homologue in some inferior animal. Hence "the advantage—the necessity, rather—of combining a general knowledge of the organization of the lower animals with that of man, which ought always to claim the first attention of the medical student, is now universally recognized. A great part, of the best part, of the proofs of the most important physiological doctrines are derived from comparative anatomy. The increasing taste for the natural sciences, and the rapidly diffusing knowledge of zoology and geology render it scarcely pardonable in a member of a liberal profession to be wholly unversed in them, and almost discreditable to a medical man to be unable to offer any sound opinion on a fossil coral, shell, or bone, which may be submitted to his inspection."* So also, the great cell doctrine which is now the basis of animal physiology, had its origin in microscopical investigations into the organization of plants. "Since it has been ascertained that the animal tissues are in their fundamental structure identical with the vegetable tissues, we may expect that botanical investigations may throw as much light upon the animal kingdom, as the study of animals may throw on the vegetable kingdom. Easy as it has been to study the structure of vegetable tissues, so difficult has it been to ascertain their functions, and the work of the various organs in plants, that the most contradictory opinions are entertained upon vegetable functions, upon the circulation of their sap, upon their respiration, and the action of respiration on their fluids. On the contrary, in animal structures the functions are easily traced. The combined action of the various functions upon each other can be easily ascertained. It was the structure, the intimate

* Lectures on the Comparative Anatomy and Physiology of the Invertebrate Animals, delivered at the Royal College of Surgeons: by Richard Owen, F. R. S.

structure which it was difficult to investigate. And now by referring the result from one kingdom to the other, it is to be hoped that much more rapid progress will be obtained than before."* Many problems connected with nutrition and reproduction in animals will probably be solved by a more careful observation of these functions in vegetables. A knowledge of cell-life, now universally admitted to be the basis of all scientific physiology, can be best acquired by examining the cells of plants which are much larger than those of animals, and visible to ordinary microscopes at every epoch of their development. The differences which exist among the organic productions are not so great as is commonly thought. There is a oneness in nature which has yet to be understood and appreciated.

One of the most striking differences of organization between the higher orders of animals and plants consists in the presence of a nervo-muscular system in the former of which the latter are totally deprived. This nervo-muscular system, which is essential to animality, appears to be gradually developed *in vegetable life,* which thus becomes inseparably bound up with the exercise of the animal functions. It is gradually developed in the inferior orders of animated being, and is manifested most perfectly in man, and those animals the most closely allied to him in organization.

Now comparative anatomy shows that the animal functions of sensation and voluntary motion, manifest themselves in proportion to the more or less perfect condition of the organs appropriated to their exercise. In man, the highest vertebral animal, the organs of the senses and the muscular

* Lectures on Comparative Embryology, delivered before the Lowell Institute in Boston, by Louis Agassiz.

system are the most highly developed, and prove successive degrees of simplification as we descend in the scale. The muscles in the human body are more than five hundred in number, and almost every movement is produced, not by the action of one, but of several of them. The muscular system in man not only moves the body but expresses thought and emotion, and is capable of a very high degree of education. The accomplished tragedian and musician manifest in their performances, the degree to which the muscles of expression and voluntary motion may be educated. The body of man is capable, through the agency of his highly developed nervo-muscular system, of an infinite variety of movement and expression. In man, the muscles of expression are chiefly in the face. In conversation, all persons to a greater or less extent communicate thought by the expression of their countenance. In some, however, the muscles of expression respond more readily to the emotions of the mind than in others, every shade of thought and feeling being beautifully depicted in their faces.* In the inferior animals, the expression of which they are capable is much more limited, and is confined to other parts of the body. The dog wags his tail, the cat elevates her back, the horse erects his ears, and the game-cock spreads out his ruff of feathers on his head. The countenance of the inferior animals is in general devoid of expression. Rage and fear are almost the only passions which are expressed in their faces. Their muscular movements are susceptible of education, as is evident from the performances of dancing dogs and bears,

* Human Physiology designed for Colleges and the Higher Classes in Schools, and for General Reading, by Worthington Hooker, M. D., Professor of the Theory and Practice of Medicine in Yale College. Chapter xiii. page 222.

but not to the same extent as those of man, owing to the low degree of their intelligence.

The organs of the anterior and posterior extremities connected with the trunk or spinal column in the higher vertebrata, are gradually absorbed in the lower, until at length in the serpent tribe, these locomotive appendages are suppressed altogether, and the body of the animal consists of little else but the spinal column itself, which is very long and extremely flexible, owing to the immense number of vertebra, and their connection with each other by a ball and socket joint. The perceptions of the animal are now obtuse, and all its movements sluggish,—a mere trailing of the body along the ground.

The same gradual simplification of the nervo-muscular apparatus, may be traced throughout the descending series of invertebrated animals. Insects may be truly regarded as the most highly developed of the invertebrata. In them the animal functions are decidedly more developed than the vegetative. Their rapidity of motion, and extraordinary display of intelligence, entitle them to this position. The tegumentary skeleton of insects is composed of a number of movable pieces articulated to each other, and is of a horny texture. This integument becomes progressively hardened, and the pieces fewer in number, and more consolidated in the different orders of the crustacea, so that the movements are necessarily much more restricted and confined. In the testaceous mollusca, the integument is finally reduced to a pair of valves, and the muscular movements of the animal are of the simplest character. Most of the bivalve muscles, such as the cardium, move along by means of a fleshy organ called a foot. The movements of the oyster are restricted to the single act of opening and closing its shell, and those of serpulæ and limpets, to the alternate protrusion and withdrawal of their tentacula within their testaceous covering. What a contrast do the simple motions of these animals present to the complicated motor machinery of the human frame! How immense the chasm of separation between these creatures and man!

The laws of phenomena really constitute science, and facts ought ever to be made subservient to their discovery. The zoologists and botanists who devote all their time and attention to the mere business of collecting species, of defining their external characters, and of forming systematic arrangements of them, undoubtedly perform a great and valuable service; but this after all, is but a coarse outline of the natural history of any country. It is not sufficient to obtain specimens of natural history for the cabinet, to group plants and animals according to their outward appearance; we must look more deeply into the mysteries of their organization, we must study their physiology and the laws of their development. It is true that little progress can be made in these investigations without we avail ourselves of the labors of the systematist; but after all, the technical description of the external organs of plants and animals, is only the infancy of science. It is not sufficient that we make ourselves acquainted with facts we must study their philosophy.

For example, it is well known to botanists that the calyx of the bloodroot (Sanguinaria Canadensis,) drops from the flower stem as soon as the petals open and expand, whilst in the blackberry (Rubus villosus;) it survives the decay and removal of the other parts. Why do the cells of the calyx perish at so early period in the one instance, and remain persistent about the fruit in the other? What is it that produces their early decay or the prolongation of their vitality? This is a very simple question, and yet in the present state of science, it is impossible to give the reader a satisfactory answer. All botanists are acquainted with the fact, its philosophy is unknown. Every branch of natural history is more or less in this imperfect condition. Botany is perhaps the most defective. It is in truth very little better than an accumulation of sterile facts. He who studies botany or any other branch of natural history in this, the true philosophical spirit, will not fail of becoming an original contributor to the department which he undertakes. In the place of a narrow circumscribed science, he will find an immense field, in which the commonest and most insignificant weed or animal, will furnish him with innumerable subjects for reflection and study.

PART I.

HISTOLOGY OF PLANTS AND ANIMALS.

CHAPTER I.

ON THE INDIVIDUALITY OF THE CELLS.

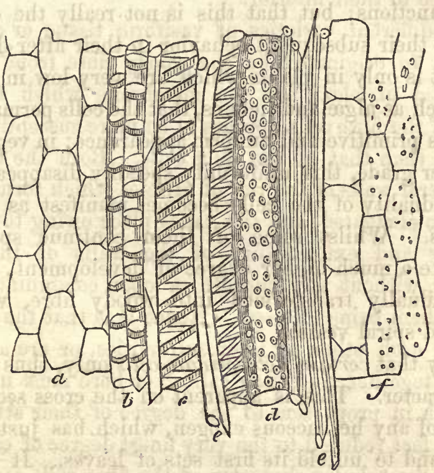
EVERY plant, germinating from the seed or spore, is subject from the commencement of germination to the close of its allotted period of life, to certain definite laws of development which are impressed on the cells of which that seed or spore consists.

If we consider the cells collectively as associated together in masses, constituting definite organs, the regularity and fixity of form assumed by those organs, shows that a certain *definite number* of cells must be developed to form them, and that these cells must attain a *determinate amount* of expansion; for growth, or the enlargement of the organs of plants, certainly appears to be as much the result of the expansion of cells already existing, as of the formation of new cells.

But the cells themselves, regarded individually, exhibit a series of phenomena which prove that they are subject to laws of development as rigid and invariable as those which govern them collectively. The primitive form of all cells, whether animal or vegetable, is that of a closed spherical vesicle or utricle. There is no plant, or organ of a plant, which is not at the commencement of its growth, fabricated exclusively of cells which approach more or less to that of a sphere in form. If we examine a bud, a young leaf or rootlet, with the microscope, in the first stages of growth, we shall find that cells which retain in a great measure their primitive sphericity, and present the same uniform appearance in their external configuration, constitute the substance of each of these organs. At this stage of growth the cells are all apparently the same, and endowed with similar functions; but that this is not really the case, is shown by their subsequent behavior in their after development. It is only in plants which are very low in organization, such as algæ and lichens, that the cells permanently retain this primitive and uniform appearance; in vegetation of a higher grade, this uniformity speedily disappears, and the individuality of the cells becomes manifest as growth progresses. Whilst some of them continue spherical, others take a much higher degree of development, and become gradually transformed into woody fibre, vascular tissue, and spiral vessels.

We say that *certain determinate cells* only, thus change their character. This is apparent on the cross section of the stem of any herbaceous exogen, which has just begun to grow, and to unfold its first sets of leaves. It will be seen that the cells in the centre and towards the circumference of the stem, which form collectively the pith and the bark, together with those of the medullary rays, are only slightly altered by mutual pressure from the spherical form. Those, on the contrary, which constitute the wood, and which occupy an intermediate position between the bark and the pith, are so changed in appearance that it seems at first impossible to refer them to the same common type. If we examine a longitudinal section of the stem, the nature and extent of the transformation which the wood cells have undergone, will be rendered more apparent. It will be seen that the fibrous portion of the wood consists of elongated, and extremely attenuated cells, which taper to either extremity and lie together in bundles, and that there are intermingled with these fibres several varieties of vasiform tissue and spiral vessels, the last being particularly abundant in the neighborhood of the pith.

Fig. 3.



Longitudinal section of Italian reed. *a*, Cells of the pith; *b*, annular ducts; *c*, spiral duct; *d*, dotted duct; *e*, woody fibre; *f*, cells of the herbaceous integument, one of the epidermal layers.

It is not difficult to follow this transformation through its successive stages, and thus to arrive satisfactorily at the important physiological fact of the individuality of the cells. It is only necessary first to examine the stem or any other organ in the embryonic condition, and then at intervals, soon after active life has begun to manifest itself in the germ.

If we observe the fibrous portion of the wood, for instance, when germination commences, we shall see that at first the fibre cells consist of a row of utricles somewhat more elongated than the neighboring cells; gradually these elongated utricles become lengthened into tubes, and the septa or partitions which separate them, and which in this instance are not absorbed, assume an oblique position with reference to their interior.

The different varieties of vasiform tissue or ducts will be seen to originate like the woody fibre from a row of elongated utricles; but the membrane which forms the walls of the fibre cells appears to be more susceptible of extension than that of the duct cells. Both the transverse and lateral walls of the row of utricles which form the fibre cells are elongated, and this takes place owing to the great tenacity and extensibility of the walls of the several cellules, without any rupture or open communication between them being effected. Hence it is that the fibre cells overlap each other at their extremities, or are as it were spliced together, and their calibre or bore must necessarily diminish in proportion to the degree of their attenuation. It is in fact reduced to the very finest degree of capillarity, so that the tubular character of the fibre cells can only be verified by employing the very highest powers of the best microscopes. The parietes of the row of utricles which originate the several varieties of vasiform tissue or duct cells, on the other hand, will not submit to a similar degree of tension; on the contrary, a very slight degree of elongation is sufficient to rupture the cross walls of the several cells, so as to form a continuous communication between them. An uninterrupted tube with a conspicuous calibre or bore, is the natural result. These ducts are generally situated on the inner side of the circle of fibre cells, and their open mouths are not unfrequently visible on the cross section without the aid of the microscope in the form of rounded openings or pores.

In their earliest condition, the cells of animals, like those of plants, present the same uniformity of appearance in their external configuration. Some of them maintain this condition throughout the life of the animal, and are the instruments by which the strictly vital operations are carried on; others rapidly undergo a change of form in accordance with those laws of growth to which they are individually subject. In this respect precisely, the same laws govern both the animal and vegetable world. "A globular mass," says Carpenter, "containing a large number of cells is formed before any diversity of parts shows itself; and it is by the subsequent development from this mass of different sets of cells, of which some are changed into cartilage, others into nerve, others into muscle, others into vessels, and so on, that the several parts of the body are ultimately formed."

There is, however, one distinction between the cells of plants and animals which must not be overlooked. It consists in the fact that the cells of plants are much larger than those of animals, and retain all the characteristics of cells throughout the life of the plant, so that a cross section of any part of the vegetable fabric will at any time show them. But the cells of animals rapidly undergo a development into tissues in which the cellular form wholly disappears. Hence it is that the cellular origin of many of the animal tissues can only be detected in the ovum; in the fully developed embryo all appearance of cell and nucleus has vanished. Thus whilst the cellular origin and structure of plants has been long known, that of animals is to be enumerated amongst the discoveries of modern times.

As an instance of this gradual obliteration of the nucleus and cell wall, we refer to those cells which originate the more permanent and solid parts of the animal body; such, for example, as the teeth of man, or the shells of the mollusca. At first these parts consist of cells more or less closely connected together, either by a general enveloping membrane, or by an intercellular substance which holds them together by its adhesive properties.

Fig. 4.

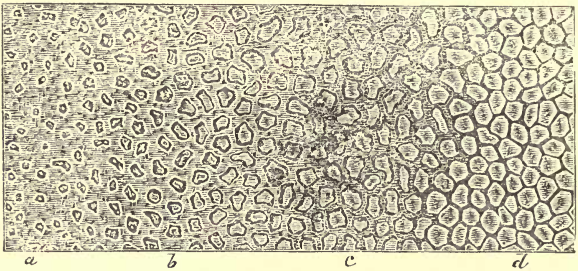


Fig. 4 represents a portion of one of the animal layers included between the calcareous laminæ of a bivalve shell; in which are shown at *a*, nuclei forming in the midst of a plastic fluid prepared and elaborated by the cells of a previous generation; *b*, the same advanced to the condition of incipient cells; *c*, the cells more developed but still surrounded by the fluid; *d*, the cells in close contact with each other, and rendered polygonal by mutual pressure.

These last cells in the enamel of the teeth attract phosphate of lime into their cavities, whilst those which form the shelly covering of the mollusca become filled with calcareous matter. The walls of the cells now disappear and there is a coalescence of their cavities, so that the solid mass appears altogether homogeneous, retaining not a single trace of its cellular origin.

In some cases, however, the cellular character of the tissue is maintained throughout the life of the animal. Thus, what is commonly called fat, consists of a mass of globular or dodecahedral cells containing fat in their interior, to which the term adipose tissue is applied, in works on anatomy and physiology.

Fig. 5.

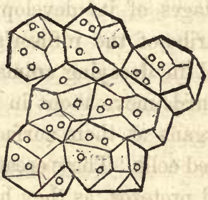
Cells of adipose tissue.

These cells may be seen at any time, even with microscopes of a very inferior quality. They retain their original cellular form, and hence the cellular character of adipose tissue has been long known.

The number of tissues in the animal is much greater than in the plant. Their morphology from the same cellular type is still a matter which requires further elucidation. Their differences, like those of plants, are not always well-marked, one form of animal tissue passing into another by insensible shades of gradation. In man and other animals of a high grade of organization, the tissues are by far the most numerous and well-defined. As we descend in the chain of being, these distinctions between the tissues become gradually effaced, the organs are not so numerous, and the whole structure is greatly simplified. The soft body of a snail, for example, is much more uniform in its composition than the body of a bird or a quadruped. The parts of the osseous frame-work are gradually blended together, the bones become cartilaginous, and finally disappear altogether from the organism, as in the medusæ or jelly fishes. At length we arrive at animals whose bodies are made up of nothing but cells in contact with each other, and which permanently retain that uniformity of appearance presented by every kind of tissue, whether animal or vegetable, in the first stages of its development. Such is the case with the vast tribe of the infusorial animals, so called because they abound in decaying animal and vegetable infusions. These animals move about in the water by means of little hair-like organs at their surface, which are themselves merely modified cells. These creatures have been very appropriately named protozoa, as they hold a corresponding rank in the animal creation to the protophytes in the vegetable. Thus animals and plants are alike in their gradually increasing simplicity of organization, as we approach the cell,—their primitive form and common starting point.

The primitive rounded form of the cells is retained whenever they are loosely aggregated, as in the pith of most herbaceous plants and the pulpy part of fruits; in the more compact tissues of the epidermis and the parenchyma of the leaves they are angular and polyhedral. In the greatest number of cases each utricle is compressed into the form of a dodecahedron, and therefore necessarily exhibits a little hexagonal cavity when seen in section. Occasionally these dodecahedral cells develope with the greatest geometrical regularity; most frequently, however, they are extremely irregular in outline, some of their walls growing at the expense of the others, which thus become greatly reduced in size or even suppressed altogether, so that the cells exhibit on the cross section pentagonal, or even cubical, as well as hexagonal cavities. This is well exemplified in the epidermis of Tradescantia discolor, the polyhedral cells of which are extremely irregular in outline. It is not difficult to see that in this case the hexagonal is the predominating form, although the heptagonal, pentagonal, and cubical varieties are also represented.

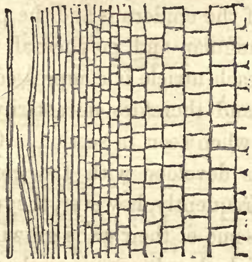
Fig. 6.



Irregular polyhedral cells from the pith of the elder.

So also cubical cells may become rectangular four-sided prisms, or even be so much compressed as to assume the appearance of fibres, as is fully seen in the annexed section of the rind of the common gourd.

Fig. 7.

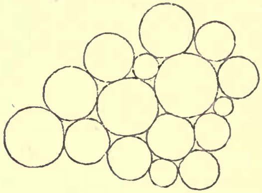


Vertical section of the rind of the gourd.

Thus, it is evident, that cells may, to a certain extent, change their form, without changing their nature or the identity of their function.

When the cells of plants are bounded by curved instead of plane surfaces, as for instance, when they assume a cylindrical or retain their spherical form, it is evident that the walls of contiguous cells will only come into contact at certain points of their surface, and that triangular spaces will be left between the cells. These intercellular passages are beautifully apparent between the cylindrical cells which constitute the pith of the stem of Anemone Pennsylvanica, and afford the most satisfactory proof that these cells do not form a continuous and homogeneous mass, but are in reality separate cavities aggregated together and communicating with each other through their contiguous walls.

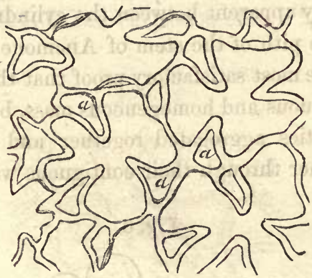
Fig. 8.



riangular intercellular canals between the cylindrical cells of Anemone Pennsylvanica.

In some instances, however, cells which are hexagonal in outline form intercellular passages, and this in a manner so interesting that it demands a particular description. If a section of the young petiole of Sparganium ramosum be placed beneath the microscope, a number of triangular apertures, known to botanists as lacunæ, will be seen; these are evidently the result of certain notches in the cell walls, which correspond with those in the walls of contiguous cells. As growth progresses these notches become deeper. The lacunæ, *a*, *a*, *a*, (Fig. 9,) enlarge at the expense of the area enclosed by the cells, until at length the cells assume a somewhat stellated aspect. In Juncus effusus the common rush, we have a beautiful example of this kind of tissue, the cell being reduced to a six-rayed star,

Fig. 9.



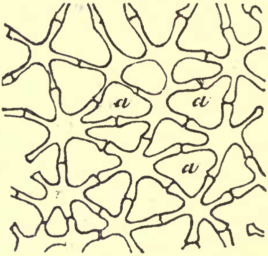
Stellate cells from the petiole of Sparganium ramosum; *a*, *a*, *a*, lacunæ.

as shown in Fig. 10. In this manner the large lacunæ or air-cells, common in most aquatic plants are formed.

These air-cells, or lacunæ, are designed not only to give buoyancy to the leaves and stems of aquatic plants, but also to prevent their tissues from saturation. The air displaces the water, which is thus excluded from entering the tissues of the plant, otherwise than by the ordinary forces of endosmosis and capillarity. The formation of the lacunæ is not in this instance the result of a mere mechanical rupture of the tissues in the interior of the plant, on the contrary, they are produced by a regular law of development, impressed on certain cells of the tissue, which are thus individualized and set apart for this purpose.

The stellate vegetable cell is of great importance as illustrating the formation of some of the animal tissues. It is obvious, that if the radiating prolongations of the cells, fig. 10, were to coalesce at the points where they come into contact, so as to throw together the cavities of the entire series, a network of anastomosing vessels would be the result. The capillary blood-vessels of animals seem to be produced in this way, by the absorption of the contiguous parietes of their several prolongations at the points of junction, their cellular origin and original separation being indicated by the persistent nuclei visible within their cavities.

Fig. 10.



Stellate cells from the stem of Juncus effusus, the common rush.

But in nothing is the individuality and independency of the cells so apparent, as in the varied character of their contents. Generally speaking, all the cells of the same tissue exercise the same function, and this remark applies especially to those which convey fluids and air, as for instance to the fibrous tissue of the wood, and the different varieties of vasiform tissue or ducts. The fibro-vascular system of plants is, in fact, altogether subordinate in the exercise of its functions to those cells which retain in a great measure or depart but slightly from their primitive form, and which are included under the general term parenchyma. It is in these cells that all the organic changes take place. The fibro-vascular tissue only subserves the simple physical purpose of transmitting the nutrient fluid or organizable matter to the cells of the parenchyma, which are the true vegetable laboratories. Endosmosis and capillarity will account for the ascent of the fluid in plants, and its distribution to the remotest parts of the organism; but when the fluid enters the cell-laboratories of the parenchyma, its constituents are transmuted into an immense variety of products by processes which have hitherto totally eluded the researches of science. Some of these products, such as chlorophyl, starch, gum, sugar, and raphides, are elaborated more or less by the cells of all plants; others are restricted to certain species, as for instance, the different varieties of endochrome, organic acids, resins, gums, alkaloids, fixed and volatile oils. In many instances there is no apparent difference in the form of the cells, which are closely united, forming part of the same parenchyma; and yet the diversity of their products proves that they are not the same cells. Thus we have cells which secrete oils, resins, and different varieties of endochrome in the midst of chlorophyl-secreting cells; in proof of which we refer the reader to the oil-cells which produce the punctated appearance in the leaves of the orange, to the resinous dotted foliage of Eupatorium rotundifolium, and to the dark purple spots on the leaves of Euphorbia maculata. Now since it is a well known maxim in physiology that nothing constant is unimportant, because experience and observation both prove that everything constant is connected with the discharge of some essential function of the organism, and as these plants never grow without a manifestation of these peculiarities; there can be no doubt whatever that these cells which produce them have a special and distinct work assigned, that they are organically different from those cells which secrete the chlorophyl, and that they are separate co-laborers in the cell-community, whose operations are perhaps as necessary to the healthy discharge of the vital functions of the plant as that of any other organ.

If we consider the contents of the cells in animals, we shall find that they vary in their character, and that this variation not unfrequently gives an apparent color to the tissues. We have seen that in plants the various and beautiful hues of flowers is produced by fluid coloring matters which are visible through the colorless walls of the cells; but in animal tissues, the coloring matter which is called pigment, occurs in the cells in the form of granules. The most striking examples of pigment cells occur in the iris of the eye, in the freckles of the skin, which are produced by aggregations of brown pigment cells, and in the colored spots on the elytra of many coleopterous insects, as for instance, the genus coccinella, which is specifically named according to the number of dark spots on the scarlet elytra. All the endless varieties of color observable in the hair of animals, in the plumage of birds, and on the wings of lepidopterous insects, are produced by aggregations of cells which contain coloring matter. The colors of shells result from the same cause. Thus one and the same law has overspread the animal and vegetable creation with endlessly diversified hues.

The cells of the animal tissues, exercise the same selecting power as the cells of vegetables, on the fluid which permeates their walls. The blood is laterally transfused through the walls of the capillaries, and its constituents pass in a molecular form through the parieties of the cells contained in the meshes of the capillary network; each cell acts on the blood in its own peculiar manner, selecting its own proper formative material. Thus the pigmentary cells select the coloring matter of the blood, rejecting every thing else, the fat cells select the fatty matters, muscle produces muscle, bone generates bone, nerve developes nerve, all drawing the appropriate materials from the same fluid; just as some of the cells of plants select from the sap starch, others oils, others fluid coloring matters; or as the gelatinous tissue called cambium, interjacent between the bark and wood, generates during the season of vegetable growth, beds of the same nature as those with which it is in immediate contact, and is developed into ligneous and cortical fibre, wood producing wood, bark forming bark, the tissues preserving their cellular organization only in those portions which correspond to the medullary rays. Here again we see the operation of the same laws in animal and vegetable matter.

We know nothing as to the *modus operandi* of the processes in the cell-laboratory, by which these various organic products are formed. It is evident that they are physiologically connected with the growth of the other parts of the organism; for the vitality of all the organs of plants is exhausted in succession, in developing the germ. To this tend all those vital changes which take place in the cells and organs of plants and animals, throughout all the ever varying phases of their existence. Here, again, we are in the dark as to the physiological uses to which many of the various products of the cells are appropriated, in the animal and vegetable economy. Many of the organic products of plants are so valuable as food and medicine to the animal creation and to man, that their preparation would appear to be the leading function of the plant, and the grand reason of its development.

The individuality of the cells of organized beings, is further proved by their different periods of life. Many of them are developed only to serve a temporary purpose,—

the preparation of the nutritive material for the more permanent parts of the fabric,—this purpose being accomplished, they die and are cast off from the organism to which they are of no further use. Thus the starch cells of the cotyledons perish as soon as the first pair of leaves, to whose nourishment they contribute, are capable of absorbing the nutritious gases of the atmosphere. So also the floral apparatus fades after the germ is fecundated. Sometimes, however, after the corolla, stamens, and the upper part of the pistil have perished, the vitality of the calyx remains unimpaired; and seems to coöperate, with the green walls of the pericarp, in the elaboration of those juices which are necessary to the growth and maturation of the seeds contained within its cavity. In the Witch Hazel, Hamamelis Virginica, the vitality of the leaves is exhausted in the development of the flowers, which do not appear until the former decay and drop from the branches. The massive stem of the tree is fabricated by the labors of the successive generations of leaves with which it was annually adorned. The same law is manifested in the exuviation of the epidermal appendages of the body of the inferior animals, such as hair, feathers, teeth, horns, scales. These organs are thrown off from the body in the fall, and their growth renewed in the spring. The cells which form them have evidently a life peculiar to themselves; their own period of growth, maturity, decay, and dissolution, which is totally different from that of the general life of the organism with which they are connected.

Thus not only the entire plant and animal, but its organs separately and individually considered, are subject to certain definite laws of development. The cells of animals and plants do not therefore lose their individuality by being associated. They have a, life of their own, as is manifest from their peculiarities of form, their secretions, and their different periods of vital activity. There appears to be a division of organic labor among them and a relation of mutual dependency, yet each contributes in its own way to the general life of the organism, and their combined action seems to be absolutely necessary to its healthy evolution from the seed, spore, or ovum.

We have endeavored to invite the attention of physiologists to the fact of the *individuality* of the cells of plants and animals. There can be little doubt, we think, that the cells of all organized beings are subject to laws of development not only *en masse,* but separately and individually considered. As yet, however, this special physiology of the cells is very little understood. In this respect we believe vegetable matter to be peculiarly instructive.

ON THE CHEMICAL COMPOSITION OF THE VEGETABLE AND ANIMAL TISSUES.

The mucus or protoplasm which forms the nidus of vegetation and animality, is formed by the union of four simple elementary bodies, Carbon (C,) Oxygen (O,) Hydrogen (H,) and Nitrogen (N.) These bodies enter the organism of plants chiefly in the form of Carbonic acid (CO 2,) water (HO,) and Ammonia (NH 3,) from the soil and atmosphere, the two grand sources of all vegetable nutrition. When thus united they are called binary compounds. Dextrine, cellulose, and sugar which are produced by the union of three elementary bodies, viz., Carbon, Hydrogen, and Oxygen, are named ternary compounds; and fibrin, albumen, and gelatin, which contain Nitrogen in addition to the other elements, are designated as quaternary compounds.

The organic compounds resulting from the union of these simple elements are termed proximate principles. They may for the most part be obtained by very simple processes. Thus if water be added to flour in small quantities, a ductile paste will be formed which,—when kneaded by the hand and washed by a slender stream of water,—becomes a grey, tenacious, and highly elastic substance termed gluten. The water employed in this process is rendered turbid and milky, and a white matter remains suspended in it, which is starch, as may be easily ascertained by testing it with tincture of iodine. So, again, when meat has been boiled for some time in water, the oil is observed to separate and float on its surface; but another substance, separated from the meat, remains suspended in the water, which solidifies on cooling. This substance is termed gelatin. The tasteless shreds which remain are fibrin. Now gluten and starch are instances of the proximate principles of plants; oil, gelatin, and fibrin are examples of the proximate principles of animals.

The walls of the cells or elementary parts of the vegetable tissues, are not formed of a simple homogeneous substance, but are made up of two layers of very different composition and properties. The innermost layer, which is the membrane first generated over the nucleus, has for this reason been called the primordial utricle. It is very thin and delicate, and escapes attention so long as it remains in contact with the outermost layer, from which, however, it is easily detached by tincture of iodine. To the primordial utricle, all the subsequent vital operations are to be referred. The external layer though commonly regarded as the real cell-wall, is in reality a deposit of cellulose which is generated on the outer surface of the primordial utricle. This is usually thick and strong compared with the other, and possesses various degrees of consolidation, from the condition of mere mucus, to a firm, tenacious, and elastic substance.

"The existence of the primordial utricle in a normal condition in a cell," says Henfrey, "generally indicates that the cell still retains the power of propagation, and it is consequently always found in cambuim cells." The primordial utricle disappears soon after the commencement of the formation of the secondary layers on the cell wall.

All the organs of plants whatever be their form, their nature, or their destination, have for their basis the same immediate principle cellulose, which when deprived of all foreign matter and brought to a state of purity, consists of carbon and the elements of water. This general character, cellulose, is the sign of the vegetable kingdom, although the rule is not without exceptions, cellulose having been recently detected by Schmidt, Löwig, and Kölliker, in the tunics of ascidia and other molluscous animals.

Cellulose is closely allied to starch in its chemical composition, but differs in giving a yellow in place of a blue color with iodine. It is generally colorless, and of a whitish hue; in some cases, however, as in ferns, it is brown. When thickened by successive deposits, it possesses a laminated structure. It is readily permeable to fluids, but without visible pores.

Plants have, therefore, essentially for the basis of their organization a ternary matter consisting of carbon, oxygen, and hydrogen, "which exists in the liquid form in the state of vegetable mucilage, dextrine, sugar, &c., or collects in a peculiar solid form in the cells, as starch, or finally constitutes the proper and permament wall of the cell, under the name of cellulose."* Nitrogen enters sparingly into the composition of plants. All the organs of plants, in their first period of development, contain Nitrogen. It

* See Gray's Botanical Text-book, p. 28.

exists in the primordial utricle or mucilaginous lining of all young and growing cells. The permanent wall of the cell is formed under its influence, and it is one of the elements of vegetable albumen, fibrin, caseine, and glutine, but it makes no part of the *permanent* frame-work of plants. Nitrogen, on the other hand, enters largely into the composition of the animal tissues, which are generally quaternary compounds, consisting of carbon, oxygen, hydrogen, and nitrogen.

CHAPTER II.

ON THE DEVELOPMENT AND PROPAGATION OF CELLS.

So far as we at present know, the cell like the plant, is the product of a previously existing cell. The principle *omne vivum ex ovo* is applicable to vegetable matter under whatever form it may present itself. Life is only known as it is manifested through the agency of cells, and the life-force appears to be generated in proportion to the extent of their combination and the development of their functions. But how do the cells of plants and animals orginate? Whence come those new utricles which without ceasing are added to those already in existence, and which augment incessantly the mass from whence they draw their origin? These are difficult but exceedingly interesting questions.

There appear to be three principal modes in which cells are multiplied, viz., by nuclei, by division, and by gemmation.

1. FORMATION OF CELLS FROM NUCLEI.

According to Schleiden, "cells can only be formed in a fluid which contains sugar, dextrine, and proteine compounds." They originate from a nucleus or cytoblast (κύτος a cell, and βλαστὸς a germ), which forms either in the fluid when contained in the cavity of a pre-existing cell, or in the midst of it when effused around the tissues of growing parts. This fluid,—to which the terms cambium, vegetable mucilage, and protoplasm have been applied,—in young developing organs exists in the greatest abundance, not only in the interior of their cells, but also in their intercellular spaces.

M. Mirbel, to whom vegetable anatomy owes so many beautiful discoveries, believes that the cytoblasts form in the midst of the fluid which fills these intercellular spaces. He gives the following account of their formation. In the points where the new cells are beginning to form, we see appear small gelatinous globules. This is the commencement of the organization of the fluid. Very soon, each of these globules, at first perfectly transparent, shows a little spot slightly opaque; this results from the formation of a cavity in its interior, and we have a globular cell formed which is the second degree of the transformation of the nutritive fluid. This cavity dilates itself, the walls become more and more transparent, and the tissue newly-formed finally presents the same characters as the older cells with which it thus becomes associated.

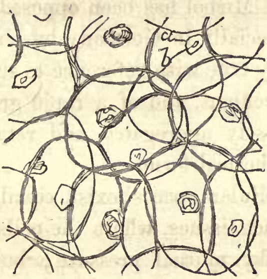
This theory of Mirbel has been opposed by many phytotomists, and especially in Germany by Unger and Mohl; but it is probably true with reference to such tissues as are swollen and succulent, and of a rapid growth, where the cells remain loosely aggregated, and retain in any great measure their spherical form.

These intercellular spaces exist equally in the more dense and compact tissues, where the cells become angular and polyhedral by mutual pressure; but they are very much reduced in size, for the walls of the contiguous cellules in this instance, touching almost completely by all their points, must necessarily render these spaces almost imperceptible.

These views of Mirbel have been in some measure confirmed by the researches of Schleiden; and as his ideas applied by Swann to the tissues of animals, are now admitted by almost all physiologists, the following abridgment of them will be acceptable :—

When there are the appropriate external conditions, the first visible stage of cell-formation consists in the appearance of minute granules which trouble the clear gummy solution in the cells, or the interspaces which surround them, rendering it turbid and opaque. Some of these granules collect together and form a nucleus around which other granules (*nucleoli*) gather, so that they ultimately acquire a larger size than the rest. These nucleated agglomerations, called by Schleiden, cytoblasts, become each an active centre around which the mucilaginous fluid of the protoplasm organizes itself. As soon as the cytoblasts are fully grown, a fine transparent vesicle developes on one side of them. This vesicle first appears as the segment of

Fig. 11.



Cells of a leek, after Quekett. *a*, nucleus; *b*, nucleolus.

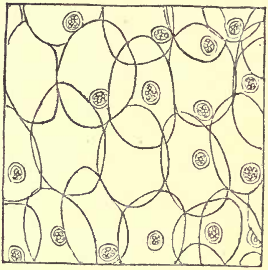
a sphere, the cytoblast forming its flat side and the walls of the vesicle its convex surface. The vesicle continues to expand until at length the cytoblast from which it originated, appears but as a small opaque body, which is either centrally located, or attached to one of its walls.

Thus, according to Schleiden, the cytoblast or nucleus visible in the cellule, has originated the cellule itself. It is seldom, however, that the cytoblast remains visible for any length of time after the cell has been fully formed; generally, it is re-absorbed.

The cytoblast is beautifully apparent in the moniliform hairs of *Tradescantia Virginica.*

The elementary cells which compose the tissues of animals also contain these nuclei or cytoblasts.

Fig. 12.



Nucleated cartilage cells from the Chorda dorsalis of a Lamprey.

Of this we have a very beautiful and striking proof afforded in the above engraving. The Chorda dorsalis is an extremely thin and delicate tube, composed of cells in close opposition with each other, and enclosing the spinal chord. It is, in fact, the vertebral column arrested in the first stage of its development. This is its permanent condition in the lamprey, and also in the lowest group of cartilaginous fishes.

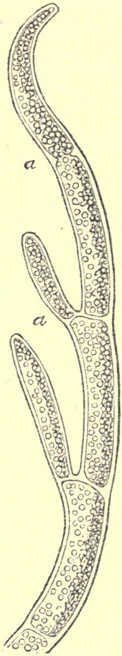
2. Formation of cells by division.

This mode of cell-multiplication is probably that which presents itself most frequently to the observer. It may be studied to the greatest advantage in that common green thread-like vegetation known to botanists as Confervæ, which is found in the beds of rivulets attached to their stones and pebbles, and which invariably shows itself on the surface of rocks whenever the water which flows over them is exposed to the action of light. This matter, examined with the microscope, presents to the eye a longitudinal series of cells which are produced by merismatic division in the following manner:—

The primordial utricle or inner wall of the cell is inflected towards its middle part. This inflection, at first a little salient, insensibly increases until finally the two inflected walls meet in the centre of the cell, and form a complete partition across its cavity, so that in the place of one we have two cells. These dilate and subdivide again in the same manner, and in this way a linear series of cells is produced, when the subdivision of them takes place in one direction, or a plane or solid mass of cells when it takes place in two or more directions. The endochrome of the primary cell, is necessarily separated into two halves by the formation of the septum, and is again subdivided with every repetition of the process, so that all the cells contain a separate portion of it. The contiguity of the cells blends together the hues of their separate endochromes, and gives an evenly diffused color to the surface of the tissues.

These fresh water confervæ illustrate the vegetative process in more highly organized plants, which acquire their complex structure from equally simple beginnings. Hence it is not original cell-formation so much as the multiplication of cells already existing, which causes growth or the extension of the parts of plants. In this respect precisely, the same laws operate in plants composed of a single row of cells, as when nature works on a more enlarged scale. The most important physiological truths may therefore be learned from vegetation apparently insignificant. "*Natura miranda est maxime in minimis.*"*

Fig. 13.



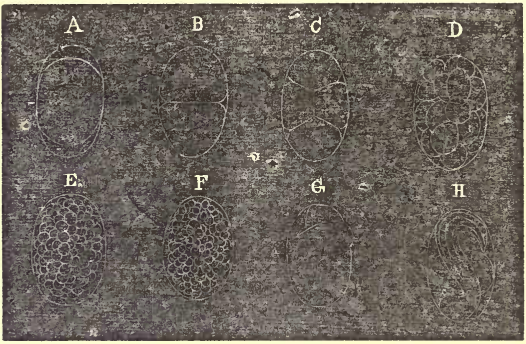
Branching summit of a fresh water plant, *Conferva glomerata*, magnified, showing at upper *a*, the partitions forming by the infolding process, and at lower *a*, the partitions complete.

* Linnæus.

The multiplication of cells by division is common among the infusoria, which increase by what is called the fissiparous method of reproduction, in a manner precisely analogous to the mode of increase among the parallel group of plants. The parenchyma of the cell at first becomes more opaque, a clear line is seen to form across its cavity, and a sort of hour-glass contraction takes place along this line. Each division now struggles to separate from its fellow, and the separation is no sooner effected than the two cells dart off in opposite directions, and rapidly assume their normal size and figure. This division sometimes takes place vertically, as in vorticella, and sometimes transversely. In some of the infusoria, the Paramecia, for instance, it occurs as often as three or four times a day.

The multiplication of cells by division, is beautifully apparent in the development of cells within the mammalian ovum, which has especially a plant-like mode of growth. The ova of all the different orders of the vertebrata, birds, fishes, reptiles, as well as mammalia, have in the beginning nearly the same uniform structure; and although it is by differences in the processes of cell-multiplication whilst in the embryonic condition, that those differences which characterize the full-grown animals are brought about, yet the principle of division is in all ova precisely the same. The process has been observed in the impregnated ovum of Ascaris acuminata, one of the oviparous Entozoa, which is a very favorable subject for the study of it, owing to the transparency of its body, and it is found that the embryonic mass commences very much after the same plan as in plants. Fig. 14 shows the successive stages of segmentation. The ovum having been impregnated, the yolk-bag slightly separates from the enveloping membrane and subdivides into two halves, each of these again subdivides into two more, and so on, so that in place of one cell we have 2, then 4, 8, 16, 32, 64, until the whole yolk assumes a mulberry-like appearance. The cells now begin to manifest their individuality, and gradually develope into the form of the future worm.

Fig. 14.

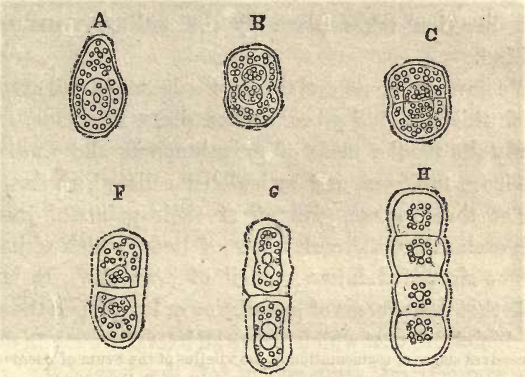


Successives stages of segmentation in the vitellus of the ovum of *Ascaris acuminata*. A, recently impregnated ovum, with yolk-bag slightly separated from the enveloping membrane; B, first fission into two halves; C, second fission forming four segments; D, E, and F, formation of mulberry mass by further segmentation; G, the mass of cells showing the form of the future worm; H, the worm formed by the conversion of the yolk-cells, now nearly mature.—CARPENTER.

In most of the animal tissues the multiplication of cells by division takes place during the embryonic state of development, but in some cartilages it appears to take place throughout the whole period of their life. Most of the articular cartilages which cover the ends of the bones retain their primitive cellular organization, which may be seen at any time. Fig. 15 shows the successive steps in the multiplication of cartilage cells. In this process, as in all the other acts of cell-life in animals, the nucleus seems generally to take a more conspicuous part than it does in plants.

Thus as soon as the first inflection can be traced in the walls of the cell, the nucleus begins to undergo subdivision, and when the cell is finally divided, each cavity contains a portion of the nucleus. These two new cells with their contained nuclei again subdivide in a similar manner,

15



Development of cartilage cells. A, original cell; B, the same beginning to divide; C, the same, showing complete division of the nucleus; F, the same with the halves of the nucleus separated; G, and H, continuation of the same process; by continued cleavage in the same direction, and the ultimate production of a longitudinal series of cells.—CARPENTER.

producing a filament or row of cells, when the division takes place in one direction, and a plane or solid mass of them, when the cleavage takes place in two or more directions.

3. FORMATION OF CELLS BY GEMMATION OR BUDDING.

This is well seen in Conferva glomerata, Fig. 13, which increases, not only longitudinally by the repeated subdivision and expansion of the cells at the extremity of its filaments, but laterally by a process of outgrowth or budding. A certain portion of the cell-wall seems to undergo an increased nutrition, so that it gradually forms an outward swelling or protuberance; the primordial utricle, or inner wall of the lateral cellule thus formed, is inflected, as in the preceding case, and a septum organizes across its cavity, by which it is completely separated from the parent cellule; after which, the multiplication and further enlargement of the cells in this direction takes place by the ordinary methods of division.

We have as yet no certain knowledge as to the extent to which this budding process takes place in plants. It is clearly the regular mode of growth among the *Characeæ.* The long, tubiform, and articulated cells which form the axis of these plants, give off at their points of junction with each other, a circular row of buds, which ultimately become elongated into a verticil of branches. It is probable that this process of gemmation or budding is the same, in principle, as that which causes all lateral growth in plants. The symmetrical arrangement of the leaves, buds and branches, proves that they are subjected to definite laws of development, and they must therefore necessarily originate in certain definite cells which have a tendency to develope laterally, and appear to be specialized or set apart from the rest for that very purpose. The process of division as seen in the longitudinal development of the cells of Conferva glomerata, is identical with the ordinary modes of longitudinal increase in all the young and growing parts of plants; and the process of gemmation as seen in the lateral development of the cells of the same plant, would seem to be only a simplified expression of that same law which, in the more elaborate productions of nature, manifests itself in the formation of the buds, branches, leaves and other appendages of the vegetable axis.

The multiplication of cells by gemmation or budding, and also by division, is seen in animals as well as plants, in the simplest as well as the most complex forms. Thus the whole zoophytic structure is produced by continuous gemmation from a single ovum, and in the lower articulata, annelida, and reptilia, the parts of the body which have been accidentally lost are speedily reproduced. It is well known that crabs and spiders, on losing a limb, acquire a new one. The same happens with the arms of star-fishes. The tail of a lizard is also reproduced. Salamanders recover their lost legs, and even the eye, with all its complicated parts. These vegetative manifestations are, however, mainly restricted to the lower forms of the animal kingdom; as animal life becomes more developed, this reparative power is proportionably lessened, although we are not without some evidence of it in our own bodies, as when a new skin is formed over a wound, or a broken bone is reunited.

CHAPTER III.

ON THE TRANSFORMATION OF CELLS INTO TISSUES.

We have already given some examples of this transformation of cells in plants, and have shown that it takes place to a much greater extent in the animal tissues. Some additional remarks are however necessary, in order to bring this subject fully before the reader.

Cellulose is at first an exceedingly tough, transparent, thin, and elastic substance, which may be compressed or extended into any shape whatever. Its impassive and yielding nature is exemplified in the innumerable varieties of shape assumed by the cells. As the earthy matter is deposited on the interior parietes of the cells, it gradually acquires rigidity and firmness.

Whilst in the embryonic condition, the woody and fibro-vascular portions of plants are not to be distinguished from the ordinary cellular tissue. The vasculares, or most highly developed of the flowering plants, are at first as low in organization as the cellulares or flowerless plants. This, however, is with them but a transient stage of existence. As soon as active life commences in the seed, the cells begin to manifest their individuality, and each to perform its peculiar part in the building up of the organism. Some of them become rapidly elongated into fibres, others coalesce into tubes, and the nutrient fluid which at first equally pervaded all parts of the organism, necessarily sets in a current through the vascular and fibrous tissue, owing to their tubular and capillary structure.

Now the water which enters the roots of plants from the soil, is impregnated with various earthy matters necessary to the health and life of the plant. These earthy matters are deposited in the cells of plants from the very commencement of their growth, but not to any great extent until they have acquired their full development. As the secondary deposit forms on the cell walls, the cells acquire rigidity, and growth is therefore necessarily arrested.

It has been shown that the fibro-vascular system of plants is subordinate in function to the cells of the parenchyma, and that it subserves the simple physical purpose of conveying to them the nutrient fluid or sap. The fibro-vascular system of the stem terminates in the leaves, where it takes a horizontal spread, and is attenuated into a plexus or network of capillaries, which anastomose with each other in the same manner as the capillary vessels in man.

The design of nature in forming the leaves of plants, is to spread the fluid over a horizontal surface, so that it may be the more readily exposed to the air and light. The anatomical structure of the leaf proves this. The leaves of plants are simply horizontal expansions of the fibro-vascular and cellular tissues of the wood and bark of the stem, with which every part of the leaf directly communicates. The sap appears to be transferred laterally through the walls of the capillaries, and to be imbibed by the parieties of the parenchymatous cells amongst the meshes of the capillary network. It is in the leaves then that the principal changes in the sap take place.

Now the current of sap is kept continually flowing through the fibro-vascular portions of the stem, owing to the constant evaporation which is going on at the surface of the leaves. Earthy matter is therefore necessarily rapidly accumulated in those cells through which the fluid is transmitted. In some instances it is deposited concentrically, as for example, in the fibrous portion of the wood, and it goes on accumulating until the tubular character of the fibre cells is wholly obliterated.

In the different varieties of vasiform tissue and ducts, the tubular character of the tissue permanently remains. These vessels originate from the union or confluence of porous, rayed, annular, and spiral cells.

There appears to be a tendency in the secondary deposit to arrange itself spirally on the inner parietes of the duct-cells. In some instances the spiral is perfectly formed, its several coils lying close together in the vessel and adhering firmly to its walls. When, therefore, the vessel is ruptured, its membrane tears in the direction of the turns of the spiral, with which it is ultimately united and from which it cannot be distinguished; but when the turns of the spiral are more or less separated from each other by the elongation of the vessel, its walls are apparent between the several coils, and the existence of the spiral fibre within its cavity is at once demonstrated.

Whilst the coils of the spiral lie close together in the cell, they are very apt to anastomose. Sometimes several of the fibres will unite throughout their entire extent and produce a banded spiral. This disposition is frequent in monocotyledonous plants, particularly in the banana. Frequently the anastomosis between two or more turns of the fibre is only partial, and in this way the so-called reticulated spiral fibre is probably produced. In some cases, as the cell elongates, the fibre breaks up into a series of rings, and annular vessels are the result. This form of the spiral fibre is common in monocotyledons. In place of rings, the fibre may separate at regular intervals and form bars, or may be even so broken up as to appear in the form of dots or opaque points on the cell wall. The scalariform and porous varieties of ducts are thus generated. That all these differences in the fibro-vascular tissue are only modified forms of the spiral deposit, is proved by the occasional presence of the spiral, the annular, the scalariform, and even the dotted varieties of deposit in the same vessel.

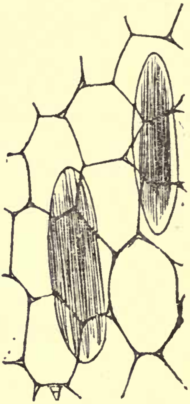
The porous or dotted cells which form the tubular tissues termed by botanists bothrenchyma, are not, however, referable to the fibrous type, from which they differ totally in their original formation. These cells are endowed with the peculiar property of restricting the earthy deposit to certain portions of their parietes; the thickening process continues at these points, the other parts of the cell-wall remaining uncovered. The dotted appearance of the cell-wall results therefore in this case, not from the presence of an opaque deposit, but from its absence. The pits, or cavities of contiguous cells, frequently correspond with each other notwithstanding the thickening of their walls, as is clearly shown in the wood of the American plane tree. These facts prove that the earthy matter is controlled in its deposition on the cell-wall, by other influences than those which are purely mechanical, and that the phenomena is to be attributed to a peculiar vital action, originating in the individuality of the cells.

To the same cause is to be attributed, the different varieties of canaliculi or radiating tubes in the more indurated deposits, termed sclerogen. The stony envelope which surrounds the seeds of the peach and plum, together with the shell covering of nuts and filberts may, in this respect, be fairly contrasted with the more solid and indurated tissues of animals. Bone, for example, exhibits the same lacunæ, canaliculi, and radiating processes, amongst other peculiarities. "In the Histological Catalogue of the

Museum of the College of Surgeons, London, all the principal varieties of the deposit of sclerogen are classified and described under the name of hard tissues, and contrasted with bone and teeth which form the hard tissues of animals."*

Earthy deposits sometimes occur in the cells of plants in the form of crystals or raphides. These consist of inorganic matter, generally of some acid and its base, which

Fig. 16.



A portion of the outer layer of the bulb of *Scilla maritima*, having acicular raphides in some of its cells.

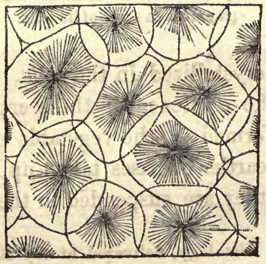
has united and crystallized in the cells. There is nothing surprising in the existence of these crystals. We know that acids are formed in the vegetable organs, and these unite with the earths or bases taken up by the roots from the soil, whilst they are suspended in the cell-sap. These

* "Lectures on Histology, delivered at the Royal College of Surgeons of England, in the session 1850–51, by John Quekett. 1852."

crystals are of different sizes and forms, rhomboidal, cubical, and prismatic; but the most prevalent figure is the acicular and needle-shaped. They occur either singly or in stellate masses. The stellate figure is generally assumed by the acicular and prismatic varieties, to which the term raphides (ῥαφις, a needle,) was originally applied by Decandolle, although it is now used indiscriminately in reference to all cellular crystals. These crystals occur in all parts of the plant, in the stem, bark, leaves, petals, and root; they usually consist of the oxalic, carbonic, malic, phosphoric, citric, and other organic acids united to lime as a base. The octohedral variety may be readily seen in the cuticular cells of the bulb of the onion. Acicular crystals may be procured from the petiole of Calla Ethiopica, by making a section and spreading the mucilaginous contents of the cells over the field of the microscope.

The adipose tissue of old persons sometimes contains acicular crystals. Fat consists of a liquid and solid principle, the former is termed elaine, the latter margarine. These acicular crystals are the solid element or margarine which has separated from the elaine.

Fig. 17.



Adipose cells, each containing needle-shaped crystals of margarine.

Fig. 17, is a specimen of adipose tissue from a female seventy years of age. Each cell contains a stellate mass of needle-shaped crystals.*

The vasiform tissue and ducts in early spring, when the ascent of the sap is most powerful, at first convey it to the leaves in conjunction with the fibre-cells of the wood. But as the flow of the sap becomes less vigorous, it gradually disappears from the ducts and spiral vessels, owing to their deficiency in the requisite amount of capillarity, which thus become filled with air. In this second period of vegetation they become organs of respiration, and as they are spread through the interior of the stem and enter the leaves through their foot-stalks, communicating with the intercellular spaces amongst the cells of their parenchyma, and with the pores on their outer surface; the sap in the interior of the plant is thus brought, through their agency, into constant communication with the nutritious gases of the atmosphere.

As the sap very soon retires from the vasiform tissue and ducts, the earthy deposits on their parieties do not take place to any very great extent, and hence they retain their tubular character throughout the life of the plant. As the force of the ascending current diminishes, it forsakes the large capillaries of the fibro-vascular tissue; for the same reason, its flow through the finer capillary tubes of the fibre-cells continues, after its flow in the fibro-vascular system ceases. Hence earthy matter goes on accumulating in the fibre-cells, until it ultimately fills up their cavities, and obliterates their tubular character. When this is the case, their vital activity ceases, and they exercise a purely mechanical function. To the deposits of earthy matter in the fibre cells of the wood, the term lignine is applied; in

* "Lectures on Histology, &c.," by John Quekett. p. 187.

order to distinguish them from those earthy accumulations celled sclerogen, which produce the more indurated tissues investing the seeds of plants. The strength of the stem and root depends on the lignine accumulated in the fibrous portion of their tissues; and the fibrous tissues, thus solidified, constitute the skeleton or frame-work of the plant.

In the same manner, earthy matter accumulates more rapidly in some of the tissues of the animal body than in others; in bone for instance, which thus becomes solid and hard, and peculiarly fitted to support the softer part of the animal frame work. Like the ligneous system of plants, the osseous system of animals is the last to arrive at maturity, the process of ossification in the human skeleton not being complete until about the 16th or 18th year. The time of its commencement and completion, varies in different parts of the skeleton. The bones first formed are those which enclose the central organs of circulation and the nervous system. The ossification of the extremities takes place at a later period.

Bone is composed of animal and earthy matter, the former consists of gelatine, the latter of phosphate of lime. If bone be burnt in a clear fire for about fifteen minutes, the animal matter is destroyed, and the earthy matter remains as a white and brittle substance, the bone retaining its form; on the other hand, if bone be digested in muriatic acid for a few days, the earthy matter is entirely removed, and the animal matter remains, as a tough elastio substance, which can be bent in any direction.

In childhood and youth the animal matter preponderates over the earthy. The gelatinous and flexible bones of the extremities of a child curve outwardly from this cause, as they are too weak to support the weight of its body, and sometimes become permanently deformed if the child is neglected. As childhood ripens into youth, earthy matter is deposited in the bones, they acquire rigidity and firmness, and the extremities straighten. In manhood, their strength has arrived at its maximum development, and they are most admirably adapted, not only to support the softer parts of the body, but to serve as a basis for the attachment of the muscles which execute its movements. As we advance in years, the vitality of the bones diminishes, and in old age they become extremely brittle, owing to the great preponderance of the phosphate of lime over the gelatine.

The blood vessels of animals appear to be formed like the ducts of plants, by the coalescence of cells arranged in a linear series. In both the ducts and blood-vessels, the organs remain permanently open; but, whilst the flow of the nutrient fluid speedily subsides in the one, it continues in the other as long as life remains. Again, all the different varieties of vasiform tissue or ducts, are distinguished by their want of any tendency to branch or anastomose. It is the function of these ducts to convey fluids and air in the most direct manner possible, from one extremity of the plant to the other, and therefore they run in parallel lines through the stem and its branches; and, as they are surrounded by a sheath of woody fibre, they can have little or no lateral communication until they enter the leaves, where the woody fibre is spread horizontally. But the organization of the animal body is such, as to require that the blood-vessels should be distributed from the very first on the ramifying principle. Accordingly, those which convey blood to any part, progressively divide and subdivide, diverging from each other like the branches of a tree from its trunk, and their several divisions divide and subdivide, again forming branchlets; this process of division and subdivision is continued, until the arterial tubes finally terminate in a network of anastomosing capillaries like those in the leaves of plants, by means of which the blood is distributed to all parts of the organ.

These capillaries not only cover the surface of the body and all its organs, but they penetrate their substance, conveying the blood to every part of the fabric. The capillary system is interjacent between the venous and arterial systems. It is in traversing these capillaries that the blood changes from scarlet to purple, in consequence of giving up its nutrient principles to the tissues.

The blood leaves these capillaries by means of the veins, each of which is first formed by the union of several capillaries; these collect and return the blood after it has traversed the organs of the body, converge and reunite into larger and larger vessels, like the roots of a tree or the sources of a river. In this manner the blood is again brought back to its original source, the heart, from whence it is driven into the lungs. There the fluid is brought into immediate contact with the atmospheric air absorbed during respiration, is oxygenated, and again returned to the heart, from whence it is again driven into the aorta, and conveyed by its ramifications as before, to all parts of the body.

Whilst therefore in plants the capillary system is confined to the leaves, in animals it pervades every part of the body. The capillary system of plants is only required during the season of vegetable activity, and is not needed during the period of vegetable repose. The leaves are therefore only temporary organs, and the plant loses its capillaries when it becomes defoliated. The woody fasciculi which form the newly developed shoots at the extremities of the branches alone remain, permanently attached to the plant, together with the dormant buds on their exterior surface. It is through the influence of the leaves with which it is temporarily adorned, that the more permanent parts, the stem and branches, are enabled to increase in size from year to year. There in no such cessation to growth and vital activity in the animal body; hence the capillaries form permanent parts of the fabric. In both plant and animal it is however manifest that they exercise the same function, and are intimately connected with the nutrition of the different parts of the organism.

Thus the plant and the animal are closely allied to each other. Histology has demonstrated not the analogy, but the absolute identity of growth in the animal and the plant. Nutrition and reproduction in animals, is as clearly a vegetative process, as that the sun shines in the heavens.

CHAPTER IV.

ON THE CONTRACTILITY OF THE TISSUES.

LIFE in the higher order of animals consists in the exercise of four grand functions, viz., nutrition and reproduction, which they possess in common with plants, and which constitute their vital or vegetative functions; locomotility and sensibility which are their special and distinctive appendage, and which form their animal functions, properly so called, because it is these which constitute their special character of animality.

Now the plant is a beautifully simplified and highly instructive representation of the laws of growth and reproduction in the animal.

There is no nervo muscular apparatus to give motion to the organism of plants. Their movements are plainly attributable, in the great majority of cases, to agencies purely mechanical. Their branches, leaves, and other organs, are moved by the wind, not by nerves and muscles. Some species, however, exhibit movements, arising from other causes as, for example,—

The *Dionœa muscipula*, or Venus's Fly-catcher. This remarkable plant grows in great abundance in the sandy swamps in the neighborhood of the Cape Fear River, especially from Wilmington to Fayetteville, North Carolina; but it has not yet been found in any other locality.

The generic name of the plant, *Dionœa*, is a derivative from Dione, one of the names of Venus. The elegance and delicacy of its snow-white corolla are alluded to in the generic name. It is called specifically *muscipula*, or fly-catcher, with reference to its curious habit of catching flies with its leaves, which are organized expressly for this purpose. The leaves have a broad, dilated petiole, and the lamina or blade, which is somewhat circular in outline, is connected by a joint with its top. The margin of the lamina is fringed with a row of stiff bristles or hairs; three shorter and more slender ones, with swellings at their base, are placed on the upper surface of the leaf, in a triangular position, on either side of the midrib. It is in these last that the irritability chiefly resides.

Fig. 19.

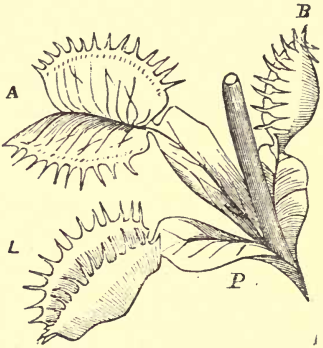


Fig. 19 represents a portion of the stem and leaves of Venus's Fly-trap. The leaf consists of two parts, a lamina or blade, *l*, and a petiole or stalk, *p*. The two sides of the lamina are united by a sort of hinge, and on the expanded leaf *a*, the three hairs may be seen on each half of the lamina, which, when touched, cause it to fold up, as represented at *b*.

When an insect, in traversing the lamina, touches these sensitive hairs, the two sides of the lamina suddenly come into contact; the bristles with which they are fringed interlace like the fingers of the hands when clasped, and the insect is as effectually caught in this vegetable snare as a rat in a steel trap. If it should escape the teeth of the trap, which is seldom the case, its only chance of liberty consists in lying perfectly still, when the leaf, freed from all sources of irritation, would gradually unclose; this, of course, the insect never does, but continues struggling for freedom till it is ultimately crushed to death by the plant. Flies and other insects are often found dead on the leaves, which have been killed in this way.

The experiments of Mr. Knight on the *Dionœa* would almost prove it to be a carnivorous vegetable. A detailed account of them may be read in the article on botany, "Lardner's Cabinet Cyclopædia." The following is the substance of what is there stated. Mr. Knight cultivated specimens of the *Dionœa* in separate pots in a suitable soil. From the leaves of some of them all the bristle were removed, but the plants were otherwise uninjured, and pieces of scraped beef were placed on their surfaces. The other specimens were allowed to retain their bristly fringe and irritable hairs on their leaves, and had as much light, air, and water as their disarmed neighbors; but all flies were prevented from gaining access to them. The result of the experiment showed the more flourishing condition of the *provisioned specimens!*

The *Hedysarum gyrans*, or moving plant of British India. A portion of the stem and leaf of this wonderful plant is seen in our engraving. The leaves of this plant are in constant motion by night and by day. We know that there may be motion in animals without consciousness, as, for instance, during deep sleep. The functions of animal life, which consist in sensation and locomotion, are then totally suspended, and those of vegetable life are in full activity. Circulation and respiration, by means of which nutrition is carried on in both animals and plants, proceeds during the period of repose. The heart continues its pulsations, and the blood is aerated in the lungs. In the *Hedysarum gyrans*, we have a parallel instance of the same perpetuity of motion.

Fig. 20.

Compound leaf of *Hedysarum gyrans*, having two pairs of leaflets, *b*, articulated to the petiole, and a large terminal leaflet.

The terminal leaflet appears to be peculiarly sensitive to light. It takes the position represented in the figure during the night, but becomes horizontal during the daytime, its midrib forming, with the petiole, a continuous and direct line. The terminal leaf is, however, manifestly depressed if the plant is only placed in the shade for a few minutes. In the changes of its position with reference to the ever varying intensity of light throughout the day, the terminal leaf forms, in fact, a natural *photometer* or light measurer of great delicacy and power.

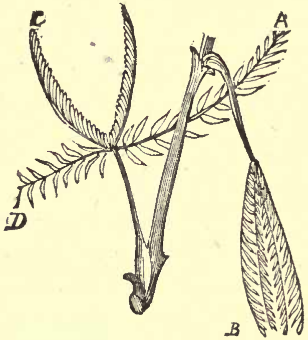
The movements of the lateral leaflets are, on the contrary, entirely independent of the influences of light, and are continuous by night and by day, even when the terminal leaflet is asleep. They move, like the second-hand of a time keeper, by a succession of little jerks, each leaflet describing the arc of a circle with its point. Whilst one leaflet is rising, the other is sinking, but in such a manner that the axes of both leaflets always remain in the same straight line. These movements, although independent of light, are rendered more active by heat, and by a more vigorous and healthy condition of the plant. The point of the leaflets describe the arc in about thirty or forty seconds; the movement then stops for about a minute, and is again resumed in the contrary direction. No satisfactory explanation of these movements has yet been given.

This plant belongs to the natural order *Leguminosæ*, of which the pea and bean are familiar examples.

The *Mimosa pudica* or sensitive plant. Everybody has heard about this plant, and we should think that many of our readers have seen it. Its movements, when touched, would almost seem to imply in it an obscure degree of consciousness; but if the phenomena be more carefully examined, however closely they may correspond with the effects of sensation and instinct, it appears very certain that they flow from simpler principles.

The leaf of the sensitive plant is a compound bipinnate one, having four partial leaf-stalks proceeding from a common petiole. The small pinnules or leaflets are expanded horizontally when the plant is in the light and unmolested; but when it is in darkness, as well as when the leaves are touched or irritated, the pinnules fold upwards, so as to bring their upper surfaces into contact; and at length the impulse reaches the base of the leaf-stalk, which immediately drops downward. When the pinnules are thus folded together, and the leaf-stalks depressed, the plant appears as if it were withered and dead; but if it be let alone, after awhile, the leaflets gradually separate from each other, and also the partial petioles; the main petiole gently rises to its former angular position with reference to the stem, and the plant resumes its usual appearance.

Fig. 21.



Branch and leaves of the sensitive plant (*Mimosa pudica*), showing the petiole in its erect state, *a*, and in its depressed state, *b*; also, the leaflets closed, *c*, and the leaflets expanded, *d*.

If the plant is sickly, the position of the leaves remains permanently the same, and no sensible motion follows any kind of excitement. When, however, it is in a healthy state, it is difficult to approach without disturbing it. Even the shaking of the ground caused by the tramp of a horse will cause the *mimosa* to fold its leaves.

These movements are manifested both in darkness and in light, in water as well as air. They are also produced by the light of the sun concentrated by a burning-glass, or by a drop of any irritating fluid, such as sulphuric or nitric acid.

The seat of motion in the sensitive plant, is evidently in the little swelling or intumescence at the articulation of the general and partial leaf-stalks. These swellings, when touched directly, communicate motion to the leaves. They appear to have two surfaces, possessing different degrees of irritability. When these swellings are gently touched with a steel point on their upper surface, the leaflets immediately fold together; but they do not move when the lower surface of the swellings is touched. With the swellings at the base of the main petiole, it is just the reverse; for the irritability resides not in their upper, but in their lower surface.

Up to the present moment, no satisfactory explanation of these movements has been afforded. The opinion most favorably received amongst scientific men with respect to them is, that they are referable to a power of contractility possessed by the tissues of the plant, analogous to that which exists in certain animal tissues, but especially in the muscular. It is well known to naturalists that certain unicellular and thread-like plants, found amongst the green hair-like vegetation which attaches itself to stones in fresh water rivulets, possess this power of contractility under the influence of external stimuli. If this capillary vegetation be placed beneath the microscope, movements among some of the filaments will be distinctly recognized. These plants have been called oscillatorias, in allusion to these motions, which resemble vibrations or oscillations to and fro, and occasionally writhing movements so well marked, that their vegetable nature has been disputed. This property of contractility exhibited by these isolated filaments, is manifested by them when associated together, in the case of the *mimosa*. The movements of the *mimosa* or sensitive plant, are probably produced by this cause, and are closely allied to the motions visible in the lowest and simplest animal, which are equally destitute of a nervous and muscular system.

The sensitive plant of the conservatories does not greatly exceed in irritability the *shrankia*, or wild sensitive plant of the Southern States, the leaves of which promptly close when touched by the hand or the foot of the traveller. Indeed, there is more than one sensitive plant in the world; the vegetable creation teems with these faint foreshadowings, as it were, of those higher powers of life manifested by animals.

To the same cause, that is to say, vegetable irritability, or the contractility of the tissues, is to be attributed, the curvature of the tendrils or even of the stems of weak plants around the objects to which they become attached. In cases where tendrils only are put forth, the irritability appears to be confined to them; but when the whole stem acts as a tendril, it seems to be diffused through its entire length.

That the irritability of the tendrils produces the spiral attachment of themselves to the bodies with which they are brought into immediate contact, is capable of direct experimental proof. All tendrils are first put forth in a right line, which is curved into a sort of hook at its apex. If, whilst the tendril is in the condition, a twig or young shoot be rubbed against it a little below the hook, in a few minutes, the tendril will be seen to be curving round the twig, and if the friction be continued, the regular spiral attachment will be ultimately formed. These phenomena must therefore be classed with the movements of the mimosa, as they are probably only feebler manifestations of the same principle.

All the movements executed by vegetables are only partial in their character. None of them enjoy the faculty of displacing themselves in toto and removing to another spot more favorable to their growth. When unfavorably located, seeds either perish, or the germination and subsequent growth of the plant is greatly retarded. In a word, voluntary locomotion exists only in animals.

That the nutritive functions of animals are affected by nervous influences, many facts abundantly prove. In blushing, the nerves evidently affect the blood, which is the grand vehicle of nutritive matter in animals, enlarging the capillaries and bringing it in an increased flow to the surface; a person affrighted becomes pale, the nerves contracting the capillaries and driving the blood from the countenance. Bad news will affect the appetite, and prevent the healthy action of the digestive organs. The sight of food will produce a flow of the secretion from the salivary glands of the mouth, necessary for its lubrication; and the excitement created in the mother by the mere presence of the new-born infant, will bring a draught of milk into the breast. Grief will render the eye tearful, or even tearless. There are no such nervous influences to interfere with the nutritive processes in plants.

Even the reproductive functions, which in animals are far more intimately associated with the nerves than those of nutrition, in plants, generally speaking, are unmarked by any higher vital phenomena than that which is manifested in the evolution of the other parts of the organism. The fecundation of the germ is effected by an appropriate arrangement of the organs, and the embryo is freed from the ovary by a mechanical rupture of the parts, or by other physical means. The whole process is simply vegetative.

In some few species, however, such as the barberry (Berberis vulgaris,) and mountain laurel, (Kalmia latifolia,) the stamens exhibit active movements during the period of fecundation, and these movements are evidently made in order to secure the proper application of the pollen to the stigma of the pistil. These parts are probably subject to a similar principle of contractility to that which influences the movements of the leaves of the mimosa.

The organization of plants corresponds with this simplicity of their functions. We have already indicated the predominance in animals of nitrogen, which exists only sparingly in plants. Analysis also only shows us two elementary tissues in plants, the cellular and the vascular, whereas we find in animals six, viz: the cellular, the fibrous, the muscular, the nervous, the osseous, and the cartilaginous; the last four being developed especially in connection with their superadded functions of sensation and locomotion.

We have therefore in the plant, the functions of nutrition and reproduction, operating under greatly simplified conditions. It is therefore proper to begin with the plant as introductory to the study of the more complicated conditions under which vegetative life exists in the animal.

PART II.

NUTRITION IN PLANTS AND ANIMALS.

CHAPTER V.

ON THE ABSORPTION AND CIRCULATION OF FOOD IN PLANTS AND ANIMALS.

The vegetative functions of nutrition and reproduction, have for their principal object the support of life in the different individuals, and the multiplication and propagation of their species.

Nutrition is undoubtedly the most important and general of the functions of animal and vegetable life. It operates in a continuous manner, commencing with life and ceasing only at its termination, whilst the other functions manifest themselves only under certain conditions, and at determinate epochs.

Nutrition in plants and animals is a very complicated function, and implies several distinct acts: 1. The introduction of food into the interior of the organism, (*absorption.*) 2. Its distribution to all its parts, (*circulation.*) 3. The elaboration of the nutritive fluid by contact with the air, (*respiration.*) 4. Its conversion into the substance of the organism, (*assimilation.*) 5. The elimination of such matters as are not necessary, (*excretion.*)

ABSORPTION IN PLANTS AND ANIMALS.

Before food can enter the tissues of any organized being, whether animal or plant, it must be reduced to a fluid or gaseous condition. This is absolutely necessary, in order to render it susceptible of being conveyed through the vessels and of permeating the walls of the cells, which we have seen to be the ultimate structure of the organism of both plants and animals. With reference to plants, no such reduction of their food to a gaseous or fluid state is necessary, because they live in the midst of their food, and in perpetual contact with it.

If we plant a seed in the ground, it grows from the very commencement of vital motion, in two opposite directions, upwards into the atmosphere and downwards into the earth: the two grand sources from whence it obtains the materials which contribute to its future growth. We may consider a plant then as a vegetable axis or stem, more or less ramified at its two extremities. That portion of the stem growing into the atmosphere puts forth from its branches, during the season of vegetable activity, certain flat, dilated organs, which we call leaves, the surface of which is porous and by means of which food is absorbed from the atmosphere. That portion of the stem which ramifies in the ground, on the other hand, becomes covered, about the same time, with numberless delicate white fibres, which are the true roots of the plant. These correspond to the leaves on the branches, performing the same function, that of absorption, and like the leaves decay and become detached from the plant in autumn. On the return of spring, the underground and atmospheric ramifications of the plant are again re-clothed, the former with fibres and the latter with leaves.

It is a mistake to suppose that *all* the underground portion of a plant is the root. The white delicate fibres put forth in early spring, at the time that the leaves grow on the branches in the atmosphere, are the true roots; they contribute to the extension of the subterranean branches by the food which they absorb from the soil, exactly as the leaves induce a growth of the branches in the atmosphere by exercising the same function. A fibre and a leaf are wonderfully different in form and color, yet both are absorbents, beautifully adapted to the media in which they develop.

The plant is nourished by inorganic substances, Oxygen, Hydrogen, Carbon, Nitrogen, and some mineral salts. Analysis shows us these elementary substances in plants, which combining among themselves, form all their various and diversified products. These elementary substances exist only in the earth and atmosphere, the two grand sources of all vegetable nutrition. Sometimes they exist there in an isolated state, or they make part of other combinations, which the plant has the power to destroy in order to appropriate them to itself.

Water is necessarily the vehicle of the alimentary substances of plants. It enters the plant from the earth, according to the common laws of endosmosis and capillarity, by the delicate hair-like fibres of the roots. The leaves favor this absorption by the evaporation which is continually taking place from their surface, which renders additionally thick and mucilaginous the fluid in the leaf-cells, and throughout the organism of the plant. The leaves also absorb water from the atmosphere, which always exists there more or less in a state of vapor, but principally carbonic acid, which enters largely into the composition of the vegetable framework.

So long as the roots can absorb as much water as the leaves evaporate, the plant will appear fresh and green, but the foliage droops (as is often seen on a hot summer's day towards noon,) when the evaporation from the leaves exceeds the supply at the roots. A copious supply of water, however, usually accumulates on the leaves during the cloudless nights of summer, which is absorbed through the pores on their surface into their organism, and in the morning, the plants refreshed by the night dews, have assumed their wonted rigidity and freshness. In this case the only absorbents are the stomata on the epidermis. How beautiful this provision of nature, which, at the time the soil is dried to dust, causes the moisture to distil from the atmosphere on every forest leaf and blade of grass in gently descending dews, to remedy as it were in some measure the evils arising from an insufficiency of water in the soil.

The stomata or pores of plants vary in their figure and size. They are, however, usually of an oval shape with a slit in the middle, and are so situated as to open directly into the intercellular spaces of the parenchyma. These pores may be called the vegetable governor. They regulate and control the evaporation from the surface of plants, thus promoting a healthy passage of the fluids through the system.

This is done on the following principle. The slit or perforation in the epidermal surface lies between two cells, which differ from the other in being very hygometrical, or easily affected by the moisture of the atmosphere. When the air is damp, and there is an abundance of moisture in the ground, these two cells become swollen and turgid, and by their outward curvature open the pore and allow the escape of the superfluous water; but when the atmosphere is dry they straighten and lie parallel, their sides being brought into close contact. The pore is thus closed, and the evaporation stopped the moment it becomes injurious to the plant.

The structure of the stomata or pores of plants may be readily perceived on the epidermis of the lily, where they are unusually large. The epidermis must be first carefully removed from one of the leaves, and having been freed from all its chlorophyl, or green matter, it must be placed

Fig. 22.

Epidermis of the white lily, showing the stomata *st*, composed of two cells, with an opening or slit between them.

between two slips of glass, with a drop of water between them, so as to give it the necessary degree of transparency. Water ought always for this reason to be used, whenever objects selected from the tissues of plants are examined microscopically. The epidermis, thus prepared, will exhibit these pores, and the nature and beauty of their mechanism will be seen and appreciated.

It must be evident to all practical men, from these facts, that it is of some importance to keep the leaves of plants free from all impurities, which are apt to accumulate on their surface and thus choke up their porous openings. During dry seasons, a supply of water to the leaves is of as much importance as a moistened soil. House-plants frequently suffer from the dust with which their leaves become covered. Their health and general appearance may be very much improved, by a careful cleansing of their leaves every other day, with a wet sponge. It is as important to keep the epidermis of a plant in a cleanly state as the skin of an animal. Neglect in either instance brings on disease, premature decay, and loss of vitality.

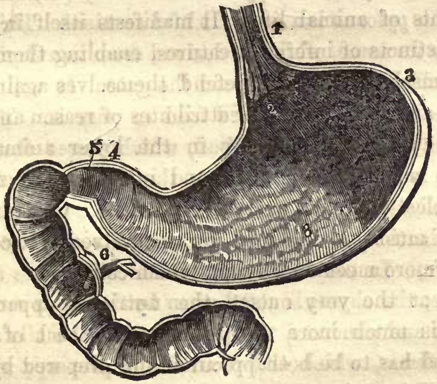
The food of animals is not furnished to them in a condition fit for assimilation and circulation. It comes into contact with their organs in a more or less solid state, and a cavity is therefore provided in the interior of their organism for its reception, and reduction to a condition fit to enter the circulation.

We have seen that one of the most striking differences between animals and plants is the possession by the former of a nervous system of which the latter are totally deprived. This nervous system is the seat of all the sensations and movements of animal life. It manifests itself in the unerring instincts of inferior creatures, enabling them to procure themselves food and defend themselves against their enemies, and in those higher attributes of reason and reflection which appear gradually in the lower animals, and obtain in man, "the minister and interpreter of nature," their noblest and most exalted expression. Creatures thus endowed must provide food for themselves. It comes to them no more mechanically and chemically.

Thus, at the very outset, the nutritive apparatus of animals is much more complicated than that of plants. Their food has to be both procured and prepared by themselves, before it can be assimilated. They are provided with senses and appropriate organs for this very purpose, and they must exercise both if they would obtain the necessary aliment. These senses and organs appear to be gradually superadded to the simple digestive cavity which constitutes the entire organism of the lowest animal. The organic apparatus for the prehension and preparation of the food prior to its introduction into the interior of the digestive cavity, becomes more complicated as we ascend in the scale of organization.

The organs of prehension and preparation are most admirably adapted to the peculiar food, habits, and instincts of each animal. In man, whose wants are infinitely more numerous, these organs exist in the highest condition of development. He is provided with a hand, which may be justly regarded as the most perfect of prehensible instruments. To the skillful use of this organ, under the guidance of reason, he owes his superiority over the other animals, whose anterior members are organized more for

Fig. 23.



the support of their bodies than for the seizure of objects. The other organs consist of an alimentary tube or canal more or less dilated in its course through the body. At the upper portion of this canal there is an opening called the mouth, which is provided with an appropriate arrangement of teeth for cutting and crushing the food, and of salivary glands for affecting its lubrication.

The food having been prepared and lubricated in this manner, descends into the stomach through the œsophagus (1,) by the left or cardiac opening where it is acted on by the gastric juice secreted by the walls of the stomach (3.) This fluid, which is of an acid nature, re-acts on the alimentary mass, penetrates, softens, and ultimately changes it into a semi-fluid, homogeneous, and pulpy substance, named chyme. At the commencement of this operation, the communication between the stomach and intestines is entirely closed by a valve, called the pylorus (5.) As the solution advances, the dissolved parts are gradually moved by the muscular contractions of the walls of the stomach to its right or pyloric extremity (4.) The valve called the pylorus is a very faithful sentinel. This is indicated by its name, which is derived from two Greek words, and signifies literally, to guard the gate. It will not ordinarily permit any undigested food to pass it. The quantity of chyme, or digested food, which passes through the pylorus, is at first small, but as the process of chymification or digestion goes on, the flow increases, and towards its termination, the chyme passes quite rapidly through the valve. In the duodenum, which commences the small intestine, the chyme is acted upon by the fluids secreted by the liver and pancreas, that is to say, by the bile and pancreatic fluids, which are poured into the upper part of the small intestines by means of a duct (6,) communicating with these organs. These fluids, which are of an alkaline nature, probably arrest the movement of dissolution produced by the gastric juice. In consequence of this new action upon the chyme, in passing through the small intestine, it is separated into a fluid of a whitish color named chyle, which as soon as it is formed, is absorbed by the radicles of a special system of vessels named chiliferous vessels or lacteals; these reunite into branches more or less voluminous, and ultimately meet in a common trunk called the thoracic duct. This duct, which is about the size of a common quill, conveys the chyle to its point of junction with the sub-clavian vein at the lower part of the neck, pouring it into the torrent of the circulation. Respiration gives to the fluid thus mingled with the blood its finishing change, so that the two become identical. The blood thus enriched, is spread through every part of the body both external and internal, by means of the capillaries interjacent between the arterial and venous ramifications, thus furnishing to the system the necessary supply of nutrient matter.

The absorption of food into the organism is, therefore, in principle, precisely the same in animals as in plants, with this difference, that there is superadded to the organism a highly complicated nervo-muscular apparatus for its prehension and preparation. The introduction of food into the digestive cavity or stomach, is wholly a voluntary act, and results from the exercise of the functions of animal life; its digestion and absorption when there, is altogether involuntary. The whole process of chymification and lacteal absorption proceeds without our consciousness, and cannot be controlled by any effort of our will. All these internal motions are therefore purely vegetative acts, proceeding from the operation of that life which we possess in common with plants.

This truth will be more apparent if the reader will only reflect for one moment. The food in the stomach and intestines is as much external to the living body as it was before its introduction into those cavities, until it is taken up by the absorbents which line their walls; and it is removed from those cavities by the radicals of the chyliferous vessels and afterwards diffused to all parts of the animal, just as the roots of plants absorb food from the soil, which is afterwards conveyed by the trunk to the branches and highest extremities. "Whilst, therefore, the roots of plants, ramify through the soil in quest of food, fixing the plant to its surface, animals which wander about from place to place in search of the food which they require, may be truly said to carry their soil about with them."*

THE CIRCULATION IN PLANTS AND ANIMALS.

In the lowest forms of animals and vegetables where the structure is wholly cellular, the movements of the nutritive fluid equally pervade all parts of the organism, proceeding forward and laterally from cell to cell without following any particular course. Such is also the condition of the circulation in the higher animals and plants during the embryonic stage of development; this, however, is with them only a transient condition of things. As growth progresses in the seed or ovum, the cells begin to manifest their individual peculiarities, and the young plant or animal finally ruptures the envelopes more or less resisting, which cover it, and speedily develops those organs necessary to its life and increase. As specific processes are carried on in distant parts of the organism, it is necessary that the nutritive juice should be conveyed in the proper channels, which develop accordingly for this purpose. In

* Carpenter.

animals this movement is called the circulation of the blood, in plants the circulation of the sap; in both, however, nature has the same object in view, the conveyance into all parts of the organism, of the elements which serve to their increase and nutrition.

In the higher order of animals the circulation is double, that is to say, the blood which has deposited in every part of the body the materials of nutrition, returns to its point of departure, or to the heart, by a series of vessels named veins, from whence it is driven by the muscular contractions of the heart into the lungs, where, by contact with the atmosphere it acquires new properties and qualities, and returns a second time to the point from whence it set out. There is, therefore, two circulatory circles, and at the base of each an agent for impelling the blood into each of them. This agent consists in a double cavity with muscular walls; one of these cavities is named the auricle, and the other the ventricle; both of them united constitute the heart, or organ of impulsion.

The auricle and ventricle of the right side of the heart, contain the dark venous blood, which returns impoverished from all parts of the body; the auricle and ventricle of the left side contain the bright red arterial blood, which arrives enriched from the respiratory organs.

In the mammifera, with the exception of the Dugong, and in birds, there is no direct communication between the right and left cavities of the heart, and consequently no mixture of the arterial with the venous blood. Respiration is therefore complete, that is to say, the *whole* of the blood which returns from the different parts of the body passes into the lungs, and is aerated before it is poured again into the torrent of the circulation. These animals are therefore capable of preserving a proper temperature, independent of that of the medium in which they live, and are called warm-blooded animals. But in reptiles and in fishes the venous and arterial blood become mixed together, the former being only partially returned to the lungs; hence respiration in these creatures is imperfect, and the blood is cold, or rather in place of having a fixed and independent temperature, it tends without ceasing to an equilibrium with that of the surrounding medium.

It follows from this, that, in certain circumstances, the temperature of animals with cold blood is considerably elevated; it is therefore better to call the mammalia, birds, reptiles, and fishes, animals of a fixed and variable temperature with reference to the heat of their blood, instead of warm and cold-blooded animals.*

The course of the blood in man and the animals most nearly allied to him in organization, appears to be as follows: The blood, charged with the restorative materials of nutrition, is brought to each organ by the arteries and their numerous ramifications. It spreads itself in the tissues of these organs by a system of fine anastomosing vessels called capillary vessels. In these same organs arises another order of vessels commencing where the arteries terminate; these tubes, at first capillary, communicate with the arteries, and constitute by their re-union, the veins which carry back the blood which has served to nourish each organ to the heart. The blood therefore flows in the veins in a contrary direction to the current which circulates in the arteries. These veins gradually unite among themselves, and finally form two large trunks called the inferior and superior *vena cavæ.* These two *vena cavæ* meet in the cavity of the right auricle, from whence the blood passes into a

* See "Elements d'Histoire Naturelle Medicale," par Achille Richard. Tome premier. Premiere partie. Zoologie, page 27.

second cavity with thick and fleshy walls named the right ventricle. The right ventricle, in contracting powerfully upon itself, drives the blood through the pulmonary artery and its innumerable ramifications into the lungs. There the blood is brought into immediate contact with the air absorbed during respiration, and is oxygenated anew, losing a part of its carbon, which forms the carbonic acid which we expire. It is returned afterwards from the lungs by the pulmonary veins to the left auricle, and from thence it is poured into the left ventricle, which, by its contractions, drives the blood through the large artery named the aorta, whose ramifications again carry it to all parts of the body.

The nutrient fluid which circulates through the organic tissues of plants, and which is called sap, exercises the same function in the vegetable that the blood does in the animal economy. Plants, however, possess no proper vessels within which a true circulation is maintained by the muscular action of a central propelling organ or heart, and the sap of plants is not confined like the blood of animals to one set of vessels, for owing to the way in which the vascular and cellular tissues of plants are interwoven with each other, and the general permeability of all the organs, a general transfusion of the sap takes place from cell to cell, endosmotically, and in every direction, so that the process is in some respects one of distribution as well as of circulation. This is particularly the case in the embryos of flowering plants during the early stages of their growth, whilst their structure continues wholly cellular, and in those cryptogamous plants which permanently remain in this low condition of development. But as soon as the vital action of the embryo of flowering plants commences, and woody fibre and vascular tissue begin to appear in its expanding organs, another force comes into play, that of capillary attraction. This last force together with that of endosmosis, sufficiently explains all the phenomena connected with the motion of the sap in plants.

It is well known that if two fluids of different densities be separated from each other by an animal or vegetable membrane, a mutual action will commence, the tendency of which is to produce an equilibrium of density between the fluids; and that the denser fluid will draw the lighter through the membrane with a force proportional to the difference of density of the two fluids. It is also known that if a number of delicate tubes of different sizes be immersed in water, the water will rise within the tubes above its natural level on the outside of them, in proportion to the fineness of their calibre or bore.

Now in winter vegetable life is passive. The huge oak tree, equally with the acorn that it has cast upon the earth, is torpid and inactive, and can no more put forth branches than the acorn can germinate. By the fall of the leaves the evaporating orifices have been removed. The cicatrices or leaf scars are all healed, and every pore is carefully closed and sealed up against the severity of the weather, sometimes by secretions especially elaborated for this purpose. The fluids in the interior of the plant are at this time in a state of equilibrium. Capillarity cannot act. Fluids do not rise in capillary tubes closed at the top.

With the return of heat and light to the earth in spring, the fountains of nutrition are again unsealed. The resinous exudation on the buds is melted, the pores are opened, and the store of starch, oil, and other secretions, which always exists in the neighborhood of all growing points, is changed into dextrine and sugar, in consequence of the absorption of the oxygen of the atmosphere. The cells immediately surrounding the buds thus become filled with a sap more dense and mucilaginous than that contained in the other parts of the plant. The equilibrium of the fluids is thus disturbed, and a strong endosmotic and capillary ascent of the thin watery juices towards the buds is gradually induced throughout the entire organism of the plant, tending to its restoration. At length when the buds are developed into branches, and the young leaves are spread abroad in the atmosphere, the ascent of the sap becomes powerfully accelerated by the evaporation which takes place at their surface.

Notwithstanding that the sap is spread by endosmosis in all directions through the cells of plants, yet it is evident that the current will be the strongest where capillary influences most abound; consequently, it will move especially in their fibro-vascular framework, which we have seen terminates in the leaves in a system of capillaries which anastomose with each other, in the same manner as the capillary vessels in which the arterial and venous systems of animals terminate.

The motion of the nutrient fluid in the animal and vegetable capillaries is mainly to be attributed to local influences. It is capable of being proved by experiment, that if two liquids communicate with each other through a capillary tube, for the walls of which both have an affinity, the liquid which has the greatest affinity for the tube will be absorbed into its cavity and drive the other before it. It is obvious that the same effect will take place, if instead of one we suppose any number of tubes to communicate in this manner. If now we suppose that the liquid absorbed into the tube undergoes, whilst there, such a change in its constituents as to have its affinity for it diminished, it is plain that it may be driven out by a fresh supply of the original fluid, and in this way a continual flow of the fluid in the same direction would be produced.

Now such appears to be, *to a very great extent*, the nature of those influences which govern the movements of the nutrient fluid in the capillaries of animals and plants. The fluid, for example, contains certain substances which are necessary to the nutrition of a certain tissue, and it is for this reason attracted into that tissue to which it immediately gives up the nutrient elements required; this neutralizes the affinity between the tissue and the fluid, and the latter is consequently driven out by the superior attraction then possessed by the tissue for a fresh portion of the fluid. The fluid which is driven out of one part may still, however, be qualified to nourish another part which requires a different portion of its elements, and between it and this new tissue an affinity now exists, the result of the loss it has already sustained, which did not exist before; it is thus drawn into the fresh tissue and repelled from it as before, by the entrance of a fresh supply, and in this manner the current moves on from cell to cell, through the entire capillary network. This important physiological law was first developed by Professor Draper;* and seems to afford a clear and satisfactory explanation of the motion of the nutrient fluid in the capillary system of plants and animals.

That the motion of the capillary currents in animals is induced by the vital processes going on in the tissues, and is not to be attributed to the muscular contractions and dilatations of the central organs of circulation, is evident from the following facts:

* See Draper "On the Forces which produce the Organization of Plants."

A careful examination of the capillary circulation in the living animal, discloses certain irregularities in the motion of the currents, which it is impossible to attribute to any other than local influences, or the alternate attraction and repulsion of the fluid by the tissues. Sometimes the current is rapid, then slow, occasionally it stops, or its direction may be even reversed.

In certain diseased states of the body, there is an unusual amount of blood in the capillaries of the affected part, as is evident from the amount of local inflammation; yet the general current of the circulation is not at all affected. This movement of the blood into the capillaries is entirely independent of the heart's action, the energy of which is not increased; it therefore depends entirely on the attraction exercised on it by the cells of the diseased parts.

Any increase of energy in the vital processes of any part of the organism, shows the action of local influences in diverting the current of the circulation into new channels. Thus, the development of the uterus, during pregnancy, induces at first an unusual degree of activity in the capillary circulation of those parts; the necessary result of the changes continually taking place in the forming tissues. An increased supply of blood is attracted in the direction of the developing organs of the fœtus, and there is a gradual enlargement of the diameter of the arterial trunk through which it is transmitted. In the meanwhile, the blood continues its uniformity of flow through the body. It is therefore evident that these organic changes, the result of the increased supply of the blood to the growing parts, take place independently of any increase in the energy of the action of the heart.

But why multiply causes unnecessarily? Nature is simple, and does nothing in vain. It is admitted that in both animals and plants the vital changes take place in the cells situated amongst the meshes of the capillary network, and that the fibro-vascular system in plants and the arterial system in animals are merely the agents employed in the transmission of the fluid to these cells, which are the animal and vegetable laboratories. Therefore the motion of the sap and blood must necessarily originate in the forces generated by the nutritive processes carried on in these cells, in the different parts of the body. There must be some cause to induce the muscular contractions of the heart, those successive impulses which drive the blood to the remotest parts of the system, and it seems clear that these phenomena have their origin in the vital processes which are continually going on in those cells with which the capillaries finally communicate.

The motion of the blood in the capillary vessels is well seen in the web of the frog's foot, when examined with a power of 250 diameters. The blood-globules are seen rolling along in single and double file through the minute capillary ramifications.

The motion of the sap in the capillary vessels of plants may be observed in those in which it is more or less discolored, and rendered opaque and milky, by the presence of floating particles of resin, caoutchouc, and other substances. It was first observed by M. Schultz, of Berlin, in 1820, and was called by him cyclosis, in reference to its circulatory character, and latex in allusion to its milky appearance.

The vessels which contain the latex or milk-sap, are cylindrical tubes with thin, transparent walls, without any appearance of transverse partitions. They are either simple or branched, and frequently anastomose among themselves, forming a network with irregular and unequal meshes.

These vessels exist in most monocotyledonous and dicotyledonous plants. We find them generally in those vascular bundles which form the salient lines on the under surface of leaves, designated as nervures. They are also found in the interior bark. In monocotyledons, we meet with them in the vascular bundles developed in the midst of the cellular tissue which forms the mass of the stem.

The latex itself is usually a fluid of a white, yellow, or reddish color. This color is due to the presence of opaque corpuscles of various hues, which being collected together in abundance in a watery and transparent liquid, communicate to it their color, just as the blood and milk-globules give to those liquids, colorless in themselves, the red and white colors by which they are characterized. The latex when poured out by itself into a vessel, behaves like the blood, and separates into two parts; a liquid, colorless or slightly colored brown, and a solid matter forming a sort of clot, composed of colored globules. These globules consist of various matters insoluble in water, such as wax, fatty matters, and caoutchouc.

The motion of the latex or milk-sap is seen in a young expanded leaf, it may be in a sepal or a petal, still adhering to the plant, especially when it contains a considerable quantity of colored sap, as for instance, the young expanded sepal of Chelidonium majus, or the large stipule which encloses the terminal bud of Ficus elastica. If the epidermis be carefully raised without injuring the vessels, the nature of the movement will be perceived. Similar movements probably take place in the anastomosing capillary vessels of all plants, but they are rendered imperceptible to us by the transparency of their juices.

CHAPTER VI.

ON THE NUTRITIVE PROCESSES OF RESPIRATION AND ASSIMILATION.

The nutritive fluid which circulates through the tissues of plants and animals, requires to be constantly brought into immediate contact with the oxygen of the atmosphere, which is the principal agent in effecting those important changes in its constituents, by means of which it is rendered capable of ministering to their nutrition and development. For this purpose plants have been provided with leaves and animals with lungs.

The sap of plants is aerated by means of their vasiform and tubular tissues, which communicate with the atmosphere through the stomata or openings in the epidermis of their herbaceous and green parts.

These vessels, contain sap during the first period of vegetable activity in early spring, which is gradually displaced by air. This fact is easily verified, by cutting under water a young green shoot which has put forth its leaves; little bubbles of air will be seen to issue from the orifices of these tubes.

Respiration consists essentially in the evolution of carbonic acid and the absorption of oxygen. The process is performed both by animals and plants, and has its origin in the same general requirements.

The first source of the demand for oxygen, common alike to plants and animals, arises out of those changes which are always going on in their interior, as a part of their nutrient operations. It is often said that plants cannot be sustained on organic nutriment, that they live on inorganic matter, which they organize as food for animals; but we apprehend parasitic plants must be regarded as exceptional cases; for these derive their nutriment from the elaborated juices of the plants on which they are found, and not at all from the earth and atmosphere, the usual sources of vegetable nutrition. These plants contaminate the air like animals, absorbing its oxygen and giving out carbonic acid. This fact is so well known and established that it will not be disputed. It is sufficient, therefore, if we refer to the experiments of M. Lory upon the respiration of the Orobanchaceæ.*

Oxygen is absorbed and carbonic acid evolved in germination, at the birth of the young plant, and in flowering, when it arrives at an adult state. In both instances, starch is oxydized and converted first into dextrine and then into sugar, for the nutriment of the young embryo, stamens, and pistils, and these processes are accompanied with a development of heat. Both the embryo and the flower, physiologically considered, may be regarded as exercising a parasitic action on the organic matter previously elaborated for them. The respiration of the cotyledonary leaves of the embryo, and of the corolline envelope of the stamens and pistils is, in every respect, a true oxydation or combustion of the store of saccharine matter, accompanied by the evolution of carbonic acid.

It is true that plants, with the exception of such as are parasitic, live on mineral matter, which they convert into organized products; but the organic matter which they thus create is not available for the development either of

* "Annales des Sciences-Naturelles." Botanique, Sept. 1847.

their own organism or that of animals, until it is first oxydized.

Now the sap is digested or de-oxydated in the leaves of plants, that is to say, the carbonic acid of the sap is decomposed under the influence of light, and all the superfluous oxygen is evolved into the atmosphere. The remainder of the oxygen, required for nutrition, is drawn through the vasiform tissue and ducts into the interior of the plant. The sap in all parts of the plant is thus brought into communication with the gaseous fluids necessary to its elaboration, and those various organic products developed, in all of which oxygen enters into composition as an element. These pneumatic vessels are most admirably situated, for this purpose, in the midst of the woody tissues of plants, through which the sap continues to flow until their vital activity ceases.

The sap is therefore first digested or de-oxydated in the leaves of plants, and the food is changed first to chyme and then to chyle in the stomach and intestines of animals, respiration or oxydation giving the finishing change to the sap in the interior of the plant, and rendering the chyle identical with the blood. Respiration is absolutely essential to the growth of plants as well as of animals.

Dutrochet ascertained by experiments, that the air contained in the ducts and spiral vessels in the interior of the stem, was altered in its composition, in proportion to its distance from its original source of supply in the leaves. He found that the air in these vessels was gradually deprived of its oxygen, which was absorbed by the sap in the neighboring vessels.

That the interior sap-cells in the neighborhood of the air-tubes absorb oxygen and give out carbonic acid, is evident from what we know of the economy of those opposite changes which take place in the exterior sap-cells in the parenchyma of the leaves. Recent experiments have shown that the evolution of oxygen gas from the leaves of plants only takes place when the sun shines directly upon them; that the process ceases when his rays are intercepted by clouds, and, as the light of day gradually fades, is actually reversed, oxygen being absorbed and carbonic acid eliminated. Light is therefore absolutely necessary to the de-oxydizing process, which varies in rapidity with the different degrees of illumination, and ceases altogether when this influence is withdrawn, oxydation taking place during the night. Therefore the cells in the interior of the plant, in proportion as they are withdrawn from the solar influence by intervening layers of tissue, must necessarily become more and more absorbent of the oxygen, which is communicated to them through the air-tubes from the leaf-laboratory, and the air in those tubes must also become impregnated with carbonic acid in proportion to the amount of tissue which they have traversed in the *dark portions* of the interior of the plant.

The process of de-oxydation or digestion in the leaves, has masked and disguised the *true respiratory process* in the interior of plants, which is carried on by the pneumatic vessels of their fibro-vascular system. In what does this differ from the process of respiration in animals? The principle is precisely the same. There is the same oxygenation of the nutrient fluid in the interior of both organisms; but the sap is oxygenated in the plant by a system of pneumatic vessels which officiate as conducts of oxygen from the leaves, and bring it into direct communication with the sap-cells in all parts of the vegetable fabric; whereas in animals, the pneumatic vessels, which oxygenate the blood, are confined to an unique and special organ developed in one part of the organism.

Another source of demand for oxygen, common to both animals and plants, arises out of the changes which are always going on in them, and the necessity for the removal of all waste matter from the system. Plants are without a nervo-muscular system, and are therefore exempt from that interstitial waste and destruction which takes place in animals, and which is the result of nervous and muscular action. Although they have no organs developed expressly for the removal of effete matter, we nevertheless see them spontaneously throwing off those parts of their fabric which are no longer of any service to them. Thus the cotyledons perish as soon as the first pair of atmospheric leaves are fully developed; the bud-scales, which protect the young shoots of trees through winter, are thrown off as soon as spring and warm weather comes. The blossoms drop from the trees as soon as they have contributed to the formation of their fruits; and the trees themselves shed those leaves which have contributed to their nourishment through the spring and summer months, on the approach of winter, because their vitality is exhausted, and they are useless to the plant. In all these instances, oxygen is absorbed and carbonic acid evolved. Thus, in both animal and plant, oxygen is the principal agent employed in the removal of the waste matter. Is it objected that waste matter is thrown off *en masse* from the plant, and not in a gaseous condition, as in the animal? We reply that the evolution of waste matter in the gaseous form, commences with the ordinary process which produces the decay of leaves; their decomposition after their separation is only a continuation of the same process. All the waste matter thrown out of the animal system is not evolved into gases before it is eliminated, but only a part of it; the rest appears under the form of those solid and liquid fæces excreted from the system by the appropriate organs, and its final decomposition takes place when it is separated from the organism, just as the leaf is resolved into its original elements after it is detached from the branch. We cannot see any difference except in the greater degree of its simplicity, between this process in the plant and in the animal. The dead matter in the interior of the organism *is of service,* since it strengthens the fabric of the plant, and therefore no provision has been made for effecting its removal. It cannot be called waste matter. It is otherwise with the foliage and flowers with which plants are annually adorned. These cease to be of any further service as soon as they are dead; they are therefore separated from the plant as waste matter.

We have seen that plants subsist on the food which they find in the earth and atmosphere, in a condition suitable for absorption into their organism; that animals, on the contrary, have to use organs for the prehension and the preparation of their food before it can be absorbed. There is the same simplicity in plants, and additional complexity in animals, in the elimination of their waste matter; it is thrown off at once from the plant, but in animals, a special system of organs has been superadded to the general organism, in order to effect its removal.

ASSIMILATION IN PLANTS AND ANIMALS.

The food of plants is digested and rendered nutritive in their leaves; that of animals is prepared for circulation in their stomach. The leaves have been called the lungs of plants, and the process of respiration has been represented as consisting in the absorption of the carbonic acid contained in the air, and its decomposition under the direct influence of the solar light. That such a process does go on in the leaves is undeniable. The carbon is fixed in the plant, and the greater part of the oxygen is exhaled through the leaf-pores into the atmosphere; at the same time it is evident, from the nature of the nutritive processes going on in the interior, and the intimate connection subsisting between the duct-cells and the leaves, that some of the oxygen will be necessarily absorbed from the leaves into the interior of the plant. A small quantity is, however, amply sufficient to supply the wants of vegetation, and the rest is poured into the atmosphere to meet the wants of animality. It is therefore true that carbonic acid, which is given off from the lungs of animals as waste matter, is taken in by the leaves of plants; that vegetables purify the air which animals contaminate; that what is poison to us is food to plants. It is also true that the leaves are to a certain extent the pulmonary organs of plants, because it is through the pores on their surface that the air gains admission by means of which the fluids, not only in the leaves but in the interior of the organism, are rendered nutritious. Now the predominating function exercised by the leaves is unquestionably that of de-oxydation or digestion, which is antagonistic in its results to animal respiration. When we speak of respiration in plants, assuredly those processes in which oxygen is consumed deserve the name, far more than the exhalation of oxygen by their leaves and other green parts.

The matters contained in the tissues of plants are very various, and are either solid, liquid, or gaseous. All solid organic matters, such as starch and chlorophyl, are formed by de-oxydizing processes, the fluid contents of the cells, such as gum and sugar, chromule, the fixed and volatile oils, organic acids, &c., are the results of oxydation. Starch and chlorophyl are therefore the products of vegetable digestion, the other substances of vegetable respiration. This will be clearly seen if we consider the nature of these substances. They are of great importance in the vegetable economy, and must be carefully studied if we would obtain correct views of the nutrition of plants.

Starch is one of the most abundant and useful products of vegetation. It exists in the seeds, roots, and stems of plants, and in the pulp of fruits; for whilst chlorophyl is formed only on the outer surface of plants, starch is re-

Fig. 22.

a. Club-shaped granules in milky juice of *Euphorbia splendens.* *b.* Three of the lactiferous vessels, with starch granules *in situ.*—QUEKETT.

stricted to their interior, light being absolutely necessary in the one case and darkness in the other. Starch exists in the cells of plants in the form of transparent and colorless granules, which vary in figure and size in different species. They are for the most part of an ovoid shape; but, in the Euphorbiaceæ, their shape is like an elongated dumb-bell or two-headed club. By wounding the plant, and placing a drop of the milky juice under the microscope, these singularly-formed granules may be easily seen by the addition of a little tincture of iodine, which gives them a deep blue tinge. Starch granules are the most easily observed in the cells of the potato where they are very large. On the application of tincture of iodine, the starch granules are readily distinguished by the deep blue color which they immediately assume, whilst the walls of the cells in which they are contained remain colorless. The mode of their formation is indicated by the peculiar markings on their outer surface, each grain having a spot at one end which is called the hilum, or ostiole, with fine concentric lines drawn around it. Sometimes there are

Fig. 23.

Grains of starch, from the potato.

two or three ostioles on the surface of the same granule. Occasionally, crevices are seen radiating from the ostiole in the form of a star, which open more or less profoundly into the interior of the granule. When very young, the grain of starch appears as a vesicle, with a perforation in its wall. It is through this opening that the matter enters, by a movement of intussusception, and is deposited in successive beds. At each deposit, the vesicle dilates by a kind of endosmotic phenomenon, until it finally acquires a degree of solidity which arrests this movement, and it is then that its growth ceases. The ostiole is, therefore, not the point by which the grain of starch is attached to the walls of the cell, but it is the cicatrice of the canal by which the matter which formed the successive layers penetrated, in a state of solution.*

Physiologically considered, starch is unappropriated cellulose, stored up in this particular form as the ready prepared material for new tissues; in this respect it performs precisely the same office in the organism of the plant, as fat does in the animal economy. Those differences in the life of herbaceous plants which has occasioned their being designated as annuals, biennials, and perennials, results from differences in the quantity of the starch deposited in their roots. The roots of annuals are fibrous, those of biennials and perennials are, on the contrary, thick and tuberous. In the first instance, all the starch is expended in the formation of the flowers and the fruit, the act of reproduction exhausts the vital energies, and the entire plant perishes the first year; in biennials and perennials, on the contrary, only a portion of the starch formed by the tissues is consumed the first year, and the remainder is stored up in the roots, as a reservoir for the growth of the next and succeeding years. In many plants, such for example as Sanguinaria Canadensis, the starch accumulated by the leaves through the summer and autumn and deposited in the rhizoma, is consumed by the flowers in early spring, which appear before the leaves.

Chlorophyl, next to starch, is the most common of all the cell contents. It is the green matter of plants, and exists in all those parts which are colored green, such as the leaves, sepals, and the bark of the young shoots. It forms

* See "Precis de Botanique et de Physiologie Vegetale," &c. Par A. Richard, 1852. Premiere partie, pp. 10–11.

itself, in fact, in the vitally active cells on the exterior surface of plants which are exposed to the light, and is wholly absent from the roots and from the interior of the stem, to which the light cannot gain access. Chlorophyl exists in the cells, in the form of separate or united granules, which remain either stationary and united to the cell walls, or float freely in the fluid contents of their cavities. These granules are usually of a globular form, and may be readily distinguished in the cells of the liverworts and mosses. They are beautifully apparent in the little lancet-shaped leaves of Selaginella apus, a common but nevertheless very interesting moss-like representative of the Lycopodiaceæ.

If the green globules of chlorophyl be subjected to the action of iodine, it will be found that they are composed of one or more starch granules, invested by a gelatinous layer of green coloring matter. This green matter becomes colored yellow or brown by the iodine, whilst the granules of starch take the blue color which characterizes them, and appear more or less easily and with a purity of tint in proportion to the thinness of the green gelatinous layer in which they are enveloped. That chlorophyl is nothing but *fecula viridis** or green starch, is further proved by testing it during the different stages of its development. If the young embryo leaves, formed in the autumnal buds of the horse-chestnut, be carefully removed from their hybernaculum, it will be found that they are of a pale-yellow color and nearly transparent. If iodine be applied, the chlorophyl granules in their interior will assume a deep blue tinge which shows that the gelatinous

* See "Outlines of Structural and Physiological Botany," by A. Henfrey, page 19.

paste which envelopes them is excessively thin. If the leaves be examined when more perfectly developed, the blue tint is more obscure, because the gelatinous bed is thicker. That the formation of this green gelatinous envelope is posterior to that of the starch granules which it encloses, is evident from the fact, that when grains of pure starch are formed in organs which afterwards become subjected to the light, they become covered with a bed of green matter, and are thus converted into chlorophyl. Thus potatoes and roots will assume a green appearance if the earth be removed from them, which results from conversion of the starch granules into chlorophyl.

Gum, or rather mucilage, which is a solution of gum, is one of the most common vegetable products, and is found plentifully in the cells of all young and growing parts. It is one of the forms through which nutritive matter passes before it is assimilated. Gum consists of $C^{12}H^{10}O^{10}$, its chemical composition being precisely the same as that of starch. It is in the form of gum that starch passes through the walls of the cells in which its granules were originally generated, when assimilated by the plant. From the bark of many trees, gum is procured in the form of an exudation. Two well-marked varieties of gum have been distinguished. Arabine, soluble in cold water, and constituting the principal ingredient of gum-arabic procured from various species of acacia; and cerasine, insoluble in cold water but soluble in boiling water, constituting the gummy secretion of the cherry and plum.

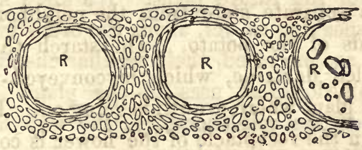
Sugar occurs abundantly in the sap of plants. There are two marked varieties of it. Cane sugar procured from the sugar-cane, sugar maple, beet, carrot, and many other plants; and grape sugar occurring in numerous fruits, as grapes, gooseberries, currants, peaches, and apricots. Sugar, though sometimes crystallized as an excretion in the nectaries of flowers, yet in the plant exists only in the fluid state. It is found very abundantly in growing parts, such as buds, germinating cotyledons, and in ripening fruits.

When starch passes from the solid to the fluid state it is converted into gum and sugar. This transformation is effected by means of a vegetable secretion termed diastase elaborated for this purpose, and which may be readily obtained in a separate state from the neighborhood of the eyes or buds of the potato. The starch thus rendered fluid is called dextrine, which is conveyed to all those parts of the plant where growth is going on. In flowering, the starch in the receptacle of the flower is converted into sugar, as nutritive material for the development of the pollen granules of the anthers and the young ovules of the germen; whilst that portion of this sugar which is not required, again assumes the form of starch in the cotyledons of the seeds, to be once more reconverted into sugar for the nourishment of the young germ, as soon as its vital activity again commences. The saccharine matter is elaborated by organs called nectaries, developed for this purpose. This sweet juice is changed to honey in the stomach of the bee. It is the food of the bee, which is furnished with collecting organs for the purpose of removing it from the plant.

Volatile and fixed oils.—The volatile or essential oils are met with in the stem, leaves, flowers, and fruit of odoriferous plants, giving them by their volatility their peculiar odor. These oils are procured by distillation along with water. They are called essences, and contain the concentrated odor of the plants. Thus otto or attar of roses is procured from the petals of various species of rose, especially Rosa centifolia; oil of peppermint from the leaves of

Mentha viridis; oil of lemons and oranges from the rinds of those fruits; oil of cloves from the fruit of Caryophyllus aromaticus; and oil of turpentine from various species of Abies and Pinus. Volatile oils are generally produced and stored up in certain special receptacles, expressly organized for this purpose. They are represented in

Fig. 24.



Vertical section of the rind of an orange, the reservoirs of volatile oil being marked *r*, *r*, *r*. The cellular tissue of the rind is seen surrounding the oil cavities, and the cells are elongated and condensed so as to form a compact tissue in the walls.

The transparent dots which are seen in the leaves of the lemon, the orange, and the myrtle are produced by these receptacles, which, being filled with volatile oil, are necessarily more translucent than the other parts of the leaves. When held up to the light, these leaves appear as if punctured with numerous fine holes. Several species of Hypericum present the same appearance.

The fixed oils are found chiefly in the seeds where they supply the place of starch, as in the cotyledons of some of the Cruciferæ, Compositæ, and many other plants. Fixed oils are generally obtained by pressure. Their economical applications are very numerous. Olive, almond, linseed, rape, cocoa-nut, and castor oils are familiar examples.

Such are the facts which have been ascertained respecting the nature of these vegetable products. Chlorophyl, starch, gum, and sugar, are almost universally diffused;

the other substances, including the different organic acids, are restricted to certain plants. Here we must stop, for we have not space for an enumeration, much less a description of the vast variety of vegetable products. Almost every plant elaborates from the sap its peculiar solid, fluid, and gaseous substances, which are connected in some way or other with the final result of its vegetative acts, the development of the future plant. We know nothing, comparatively speaking as yet, about the order in which these substances are produced, their peculiar chemical relations, or their physiological uses to the plant. The subtle chemistry of the cell-laboratory, the way in which the cells and tissues separately work, or the nature of that *composite* influence which produces the future germ,—all this is very little understood. And let us not pride ourselves on our knowledge of the economical uses of the various vegetable products. Here also, science is in its infancy. Those who think much of their attainments, or imagine the subject *ever has, or ever can be exhausted,* have never yet viewed it aright. They have yet to learn the limited extent of human knowledge and the riches and fecundity of nature. The finite mind can never fully comprehend the works of an Infinite Being. The glorious sun must pour all his rays into a twinkling star; the illimitable ocean be comprehended within a drop.

It would seem that the nutritious portion of the sap not required for development, is deposited in the cells in the form of starch, which substance retaining its colorless appearance in the interior of the plant where it is excluded from the light, is changed into chlorophyl in their leaves, young shoots, and other superficial parts to which the light has free access. Chlorophyl is a substance closely allied to starch; and appears to be equally nutritious to the plant; for it disappears from the leaves and other organs of plants when their vitality is exhausted. A partial oxydation of this starch produces the chromule, and as the oxydation increases, gum and sugar. This oxydating or consuming process necessarily partially arrests the further development of the organs; the growth of the plant is to some extent stopped, the petiole assumes the form of a filament, and the lamina being contracted into an anther, a stamen is produced.

The change, however, from the de-oxydating to the oxydating process is undoubtedly gradual. Hence those transition forms between the leaf and stamen, which so satisfactorily prove that the two are but one and the same organ.

We have already shown that the fibro-vascular system of plants and the blood vessels of animals are subordinate in function to the cells with which their terminal capillary ramifications finally communicate, and that it is in these cells that the changes take place by which the fluid is transmuted into the various products necessary to the nutrition of the organism. The sap of plants in traversing the tissues is elaborated into starch, chlorophyl, chromule, gum, and sugar; and, in like manner, the blood which is conducted by means of the capillaries, not only through all the softer parts of the framework, but even into the solid substance of the bones, gives up its constituents to the several tissues which it traverses, the cells attracting from it their own proper formative material. Its constituents are thus transmuted into bile, saliva, tears, and various coloring matters. The plumage of birds and the hues of flowers are alike the results of this selecting power exercised by the cells on the constituents of the nutrient fluid.

Assimilation in animals is therefore as plant-like as the rest of the nutritive processes.

A great many plants, when their sap has been digested in the leaves, reject at their exterior various matters which are often condensed and solidified. Thus the leaves of the sycamore are covered with a saccharine matter; the stems of pines and firs exude resins, and the fruits of the bay-berry (Myrica cerifera,) are coated with a thick vegetable wax. In these instances, the plant excretes these substances which are the products of nutrition, but which are not necessary for the accomplishment of that function. Their appearance is the result of their superabundance in the subjacent tissues, the distension of which is relieved by this exudation.

PART III

REPRODUCTION IN PLANTS AND ANIMALS.

CHAPTER VII.

GENERAL CONSIDERATIONS ON REPRODUCTION IN PLANTS AND ANIMALS.

THE nutritive functions of digestion, circulation, and assimilation, have for their object the support of life, by furnishing to organized beings without ceasing, new and proper materials for the development of their organs, and the reparation of the waste occasioned by the movements of animality. But it is the nature of all organized beings to have but a limited existence. Their organs finally lose the faculty of sustaining life, and the cessation of their functions brings on death. All the organized beings existing on the earth, end by disappearing from its surface; and their races would speedily become extinct, if nature had not given them the means of reproducing and multiplying themselves.

Through reproduction the power of life is made to pass without ceasing into other bodies. Our parents are reproduced in us as we are engendered in our descendants. Thus the individual perishes, but the species is continued.

Wherever there is life, there is attraction. The appearance of matter in organized beings implies a draught on the resources of nature. Each germinating seed exercises a *special* attraction on the earth and atmosphere, and dead inorganic matter collects around it, to be embued with vitality and moulded into an organized form.

But there is only a limited amount of organizable material existing in nature, and her resources would therefore be speedily exhausted were there not an equivalent amount returned. The matter which composes the bodies of animals and plants is only "*borrowed* from the earth and atmosphere, and united together by the operation of natural laws for a *little* space of time."* A rotation of these substances is therefore absolutely necessary.

Wherever there is death, there is repulsion. The matter which was collected by life, is scattered by death. The plant or animal decays and disappears from our sight. Both are alike dissolved by the repulsive principle into earthy elements and invisible gases, and the atoms held together by life thus sundered by death, once more roam through the universe and gather around the living centres of attraction, to be again re-moulded anew into living organized forms.

Matter, whether organized or inorganic, never perishes. Every atom bears on it the impress of its everlasting and infinite Author. If it disappears from observation, it is only to enter into new combinations. You may crush the parts of a body to powder, melt it into a liquid, or by a still intenser application of heat, dilate it into a gas and dissipate it in vapor; but it still exists, and in many instances can be collected into the same body without change of form. Mercury and water may be converted into vapor, and again recovered without the loss of a single particle. The decay of animal and vegetable bodies is only a process by which their particles are liberated to assume new forms.

What life borrows, death will sooner or later claim. The living incur a debt which must be paid. Matter is the grand circulating medium of nature, and all that is loaned even to the minutest particle, must be returned.

* See the author's "Principles of Botany as exemplified in the Cryptogamia," page 7.

Nothing is ever lost by nature. Death is the agent employed to enforce the claim, and we must surrender what we have appropriated. We may be unwilling to pay the debt, but in this instance at least no fraud can be practised. We may cheat our fellow-men out of "*their own*," but nature, NEVER.

It is this ceaseless return of organizable material which keeps up the continuity of the stream of life and renders the fountain inexhaustible. Hence the matter of which every animal and vegetable was formed in the earliest ages is now in existence. We ourselves are composed of matter as old as the creation; in time, we must suffer in our turn, decomposition, as every living body has done before us, and thus resign the matter of which we are composed, to form new existences.

The reproduction of organized beings takes place in a variety of ways. We have already described the gemmiparous and fissiparous modes, which take place, the former among compound zoophytes, and the latter among the infusoria. These two modes of multiplication require no special organs for the formation of the new individuals, since in the first case they originate on all the points of the exterior surface of the body, and in the second, it is its totality which divides into fragments, each becoming a new individual.

But it is not in this manner that the generality of plants and animals are reproduced. In the immense majority of cases organized bodies, animals and plants, reproduce themselves by means of fecundated germs which we call embryos. These embryos form in a particular organ which is called an ovule, in consequence of receiving from another special organ, an influence which impresses on them the vital movement, or in other words, fecundates them. The organs in which these germs are developed, are called female sexual organs; the organs which form the matter which fecundates them, are called male sexual organs.

That all animals are produced from eggs, *omne vivum ex ovo,* is an old adage which modern researches have abundantly confirmed. In tracing back the phases of animal life, we invariably arrive at an epoch when the incipient animal was enclosed in an egg. It is then called an embryo, and the period passed in this condition, which is more or less long according to the nature of the animal, is called the embryonic period.

Before the various classes of the animal kingdom had been attentively compared during the embryonic period, all animals were divided into two great divisions; the *oviparous,* comprising those which lay eggs, such as birds, reptiles, insects, and mollusks; and the *viviparous,* which bring forth their young alive, viz., the mammalia. This distinction has, however, lost much of its importance; for it has been ascertained that viviparous animals are produced from eggs as well as the oviparous, and that both have one and the same uniform structure in the beginning. In viviparous animals, however, the eggs undergo their early changes in the body of the mother, that is to say, the embryo develops in the uterus, and bursts the membrane of the egg, which it leaves there, coming out of the body of the mother naked and already formed; whereas in oviparous animals, the egg is laid with its membranes and the germ which it contains, and the development of the embryo is extra-uterine.

Production from eggs must therefore be considered as a universal characteristic of the animal kingdom. Even animals which propagate by gemmiparous and fissiparous reproduction, also lay eggs. The former are only additional means employed by nature to secure the perpetuation of the species, super-added to the usual method of propagation.

Now plants have sexes or sexual organs as well as animals. The female sexual organs in plants are called

Fig. 24.

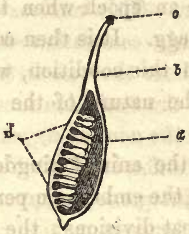


Fig. 25.

Fig. 24. A pistil exhibited in section to show the young ovules *d*, attached to the placenta or walls of the ovary *a*, and contained within its cavity. *c*. The stigma or summit of the pistil, to which the pollen grains adhere when fertilization takes place. *b*. The style of the pistil, through the loose cellular tissue of which the pollen tubes descend in their passage to the ovary.

Fig. 25. A stamen. Its filament or support *a*, and its anther *b*, discharging the fecundating matter or pollen.

carpels. The pistil which consists of stigma, style, and germen, is only a fully developed carpel. The male sexual organs are named stamens, the anthers of which contain the pollen or fecundating matter. The stamens and carpels are the essential organs of reproduction in plants, since it is by the mutual action of these bodies that the vegetable embryo is formed.

The ovules contained in the germen or ovary are the bodies which after impregnation become seed. Their existence may be verified by making a section of the germen, whilst the flower is still in the bud, and before the anther cells have been ruptured, and, in this condition, they undoubtedly correspond to the unimpregnated ova of animals. The line or ridge on the interior walls of the ovary to which the ovules are attached, is called the placenta. The ovule is attached to the placenta either directly or by means of a prolongation or umbilical cord, termed the funiculus. The ovule when fully developed, consists of a conically shaped nucleus of cells containing a cavity, termed the embryo sac, in its interior. This nucleus has two coverings which have no organic connection with each other excepting at the base, where the vessels from each covering meet, passing through the funiculus into the placenta, which communicates with the nourishing walls of the germen. This common point of union is called the chalaza. At the apex of the ovule, both integuments leave an opening which has been termed the foramen or micropyle.

The reproductive function is exercised by animals and plants when they have attained to the full development of all their parts, or arrive at an adult state. The period when this occurs varies greatly in each species and depends entirely on the peculiarities of its constitution. When this epoch arrives in plants, a visible change takes place in the organic functions; the stem ceases to elongate, and its internodes no longer developing, the leaves remain crowded together in closely approximated whorls, undergo peculiar modifications in form and coloring, and a flower is produced.

It is not the beauty and variety of the hues of flowers, *so much as the plan on which they are constructed,* which is the chief point of attraction about them. The terminal rosette of leaves called the flower, so different in size and appearance from the ordinary leaves of the stem, is simply metamorphosed stem leaves, crowded together in order that they may act on each other. For example, all must have noticed the folding up of the calyx and corolla in wet weather, or at sunset. The function exercised by the two outer whorls of floral leaves is, in this case, purely protective, and the design of their close proximity to the stamens and pistils is at once apparent; that they may fold over the stamens and pistils, and thus protect them from the effects of the night dews and falling rain, which would otherwise act injuriously on the pollen contained in the cells of the anthers.

Fig. 26.

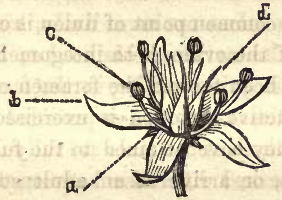


Fig. 26. The different parts of a flower. *a.* The calyx; *b.* the corolla; *c.* the stamens; *d.* the pistils.

The reproductive organs of plants, popularly called their flowers, are commonly the most showy and attractive parts. To this rule, however, there are some exceptions. For example, the radicle leaves of the rattlesnake plantain (Goodyera pubesceus,) one of the North American Orchideæ, found in shady woods, far surpass the floral leaves in the elegance of their form and coloring. This plant is much prized in Europe, and is cultivated on account of the beauty of its foliage. It bears a spike of greenish white flowers of a very ordinary aspect; the foliage of the plant, on the contrary, is a deep rich green, most beautifully reticulated and blotched with white, and retains its verdure through the winter.

Among animals the *majority* of species, and among plants the *minority* are unisexual, or diœcious; that is to say, the male and female organs of generation are on separate individuals of the same species.

Difference of sex is much more marked among animals than among plants. Among insects the difference of sex is readily perceived, not only by a difference in the organs of generation, but by exterior characters which are easily recognized. Thus, in general, the male is smaller than the female; his antennæ are longer and better formed; very often his colors are more lively, his mandibles more powerful, and he carries on his head or his thorax appendages which are quite wanting in the female. The female insect is sometimes apterous or provided with rudimentary wings, whilst those of the male are fully developed. There is no such marked difference between the sexes in diœcious plants. The Ailanthus glandulosa may be adduced as an illustration of this uniformity of appearance. With the exception of its peculiar pollenic odor and the total absence of pistils from its flowers, the male tree differs not from the female in any other particular. The leaves of both plants are precisely the same in configuration and surface. The male and female trees are in fact so exactly the same in appearance, that it is utterly impossible to recognize the difference of sex, except at the epoch of flowering. We are not aware of any diœcious plants which are an exception to this law of uniformity, although doubtless such exist in nature.

Unisexual plants are apparently not so favorably situated for sexual intercourse as the hermaphrodite species, where the male and female organs are present in the same flower.

The pollen or fecundating matter is however wonderfully organized, so as to facilitate its action on the pistils. The granules of which it is composed are so small and numerous, that they form a fine, light powder, which is easily transported by the winds to a very considerable distance from the plant. Instances might be cited of diœcious trees, such as palms and pistachio nuts, the females of which have been fecundated by pollen from male trees separated from them a distance of several leagues.* The wind drives the pollen far and near, and the air becomes sometimes so charged with it, that the rain in falling brings it in considerable quantities to the ground, producing the so-called sulphur showers of which we read about in history. There is no doubt also, that the bee and other insects in search of honey, convey the pollen from the stamens to the pistils, in unisexual plants.

HYBRIDIZATION IN PLANTS AND ANIMALS.

If pollen is conveyed by means of the atmosphere and insects, it must happen that plants will occasionally hybridize, or the pollen of one species will sometimes fertilize the ovules of another species of the same genus. The seeds thus produced give rise to individuals of an intermediate character, but which are unable to perpetuate themselves; or if they have that power, lose it in the second or third generation.

The analogies between animals and plants are in no instances more striking, than in their power of hybridizing, and in the similarity of the restrictions imposed by all-provident nature on the exercise of this function. In both, it

* Precis de Botanique et Physiologie Vegetale, par Achille Richard, page 254. 1852.

is restricted to the nearly allied species of the same genera, and in neither case is the hybrid capable of perpetuating its kind, in animals, beyond a single generation, and in plants, beyond the second or third. The hybrid vegetable if reproduced from seed, either reverts back to the character of one of its parents, or becomes sterile.

Among the native plants of North America, hybrids are not produced to that extent which we would be led to suppose. The numerous pollen grains of different species borne on the wandering winds from the male flowers of any particular species of plant, are so exactly adapted to the female flowers of the same species, that they become abortive on the pistil of any other plant. Hybrids are therefore very rarely produced by wild plants, as the stigma of any particlar species of plant is much more likely to attract the pollen of its own stamens than that of other plants. The species of the genus Verbascum, or shepherd's flannel, a tall plant, very common along road-sides, with a leaf not unlike a piece of flannel, and a spike of yellow flowers, show a greater tendency to hybridize than almost any other species.

Hybrids are much more common among cultivated and domesticated plants, than among wild ones. It is a fact well known to cultivators of Ericas, Pelargoniums, Mesembryanthemums, and Stapelias, in the green-house, that when several species of any of these genera are grown together, and plants are raised from seed, they will frequently turn out hybrids.

It is the constant practice of gardeners to produce the different varieties with which their green-houses are adorned, by conveying the pollen from one plant with a corolla of a certain color, to the pistils of another plant with a corolla of a different hue. The seed thus generated will develop a plant of an intermediate shade of color. This principle of cultivating and propagating new varieties has been carried to such an extent by florists, among certain genera that are in their power, that the original species can now scarcely be distinguished. Unfortunately for science, if a slight variety of any popular flower is developed by this hybridizing process, it is immediately sought after, and will bring the florist a higher premium than some newly introduced, and perhaps, beautiful exotic species. This is certainly very bad taste. The introduction and cultivation of new species ought to be encouraged, because it is of far more importance than the breeding of hybrids. We should become better acquainted with exotic flowers, and many undiscovered and valuable properties would doubtless be brought to light in some of them, by that watchful and studious attention to their habits which would be required for their successful cultivation. The numerous and beautiful homes of wealthy citizens would no longer be surrounded by gardens filled with common flowers, but we should find in them what is far more becoming, select and choice collections of foreign plants.

Nearly allied plants of the same genus can alone be made to hybridize. Thus the different species of the lily, strawberry, and the geranium, intermix freely with the individuals of the same genus; but the lily and strawberry, two different genera, cannot be made to fertilize each other.

To the facility with which the species of some genera hybridize, are we indebted for all the splendid varieties of the rose, dahlia, and geranium. These can only be propagated by cuttings, or by offsets or portions of the root.

The study of the laws of hybridization is important, as connected with the origin and limitation of species. If, as some authors believe, there are only a few original species, and all the rest are the result of hybridization, then there is no limits to species and no permanence whatever in their characters. This, however, is not borne out by facts. It is necessary in order to conception, not only that the pollen or sperm should reach the vegetable or animal ovule, but also that there should be some harmony of relation between the germ and the nature of the fecundating element, otherwise vivification will not ensue. Thus, notwithstanding the mixture of the fluid of the milt of different male fishes in the same waters, where there are dispersed so many different species of eggs, hybrids amongst them are rare; in like manner, each diœcious plant develops only on the stigmas of its pistils, the pollen of its true species, from amongst so many other kinds of pollen carried by the same winds. It is thus that the character of each species is perpetuated in its native purity.

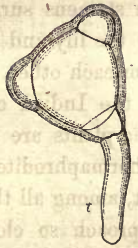
Most plants are hermaphrodite, that is to say, the male and female are united in the same individual. Thus in the majority of flowers the stamens surround the pistils on a common support, as in the lily and geranium, or they may be developed apart from each other, in separate flowers on the same plant, as in the Indian corn and mock-orange. In this last instance the plants are said to be monœcious. Some animals are also hermaphrodite, such as muscles, oysters, zoophytes; in fact, among all the immovable mollusca and radiata which approach so closely in functions and habits to plants, hermaphrodism prevails, which is the most common manifestation of sexuality in the vegetable world.

CHAPTER VIII.

ON THE ESSENTIAL AND CONSECUTIVE PHENOMENA OF REPRODUCTION.

The process of fecundation appears to be as follows: As soon as the calyx and corolla are expanded, the stamens free from all confinement take a rapid development, and the anthers up to this time unruptured, moist, and closed, become dry, and opening their cells, discharge the pollen over the stigma, and very frequently over the other parts of the flower. The stigma, or apex of the pistil, is about this time bedewed with a clammy fluid, which serves to retain

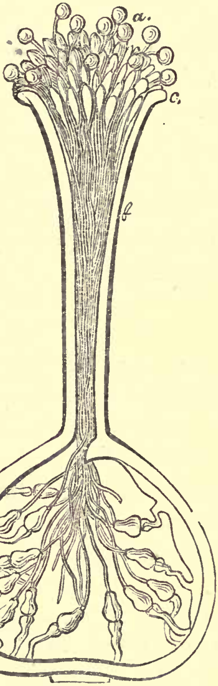
Fig. 27.



Triangular pollen grain of the evening primrose, (Œnothera,) with one pollen tube *t*, protruded. This tube is formed by the intine, which is also seen projecting at the other angles.

the grains of pollen on its surface. The grains of pollen, after remaining for some time on the humid stigma, absorb its moisture, and are seen to swell, so that those which are elliptical assume a spherical form. A few hours contact is all that is necessary to produce this change in some species, whilst many days are required for others. The swelling increases, until at last the thin and highly extensible intine, or inner coat of the pollen grain, is pushed through one of the pores or ostioles in the surface of extine or outer coat, the

Fig. 28.



Longitudinal section of the pistil of *Helianthum denticulatum*, showing the ovules in the interior of the ovary attached to the placenta, by means of the funiculus, or vegetable umbilicus; *b*, style; *c*, stigma; *a*, pollen granules, the tubes of which have descended the style and entered the micropyle of the ovules.

mode of dehiscence being always determined by the nature of that surface. This pollenic tube penetrates the loose cellular tissue of the stigma, grows downward through the central portion of the style, and having arrived at its base, enters the germen or ovary, in which the ovules are found up to this period unfertilized. The pollen tube enters one of the unimpregnated ovules through the micropyle, penetrating the tissue of the nucleus till it reaches the embryo sac. Fecundation appears to be produced by the simple contact of the pollen tube with the embryo sac, and the imbibition by the embryonal vesicle of the contents of the pollen grain through the intervening membrane, the fluid contents of the two cells being thus commingled. The fluid matter of the pollen grain is called fovilla, and its flow through the pollen tube is easily perceived by the movements of those microscopic corpuscles which it contains.

The pollen tubes may be readily inspected under the microscope in many plants, and in none more readily than in the Asclepias, or Milkweed. In that family the pollen grains cohere together in masses termed pollinia, and their united tubes being protruded, are consequently of such a size, as to be readily perceived by a moderate magnifying power.

The young ovules which are attached to the placenta or wall of the germen, before the flower opens, continue to grow until that time, but no longer, unless they are acted upon by the pollen of the anthers. The necessity for this process shows why it is that stamens and pistils are so frequently found together in flowers, and why the former surround the latter so nicely as they in general do; and, in circumstances which are apparently adverse to fertilization, the admirable contrivances to bring about the same end. Thus, in pendulous and upright flowers, the filaments of the stamens and the style of the pistil are so developed, as to bring the anthers and stigma into the most favorable relative position for communicating with each other. This is beautifully exemplified in the ladies ear-drop (Fuschia,) which is a pendulous or drooping flower. The style of the pistil is considerably elongated, and the filaments of the stamens are short, so that the anther cells are necessarily situated above the pistil, in order that its viscid stigma or summit may receive the pollen as it falls out of them. In upright flowers, on the other hand, we have a reverse arrangement of the parts; for the style of the pistil is in a great measure suppressed, and the filaments of the stamens are so developed as to place the anthers above the stigmatic surface.

The ovules having received the impregnating matter, the pollen tubes wither from above downwards, the foramen or micropyle of the ovules closes, embryos or miniature plants begin to form in them, and they are gradually transformed into seeds. The ovary or cavity of the pistil containing the ovules, gradually swells under these influences. Enlarged and ripened, it constitutes the pericarp or seed vessel.

While the fruit enlarges, the sap is drawn towards it, and a series of changes soon announce that a new vitality is established in the impregnated parts to the detriment of the others. The flower, beautiful up to this moment, and adorned with the most lively colors, loses its pleasing aspect. The petals fade and fall. The stamens, having fulfilled their functions, prove the same degradation. The stigma and style of the pistil being now useless to the plant, disappear equally with the other parts. The germen alone remains in the centre of the flower, and swells into a fruit abounding with seed by which the species is continued. It is not an unusual thing to see the calyx persistent with the germen, and contributing along with the green walls of the pericarp or seed vessel to the nourishment of the young embryo. The vitality of *all* the organs of the flower is, however, exhausted in succession before the seed arrives at maturity and the embryo is fully developed; the calyx and pericarp alike perish, when they have fulfilled this the last and most important function of vegetable life. An attentive observer may watch these changes throughout the summer months, in any plant that produces flowers and fruit, and may thus satisfy himself of the general correctness of these statements.

At the period of flowering, a great exhaustion of the nutritive juices of plants invariably takes place. In annual herbaceous plants, the formation of the seed not only exhausts the vitality of the flower, but of the stem and leaves, and the whole plant perishes the first year. In biennials, a store of nutritive matter is assimilated during the first year, which is deposited in the root, and consumed by the act of flowering the second year; the plant therefore necessarily perishes. In perennial herbaceous plants, which invariably rise from an underground stem, the aerial portion of the plant always dies down to the ground at the close of the flowering season; but the subterranean part remains alive through winter, and as invariably re-appears above the ground in spring; therefore, only the upper part of such plants is exhausted in flowering. But in woody perennials, the formation of the flowers and fruit consumes only the nutriment contained in the peduncle and its immediate supports; but the rest of the plant is not injured. The first and succeeding year's growth of stem is therefore persistent, or remains alive above the ground. It is true that the tree sheds its summer leaves, and spreads its naked branches to the wintry sky; but the stem, the numerous branches and branchlets of the naked tree are not dead. Life exists all along the central axis, and is lying in the bud or hibernaculum of the young shoot, in a dormant state, till spring awakens it to a new existence. Hence it is, that every year, a plant with a ligneous persistent stem increases in altitude, until it becomes a shrub or tree with a noble canopy of foliage. Such may be fairly considered as the highest developments of vegetable matter.

The term fruit has a more extended signification in botany than in ordinary language. It is applied to the full grown ovary or pericarp, whatever may be its size, form, color, or texture, and whether it is edible or not. A grain of wheat or corn, or the pericarp of a sunflower or thistle, considered botanically, is as truly a fruit as a peach, a gooseberry, or a melon.

Sometimes the texture of the fruit or pericarp remains nearly the same as at first, or it may grow into a fleshy body, which gradually changes into an agreeable pulp, as in the grape. Occasionally the pericarp becomes crustaceous and woody in its structure, as in the nut; or it may become in part hard and dry, like a nut, and in part a delicious pulp, as in the plum and peach.

There are few plants in which all the ovules become perfect seeds. Many are suppressed during their progress of growth, so that frequently one seed is developed at the expense of several ovules. This is well seen in the prickly pericarp of the chestnut, (Castanea vesca,) which, when ripe, opens by four valves, and drops the one or two nuts contained in its interior. In the ovary of the chestnut there are usually fourteen ovules. Most of these however become abortive, or perish as the ovary ripens into the pericarp; whilst such as remain are generally very much reduced in size, one or two nuts growing at the expense of the rest, and filling the whole cavity of the pericarp. When, however, the embryo is fully developed within it, the ovule becomes the seed, and the ovary the fruit. The seed is detached from the parent plant, and the life which has passed away from the other parts in succession, now lies dormant within its folds.

The separation of the seed at maturity from the parent plant may be regarded as the parturition of the plant. Sometimes the pericarp or seed-vessel opens with a spring-like mechanism, and the seeds are thrown to some considerable distance. The pericarp of the common garden balsam, (Impatiens,) and that of the castor oil plant, (Ricinus,) may be given as illustrations. When the pericarp or seed-vessel does not open elastically, and the seeds remain attached to its walls, the atmosphere sometimes frees them from their confinement. We see every day the wind transporting the seeds of plants which have developed little feathery appendages, contrivances evidently intended to catch the breeze, by means of which they are detached from the pericarp and carried often to a great distance from the parent plant. Neither is there any mistaking the intention of nature in furnishing the seeds of some plants with barbs or hooks, by means of which they adhere to the dress of the passing traveller, who thus unconsciously becomes the instrument in effecting their removal. In the autumnal months, all persons must be familiar with seeds which, thus furnished, have attached themselves to their dress, and forced themselves on their attention. The seeds of the Spanish Needles, (Bidens bipinnata,) are in this respect, particularly troublesome.

If the seed, thus separated by any of these agencies, is favorably located, all is quiet until the return of suitable conditions of temperature, air, and moisture, when the vital movements of life again commence those impulses which it received from the parent plant. The chick bursts through the egg, impatient of confinement, and the embryo plantule ruptures the integuments of the seed, running through the same phases of development as the plant on which it originated.

As soon as the seed begins to germinate, the first thing that we notice is the softening and swelling of its envelopes; its testa or outer covering is ruptured, and the embryo elongates downwards by its radicle or young root, and upwards by its plumule or young stem, lifting the cotyledons or seed leaves above the earth's surface. These seed leaves, when exposed to the light, speedily acquire a green hue, and in dicotyledonous embryos ultimately assume the form of two opposite leaves. These leaves are somewhat thick and fleshy, their margin is invariably entire, and they ultimately become so altered in appearance, as to be altogether different from what they were when wrapped up within the folds of the testa. If the plant has but one of these leaves, it is called a *Monocotyledon*, if it has two, a *Dicotyledon*. Plants that spring up without these appendages are called *Acotyledons*. These last develop, not from seeds, but spores.

The cotyledonary leaves attached to the embryo contain a store of starch, which contributes to the development of the first pair of atmospheric leaves and also to the extension of the root in the soil; hence, at the end of a certain time they fade and fall, having discharged their allotted functions. The second pair of leaves take the form peculiar to the plant and remain permanently attached to its stem; as they aerate the fluid absorbed into the interior of the plant by the radicles, much more perfectly than the cotyledonary leaves did, the growth of the plant is necessarily more rapid.

It is important then to take all possible means of favoring the growth of the second pair of atmospheric leaves. As the power of absorbing food from the atmosphere and soil increases with every fresh growth of leaves and fibres, and is necessarily very feeble in the beginning, when the plant is in the cotyledonary stage of development, it is obvious that the beds must be kept carefully weeded, and where the young plants are very much crowded together, the feebler must be removed, in order to encourage the growth of such as are more vigorous.

Perennial plants lose their sexual organs when they have served them but once, and develop others each year; but vertebrated animals, such as mammalia, and birds, preserve those with which they are provided. In all the inferior orders of animals, these organs have their times of repose and periods of activity.

"The period of ovulation is to animals what flowering is to plants; and, indeed, few phenomena are more interesting to the student of nature than those exhibited by animals at the pairing season. Then their physiognomy is the most animated, their song the most melodious, and their attire the most brilliant. Some birds appear so different at this time, that zoologists are always careful to indicate whether or not a bird is represented at the breeding season. Similar differences occur also among fishes and other animals whose colors are then much brighter."* Thus in early spring, when plants put forth new leaves and flowers, we have renewed at the same time the hair, feathers, scales, horns, and other external appendages of animals. Both are alike

* Principles of Zoology, by Louis Agassiz.

re-clothed. It is the season of love and happiness. All nature rejoices. To many organized beings it comes only once. In this respect many animals are like annual plants, perishing as soon as they have given birth to their eggs. The lives of insects especially are thus limited.

The cause of this grand revolution of the exterior of organized beings, results from the antecedent restraint of their functions by the cold of winter. The vital properties of the tissues of animals and plants are still retained, although neither may exhibit any outward indications of life. As the temperature of the air declines to the freezing-point, the movements of life either cease altogether or become quite imperceptible; but when the temperature again rises, the usual activity of the plant and animal returns.

There are different degrees of torpidity in both animals and plants. Some animals retire into situations favorable to the retention of their warmth, and occasionally awaken in mild weather and apply themselves to the store of food which they have previously accumulated in autumn. In other species, there is an accumulation of fat in the body of the animal which keeps up its temperature above that of the surrounding air. These animals may be roused from their torpidity into which they soon fall again; their respiratory movements, though diminished in frequency, are still continued. But in the Marmot and other animals which hibernate completely, the heat of the body almost entirely accords with that of the surrounding air, being seldom more than one or two degrees higher. The respiratory movements fall from 500 to 14 per hour, and the pulse sinks from 150 to 15 beats per minute.* Thus the

* See Carpenter.

functions of animal life are never totally suspended during winter.

There appears to be also some continuance of vital activity amongst plants, as for example, evergreens. From the very nature of things these plants must change their leaves; but they do it in a manner less rapid and visible, one leaf replacing the other in such a way that the tree is never totally defoliated. In the spring of the year there is a partial leaf-fall from the branches of evergreens. These plants therefore retain their capillaries, which are more or less in action through the winter months.

A low degree of warmth will, even in the depth of winter, start the sap of plants. Thus, if incisions be made into the stem and branches of a young maple in winter, if the weather should become mild, the sap will be seen to trickle from the wound. So also coniferous plants, which abound in resin, maintain their temperature above the freezing-point in the severest weather. Their fluids are never congealed, owing to their viscidity, and they can therefore resist the cold when it destroys all the vegetable life around them.

Vegetable and animal life is therefore more or less in a state of activity during the winter months, although as a general thing, winter is a state of repose to *all the lower forms* of organized nature,—the nutritive fluid slowly accumulating in their tissues.

But the vernal sun once more pours forth on the cold, damp earth, his warm, life-giving radiance; the earth and atmosphere are by the force of vital attraction again woven into green leaves and beautiful flowers, and the animal creation issue forth from their hiding-places to partake of the rich feast. This rapid development of vegetable and animal life, together with all its varied and deeply instructive phenomena, what is it but the bursting forth of the pent-up stream of vitality? This display of its strength is commensurate with its former manifestations of feebleness. It is re-invigorated nature awakening from repose, and offering her tribute of thankfulness to that beautiful star the sun, during whose absence all nature mourns, at whose coming all nature rejoices, whose many-colored rays diffusive of life and beauty wherever they fall, are but pencilings from the Eternal for our instruction.

Every organized being, whether plant or animal, springs invariably from an individual perfectly similar to itself, to which it adheres during a space of time more or less long, and from which it is finally separated at a definite period under the form of a seed, spore, or ovum. The seed and ovum, under envelopes more or less resisting, enclose a germ. Within this germ all the organs of the adult animal and plant exist in a rudimentary condition. Germination, or the act by which these organs disentangle themselves from their envelopes, does not increase their number, but only augments their size and modifies their form.

The development of the embryo within the ovum of the animal and plant, takes place in pretty much the same way. We have seen that vegetable fecundation consists in the simple contact of the free extremity of the pollen tube with the embryo sac of the ovule. It is then that the embryo develops in the interior of the embryonic vesicle, and it is interesting to follow the series of changes which take place in this last organ.

The embryonic vesicle is at first, simply a spherical cell, developed at the end of the suspensory filament, filled with fluid, and containing granular matter. A little time after fecundation, a longitudinal septum, in the same direction as the suspensor, is seen to form across the cavity of the cell, which thus becomes divided into two cells. Very soon each of these cells is divided into two others, which again prove the same segmentation; the mass of cellular tissue thus formed, goes on developing, and ultimately organizes itself into a seed which contains an embryo capable of reproducing the plant.

Now what relation subsists between the ovule of flowering plants and the ovule of animals? This is an interesting question, deserving of some attention. In the higher order of animals the ovule exists in the ovarian mass, or in tubes which supply its place in animals of a simpler organization. It appears at first under the form of a simple utricle, in the inside walls of which exists another much smaller, called the *germinal vesicle*. This last disappears after fecundation. It is within the primitive utricle that the vitellus exists, a matter formed at first of a granular substance, which, by successive segmentation, divides itself into globules more and more numerous. This body, the vitellus, by degrees organizes itself into a tissue, the basis and framework of the germ or embryo. The animal ovule is therefore represented in the plant by the embryonic vesicle, and the granular matter which it contains is analogous to the vitellus of the egg; since both are transformed by successive segmentations into cellular tissue, and finally into the embryo. The embryonic sac and the walls of nucleus are only the accessory parts, analogous to the yolk of the egg in birds; that is to say, they furnish to the young embryo the first materials of nutrition, and end by being totally absorbed.

Among vertebrated animals the development of the embryo may be best observed in the eggs of fishes. Being transparent, they do not require to be cut open, and by sufficient caution the whole series of changes may be observed on the same individual; whereas, if the eggs of birds are employed, which are opaque, an egg must be sacrificed for each observation.*

The only essential difference between the egg of mammifers, and the human species in particular, compared with the eggs of oviparous animals, is in its excessive minuteness. When fully developed, its diameter hardly amounts to the tenth of a line. It consists in a very small vitelline mass, enveloped in a thick transparent membrane, which some authors have called the chorion, whilst others have considered it as representing the albuminous part. These ovules are each placed in the vesicles of Graaf, which are small bladder-like bodies, contained within the ovarium, the remainder of the vesicle being filled with albuminous fluid. At the time corresponding to the epoch of rut or menstruation, the Graafian vesicles are ruptured and the ovule escapes, is immediately seized by the fimbriated processes of the fallopian tube, and thence conveyed along the tube as far as the uterus. If, in its course, the egg encounters the seminal matter of the male, fecundation is effected. It then becomes attached to a point of the matrix, where it passes through all its developments till the moment when it arrives at maturity. It then comes out to the exterior and its extra-uterine life commences. If, on the contrary, the egg is not fecundated, it usually dies within a few days, and is lost to reproduction.

The seminal matter which fertilizes the ovule, is in animals ordinarily a compact fluid, which contains granulations more or less abundant, and animated corpuscles called spermatozoa, or spermatic animalcules of a very variable form. The spermatozoa have a body sometimes round, and occasionally pyriform or cylindrical,

* Louis Agassiz.

terminated by a long tail. Sometimes they are spiral in their outline. We observe them more or less in the male semen of all animals.

The spermatozoa are the essential constituents of the seminal fluid. The fluid without them has not in itself any fertilizing power. Sometimes the seminal fluid is absent altogether, so that they constitute the sole element of the semen. The fecundation of the ovum is therefore accomplished, by contact with the spermatozoa which swim in the seminal fluid. It seems to be by undulations of their tail rather than by ciliæ that their movements are effected; and it is obvious that they are thus endowed with mobility, in order to facilitate their access to the germinal vesicle of the ovum.

In all the orders of Cryptogamous plants, bodies analogous to stamens and pistils, termed antheridia and pistillidia, have been discovered. The mutual action of these bodies is necessary to the development of all the orders of the Cryptogamia. Now the cells of the antheridia of mosses each contain a spiral filament which has a globular head and a long tail, exactly like that of a spermatozoa, and when examined with a power of 250 diameters, it is seen to be in rapid motion in the cell. The spiral filament has therefore been called a phytozoon, and is believed to exercise the same function in the vegetable as the spermatozoon in the animal economy. Similar phytozoa have been detected in the antheridia on the pro-embryo of ferns, in that part of the fructification of Chara, known as the globule; in short, in all the organs, which represent the stamens, in Cryptogamous plants.

The antheridia are globular in Chara, but they are somewhat ovoid in mosses. They are generally composed of a mass of cells, variable in their form, each containing a movable phytozoon. There is, therefore, more analogy between the fecundating matter of Cryptogams and that of animals, than between the fecundating matter of Phanerogams and that of animals. The fine movable corpuscles or fovilla which may be seen in the fertilizing fluid matter which descends the pollen tube to the embryo sac where formerly thought to be spermatozoa; but they are only molecules of starch, being colored blue by iodine. They are not spermatozoa, as a great many authors have thought.

PART IV.

ON THE GEOGRAPHICAL DISTRIBUTION OF PLANTS AND ANIMALS.

CHAPTER IX.

ON THE LAWS, ACCORDING TO WHICH, ANIMALS AND PLANTS ARE DISTRIBUTED ON THE SURFACE OF THE GLOBE.

When we examine the plants and animals in different parts of the earth, we find that each great country on the globe has its own flora and fauna. This diversity in their vegetable productions is one of the causes of that particular physiognomy which landscapes present in the different parts of the earth. Thus the vegetation which covers the countries to the north, consisting of immense forests of pine, fir, and birch, is very different from that of the more temperate climates, where the forests are less abundant, and possess more of variety in the species which compose them; and the plants of the temperate zone are not the same as that of tropical countries, where the climacteric conditions are favorable to the support and development of a continuous vegetation which is never arrested.

The geographical distribution of animals is intimately associated with that of plants; for herbivorous animals can exist only where there is an adequate supply of vegetables suitable for their food; and the carnivorous prey upon the herbivorous races. Hence it is that the fauna of the different parts of the earth presents the same ever-varying aspect as its flora. The animals of Oregon and California, for example, are not the same as those of New England; and in like manner the animals of temperate Asia differ from those of Europe and the torrid regions of Africa. Under the torrid zone, the animal as well as the vegetable kingdom, attains its highest development, whilst about the poles it manifests the same organic inferiority.

If we begin to reflect on the probable causes which have produced this diversity of vegetation and animality in the different parts of the world, we shall soon perceive that the whole may be referred to a few general laws. This part of the sciences of Zoology and Botany, however, demands new researches. The nature and number of the animals and plants in all parts of the world is not yet known; and it is only this particular knowledge of the plants and animals of each country, joined to numerous and exact geographical and meteorological observations, which will guide us to a correct knowledge of those general laws which regulate the distribution of the plants and animals on the earth's surface.

This branch of Natural History is of very recent origin, and owes its existence to the philosophical researches of Humboldt, Decandolle, Robert Brown, Schow, Mirbel, and other eminent naturalists of the present century. Through their labors, considerable progress has been made in this interesting department of the natural sciences.

Some plants appear to be capable of adapting themselves to almost any climate. Thus many ferns and mosses are common to both Europe and America, and numerous European weeds infest the fields and woods throughout the United States, to the exclusion in some instances, even of the native denizens of the soil. So the spores of Cryptogamous plants are so light that they are easily borne on atmospheric currents across mountains and oceans, and this accounts for the wide spread of the same genera and species over the European and American continents; but the European weeds which everywhere present themselves to the eye in America, are certainly the result of commercial intercourse between the two countries, as there is nothing in their organization to convey them in such abundance to such vast distances from their native localities.

Some species of animals have also a very extensive geographical range. The muskrat is found from the mouth of Mackenzie's river to Florida. The field-mouse has an equal range in Europe. Commerce has mingled together the animals as well as the plants of the old and new worlds. The horse, originally from Asia, was introduced into America by the Spaniards, where it was allowed to run wild, and has thrived so well, that immense herds are now found scattered over the pampas of South America and the prairies of the West; and in the same manner the domestic ox has become wild in South America. Many animals, such as the dog, the different kinds of poultry, and several singing birds, seem to be capable of living in almost any climate, and are fostered and encouraged to associate with man on account of the pleasure and service which they afford him. Many less welcome animals have also followed him, as for instance, the rat and the mouse, as well as a multitude of insects, such as the house-fly, the cockroach, and those which live on the vegetables which he cultivates, as the white butterfly, the Hessian-fly, &c.

The generality of animals and plants are not, however, so flexible in their constitutions. No animal, excepting man, inhabits every part of the earth. Each great geographical and climatal region is occupied by some species not found elsewhere; and each animal flourishes best within certain limits beyond which it does not range. It is the same with plants. Comparatively speaking, vegetable cosmopolites are few in number. The greater number of plants are very exacting as to the conditions of their development, and will only put forth foliage, flowers, and fruit, in a certain soil and, under certain definite conditions of heat, light, and moisture. In this respect the animal and vegetable world are governed by the same laws.

Soil exercises a marked influence on the geographical distribution of species. It is impossible to examine the flora or fauna of any country without arriving at this conclusion. The mountains and the valleys, the margin of rivers and the shores of the ocean have all their appropriate vegetable and animal forms. When we burn a plant, the materials attracted from the earth and atmosphere and blended together in its organism are separated, and we restore to the atmosphere the gaseous part of the plant which was taken from it, isolating the mineral matter derived from the soil under the form of the incombustible ash which remains. Now the small amount of ash left, proves that the atmosphere is the chief source of vegetable nutrition; yet nevertheless its importance is not on this account to be underrated. This ash does not enter the organism of the plant mechanically along with the fluid matters absorbed by the roots from the soil, for analysis has proved that its chemical composisition varies in different plants. Therefore, each nucleus of cells which forms the substance of the germinating seed, must exercise a *special attraction* on certain inorganic elements, which it separates from the other mineral matters, in the midst of which it grows, and which inorganic elements are absolutely necessary to the healthy evolution of the embryo which it encloses. Plants are therefore unquestionably influenced in their localization, by certain peculiar inorganic elements which they derive from the soils in which they grow.

When the soil is of such a nature as to favor the growth of one particular species more than another, it becomes covered exclusively by that species, of which the individuals form a true society and give a peculiar aspect to that region. This congregating together of numerous individuals of the same species, constituting what Humboldt calls social plants, always indicates great uniformity in the nature of the soil. It is thus that the Sphagnum, or bog-moss, covers the soil to a considerable extent in humid and exposed parts of forests; that sedges, heaths, rhododendrons, and firs, occupy immense spaces on the surface of the earth, to the exclusion of all other species, which find themselves smothered out by the social plants, these regions being their especial domain.

The knowledge of the choice or predilection of a species for this or that situation, is current amongst all engaged in practical horticulture, and is called into requisition every day, in the formation of groups and beds of flowers in parks and gardens.

It is well known that many animals are equally social in their habits. Birds migrate in flocks; sheep congregate in pastures; and the prairies of the far West are sometimes covered with herds of buffaloes.

Temperature.—If the earth were throughout homogeneous, if its surface were not formed of land and sea, of islands and continents, of mountains and plains, the temperature of a determinate point of the globe would be given by its latitude, and the isothermal lines, or lines of equal temperature, would be parallel to themselves and to the equator. But the surface of the earth is not homogeneous. Elevation has the same effect on temperature as an increase of distance from the equator, even under the same parallels of latitude. Now in proportion as countries are elevated, in the same ratio is their temperature reduced. This remark applies not only to those mountain chains whose snowy peaks are seen, even in tropical countries, but also to those plateaus or elevated table-lands, which abound in different parts of the world. The water with which a vast portion of the earth's surface is overspread greatly modifies its temperature. Countries situated in the neighborhood of the ocean, are always cooler than those which are removed from its influence. The isothermal lines are not therefore parallel to the equator, excepting in the neighborhood of the equinoctial line, but form an irregular curve around the earth's surface. Temperature undoubtedly influences the geographical distribution of plants. To every species of plant there is a certain degree of temperature necessary before it will germinate. Hence it is that every month produces its own flora, the result of the ever-varying temperature of the year, and each zone produces its own vegetation which would not flourish elsewhere.

Light.—The influence of light on vegetation is perhaps not so great as that of temperature, yet it is nevertheless deserving of an especial notice. The decomposition and consolidation of the elementary food of plants, the formation of the green parts, the exhalation of moisture by their leaves, its absorption by their roots, and all the other circumstances of vegetable life, are owing to the illuminating power of the sun. In tropical countries, where the light of the sun is the most powerful, we meet with plants which have the most intense colors, the strongest odors, and the most active properties. These plants when cultivated in the stove, never acquire the fragrance and virtues which they possessed in their native country; for although we can place them in an atmosphere of the same temperature as their own in these northern climates by applying artificial heat, yet it is impossible to replace the splendor of the southern sun.

In tropical countries, the rays of the sun fall perpendicularly, and therefore his light is much more intense there than in the temperate or polar regions. As we pass from the equator to the poles, the incidence of the rays becomes more oblique, and consequently, their brightness and stimulating power on the vegetable and animal creation must be diminished in the same ratio.

All the effects of light on vegetation are not yet fully understood. In temperate climates, in early spring, the temperature depends in a great measure on the prevailing currents of air. If these currents come to us from the north, although the sky is cloudless and the vernal sun smiles cheerfully once more on the leafless forests and the flowerless fields, yet the cold will prevent the development of vegetable life. But are the plants wholly uninfluenced by the light in such circumstances? It seems possible that, independently of the heat, the constantly increasing light may have a somewhat stimulating effect on vegetation. We are not aware of any facts which confirm this suggestion, but the subject is deserving of attention.

It is well known that plants grown in a window turn their leaves to the light, and that the pots in which they are kept require to be turned occasionally in order to prevent them from growing all on one side. The daisy and dandelion are supported on a long stalk, if their flowers grow in rank grass; and become sessile on a shaven lawn, or in spots to which the light has free access. Light also influences the position of leaves on the stem, which are always arranged so as to be most favorably situated for its reception. The opposite leaves of labiate plants which usually cross each other at right-angles, develop in the same plane, when the stem becomes horizontal or its branches take a drooping growth. This change of position may be observed especially in the ground-ivy (Glechoma hederacea.) The direction of the branches of trees is also greatly influenced by the light. Thus the lower branches are more horizontal and stretch further from the stem than those towards the summit of the tree.

Humidity.—Vegetation is greatly promoted by a moist condition of the atmosphere. Water is as necessary in germination, as in all the other phenomena of vegetable life. It penetrates into the substance of the seed, softens its envelopes, and makes the embryo swell. It therefore places the seed in the conditions which are the most favorable for germination.

The quantity of rain which falls, varies greatly in different parts of the world. There are enormous tracts of land on which rain never falls. In some places it rains almost perpetually. Between the tropics, the rains follow the sun; when he is north of the equator, the rains prevail in the northern tropics, and when he is south of that line, in the southern tropics; hence one half of the year is extremely wet, and the other half very dry. The changes take place at the equinoxes, when the sun crosses the line. In the temperate zone rain falls at all seasons, though more abundantly in some, than in others. This unequal distribution of heat, light, and rain, over the earth's surface, must necessarily produce a great difference in vegetation.

If we would however approximate to more correct and philosophical views respecting the influences of these grand stimulants of vegetation and animality, it is necessary to consider their influence, not so much separately, as in a state of combination, and its effect in different parts of the earth.

Tropical countries may be truly regarded as the paradise of trees and flowers. The intense heat and light of the sun combined with the humidity of the atmosphere, cause the rapid development of a rich and varied flora. There are no wintry winds, falling snows, or hard frosts, to blight the magnificent vegetable beauty with which these regions are overspread. The forests of the tropics, instead of being composed, as in temperate climates, of a small number of trees with desiduous leaves, presenting the same wearisome, monotonous aspect, exhibit a much greater variety of arborescent forms, which, clothed with perpetual verdure, are covered throughout the year with fruits and flowers in different stages of growth. The grasses are there ligneous and gigantic, some of them equal in height to the trees of temperate climates; immense woody vines of fantastic and ever varied form, elevate themselves to the summit of the tallest trees, with the leaves and blossom of which their foliage and flowers are often beautifully intermingled. The tall and elegant palms and tree ferns, with their magnificent bouquet of gigantic and pendulous fronds towering above the rest of the trees of the forest, are seen afar off on the ocean, and are the first objects which present themselves as the traveller approaches the shores of tropical countries.

The development of animality is equally luxuriant. All the principal types of animal life are represented on the most magnificent scale. An astonishing variety of birds with the most brilliant plumage, make the forests vocal with their melody. We need only refer to the tribe of humming birds which numbers no less than 300 species. Here reside the noble lion, the beautiful though ferocious tiger, the largest of the cat tribe. This is the home of the great pachydermata, the elephant, the hippopotamus, and the tapir. The reptilia assume their largest forms. Immense crocodiles, tortoises, and serpents frequent the rivers, marshes, and moist woods. The seas teem with crustaceans and every order of molluscous animals. The shores are covered with their shells, which, in these sunny regions, acquire the most rich and variegated hues. The insects are as brilliant as they are numerous. There can be no doubt whatever that all the rich coloring which is spread over animality as well as vegetation in tropical countries, is to be attributed to the brightness of the sun's rays. Tropical birds, for example, reared under an artificial temperature in cold countries, never acquire that brilliancy of plumage which distinguishes them in their native haunts.

As we pass from tropical into temperate climates, the heat decreases, the rays of the sun become more oblique, and consequently less vivid; in a word, all the exciting causes of vegetation gradually diminish in intensity. The tall and graceful palm tree, the plantain and the banana, the cotton-tree and the sugar-cane are no longer visible. Vegetation is despoiled of its magnificence and variety, and takes a humbler and simpler form. Accordingly we find that plants with ligneous and persistent stems are fewer in number, and that there is a greater predominance of such as are herbaceous, and which therefore perish annually.

Plants with herbaceous stems have precisely the same growth, *as far as it goes*, as those which are ligneous and persistent. Any one can speedily convince himself of this. There is visible on the cross section the same concentrical disposition of the matter of the stem into pith, wood and bark, and the same development of branches in the axils of the leaves. But the heat is not spread through a sufficient number of months, and the period is too short for the plant to run through all the phases of its development. The whole process is therefore stopped in its first stages, and the stem with its branches and flowers, dies down to the ground, and disappears from the earth's surface on the approach of winter. In other instances, where woody matter is deposited in greater abundance, the leaves and flowers perish, but life remains passive in the stem. The cold has arrested the vegetable machinery but produces no disarrangement of its parts, on the contrary, a section of the autumnal bud, shows beautifully the young embryo leaves and the undeveloped internodes of the next year's growth, already formed in them, and but awaiting the return of the warmth and brightness of the sun, to come forth out of this their hybernaculum, and again exhibit the same vital movements.

The seed and ovum in vegetables and in the lower forms of animals, is but a retreat into which exhausted vitality retires for a season in order to recover its wonted energies; it also affords a shelter for the young embryo during the prevalence of those conditions which are unfavorable for its development. Accordingly, we find that the seeds of many early flowering annuals germinate again in autumn, *as the light and heat of the sun are then much the same as in early spring.* A little family of plants is thus seen rising around their aged and dying parent. In some instances, the individuals of this family arrive again at an adult state, and flowers as well as leaves appear; generally, however, the germinating seeds can only produce leaves, the approach of cold weather arresting all further development. These and many other appearances in nature are deserving of a greater share of attention than has hitherto been allotted to them. All practical gardeners and botanists are acquainted with many plants which flower in spring, and again develop in autumn, on a return of similar conditions of light, temperature, and moisture.

That the vegetable machinery would continue in motion and simply stops in consequence of the decreasing heat and light of the sun, is evident from the fact, that plants which are annual and herbaceous in temperate climates, become ligneous perennials in the tropics. The castor oil plant, (Ricinus communis,) for example, in Pennsylvania, puts forth large peltate-palmate leaves, and grows from three to eight feet in height, but is destroyed by the first frosts of autumn. In the happy regions within the tropics, its stem is ligneous and persistent, and it grows into a powerful and lofty tree. It is the same with the Euphorbiaceæ, Labiatæ, Leguminosæ, Boraginaceæ, Hypericaceæ, Rubiaceæ, Verbenaceæ, Polygonaceæ, Compositæ, and a host of other plants which we tread under our feet in Pennsylvania; these die down to the earth's surface and disappear from the landscape on the approach of winter, which arrests the movements of life in all the lower forms of organization in temperate climates. In the tropics, these very plants, so herbaceous and perishable with us, take a ligneous and persistent form, and elevate themselves majestically into the air. Excepting on the mountain summit, snow never falls on any other part of the warm and sunny landscape, and the traveller wanders amid the arborescent forms of Leguminosæ, Euphorbiaceæ, Labiatæ, and Boraginaceæ; or if he be in the island of St. Helena, reposes beneath the shade of forests of Solidago, Sonchus, and Echium. The herbaceous and perishable annual has become transformed into the ligneous and enduring perennial. The plant whose humble growth and delicate beauty drew our admiration as it grew at the foot of some tall oak or lofty buttonwood, is now itself one of the noblest trees of the forest. Development has gone on, and we see the result of the magic influence of a continuity of warmth and brightness in the majestic form which now stands before our eyes.

The fauna of temperate climates, like its flora, presents the same picture of arrested development and temporary suspension of the powers of life during the winter months. We have a considerable number of animals of graceful form, animated appearance, and varied colors, though they are less brilliant than those found in tropical regions. There is a greater uniformity amongst them. Notwithstanding the immense extent of country, the same families, and frequently the same genera, are found in countries widely apart from each other. There are even a few terrestrial species, regarded as identical in the temperate regions of America and Europe; but their supposed number is constantly diminished as more accurate observations are made. The reptilia are much reduced in size; the lizard and viper take the place of the gigantic crocodile and boa constrictor. The tortoises are small and of medium size. All classes of molluscs are represented; but their shell, are deprived of much of that beauty which characterizes the shells of warmer climates. The patient camel and dromedary, the half-reasoning elephant, the beautiful zebra and tiger, are replaced in temperate climates by the horse and ass, the dog, wolf, and wild cat.

All animals which store up provisions, such as the squirrel, the marmot, the beaver, and the bee, are peculiar to the temperate regions of the earth. It is obvious that such instincts would be out of place in tropical countries, where vegetation presents herbivorous animals and insects with an abundant supply of food at all times.

On the approach of cold weather the trees, with the exception of the pine, fir, and other coniferæ, drop their leaves; the insects retire, and the animals which live on them, either migrate to other countries, or pass the winter in a state of torpor, from which they awake in spring. This is especially the case with the birds, which are all migratory in their habits. The most beautiful species come to us from the sunny south, and disappear on the approach of winter.

In proportion as we approach the polar regions, the trees become stunted and dwarfed in their growth, the number of genera and species is still further diminished, the oak, the walnut, the chestnut, and the hickory, are replaced by dark and sombre forests of coniferous plants, amongst which pines and firs are the most prominent. Finally, these plants gradually disappear, and the last lingering remnants of vegetable life are seen in the form of mosses, lichens, and other cryptogamous plants, the excessive rigors of the climate preventing any higher indications of vegetable life.

The animals in the arctic regions are few in number, and their tints as dusky as the northern heavens. There is not a single bird with brilliant plumage, and not a fish with various hues. The artic regions form a district common to Europe, Asia, and America. On this account the animals inhabiting them are sometimes identical; in fact, there is no genus of quadrupeds in the Arctic regions which is not common to the three continents. The most conspicuous animals are, the reindeer, the white bear, the polar hare, the white fox, lemming, and various seals. There are immense flocks of predaceous and aquatic birds, gulls, cormorants, ducks and geese, all belonging to the lowest orders. Reptiles are altogether wanting. The articulata are represented by numerous marine worms and minute crustaceans. Insects are rare and of inferior types. Mollusca are sparsely scattered in the adjacent seas along with a few star fishes and echini. We must not omit the whales, which are, however, the lowest of all the mammalia. This assemblage of animals is decidedly inferior to the temperate and tropical faunas.

We have already intimated that "elevation has the same effect on temperature as an increase of distance from the equator." Hence there is a remarkable similarity between the plants and animals which cover a hemisphere from the equator to the poles, and those which clothe the sides of a tropical mountain, from its warm and sunny base to its cold and snowy summit. The species, genera, and even the families of both plants and animals growing in the country surrounding its base, may be entirely different from the vegetable productions of Europe. But here, elevation above the ocean level, acts in the same manner on vegetation as an increase of distance from the equator. In proportion as we ascend the mountain, the fauna and flora gradually lose their tropical character, and assume the appearance of that without the tropics; the climate becomes cooler, until at length the tropical plants disappear, and European genera, and even species analogous if not absolutely identical with those of the temperate climates of Europe, present themselves to the eye of the astonished observer. As we approach the limits of perpetual snow, the vegetation becomes wholly cryptogamous, and similar to that of the arctic regions.

M. Mirbel has therefore very properly compared the terrestrial globe to two immense mountains, whose bases are united at the equator, and whose summits are the arctic regions around its northern and southern poles.

CHAPTER X.

ON THE GEOLOGICAL SUCCESSION OF PLANTS AND ANIMALS, OR THEIR DISTRIBUTION IN TIME.

In the preceding chapters we have endeavored to show that the operations of organic law are the same in plants and animals. In order to render the argument complete, it is necessary to consider them in the order of their appearance on the earth's surface; and for this purpose we must examine their fossil remains and their position in the rocks. The study of these remains constitutes the science of Paleontology—one of the most essential branches of Botany and Zoology.

By this science we are taught that the present arrangements of land and water, and the forms of animal and vegetable life on the earth's surface, are the result of a long succession of antecedent changes of which the earth's crust has preserved the memorial. The History of the Earth has been written in its strata, which have been very properly termed "the leaves of the stone book." But the language left on these stony pages can only be interpreted by a careful and accurate knowledge of the living creation, and of the laws which now govern the distribution and development of species. Natural History is the alphabet of geology. The highest attainments in the natural sciences are required for these researches.

The knowledge of Botany which is required to throw light on fossil plants, must be both varied and extensive. It is obvious that the Linnæan system is of no use in determining genera and species, because it is founded on characters which have not been preserved, viz., the different parts of the flower. Fossil plants are not so easily determined as recent species, because their parts are usually separated from each other. It is very seldom that any traces of their reproductive organs are left. Fragments of stems, leaves, and occasionally seeds, are the only data by which the plant can be determined. We have to fall back, therefore, on our knowledge of the natural system. There must be a thorough acquaintance with the different natural orders, and a familiarity with vegetable anatomy. There must be a competent knowledge of the minute structure of all the organs of plants, such as their root, stem, leaves, bark, and fruit, and of the markings which they exhibit on their exterior surface, together with some general ideas of the vegetation of tropical climates as well as of cooler latitudes, before the living affinities of the fossil plant can be determined.

As fossil plants are generally found in detached fragments, it is necessary to reconstruct the plant as completely as possible, and to determine the relations of its several portions to each other. It is evident that this must be a very difficult task; but it is a very necessary one, for the neglect of it has led to a needless multiplication of fossil species, portions of the same plant having been described as separate species or genera.

A knowledge of Comparative Anatomy is also necessary. To a person unacquainted with this science it may appear impossible, that from a single fragment of a fossil bone or tooth, Naturalists are able to determine the general character of its skeleton, and from thence to infer its appearance and mode of life. Yet all this is true. If we find, for example, a single fossil tooth, if it be a molar, it is sufficient to indicate the mode of life of the animal to which it belonged, and to show that it fed on vegetables, as the other organs of the body constantly correspond in structural adaptation to the same function. There is the utmost harmony and adaptation of parts to each other amongst the several bones of the skeleton, and hence each, taken by itself, indicates and gives form to all the others. This has been shown by the acute and laborious researches of Cuvier and Owen.

There is every reason to believe that the history of the development of vegetation on any barren rock, or newly formed coral island, illustrates those stages by which the earth itself became covered with verdure. The first vegetable denizens of the rocky surface in modern times, are usually cryptogamous plants, such as crustaceous lichens, these are succeeded by the foliaceous species, and by such mosses as Polytrichum commune, Hedwigia ciliata, and the different varieties of Leskia and Hypnum, plants which are of very humble growth, and of exceedingly simple structure, consisting, comparatively speaking, of only a few cells. The oxalic acid contained in the thalli of the lichens, together with the oxygen of the atmosphere, slowly disintegrate the rocky surface, and successive generations of these lowly protophytes finally create a humus which gives birth to a more highly organized vegetation. The higher cryptogamia now make their appearance, Polypodium vulgare, Asplenium trichomanes, Asplenium ebeneum, together with the Saxifrages, Arenarias, Aquilegia Canadensis and other phanerogamous plants. Such appears to be the order of nature—the cellular Cryptogamia preparing the way for ferns and flowering plants—the simple preceding the complex.

That cryptogamous plants are the most ancient inhabitants of the earth; that they existed anterior to the Phanerogamia, and formed for a long succession of ages a leading feature in the flora of the antediluvian world, is evident, if we consult the pages of geological history. It is true that the cellular Cryptogamia, such as lichens and mosses, are very seldom found in a fossil state; but this is not to be wondered at, when we remember that the preservation of plants in this condition necessarily depends on their structure. The fossil Cryptogamia, which have a woody and vascular structure, have however, been preserved in the greatest abundance.

The absence of organic remains in rocks is not always sufficient to enable us to state that these rocks were formed before animals or vegetables existed, since the late Prof. Forbes has shown that, even in the present day, there are depths in the ocean which are destitute of organic life. Hence rocks deposited at such depths might contain no organic remains.

Fossil plants are found in the aqueous and stratified formations, which have been divided into three great groups, the Paleozoic, the Secondary, and the Tertiary. The Paleozoic rocks include the Silurian, Cambrian, and Old Red Sandstone and Carboniferous formations. In the Silurian, Cambrian, and Old Red Sandstone we meet with the remains of marine plants, and also a few terrestrial species. In the Old Red Sandstone of Scotland, Miller has detected fucoid ferns, and in the same formation at Oporto, Bunbury has found Pecopteris cyathea, P. muricata, and Neuropteris tenuifolia, ferns which are closely allied to those of the carboniferous period. There was land, therefore, as well as water at this remote epoch, although the abundance of fishes and marine plants seems to indicate that the sea covered the greater part of the earth's surface.

Towards the close of the paleozoic period, however, land plants appear to have been developed on an enlarged scale. Coal owes its origin to the abundant vegetation of this era; for it is now universally admitted that this substance is of vegetable origin. This the microscope has fully demonstrated. In some kinds of coal, punctuated woody fibre has been detected, in others dotted and scalariform tissue, as well as cells of various kinds. The occurrence of dotted and scalariform vessels indicates the presence of ferns and their allied forms, such as Sigillaria, Stigmaria and Lepidodendra, whilst true punctuated wood implies the presence of Coniferæ.

Impressions of these plants are abundant amongst the argillaceous and sandy beds of the carboniferous system. About one hundred and fifty species of fossil ferns have been distinguished by Botanists in the coal system of England, and many of the fronds of these ferns have been clearly ascertained to have fallen from the stems of tree-ferns, which grew at the time that the coal was deposited. The Lepidodendrons were gigantic Lycopodiums, or club mosses, which rose to the height of sixty feet, although the representatives of these plants are now mere herbs.

In the Secondary formations we meet with a greater number of Coniferæ and Cicadaceæ, whilst ferns and Lycopodiaceæ are not so abundant, and less gigantic in their growth.

The Tertiary period is characterized by an abundance of Dicotyledonous and Monocotyledonous plants, especially palms.

Many of the fossil plants of these deposits, such as pines, elms, beeches, and maples, may be referred to genera at present existing, and merely present specific differences. The general result of all researches in fossil botany tends to prove that the early vegetation of the globe consisted of plants of extreme simplicity of organization. The more ancient the geological formation the greater is the difference between its fossil plants and those now living; whilst on the other hand, the Tertiary deposits which are, comparatively speaking, recent in the history of creation, contain in addition to species now extinct, botanical remains which are identical with species now living. There has therefore been a gradual approximation of vegetation to its present condition.

There appears to have been a similar progression in the animal creation. All naturalists admit that the animal remains found in the Primary or Paleozoic rocks are characterized by great simplicity of organization, and that the animals of this period present the least resemblance to those now living. The articulata are mostly trilobites—animals which evidently belong to the lower order of the Crustaceans. There is an incompleteness and want of development in the form of their body, that strongly reminds us of the embryo among the crabs. The class of insects is entirely wanting. The radiata are represented by the Crinoidea, or lily-like zoophytes, animals remarkable for the simplicity of their organization, and the peculiarly complicated structure of their skeleton. The body of these Crinoids was supported on a long and flexible column, which was attached to a rock or some other hard substance, at the bottom of the sea. This column was composed of an immense number of joints, through which an aperture descended from the stomach to the base or support. The bodies of the Crinoidea, like that of the Hydra, were simple digestive cavities surrounded with jointed tentaculæ of the same structure as the stem, which the animal had the power of spreading abroad for the purpose of grasping its prey. These animals belonged to the class of Echinoderms, represented at present by the star fishes and sea-urchins, a far more highly organized race. Numerous brachiopod molluscs, the lowest of the class, have been discovered in the Paleozoic rocks. The class of worms is represented by a few serpulæ. But the most convincing proof of the organic inferiority of the first animal inhabitants of our globe is afforded by the remains of the fossil vertebrata of this epoch which are those of a low order of fishes. These were then the most highly organized animals. Hence the period has been called by Agassiz, the Age of Fishes. There was as yet neither reptiles, birds, nor mammals. The sea appears to have covered the greater portion of the earth—an ocean without a shore. The animals were all aquatic, and the vegetation marine; and "among the aquatic population no sound was heard. All creation was then silent."*

Towards the close of the paleozoic period, the earth appears to have presented the aspect of a vast ocean studded with an immense number of islands, which were covered with a luxuriant vegetation, consisting principally of arborescent ferns, Equisetaceæ, Calamites, Lycopodiaceæ, and Coniferæ—plants of very simple structure, but of gigantic size. It was during this geological era that the coal was deposited.

The animals of the carboniferous formation resemble, in many respects, those of the paleozoic epoch. The crustaceans, however, have evidently improved. In addition to the trilobites, we have the horse-shoe crabs, and other gigantic forms. We also meet with traces of insects and scorpions. We come now to that immense period in the natural history of the earth, which geologists have called

The Secondary Age, or the Age of Reptiles. The

* Louis Agassiz.

carboniferous rocks have been included within the geological formations of this period by some geologists, because they contain the remains of the first land animals; whereas in the paleozoic age, the animals were altogether marine, breathing by gills. Reptiles, however, are not found in the coal measures, and do not make their appearance until about the time of the deposition of the New Red Sandstone, which took place immediately after the formation of the carboniferous rocks. The tracks of a gigantic Batrachian animal, a creature allied to the frog, have been left on the New Red Sandstone of Pennsylvania and Germany; enormous aquatic birds have also left the impression of their footsteps on the same rocks in Connecticut.

The reptiles seem to have attained their maximum development during the Oolitic period. We find in this formation those enormous amphibia known by the names Ichthyosaurus, Plesiosaurus, Megalosaurus and Iguanodon, animals somewhat allied to the lizard and crocodile in structure. But the most wonderful relic of the age of reptiles, is the Pterodactylus, which resembled a gigantic bat, and is thought to have been capable of flying. The trilobites are now extinct; but in the upper stages of the Oolitic, we meet with tortoises and also the impressions of several families of insects, among which dragon flies and beetles are conspicuous.

All the invertebrated animals, including the mollusca, the articulata, and the radiata, are largely represented. The peculiar forms of the paleozoic age have nearly all disappeared, and are replaced by creatures whose organization is adapted to the new conditions. Of the brachiopod molluscs, only one type is abundant, that of the Terebratula. The Gasteropods display a great variety of species, and also the Cephalopods, among which the Ammonites are the most prominent. The Belemnites also abound, creatures resembling the cuttle fish. The polyparia were very abundant in the seas of the Oolitic period. Whole rocks are entirely formed out of the remains of these animals. The crinoids are not quite so numerous as in former ages; but star-fishes abound, and an extraordinary and beautiful variety of sea urchin with large spines, the Cidaris coronata. The animals of the Cretaceous period bear the same general characters as those of the Oolitic, but with a more marked tendency towards existing forms. It is true that there is some evidence of the existence of mammalia, but they are few and insignificant. The only traces of mammalia consist of two or three marsupial animals—creatures allied to the opossum. Throughout the whole of this immense period of time, the class reptilia was the preponderating form. The lower forms of both animal and vegetable life attained a gigantic development. "With flocks of pterodactyles flying in the air, and shoals of no less monstrous ichthyosauri and plesiosauri swarming in the ocean, and gigantic crocodiles and tortoises crawling on the shores of the primeval lakes and rivers; air, sea, and land must have been strangely tenanted in these early periods of our infant world."*

In those geological periods immediately following the deposition of the chalk, the last formation of the secondary age, the marine or amphibian reptiles are replaced by numerous mammalia of enormous size. These periods comprise the different tertiary formations. This era has, therefore, been called the AGE OF MAMMALS. The animal remains contained in these formations, strikingly approximate in organic development to the species now living.

* Dr. Buckland.

Many of the animals peculiar to former eras have passed away. The two great families of Ammonites and Belemnites are no more. A multitude of species of molluscs are however found, which more or less resemble those of the present era, some of them being in fact identical with those in the adjacent seas.

The most ancient of the tertiary deposits is characterized by the presence of great pachyderms, or thick-skinned animals, among which we may mention the Paleotherium and Anoplotherium, creatures which approached the rhinoceros and tapir in the peculiarities of their organization. These fossil mammalia were first found in the gypsum beds of the Paris basin. Their bones were brought to Cuvier, who re-constructed them, and thus laid the foundations of the science of Paleontology. In these ancient tertiary deposits the earliest remains of monkeys have also been detected.

The animals of the most recent tertiary formations resemble, still more closely, those of the present epoch. The fossil remains represent all the terrestrial and aquatic species now living around us, and besides these, many types now extinct, some of them of monstrous size, such as the mastodon, or fossil elephant, which is probably the last large animal which became extinct prior to the creation of man.

By these revolutions of organic and inorganic nature was the world finally fitted for the abode of man. In the tertiary formations, which preceded the Age of Man, no human remains have been discovered, no skeletons except those of the hitherto irrational denizens of the earth. Man is, therefore, comparatively speaking, a recent creation.

If we consider the men of the earliest time as children in intellectual capacity, gradually advancing from a state of the most brutal ignorance, to a clear and rational perception of their own capabilities, and their power of understanding and controlling nature, we shall probably entertain an opinion which approximates to the truth.

Whilst an untutored savage, man must have lived on the spontaneous productions of the earth which he was unable at this period of his history to cultivate. Slowly did he arrive at a consciousness of his power over the other animals, which at first disputed his dominion, but ultimately fled before him. This stimulated pursuit. He became a hunter; especially as he found the skins of the wild inhabitant of the woods useful as an article of clothing, and the flesh of some of them nutritious. He chose for his dwelling the margin of rivers and lakes, or the sea shore, whose banks were more or less covered with plants, and whose waters abounded in fish. These he sought by force or craft to obtain.

Even now the red Indians, in those portions of this continent yet uncivilized, subsist in this manner; and such appears to have been originally the condition of the ancestors of all civilized nations.

To avoid the trouble of hunting perpetually, such animals as he found useful for the supply of his wants, he endeavored to tame them. But the animals most readily subjugated were ruminants or plant-eaters, for which pasture ground must be provided. As a herdsman with his flock, from one place to another, he now wandered, dwelling in huts, until experience finally taught him to select those spots which produced the plants most useful for his animals, and sufficient in quantity to give them continuous support.

He now erected for himself settled habitations, and resorted to stones and metals to give them greater durability and strength. United he put forth mightier efforts, he built cities and founded empires. We have arrived now at the historical era. From the written accounts which have been transmitted to us, it is clear that the long reign of instinct is giving place to that of reason, and that the present period of the world's history is characterized by its slow development.

The occurrence of human skeletons, and of coins and works of art, in modern fluviatile and marine deposits; the preservation of the bones of the existing species of animals, and of the leaves and branches of plants now growing on the earth's surface, in the various geological formations now in progress, shows the immutability of nature, and proves that the same enduring monuments of the present state of things will be transmitted to future ages. When the beds now forming in the existing seas shall be elevated above the waters and covered with woods and forests; when the deltas of our rivers shall be converted into fertile tracts, and become the sites of towns and cities; in excavating the earth thus newly created, there is little doubt that the then existing races of men will discover the same indelible records of the physical history of our times, as we have now of that of former ages.

The Linnæan maxim, "*Natura miranda est maxime in minimis*," nature is chiefly to be admired in the least things, is as yet only partially appreciated by a few distinguished minds, although it should never be lost sight of in the investigation of vital phenomena. If it be philosophical to pursue researches in the physical sciences by experiments and observations on the properties of inorganic matter; it would seem to be equally in accordance with the principles of science, in the study of organic nature, to adhere as closely as possible to the plan of nature, and trace her operations in the simpler forms of life before we attempt the study of those that are more complicated. The development of the simple before the complex, appears to have ever been the plan of nature, whether her operations be traced in time or through the dark geological periods of the past; and whether we contemplate the successive phases through which life has already passed, or the organic phenomena of the present living races of plants and animals, we see everywhere evidence of the immutability of nature, and the uniformity of her organic laws.

THE END.